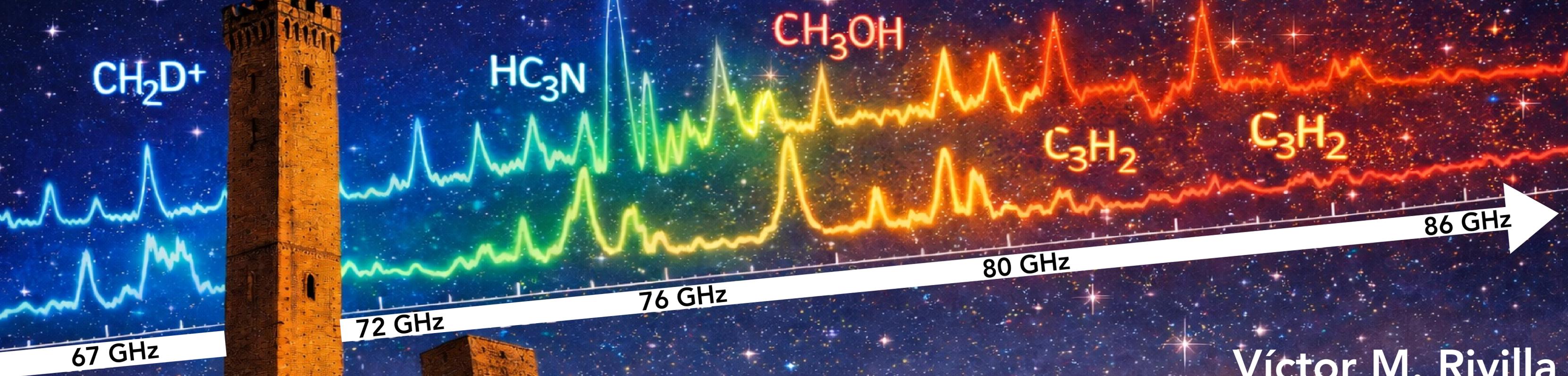


# Prebiotic molecules in ALMA Band 2



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Miguel-Sanz Novo, Álvaro López-Gallifa, David San Andrés, Laura Colzi, Chiara Mininni, Sandy Zeng, Francesco Fontani, Riccardo Cesaroni, Izaskun Jiménez-Serra, Maite Beltrán, Sergio Martín

**UNVEILING ALMA  
BAND 2**

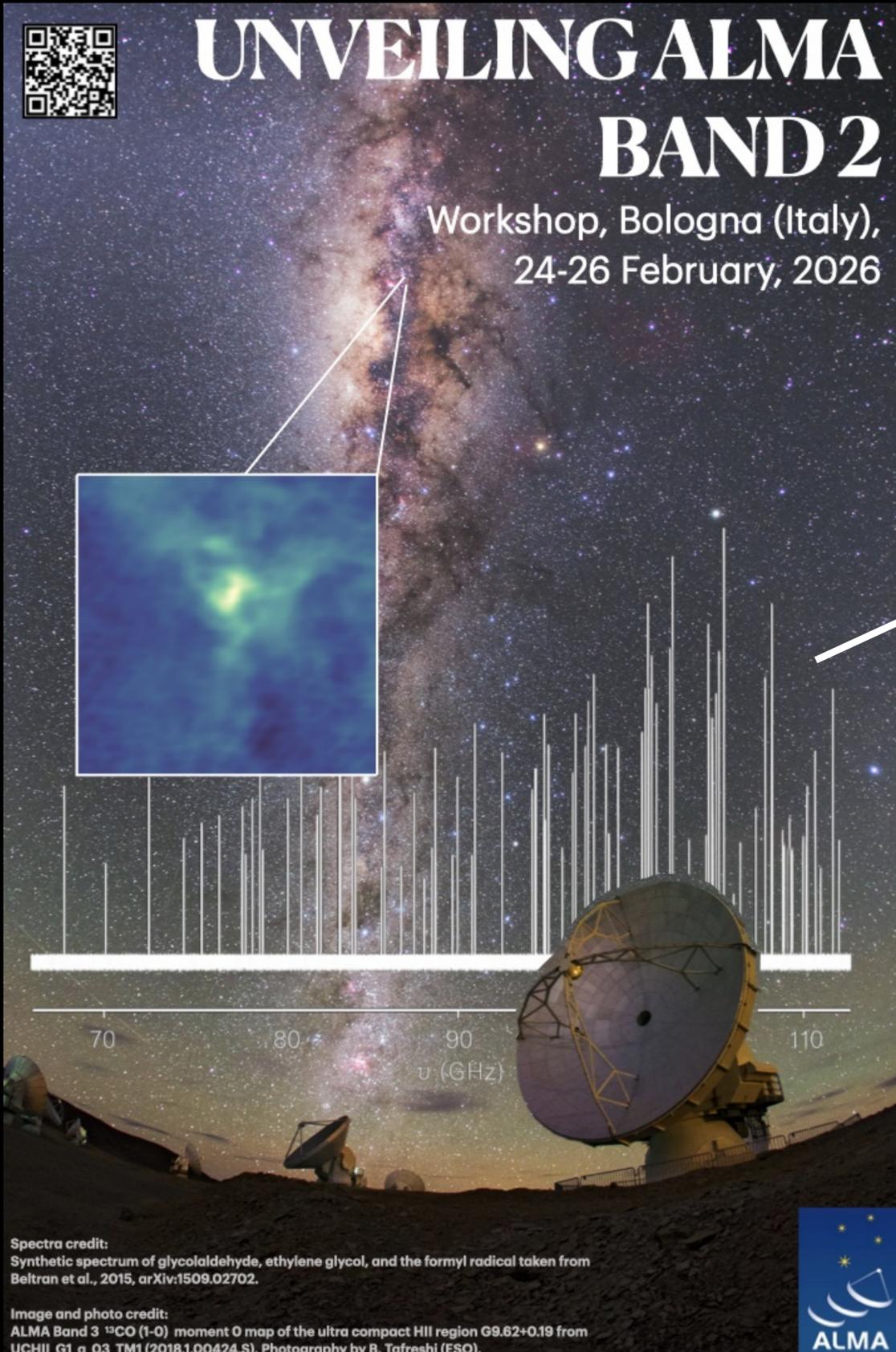
Workshop, Bologna (Italy),  
24-26 February, 2026

70 80 90 110  
 $\nu$  (GHz)

**Spectra credit:**  
Synthetic spectrum of glycolaldehyde, ethylene glycol, and the formyl radical taken from Beltran et al., 2015, arXiv:1509.02702.

**Image and photo credit:**  
ALMA Band 3  $^{13}\text{CO}$  (1-0) moment 0 map of the ultra compact HII region G9.62+0.19 from UCHII\_G1\_a\_03\_TM1 (2018.1.00424.S). Photography by B. Tafreshi (ESO).

ALMA



## Italian Science Case for ALMA Band 2+3\*

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Figure 4: *Simulated spectrum of GA, EG and HCO in the spectral range covered by ALMA Band 2+3 (67-116 GHz), considering the size of the G31 HMC (~1''), a temperature of 100 K and the molecular column densities estimated from the single-dish detections (Rivilla et al., in preparation). The noise provided by ALMA in 30 min hour on-source within beam of 1'' is 4.35 mJy/beam, and has been added to the theoretical spectrum.*

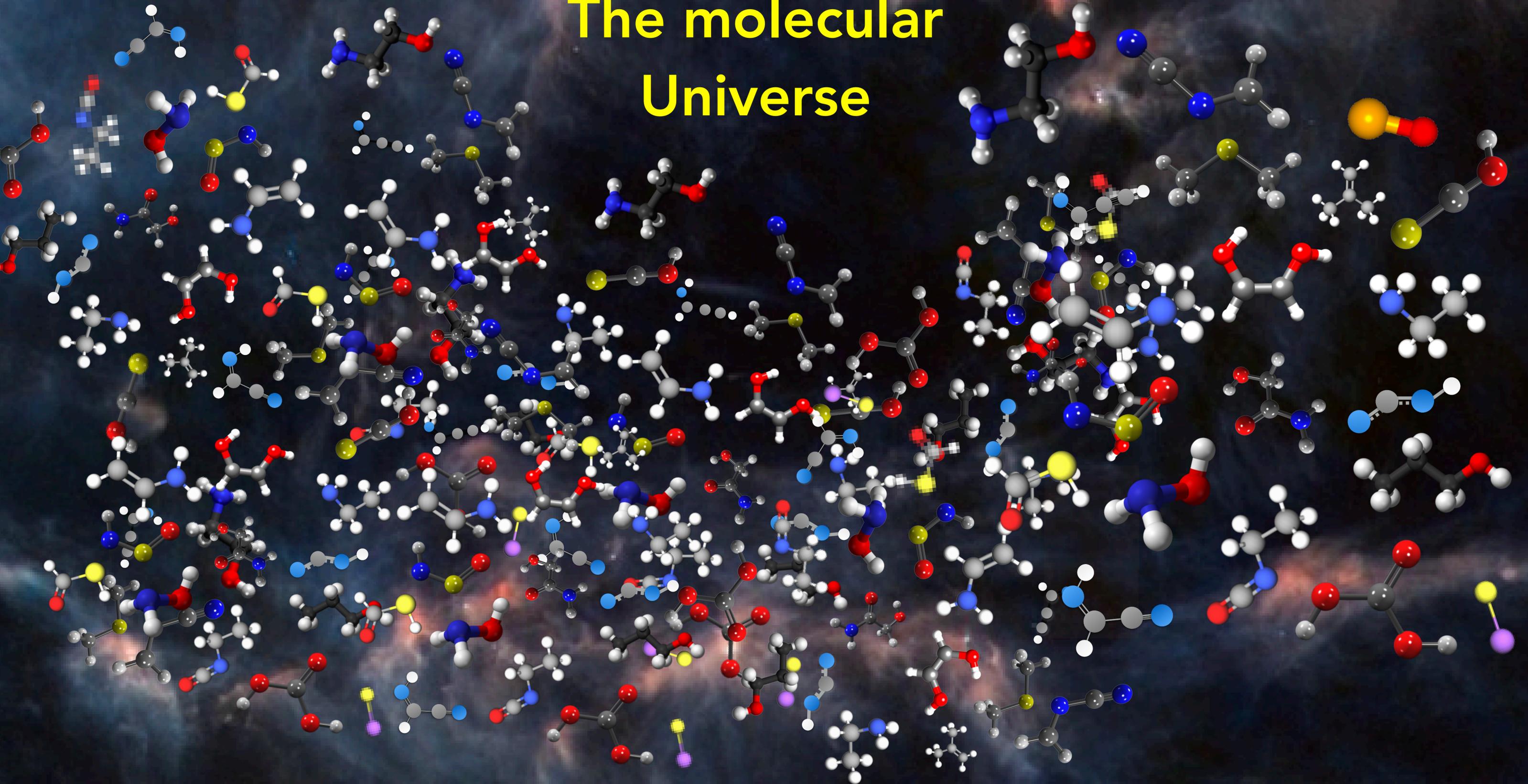
**G31.41 hot core - ALMA Band 2 SV**

Spectra credit:  
Synthetic spectrum of glycolaldehyde, ethylene glycol, and the formyl radical taken from Beltran et al., 2015, arXiv:1509.02702.

Image and photo credit:  
ALMA Band 3 <sup>13</sup>CO (1-0) moment 0 map of the ultra compact HII region G9.62+0.19 from UCHII\_G1\_a\_03\_TM1 (2018.1.00424.S). Photography by B. Tafreshi (ESO).



# The molecular Universe





**PHYSICS**

**MOLECULES** are  
powerful tools

**CHEMISTRY**



## Kinematics

infall  
outflows  
rotation

# PHYSICS

MOLECULES are  
powerful tools

# CHEMISTRY



**Gas Density**  
CO CS  
HC<sub>3</sub>N

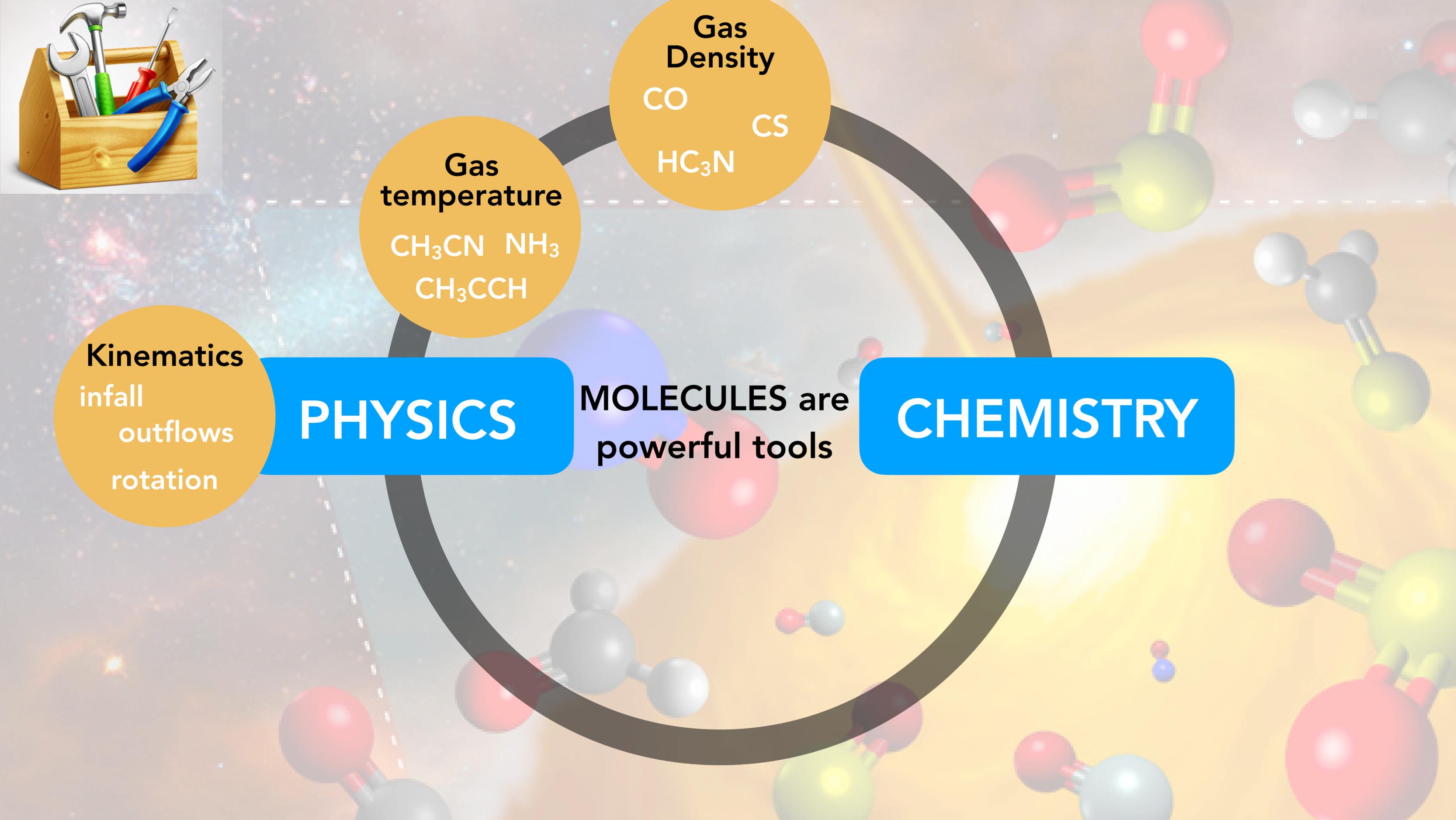
**Gas temperature**  
CH<sub>3</sub>CN NH<sub>3</sub>  
CH<sub>3</sub>CCH

**Kinematics**  
infall  
outflows  
rotation

**PHYSICS**

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**CHEMISTRY**





**Kinematics**  
infall  
outflows  
rotation

**Gas temperature**  
CH<sub>3</sub>CN NH<sub>3</sub>  
CH<sub>3</sub>CCH

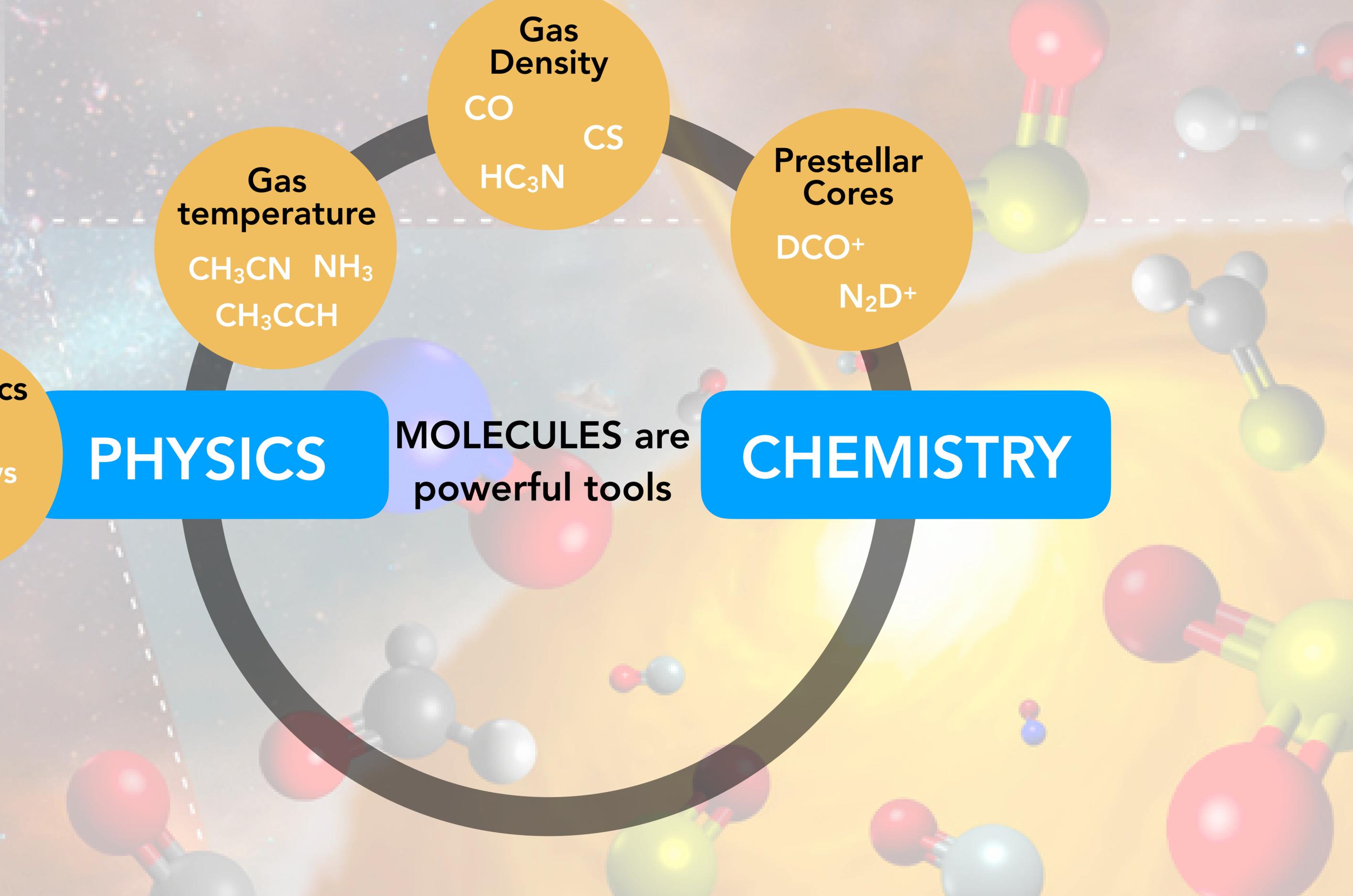
**Gas Density**  
CO CS  
HC<sub>3</sub>N

**Prestellar Cores**  
DCO<sup>+</sup>  
N<sub>2</sub>D<sup>+</sup>

**PHYSICS**

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**CHEMISTRY**





**Kinematics**  
infall  
outflows  
rotation

**PHYSICS**

**MOLECULES** are  
powerful tools

**CHEMISTRY**

**Gas temperature**  
CH<sub>3</sub>CN NH<sub>3</sub>  
CH<sub>3</sub>CCH

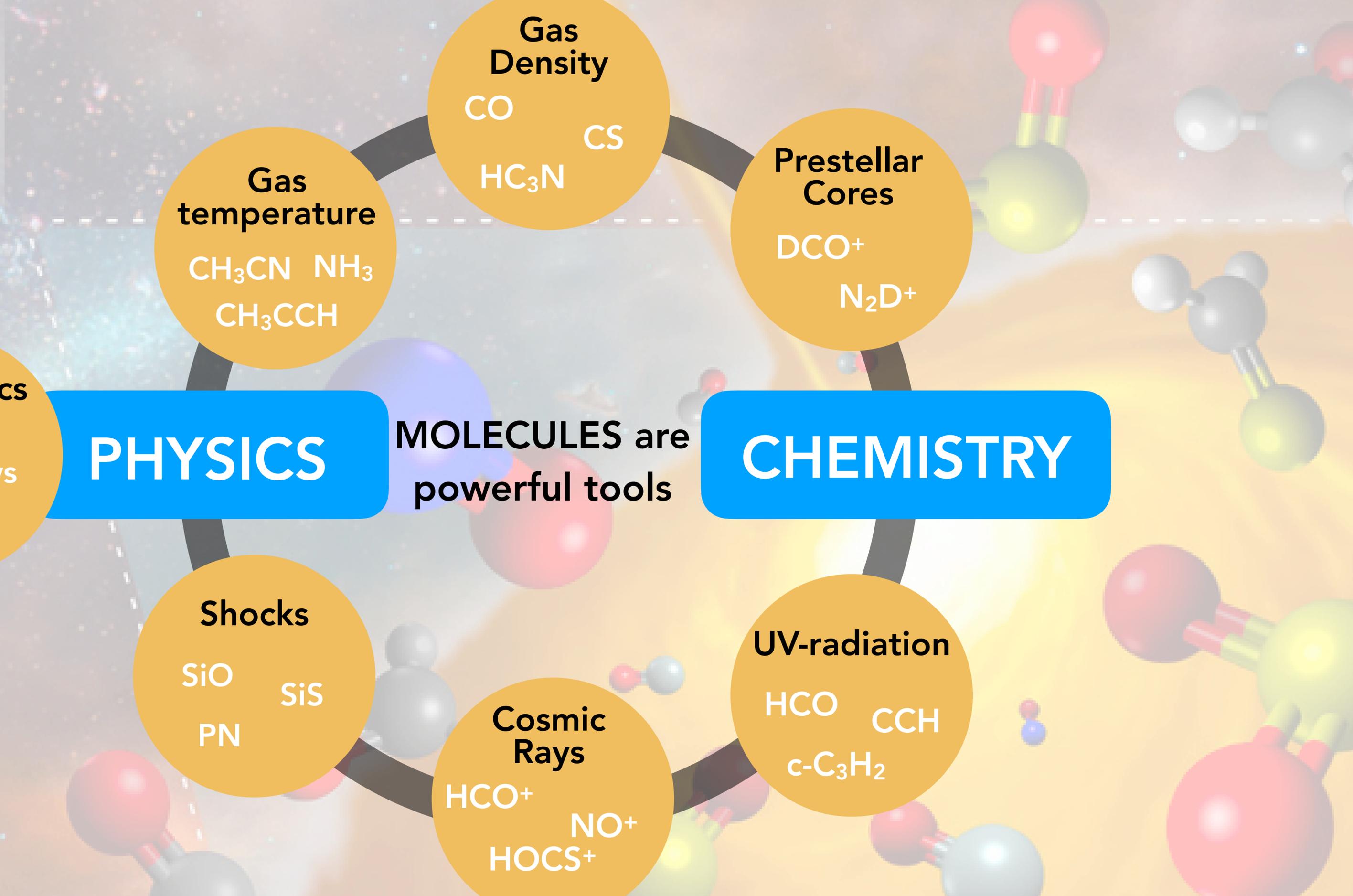
**Gas Density**  
CO CS  
HC<sub>3</sub>N

**Prestellar Cores**  
DCO<sup>+</sup>  
N<sub>2</sub>D<sup>+</sup>

**Shocks**  
SiO SiS  
PN

**Cosmic Rays**  
HCO<sup>+</sup> NO<sup>+</sup>  
HOCS<sup>+</sup>

**UV-radiation**  
HCO CCH  
c-C<sub>3</sub>H<sub>2</sub>





**Kinematics**  
infall  
outflows  
rotation

**PHYSICS**

**MOLECULES** are  
powerful tools

**CHEMISTRY**

**Census  
&  
Abundances**

**Gas temperature**  
CH<sub>3</sub>CN NH<sub>3</sub>  
CH<sub>3</sub>CCH

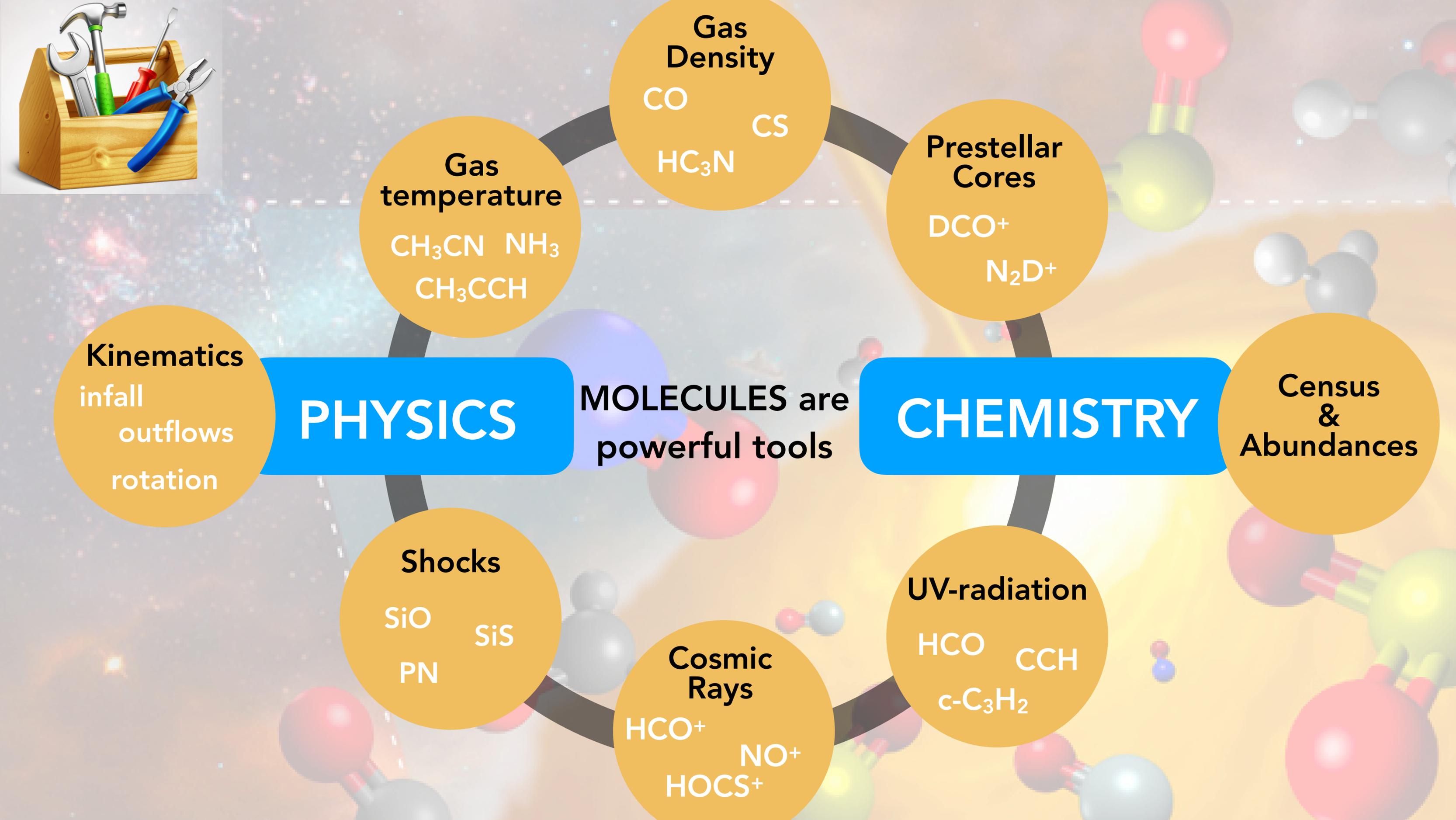
**Gas Density**  
CO CS  
HC<sub>3</sub>N

**Prestellar Cores**  
DCO<sup>+</sup>  
N<sub>2</sub>D<sup>+</sup>

**Shocks**  
SiO SiS  
PN

**Cosmic Rays**  
HCO<sup>+</sup> NO<sup>+</sup>  
HOCS<sup>+</sup>

**UV-radiation**  
HCO CCH  
c-C<sub>3</sub>H<sub>2</sub>



# 1937



**methylidyne (CH or C<sub>1</sub>H<sub>1</sub>)**  
(Swings & Rosenfeld 1937)

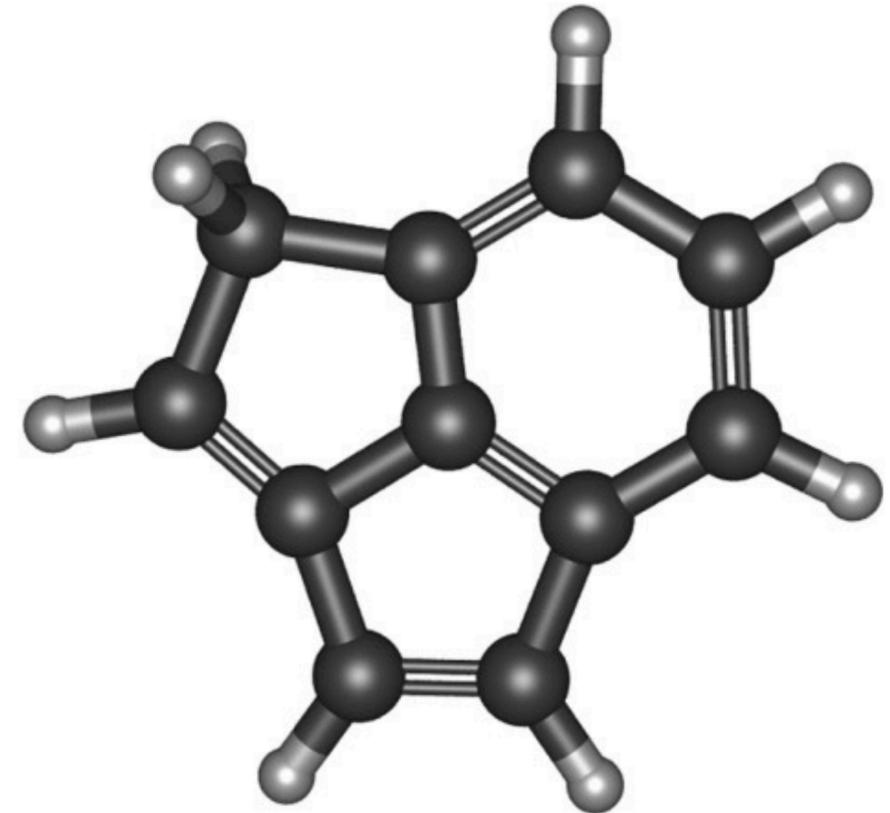
**1937**



**2026**



**methylidyne (CH or C<sub>1</sub>H<sub>1</sub>)**  
(Swings & Rosenfeld 1937)



**Cyclopentindene (c-C<sub>11</sub>H<sub>8</sub>)**  
Fuentetaja et al. (2026)

**CHEMICAL COMPLEXITY**



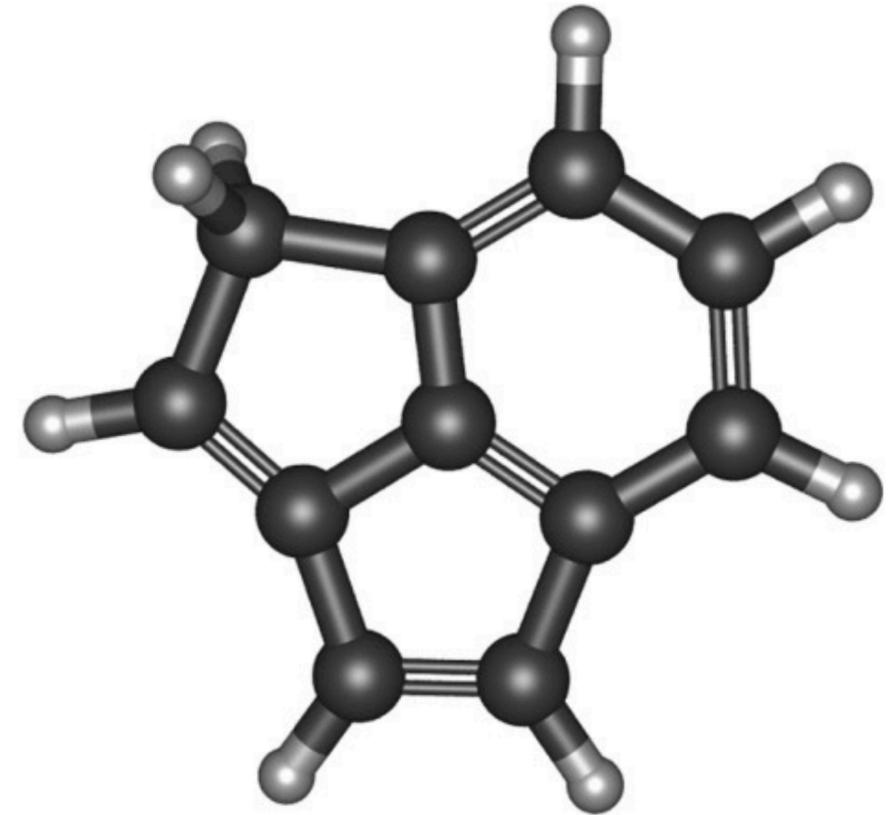
**1937**



**methylidyne (CH or C<sub>1</sub>H<sub>1</sub>)**  
(Swings & Rosenfeld 1937)



**2026**



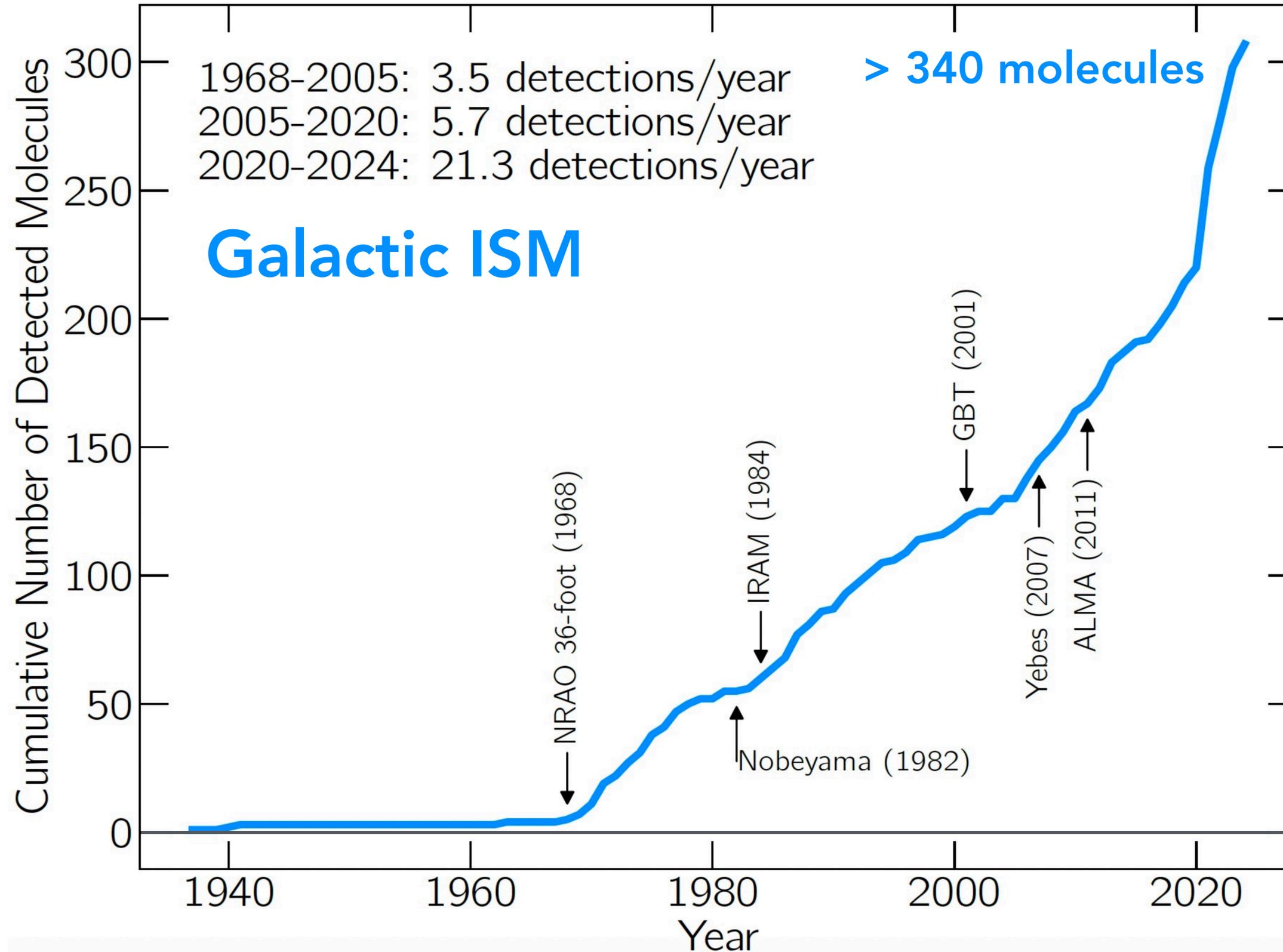
**Cyclopentindene (c-C<sub>11</sub>H<sub>8</sub>)**  
Fuentetaja et al. (2026)



**Cyanocoronene (c-C<sub>24</sub>H<sub>11</sub>CN)**  
Wenzel et al. (2025)

**CHEMICAL COMPLEXITY**

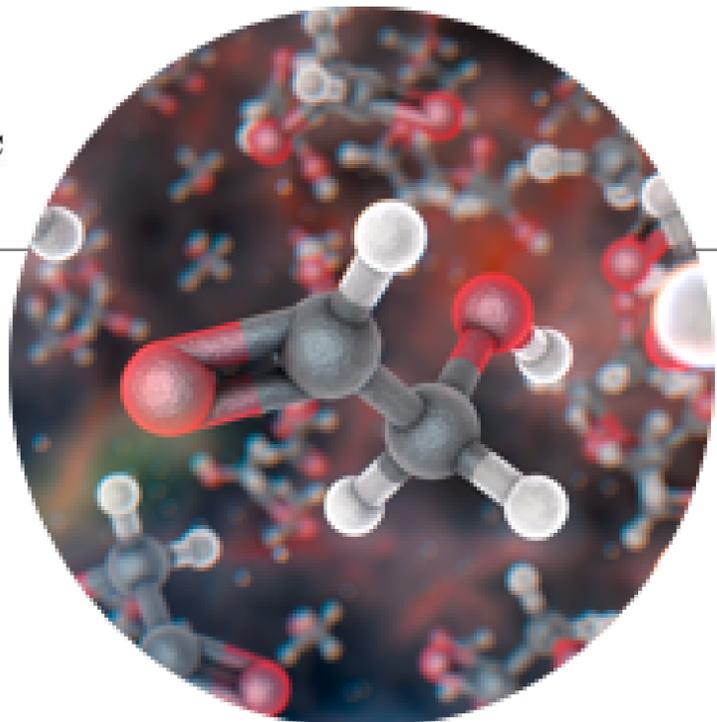




# CHEMICAL COMPLEXITY

2 Atoms		3 Atoms		4 Atoms		5 Atoms		6 Atoms		7 Atoms		8 Atoms		9 Atoms		10 Atoms		11 Atoms		12 Atoms		13 Atoms		PAHs	Fullerenes																																																																																																																																																																																																																																																																																																																																																																																																				
CH	NH	H <sub>2</sub> O	MgCN	NH <sub>3</sub>	SiC <sub>3</sub>	HC <sub>3</sub> N	C <sub>4</sub> H <sup>-</sup>	CH <sub>3</sub> OH	CH <sub>3</sub> CHO	HCOOCH <sub>3</sub>	CH <sub>3</sub> OCH <sub>3</sub>	CH <sub>3</sub> COCH <sub>3</sub>	HC <sub>9</sub> N	C <sub>6</sub> H <sub>6</sub>	C <sub>6</sub> H <sub>5</sub> CN	1-C <sub>10</sub> H <sub>7</sub> CN	C <sub>60</sub>	CN	SiN	HCO <sup>+</sup>	H <sub>3</sub> <sup>+</sup>	H <sub>2</sub> CO	CH <sub>3</sub>	HCOOH	CNCHO	CH <sub>3</sub> CN	CH <sub>3</sub> CCH	CH <sub>3</sub> C <sub>3</sub> N	CH <sub>3</sub> CH <sub>2</sub> OH	HOCH <sub>2</sub> CH <sub>2</sub> OH	CH <sub>3</sub> C <sub>6</sub> H	n-C <sub>3</sub> H <sub>7</sub> CN	HC <sub>11</sub> N	2-C <sub>10</sub> H <sub>7</sub> CN	C <sub>60</sub> <sup>+</sup>	CH <sup>+</sup>	SO <sup>+</sup>	HCN	SiCN	HNCO	C <sub>3</sub> N <sup>-</sup>	CH <sub>2</sub> NH	HNCNH	NH <sub>2</sub> CHO	CH <sub>3</sub> NH <sub>2</sub>	C <sub>7</sub> H	CH <sub>3</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> CHO	C <sub>2</sub> H <sub>5</sub> OCHO	i-C <sub>3</sub> H <sub>7</sub> CN		C <sub>9</sub> H <sub>8</sub>	C <sub>70</sub>	OH	CO <sup>+</sup>	OCS	AlNC	H <sub>2</sub> CS	PH <sub>3</sub>	NH <sub>2</sub> CN	CH <sub>3</sub> O	CH <sub>3</sub> SH	CH <sub>2</sub> CHCN	CH <sub>3</sub> COOH	HC <sub>7</sub> N	CH <sub>3</sub> C <sub>5</sub> N	CH <sub>3</sub> COOCH <sub>3</sub>	1-C <sub>5</sub> H <sub>5</sub> CN				CO	HF	HNC	SiNC	C <sub>2</sub> H <sub>2</sub>	HCNO	H <sub>2</sub> CCO	NH <sub>3</sub> D <sup>+</sup>	C <sub>2</sub> H <sub>4</sub>	HC <sub>5</sub> N	H <sub>2</sub> C <sub>6</sub>	CH <sub>3</sub> C <sub>4</sub> H	CH <sub>3</sub> CHCH <sub>2</sub> O	CH <sub>3</sub> COCH <sub>2</sub> OH	2-C <sub>5</sub> H <sub>5</sub> CN				H <sub>2</sub>	N <sub>2</sub>	H <sub>2</sub> S	HCP	C <sub>3</sub> N	HOCN	C <sub>4</sub> H	H <sub>2</sub> NCO <sup>+</sup>	C <sub>5</sub> H	C <sub>6</sub> H	HC <sub>6</sub> H	CH <sub>3</sub> CONH <sub>2</sub>		C <sub>5</sub> H <sub>6</sub>					SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH									
CN	SiN	HCO <sup>+</sup>	H <sub>3</sub> <sup>+</sup>	H <sub>2</sub> CO	CH <sub>3</sub>	HCOOH	CNCHO	CH <sub>3</sub> CN	CH <sub>3</sub> CCH	CH <sub>3</sub> C <sub>3</sub> N	CH <sub>3</sub> CH <sub>2</sub> OH	HOCH <sub>2</sub> CH <sub>2</sub> OH	CH <sub>3</sub> C <sub>6</sub> H	n-C <sub>3</sub> H <sub>7</sub> CN	HC <sub>11</sub> N	2-C <sub>10</sub> H <sub>7</sub> CN	C <sub>60</sub> <sup>+</sup>	CH <sup>+</sup>	SO <sup>+</sup>	HCN	SiCN	HNCO	C <sub>3</sub> N <sup>-</sup>	CH <sub>2</sub> NH	HNCNH	NH <sub>2</sub> CHO	CH <sub>3</sub> NH <sub>2</sub>	C <sub>7</sub> H	CH <sub>3</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> CHO	C <sub>2</sub> H <sub>5</sub> OCHO	i-C <sub>3</sub> H <sub>7</sub> CN		C <sub>9</sub> H <sub>8</sub>	C <sub>70</sub>	OH	CO <sup>+</sup>	OCS	AlNC	H <sub>2</sub> CS	PH <sub>3</sub>	NH <sub>2</sub> CN	CH <sub>3</sub> O	CH <sub>3</sub> SH	CH <sub>2</sub> CHCN	CH <sub>3</sub> COOH	HC <sub>7</sub> N	CH <sub>3</sub> C <sub>5</sub> N	CH <sub>3</sub> COOCH <sub>3</sub>	1-C <sub>5</sub> H <sub>5</sub> CN				CO	HF	HNC	SiNC	C <sub>2</sub> H <sub>2</sub>	HCNO	H <sub>2</sub> CCO	NH <sub>3</sub> D <sup>+</sup>	C <sub>2</sub> H <sub>4</sub>	HC <sub>5</sub> N	H <sub>2</sub> C <sub>6</sub>	CH <sub>3</sub> C <sub>4</sub> H	CH <sub>3</sub> CHCH <sub>2</sub> O	CH <sub>3</sub> COCH <sub>2</sub> OH	2-C <sub>5</sub> H <sub>5</sub> CN				H <sub>2</sub>	N <sub>2</sub>	H <sub>2</sub> S	HCP	C <sub>3</sub> N	HOCN	C <sub>4</sub> H	H <sub>2</sub> NCO <sup>+</sup>	C <sub>5</sub> H	C <sub>6</sub> H	HC <sub>6</sub> H	CH <sub>3</sub> CONH <sub>2</sub>		C <sub>5</sub> H <sub>6</sub>					SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																											
CH <sup>+</sup>	SO <sup>+</sup>	HCN	SiCN	HNCO	C <sub>3</sub> N <sup>-</sup>	CH <sub>2</sub> NH	HNCNH	NH <sub>2</sub> CHO	CH <sub>3</sub> NH <sub>2</sub>	C <sub>7</sub> H	CH <sub>3</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> CHO	C <sub>2</sub> H <sub>5</sub> OCHO	i-C <sub>3</sub> H <sub>7</sub> CN		C <sub>9</sub> H <sub>8</sub>	C <sub>70</sub>	OH	CO <sup>+</sup>	OCS	AlNC	H <sub>2</sub> CS	PH <sub>3</sub>	NH <sub>2</sub> CN	CH <sub>3</sub> O	CH <sub>3</sub> SH	CH <sub>2</sub> CHCN	CH <sub>3</sub> COOH	HC <sub>7</sub> N	CH <sub>3</sub> C <sub>5</sub> N	CH <sub>3</sub> COOCH <sub>3</sub>	1-C <sub>5</sub> H <sub>5</sub> CN				CO	HF	HNC	SiNC	C <sub>2</sub> H <sub>2</sub>	HCNO	H <sub>2</sub> CCO	NH <sub>3</sub> D <sup>+</sup>	C <sub>2</sub> H <sub>4</sub>	HC <sub>5</sub> N	H <sub>2</sub> C <sub>6</sub>	CH <sub>3</sub> C <sub>4</sub> H	CH <sub>3</sub> CHCH <sub>2</sub> O	CH <sub>3</sub> COCH <sub>2</sub> OH	2-C <sub>5</sub> H <sub>5</sub> CN				H <sub>2</sub>	N <sub>2</sub>	H <sub>2</sub> S	HCP	C <sub>3</sub> N	HOCN	C <sub>4</sub> H	H <sub>2</sub> NCO <sup>+</sup>	C <sub>5</sub> H	C <sub>6</sub> H	HC <sub>6</sub> H	CH <sub>3</sub> CONH <sub>2</sub>		C <sub>5</sub> H <sub>6</sub>					SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																													
OH	CO <sup>+</sup>	OCS	AlNC	H <sub>2</sub> CS	PH <sub>3</sub>	NH <sub>2</sub> CN	CH <sub>3</sub> O	CH <sub>3</sub> SH	CH <sub>2</sub> CHCN	CH <sub>3</sub> COOH	HC <sub>7</sub> N	CH <sub>3</sub> C <sub>5</sub> N	CH <sub>3</sub> COOCH <sub>3</sub>	1-C <sub>5</sub> H <sub>5</sub> CN				CO	HF	HNC	SiNC	C <sub>2</sub> H <sub>2</sub>	HCNO	H <sub>2</sub> CCO	NH <sub>3</sub> D <sup>+</sup>	C <sub>2</sub> H <sub>4</sub>	HC <sub>5</sub> N	H <sub>2</sub> C <sub>6</sub>	CH <sub>3</sub> C <sub>4</sub> H	CH <sub>3</sub> CHCH <sub>2</sub> O	CH <sub>3</sub> COCH <sub>2</sub> OH	2-C <sub>5</sub> H <sub>5</sub> CN				H <sub>2</sub>	N <sub>2</sub>	H <sub>2</sub> S	HCP	C <sub>3</sub> N	HOCN	C <sub>4</sub> H	H <sub>2</sub> NCO <sup>+</sup>	C <sub>5</sub> H	C <sub>6</sub> H	HC <sub>6</sub> H	CH <sub>3</sub> CONH <sub>2</sub>		C <sub>5</sub> H <sub>6</sub>					SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																															
CO	HF	HNC	SiNC	C <sub>2</sub> H <sub>2</sub>	HCNO	H <sub>2</sub> CCO	NH <sub>3</sub> D <sup>+</sup>	C <sub>2</sub> H <sub>4</sub>	HC <sub>5</sub> N	H <sub>2</sub> C <sub>6</sub>	CH <sub>3</sub> C <sub>4</sub> H	CH <sub>3</sub> CHCH <sub>2</sub> O	CH <sub>3</sub> COCH <sub>2</sub> OH	2-C <sub>5</sub> H <sub>5</sub> CN				H <sub>2</sub>	N <sub>2</sub>	H <sub>2</sub> S	HCP	C <sub>3</sub> N	HOCN	C <sub>4</sub> H	H <sub>2</sub> NCO <sup>+</sup>	C <sub>5</sub> H	C <sub>6</sub> H	HC <sub>6</sub> H	CH <sub>3</sub> CONH <sub>2</sub>		C <sub>5</sub> H <sub>6</sub>					SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																	
H <sub>2</sub>	N <sub>2</sub>	H <sub>2</sub> S	HCP	C <sub>3</sub> N	HOCN	C <sub>4</sub> H	H <sub>2</sub> NCO <sup>+</sup>	C <sub>5</sub> H	C <sub>6</sub> H	HC <sub>6</sub> H	CH <sub>3</sub> CONH <sub>2</sub>		C <sub>5</sub> H <sub>6</sub>					SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																			
SiO	CF <sup>+</sup>	N <sub>2</sub> H <sup>+</sup>	CCP	HNCS	HSCN	SiH <sub>4</sub>	NCCNH <sup>+</sup>	CH <sub>3</sub> NC	c-C <sub>2</sub> H <sub>4</sub> O	CH <sub>2</sub> CHCHO	C <sub>8</sub> H <sup>-</sup>							CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																					
CS	PO	C <sub>2</sub> H	AlOH	HOCO <sup>+</sup>	HOOH	c-C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> Cl	HC <sub>2</sub> CHO	CH <sub>2</sub> CHOH	CH <sub>2</sub> CCHCN	CH <sub>2</sub> CHCH <sub>3</sub>							SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																							
SO	O <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> O <sup>+</sup>	C <sub>3</sub> O	l-C <sub>3</sub> H <sup>+</sup>	CH <sub>2</sub> CN	MgC <sub>3</sub> N	H <sub>2</sub> C <sub>4</sub>	C <sub>6</sub> H <sup>-</sup>	NH <sub>2</sub> CH <sub>2</sub> CN	CH <sub>3</sub> CH <sub>2</sub> SH							SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																									
SiS	AlO	HCO	H <sub>2</sub> Cl <sup>+</sup>	l-C <sub>3</sub> H	HMgNC	C <sub>5</sub>	HC <sub>3</sub> O <sup>+</sup>	C <sub>5</sub> S	CH <sub>3</sub> NCO	CH <sub>3</sub> CHNH	HC <sub>7</sub> O							NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																											
NS	CN <sup>-</sup>	HNO	KCN	HCNH <sup>+</sup>	HCCO	SiC <sub>4</sub>	NH <sub>2</sub> OH	HC <sub>3</sub> NH <sup>+</sup>	HC <sub>5</sub> O	CH <sub>3</sub> SiH <sub>3</sub>	CH <sub>3</sub> NHCHO							C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																													
C <sub>2</sub>	OH <sup>+</sup>	HCS <sup>+</sup>	FeCN	H <sub>3</sub> O <sup>+</sup>	CNCN	H <sub>2</sub> CCC	HC <sub>3</sub> S <sup>+</sup>	C <sub>5</sub> N	HOCH <sub>2</sub> CN	NH <sub>2</sub> CONH <sub>2</sub>	H <sub>2</sub> CCCHCCH							NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																															
NO	SH <sup>+</sup>	HOC <sup>+</sup>	HO <sub>2</sub>	C <sub>3</sub> S	HONO	CH <sub>4</sub>	H <sub>2</sub> CCS	HC <sub>4</sub> H	HC <sub>4</sub> NC	HCCCH <sub>2</sub> CN	HCCCHCHCN							HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																																																	
HCl	HCl <sup>+</sup>	SiC <sub>2</sub>	TiO <sub>2</sub>	c-C <sub>3</sub> H	MgCCH	HCCNC	C <sub>4</sub> S	HC <sub>4</sub> N	HC <sub>3</sub> HNH	CH <sub>2</sub> CHCCH	H <sub>2</sub> CCHC <sub>3</sub> N							NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																																																																			
NaCl	SH	C <sub>2</sub> S	CCN	HC <sub>2</sub> N	HCCS	HNCCC	CHOSH	c-H <sub>2</sub> C <sub>3</sub> O	c-C <sub>3</sub> HCCH									AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																																																																																					
AlCl	TiO	C <sub>3</sub>	SiCSi	H <sub>2</sub> CN		H <sub>2</sub> COH <sup>+</sup>		CH <sub>2</sub> CNH										KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																																																																																																							
KCl	ArH <sup>+</sup>	CO <sub>2</sub>	S <sub>2</sub> H					C <sub>5</sub> N <sup>-</sup>										AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																																																																																																																									
AlF	NS <sup>+</sup>	CH <sub>2</sub>	HCS					HNCHCN										PN	HeH <sup>+</sup>	C <sub>2</sub> O	HSC					SiH <sub>3</sub> CN										SiC	VO	MgNC	NCO					MgC <sub>4</sub> H										CP		NH <sub>2</sub>	CaNC					CH <sub>3</sub> CO <sup>+</sup>												NaCN	NCS					H <sub>2</sub> CCCS												N <sub>2</sub> O						CH <sub>2</sub> CCH																																																																																																																																																																																																																																																																																																																											
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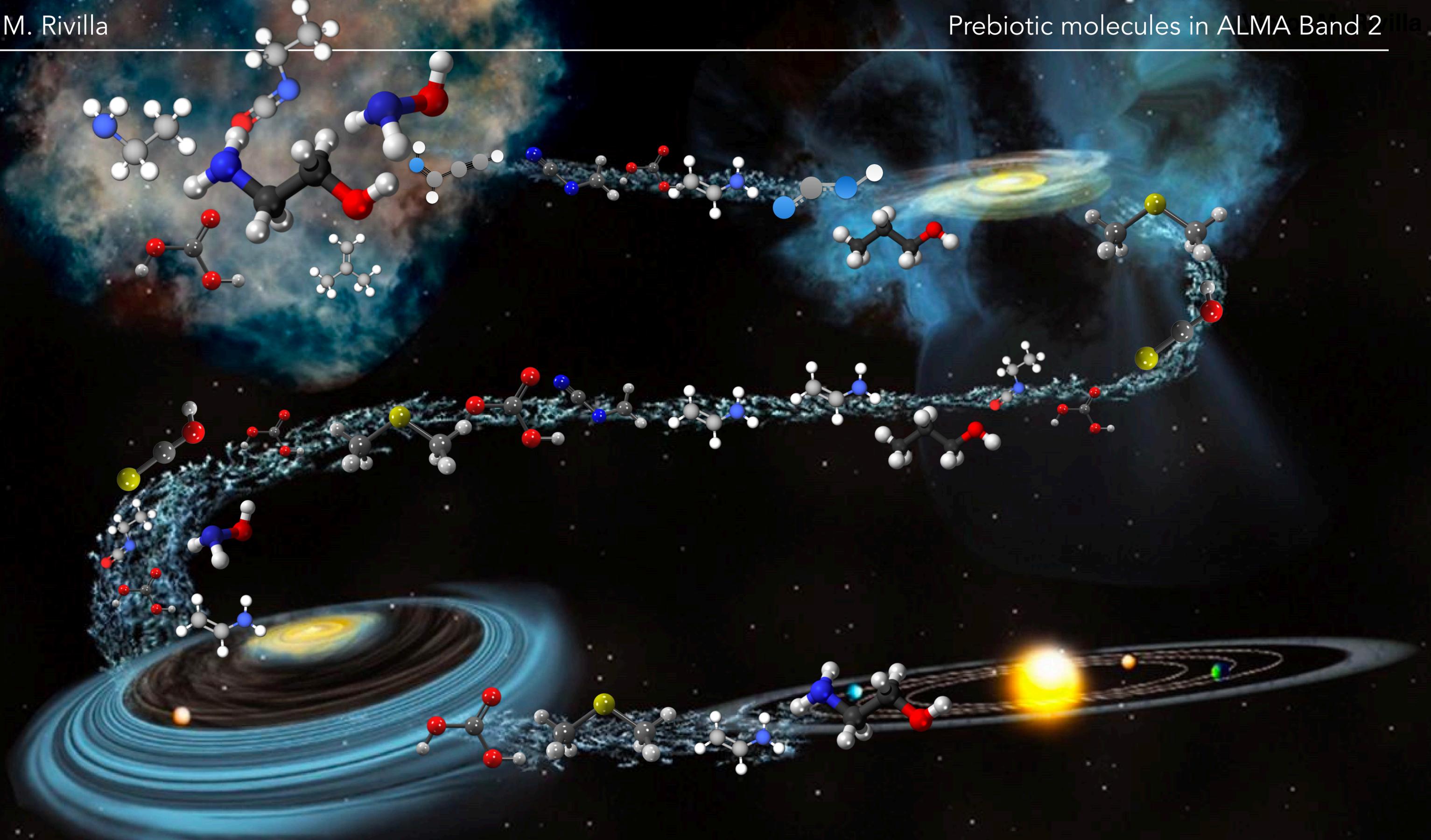
McGuire et al. (2022)



> 340 molecules

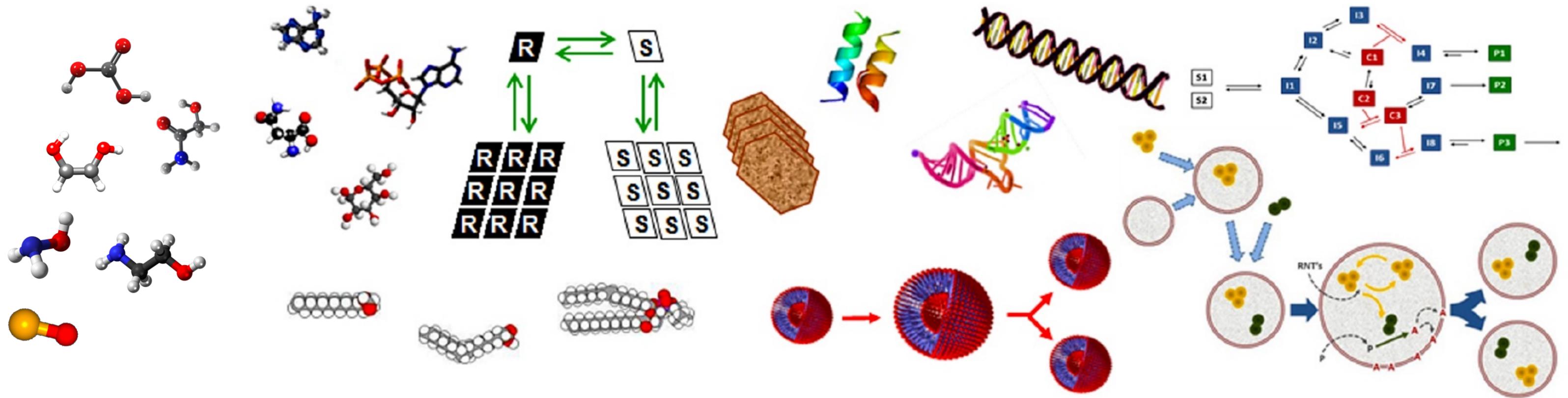
From 2021 ....

>100 new species



# Ingredients for life

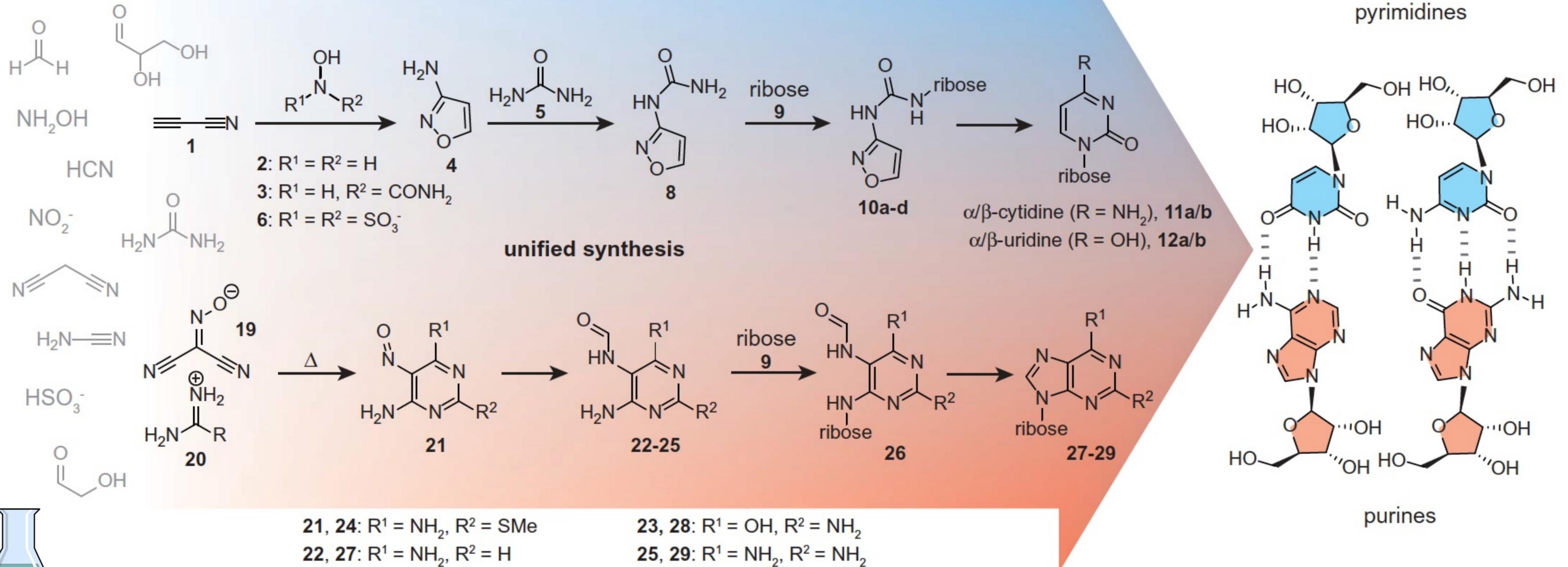
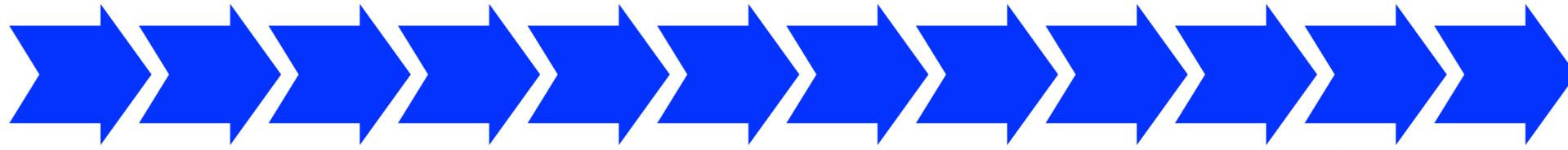
## CHEMICAL COMPLEXITY



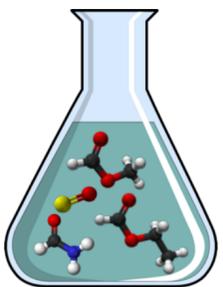
Ruiz-Mirazo et al. (2014)

Molecular Precursors

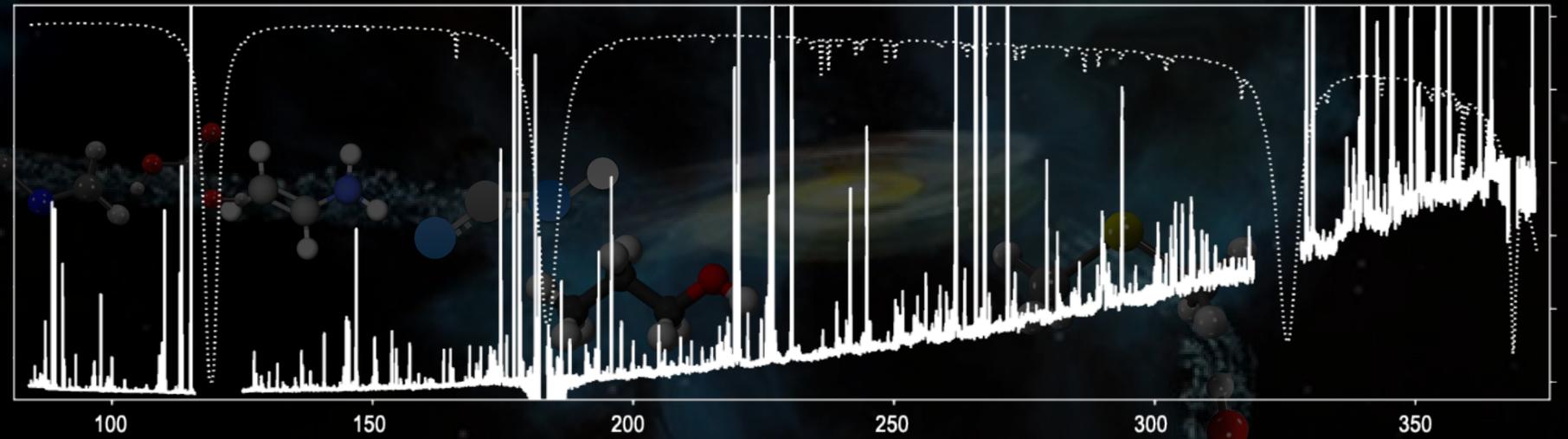
RNA nucleotides



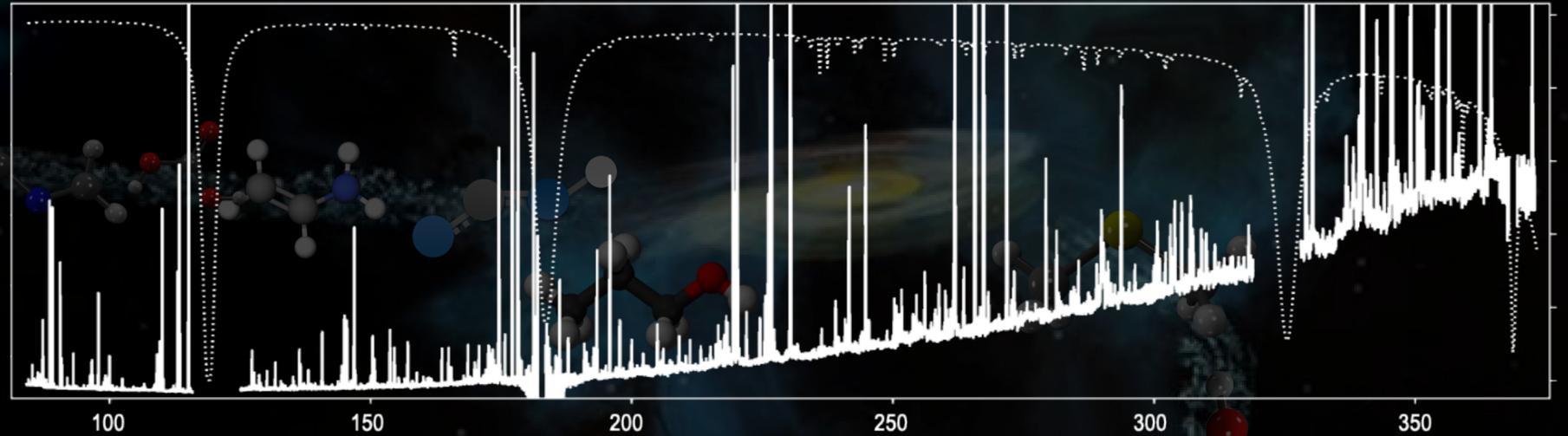
Becker et al., Science (2019)



# Deep unbiased broadband spectral surveys



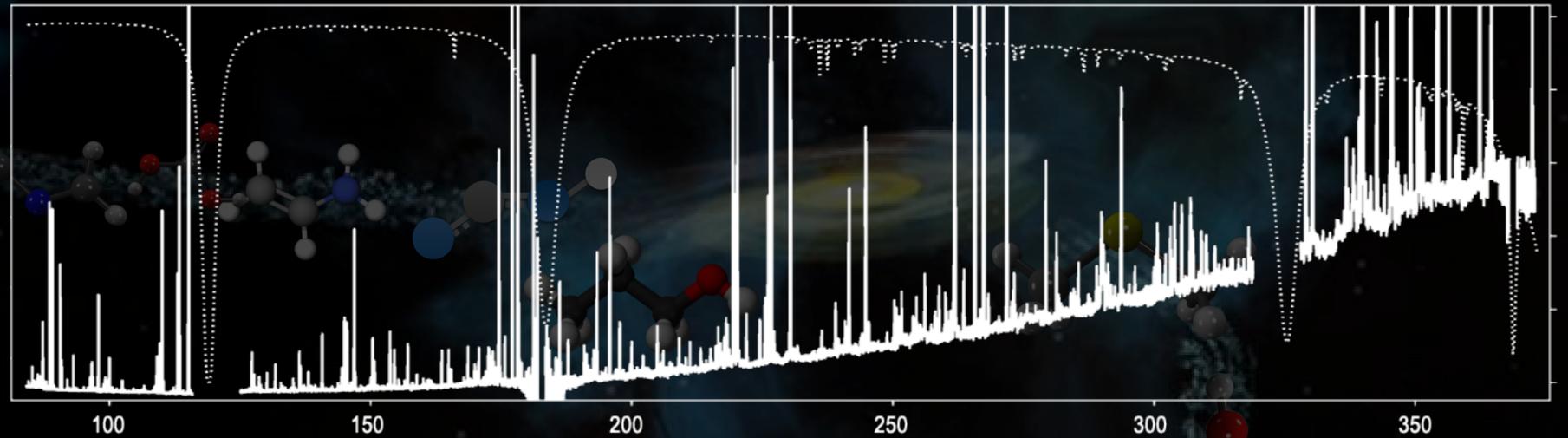
# Deep unbiased broadband spectral surveys



## Large spectral coverage

- Many molecules
- Many transitions
- Solid identification
- Excitation  $\rightarrow N \rightarrow$  abundances

# Deep unbiased broadband spectral surveys



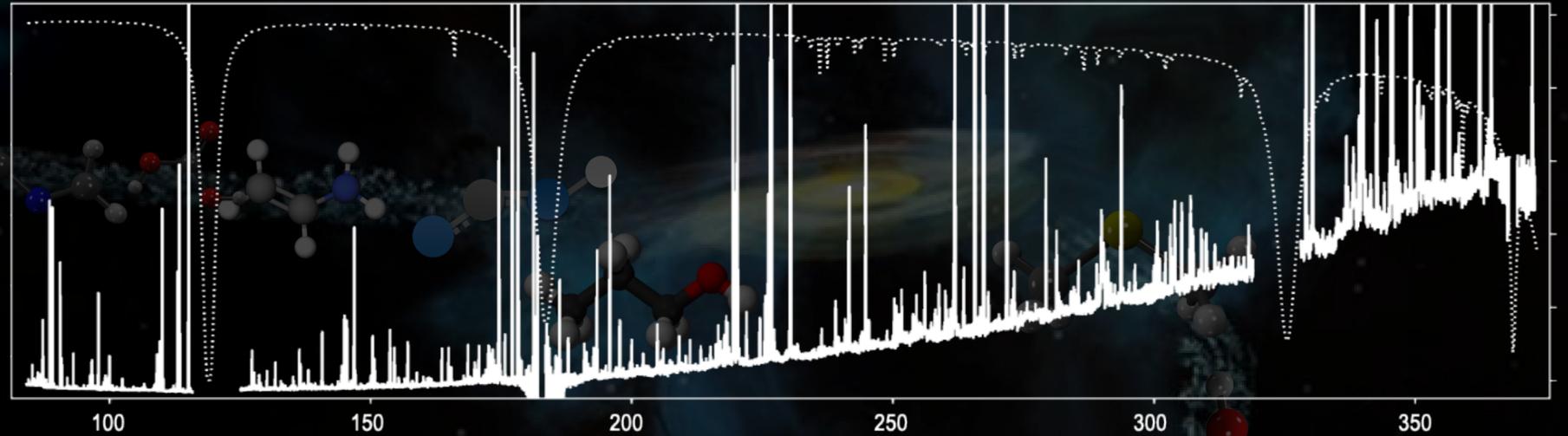
## Large spectral coverage

- Many molecules
- Many transitions
- Solid identification
- Excitation  $\rightarrow N \rightarrow$  abundances

## High Sensitivity

- Weak transitions of low-abundant species
- Increasing molecular complexity
- Isotopologues (double!)

# Deep unbiased broadband spectral surveys

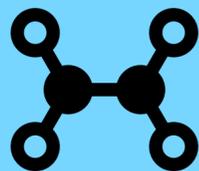


## Large spectral coverage

- Many molecules
- Many transitions
- Solid identification
- Excitation  $\rightarrow N \rightarrow$  abundances

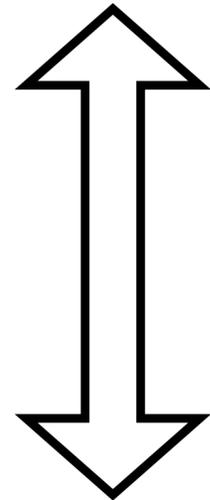
## High Sensitivity

- Weak transitions of low-abundant species.
- Increasing molecular complexity.
- Isotopologues (double!)

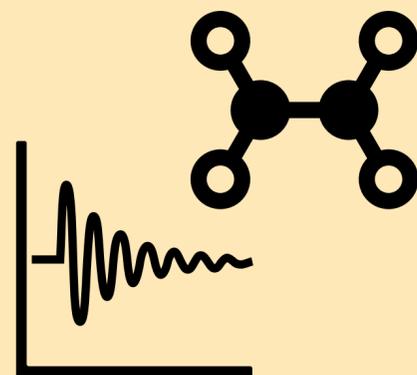


- Large sample of molecules
- Homogeneous datasets
- New interstellar molecules

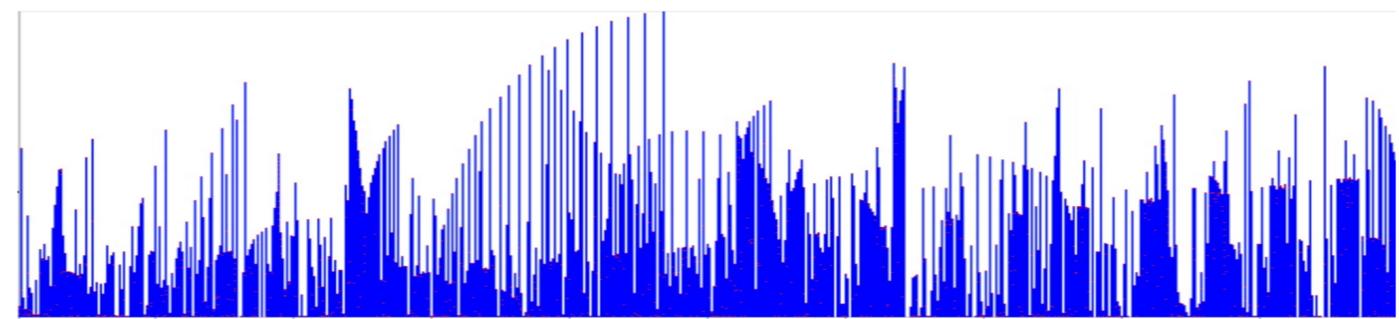
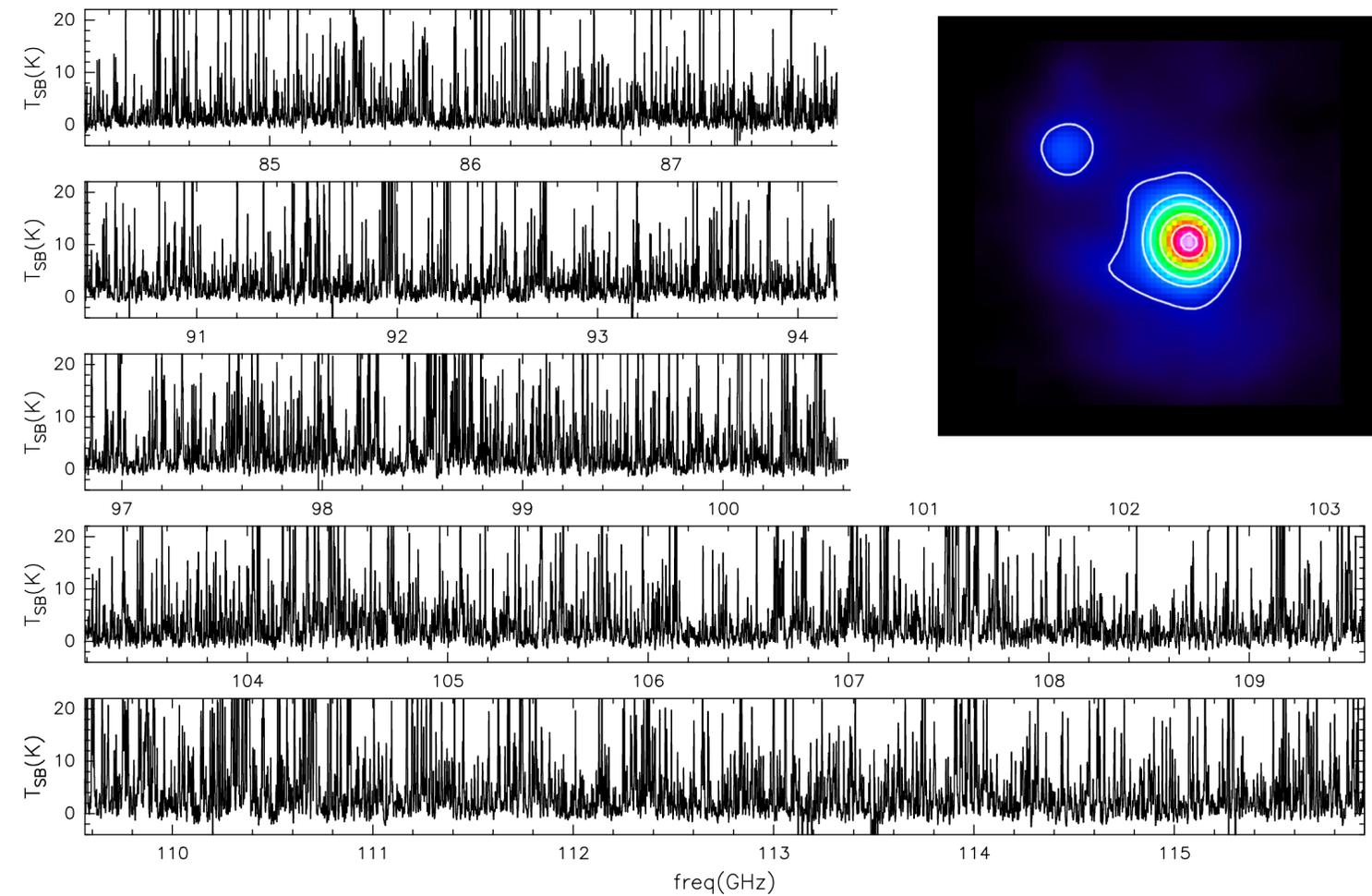
**ULTRADEEP  
ASTRONOMICAL  
OBSERVATIONS**

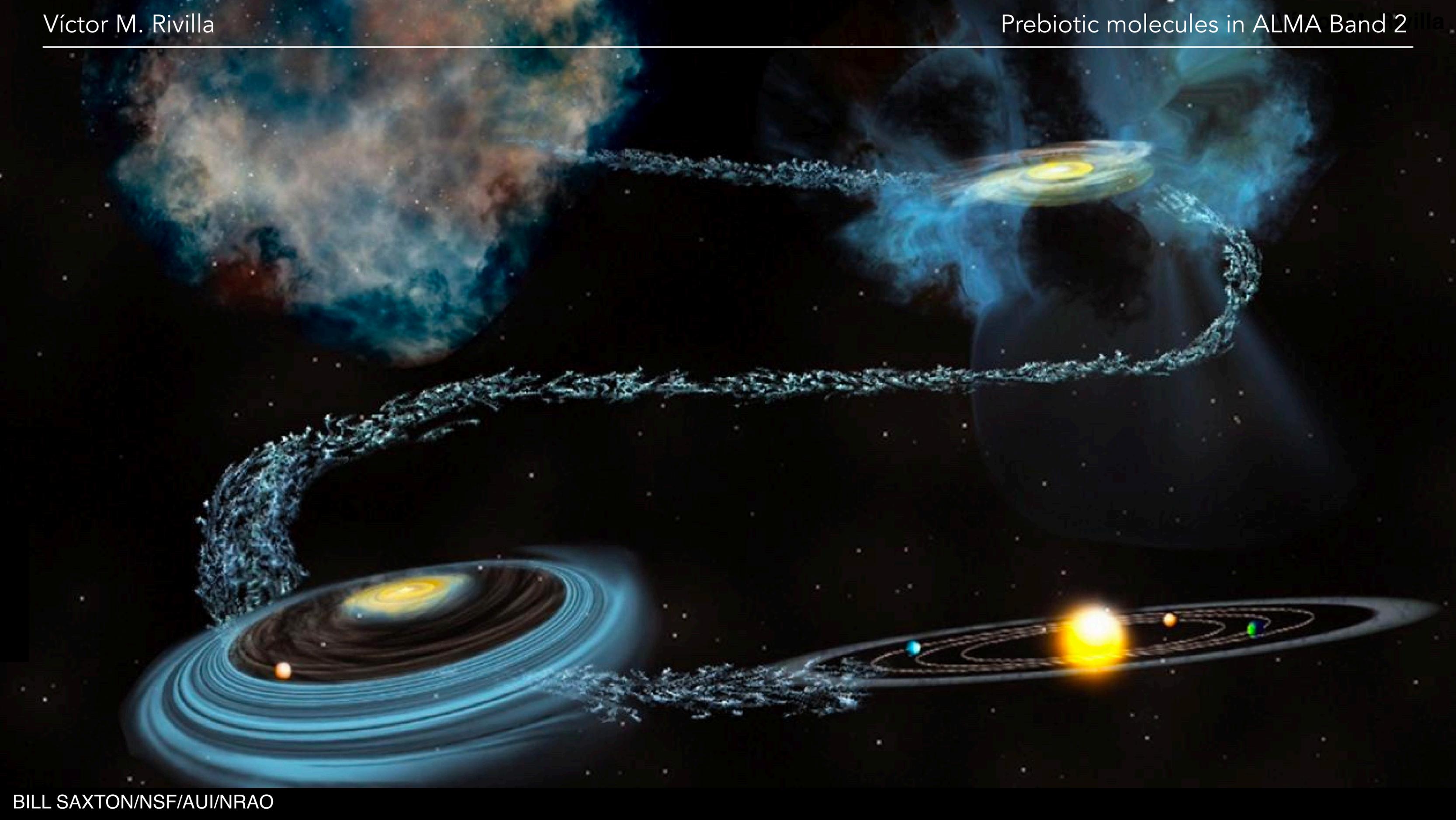


**MOLECULAR  
SPECTROSCOPY  
IN THE LAB**



GUAPOS: G31.41+0.31 Unbiased ALMA sPectral Observational Survey





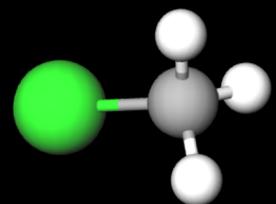
# Star-forming regions



Hot cores/corinos

# Well "known" astrochemical star-forming regions: hot cores/corinos

## IRAS 16293-2422



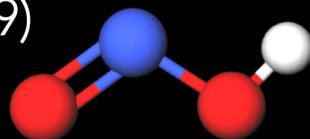
Fayolle et al. (2017)

Methyl chloride



Coutens et al. (2019)

Nitrous acid



Zeng et al. (2019)

Glycolonitrile

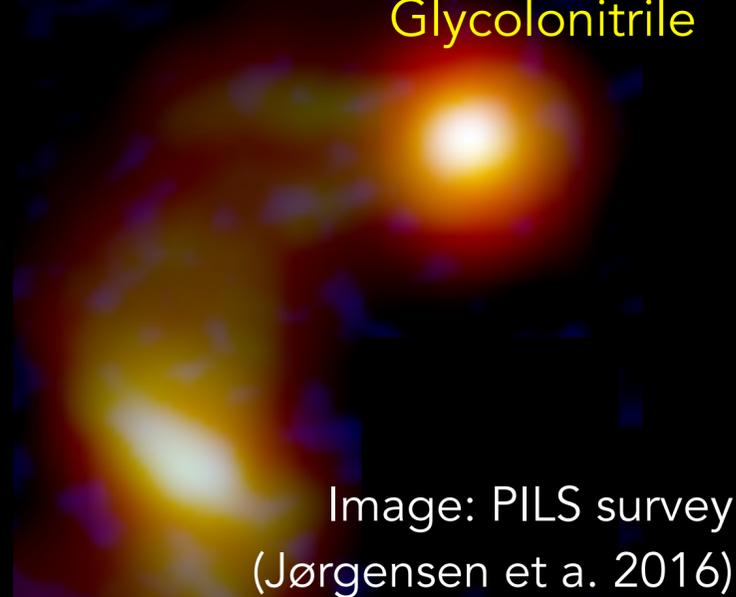
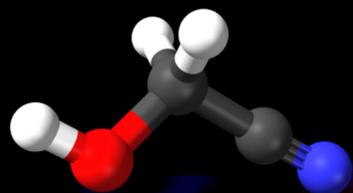
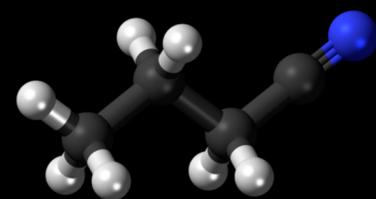


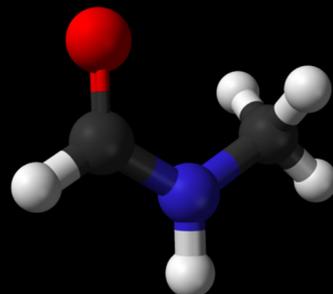
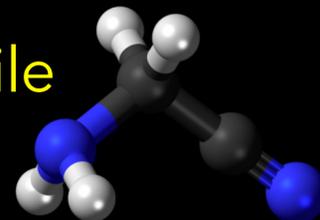
Image: PILS survey (Jørgensen et al. 2016)

## Sgr B2(N)



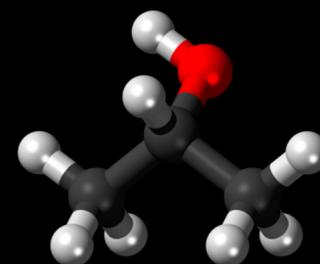
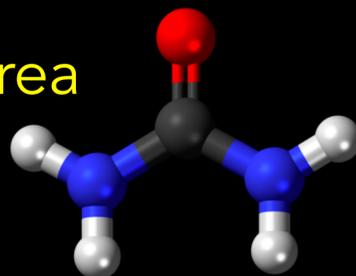
Propylcyanide

Aminoacetonitrile



N-Methyl formamide

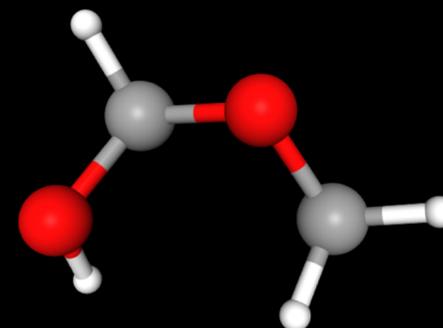
Urea



i-propanol

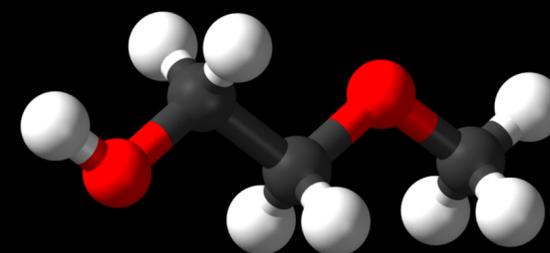
eMoCA & ReMoCA survey (Belloche et al.)

## NGC 6334I



Methoxymethanol

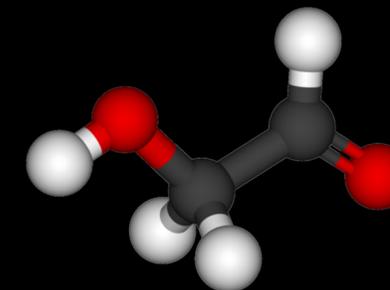
McGuire et al. (2017)



Methoxyethanol

Fried et al. (2024)

## G31.41+0.41



Glycolaldehyde<sup>(\*)</sup>

Beltrán et al. (2009)



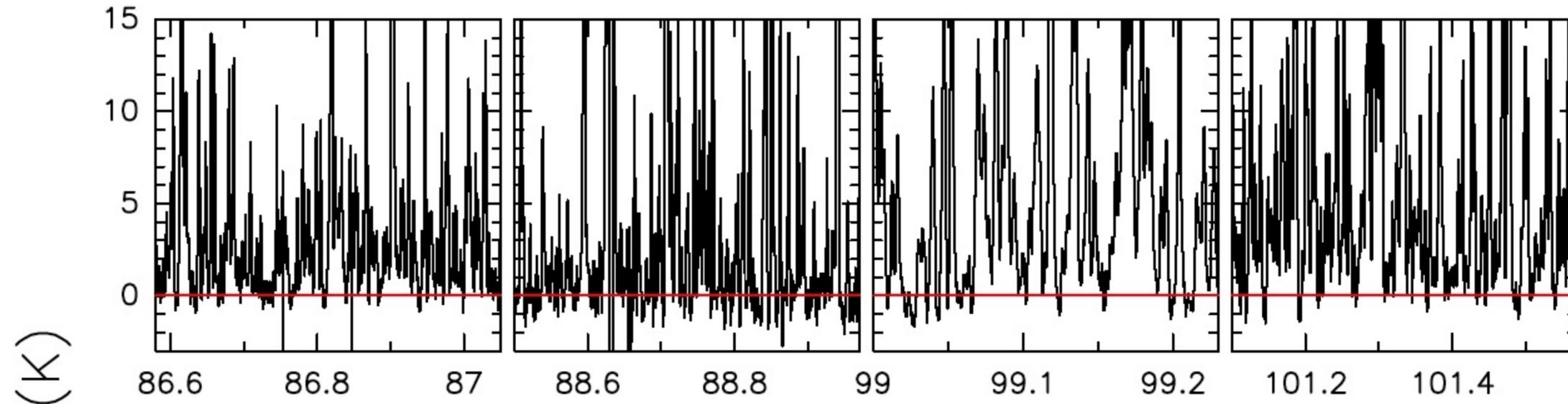
Minninni et al. 2020, 2023,  
Colzi et al. 2021,  
Fontani et al. 2024,  
López-Gallifa et al. 2024, 2025,  
Cesaroni et al. (2026).



# Line confusion



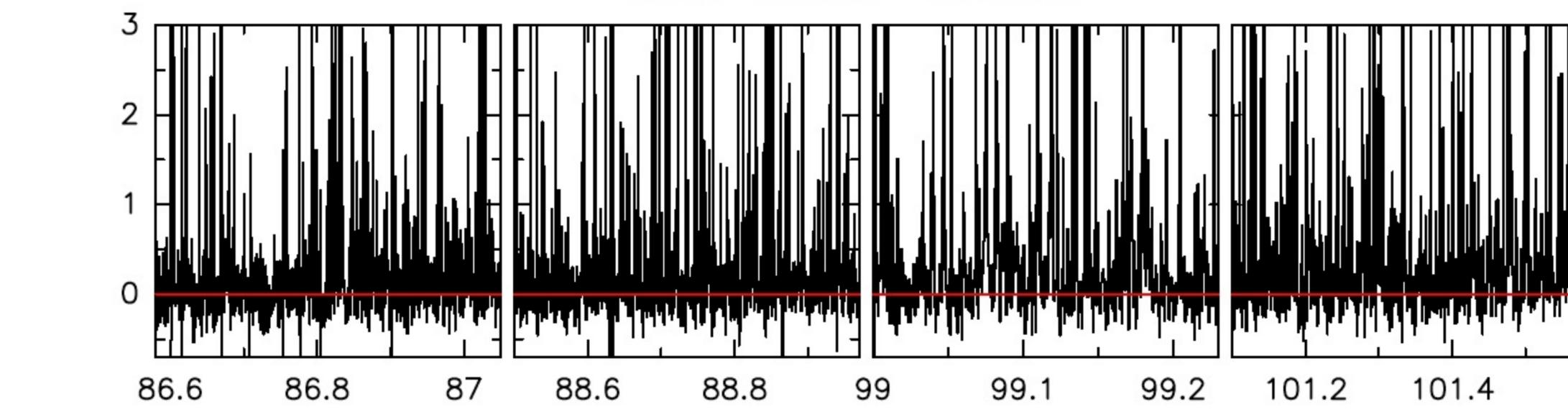
G31.41+0.31



High-mass  
star-forming region



IRAS 16293-2422 B



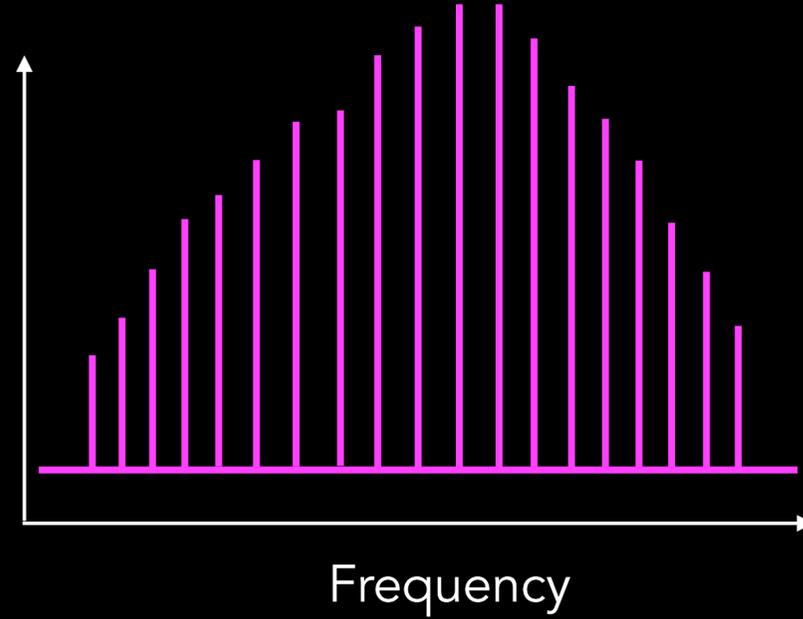
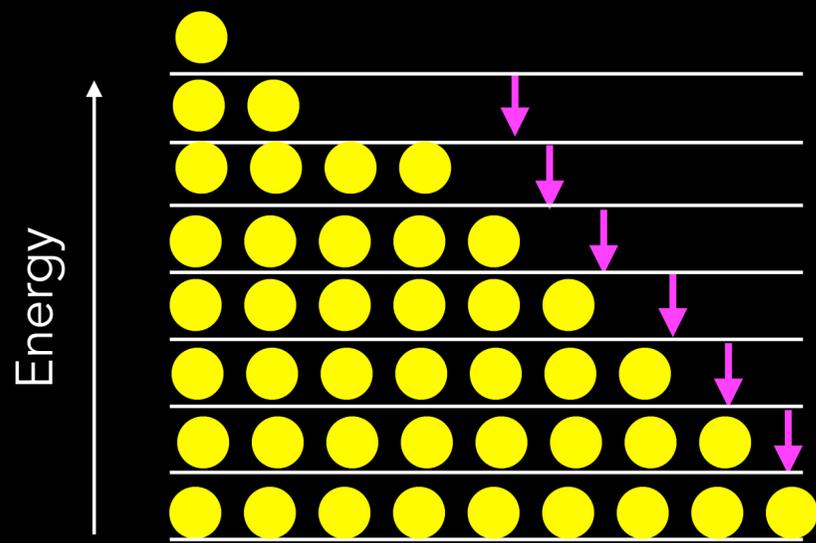
Low-mass  
star-forming region

Frequency (GHz)

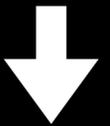
ALMA data



Hot regions  
( $T_{\text{ex}} > 100 \text{ K}$ )



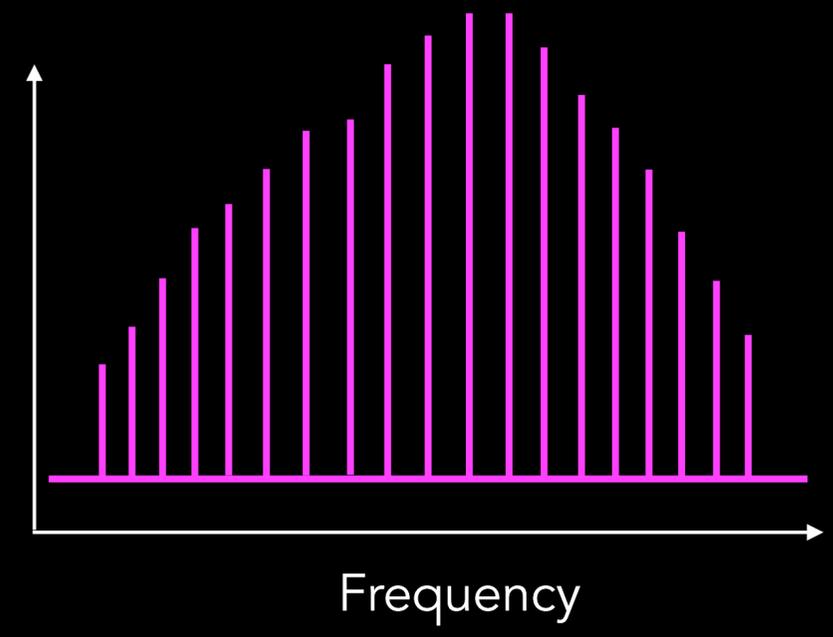
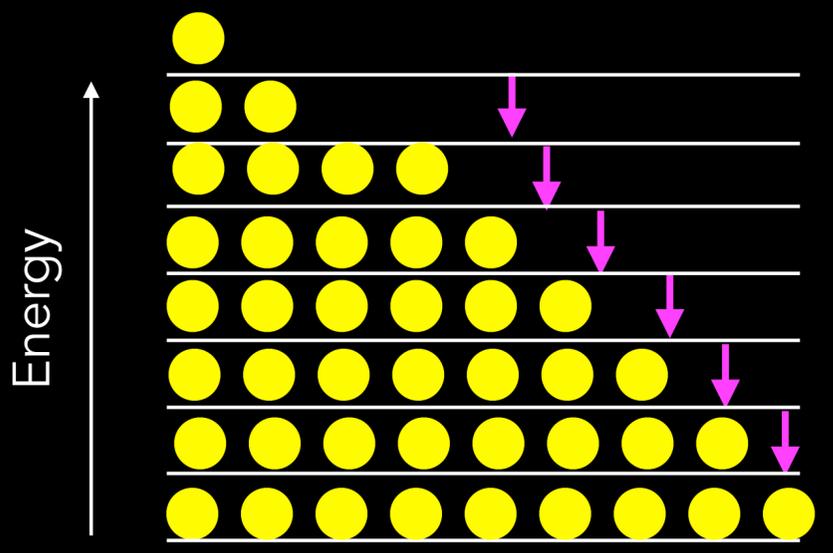
Crowded spectra



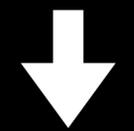
Line confusion



Hot regions  
( $T_{\text{ex}} > 100 \text{ K}$ )



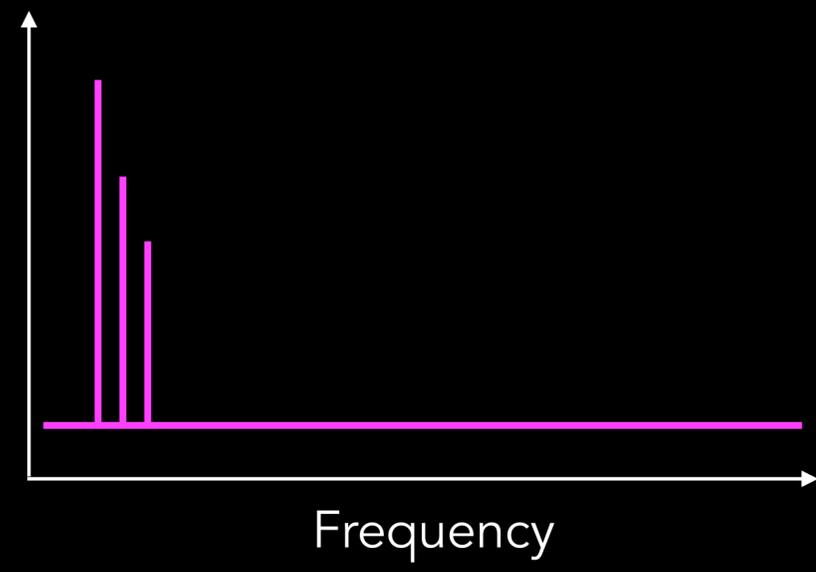
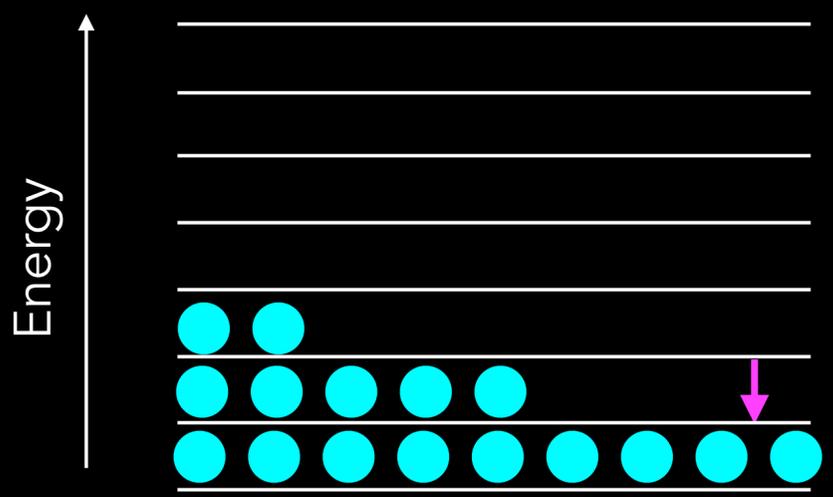
Crowded spectra



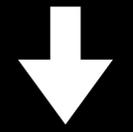
Line confusion



Regions with  
 $T_{\text{ex}} < 20 \text{ K}$



"Cleaner" spectra



**IDENTIFICATION  
OF NEW  
MOLECULES**



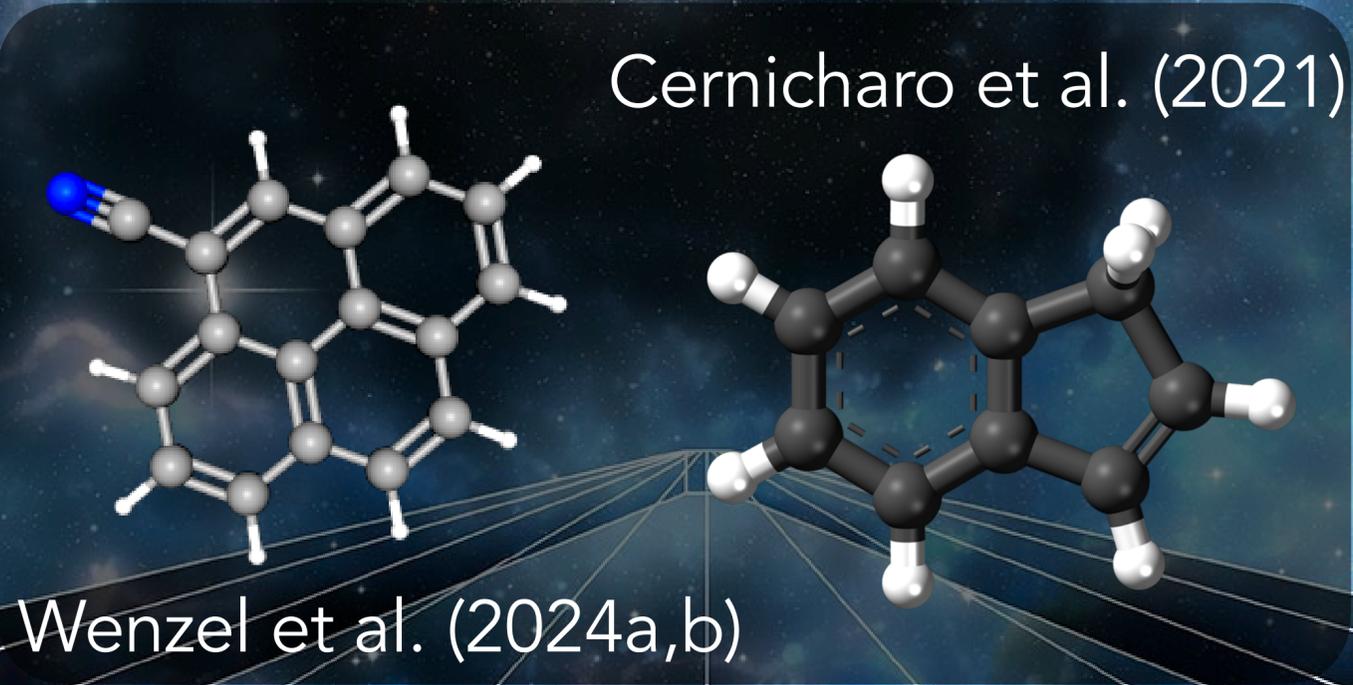
# Cold molecular clouds

## TMC-1

GOTHAM  
McGuire et al.

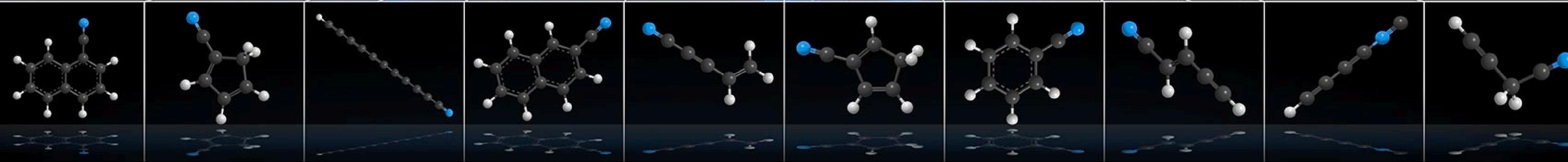


Cernicharo et al. (2021)



Wenzel et al. (2024a,b)

QUIJOTE  
Cernicharo et al.





**G+0.693-0.027**  
**molecular cloud**



**The Central Molecular Zone (CMZ) of the Galaxy**

Credit: Ian Heywood (Oxford U.), SARA0 / Juan Carlos Muñoz-Mateos (ESO)

# The G+0.693-0.027 molecular cloud

G+0.693-0.027

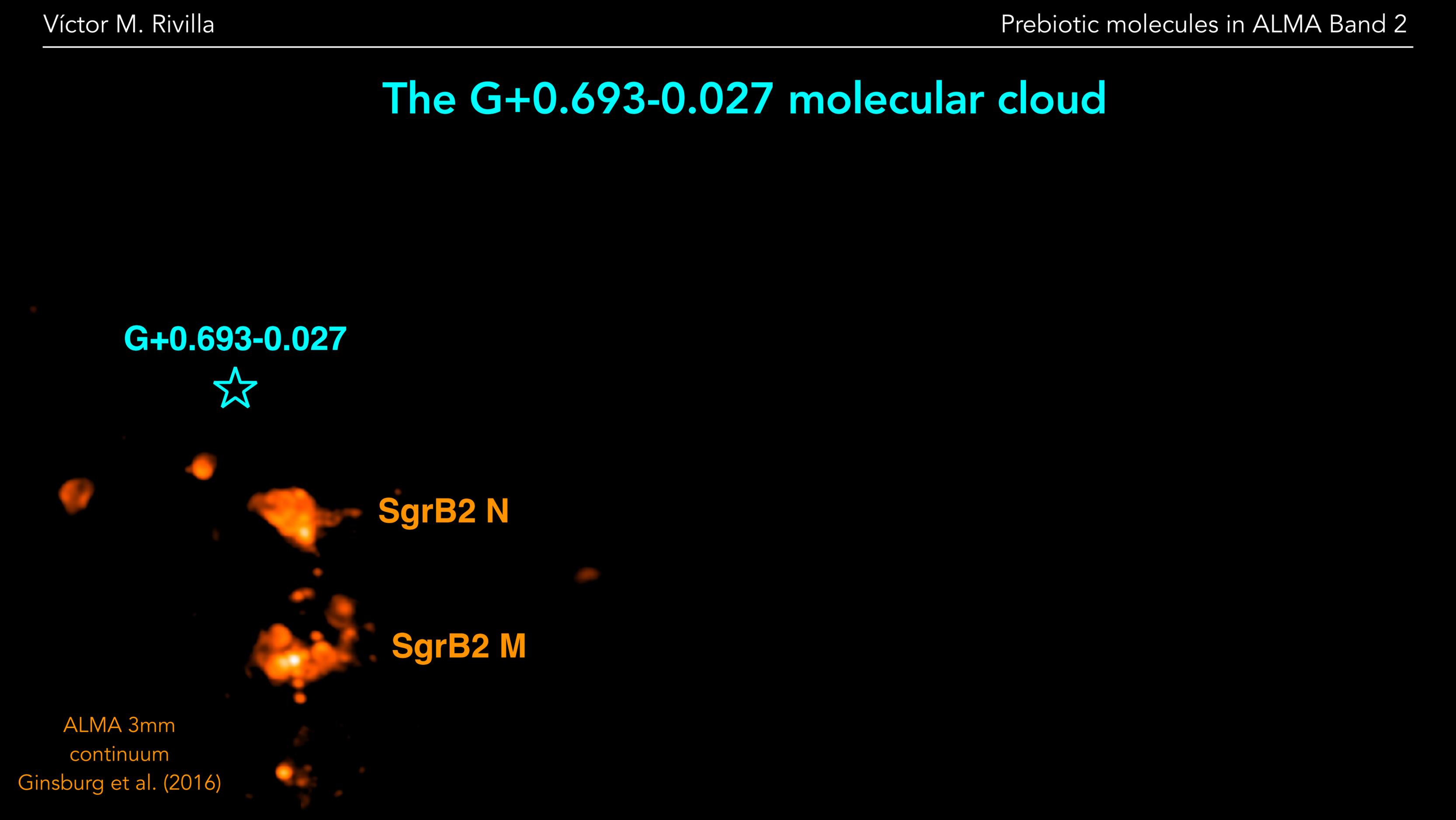


SgrB2 N

SgrB2 M

ALMA 3mm  
continuum

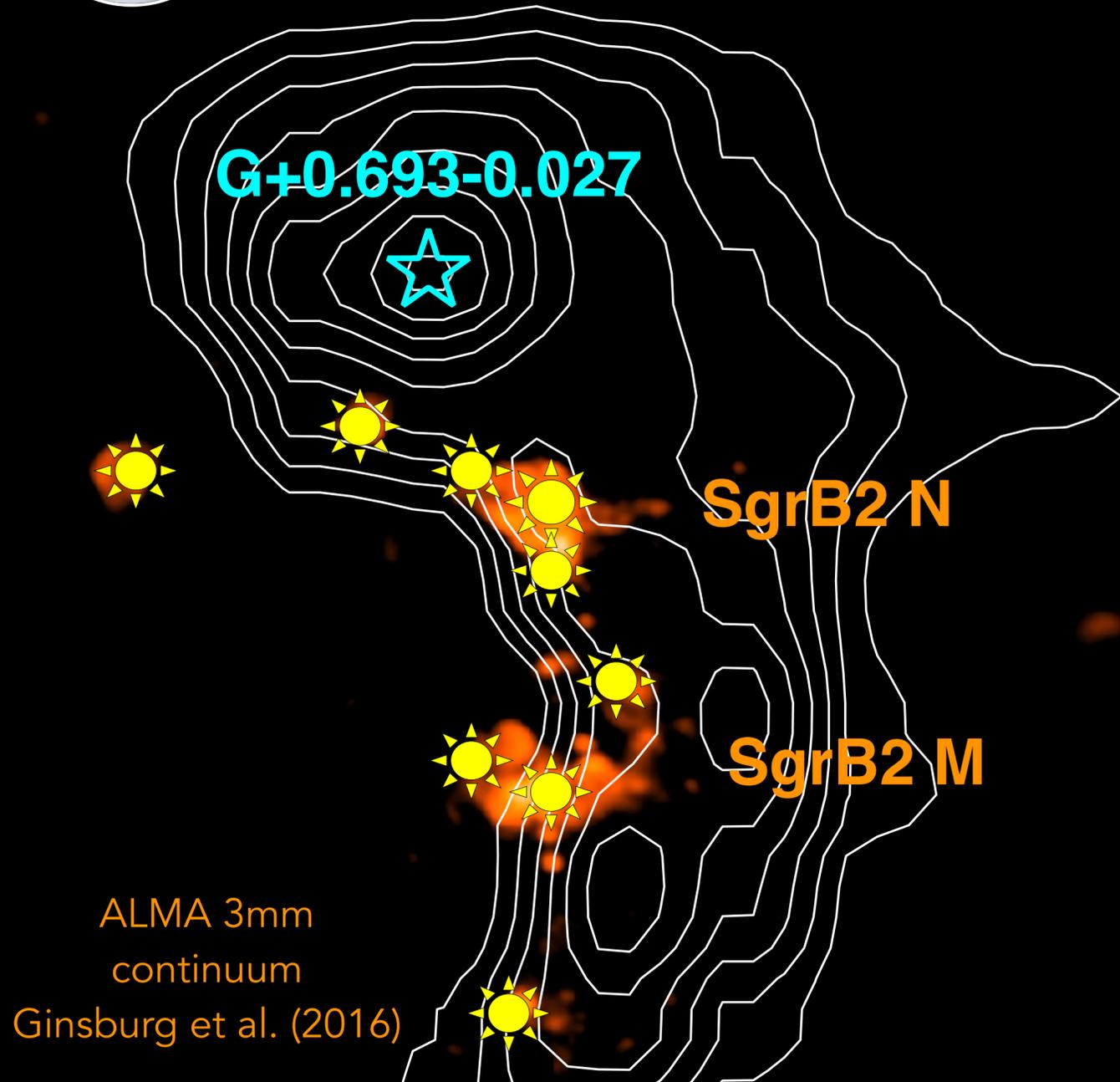
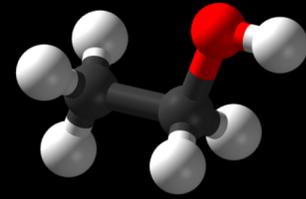
Ginsburg et al. (2016)



# The G+0.693-0.027 molecular cloud



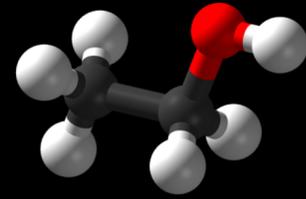
Ethanol  
(CH<sub>3</sub>CH<sub>2</sub>OH)



# The G+0.693-0.027 molecular cloud



Ethanol  
(CH<sub>3</sub>CH<sub>2</sub>OH)



- No signposts of ongoing star formation (yet)  
 → prestellar cluster candidate (Colzi et al. 2022,2024)

G+0.693-0.027

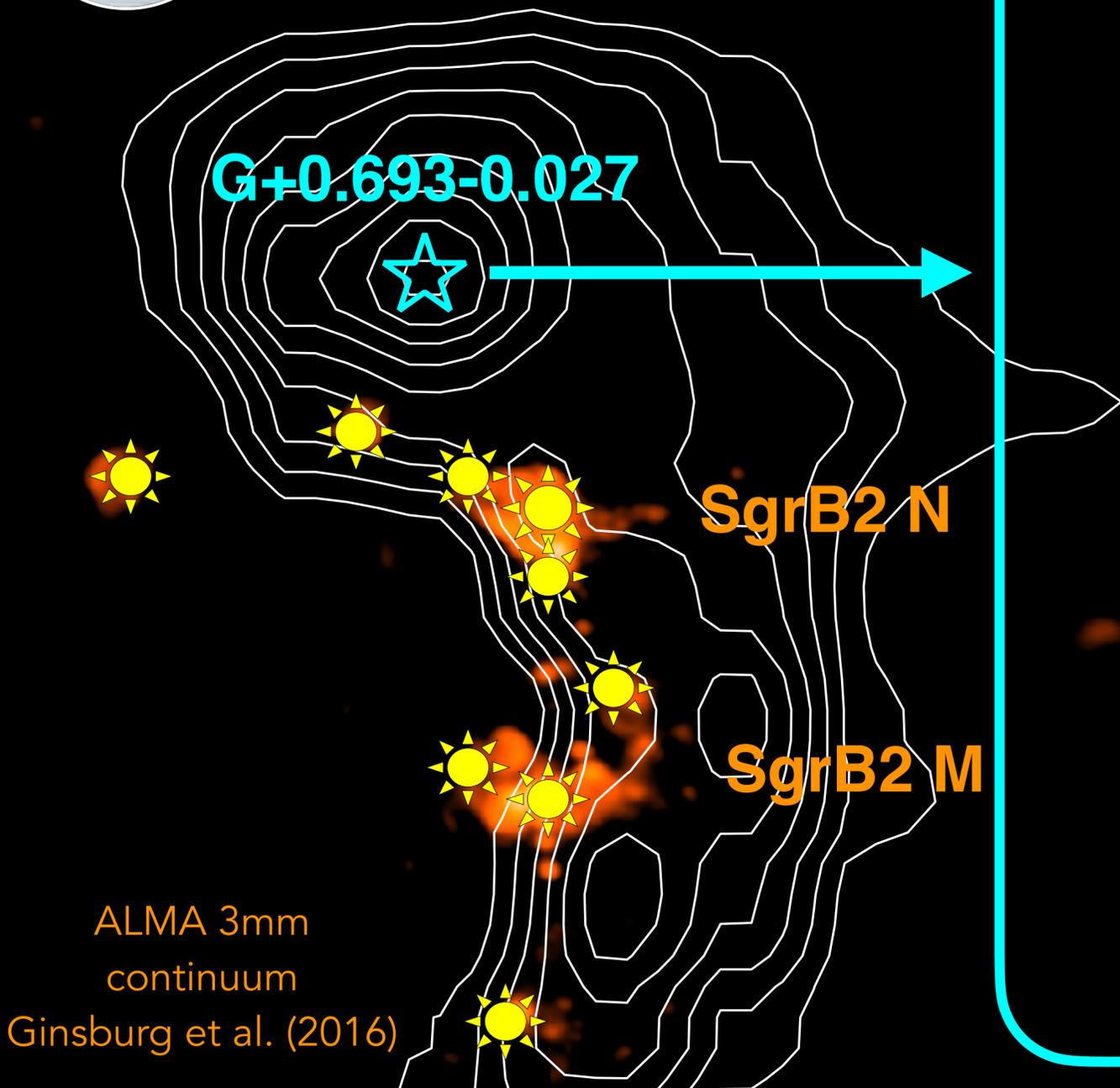


SgrB2 N

SgrB2 M

ALMA 3mm  
continuum

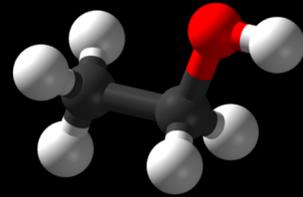
Ginsburg et al. (2016)



# The G+0.693-0.027 molecular cloud



Ethanol  
(CH<sub>3</sub>CH<sub>2</sub>OH)



G+0.693-0.027



SgrB2 N

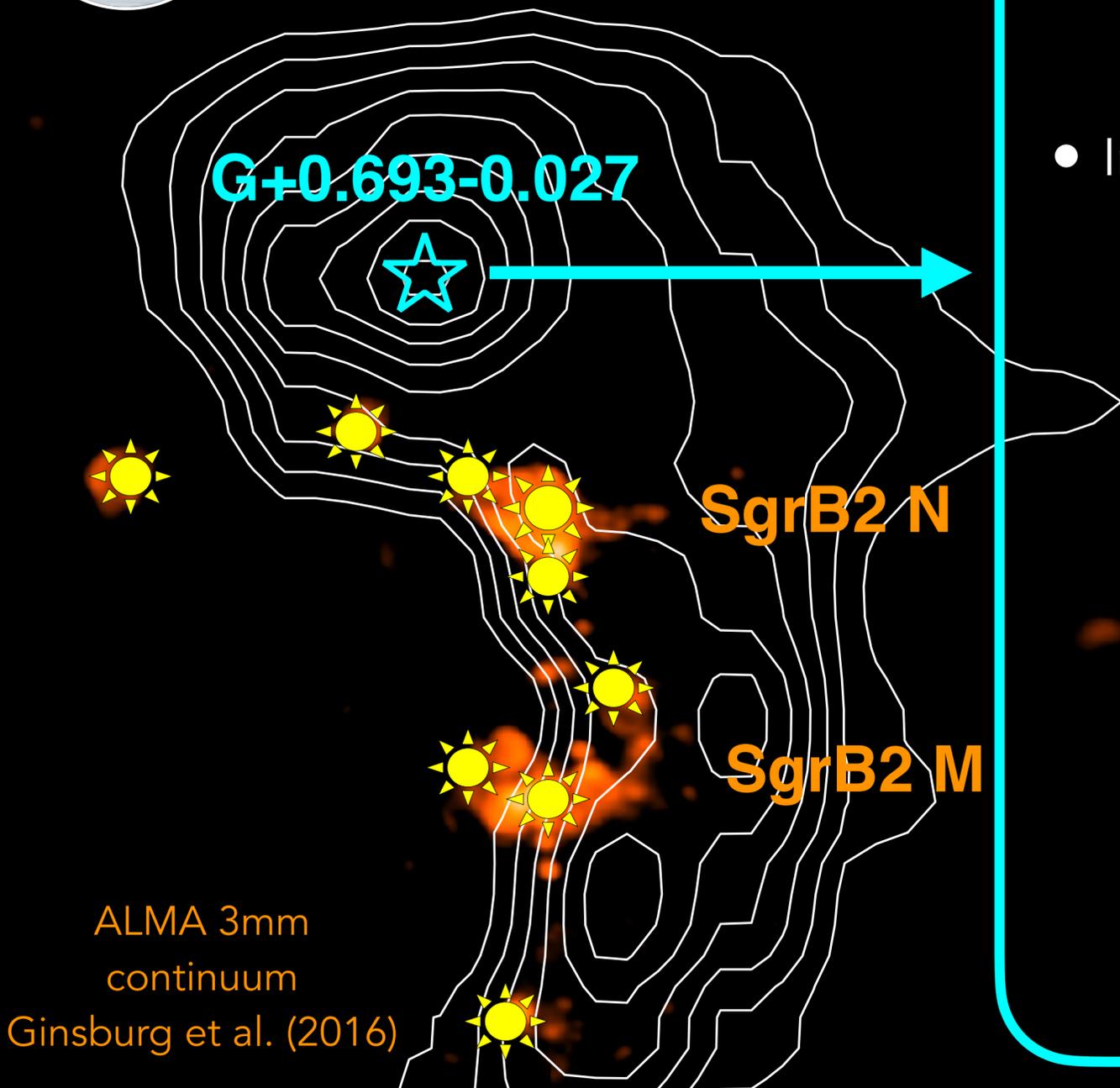
SgrB2 M

- No signposts of ongoing star formation (yet)
  - ➔ prestellar cluster candidate (Colzi et al. 2022,2024)
- Intermediate densities  $n(\text{H}_2) \sim 10^4\text{-}10^5 \text{ cm}^{-3}$  (Zeng et al. 2020, Colzi et al. 2024)
  - ➔ sub-thermal molecular excitation
  - ➔ low excitation temperatures  $T_{\text{ex}} = 5\text{-}20 \text{ K} \ll T_{\text{kin}} \sim 100 \text{ K}$

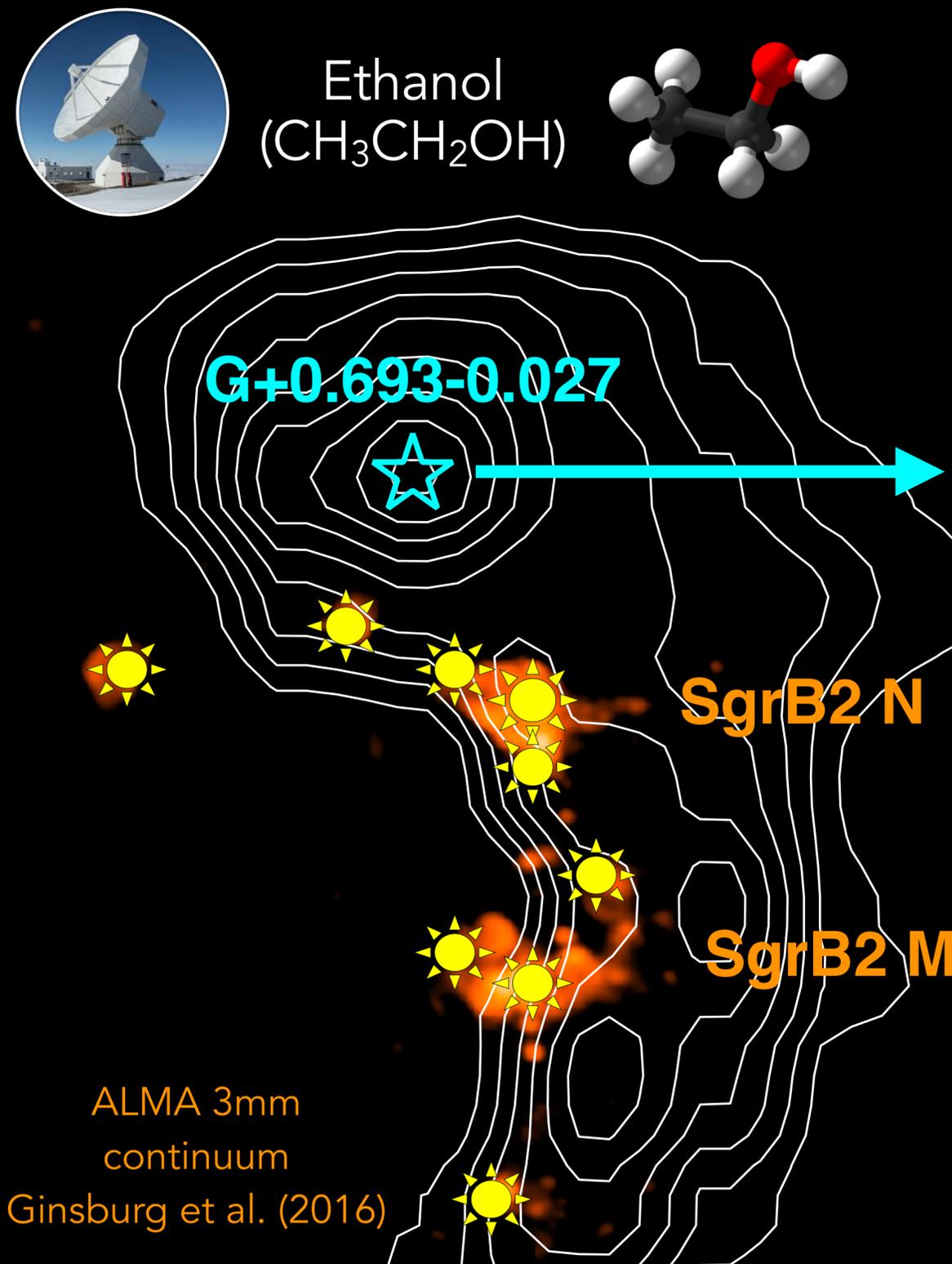


ALMA 3mm  
continuum

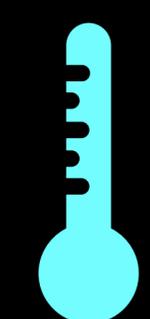
Ginsburg et al. (2016)



# The G+0.693-0.027 molecular cloud



- No signposts of ongoing star formation (yet)
  - ➔ prestellar cluster candidate (Colzi et al. 2022,2024)
- Intermediate densities  $n(\text{H}_2) \sim 10^4\text{-}10^5 \text{ cm}^{-3}$  (Zeng et al. 2020, Colzi et al. 2024)
  - ➔ sub-thermal molecular excitation
  - ➔ low excitation temperatures  $T_{\text{ex}} = 5\text{-}20 \text{ K} \ll T_{\text{kin}} \sim 100 \text{ K}$



Only low  $E_{\text{up}}$  transitions are excited



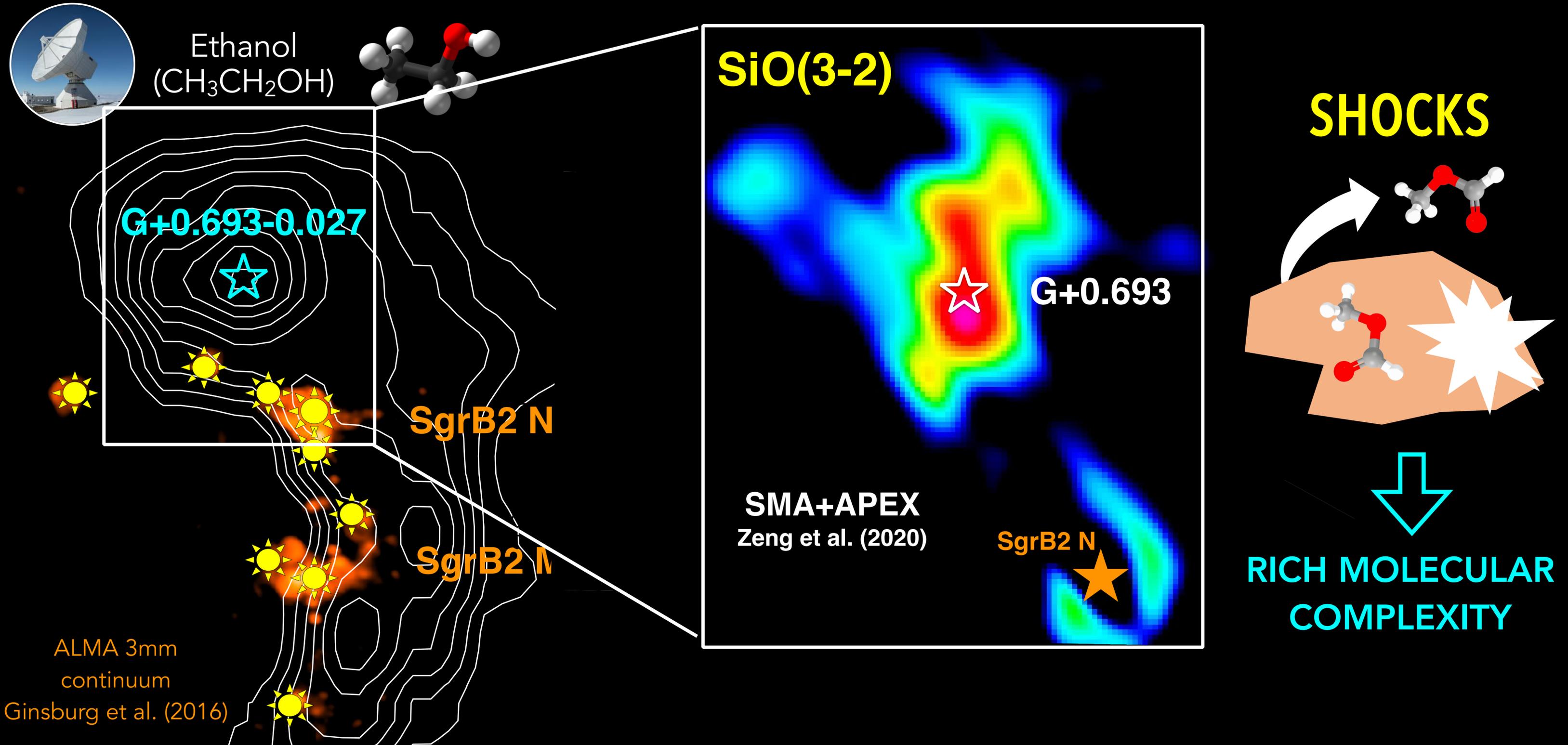
Spectrum much less crowded, with less line contamination



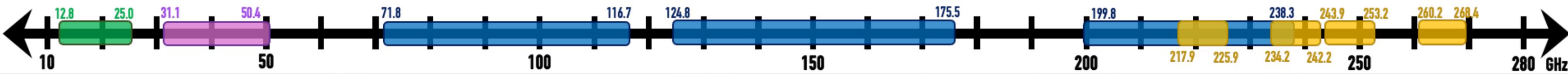
Identification of new species

ALMA 3mm continuum  
Ginsburg et al. (2016)

# The G+0.693-0.027 molecular cloud



# Ultrasensitive broadband spectral survey towards G+0.693-0.027



GBT 100m  
(West Virginia)



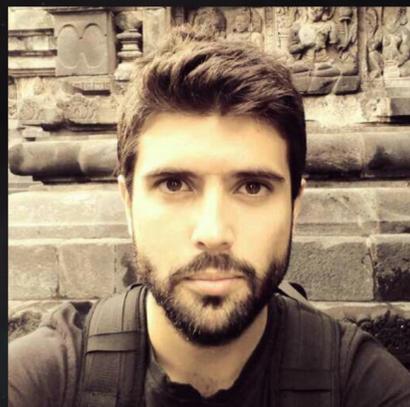
Yebes 40m  
(Spain)



IRAM 30m  
(Spain)



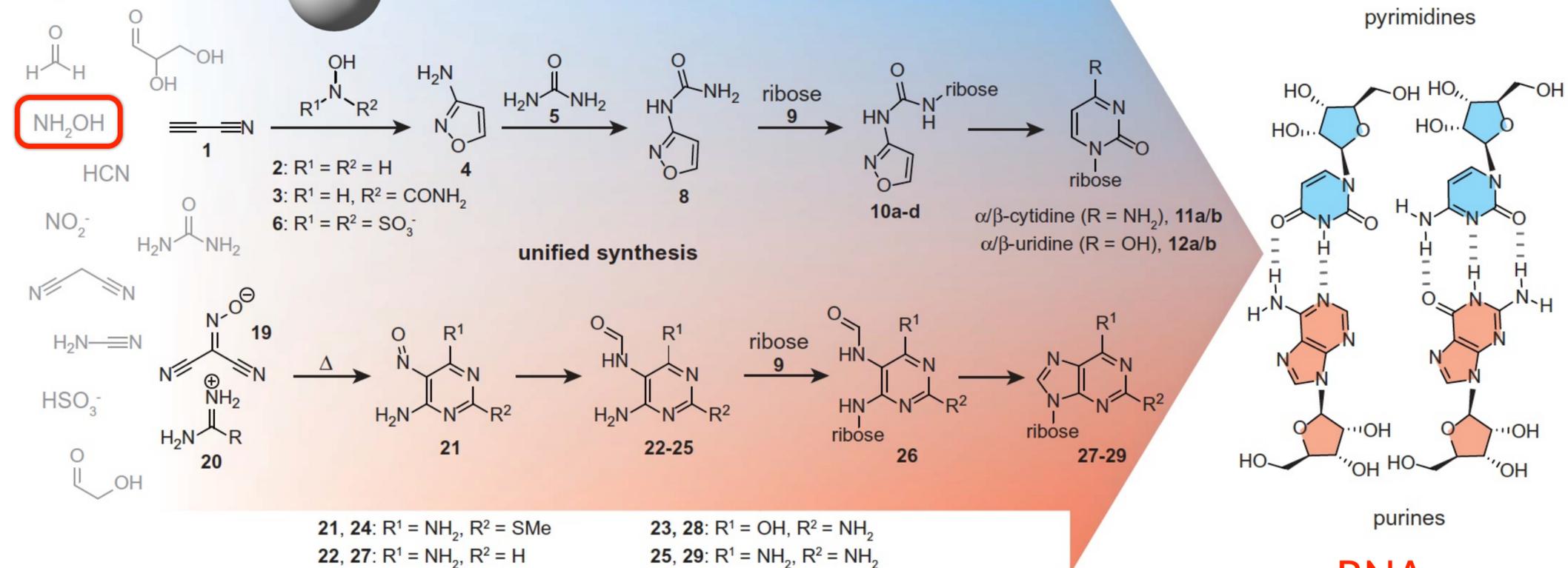
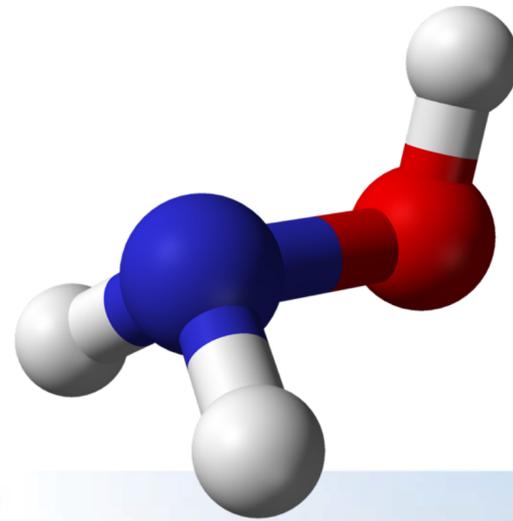
APEX 12m  
(Chile)



- ~ 300 hr of telescope time
- Frequency coverage from 12.73 GHz to 275.98 GHz
- Total bandwidth of 196.7 GHz
- Extremely high sensitivity: rms < 0.5 mK

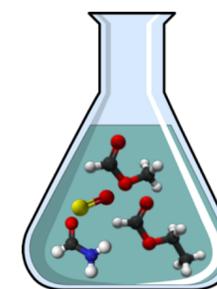


# hydroxylamine (NH<sub>2</sub>OH)



**RNA WORLD**

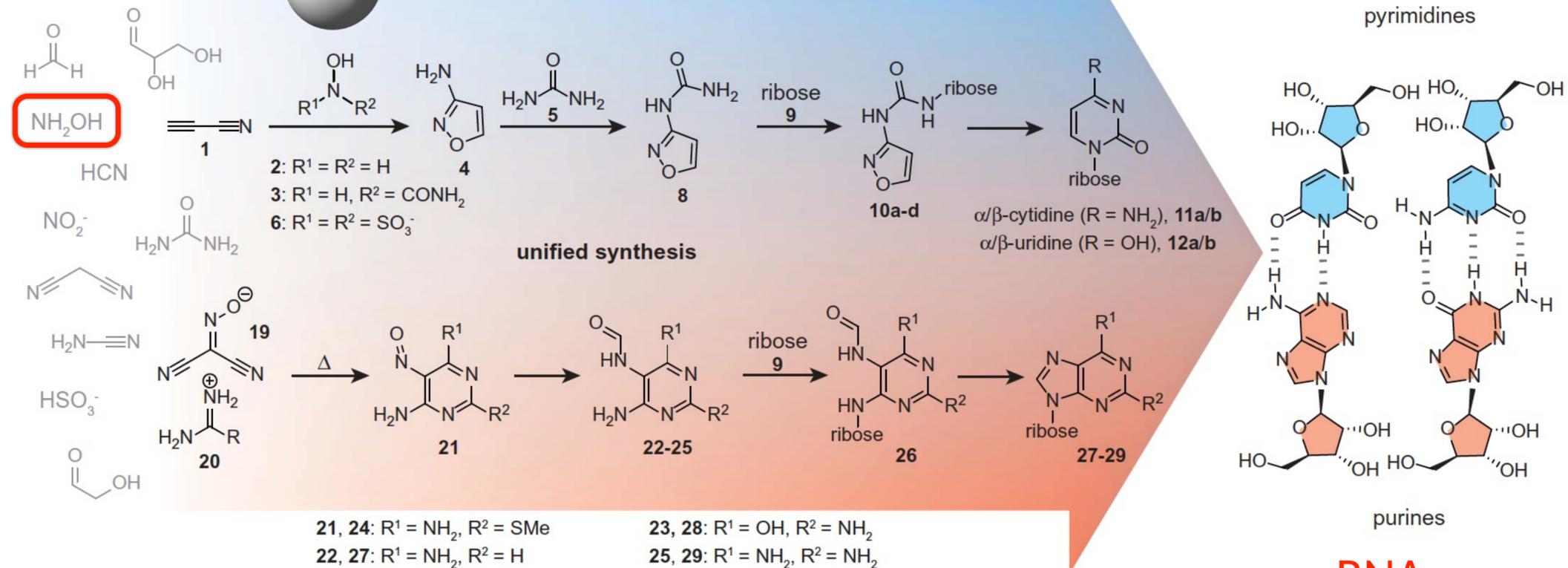
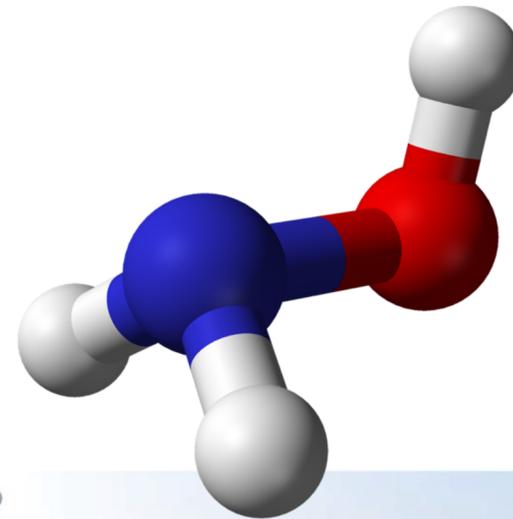
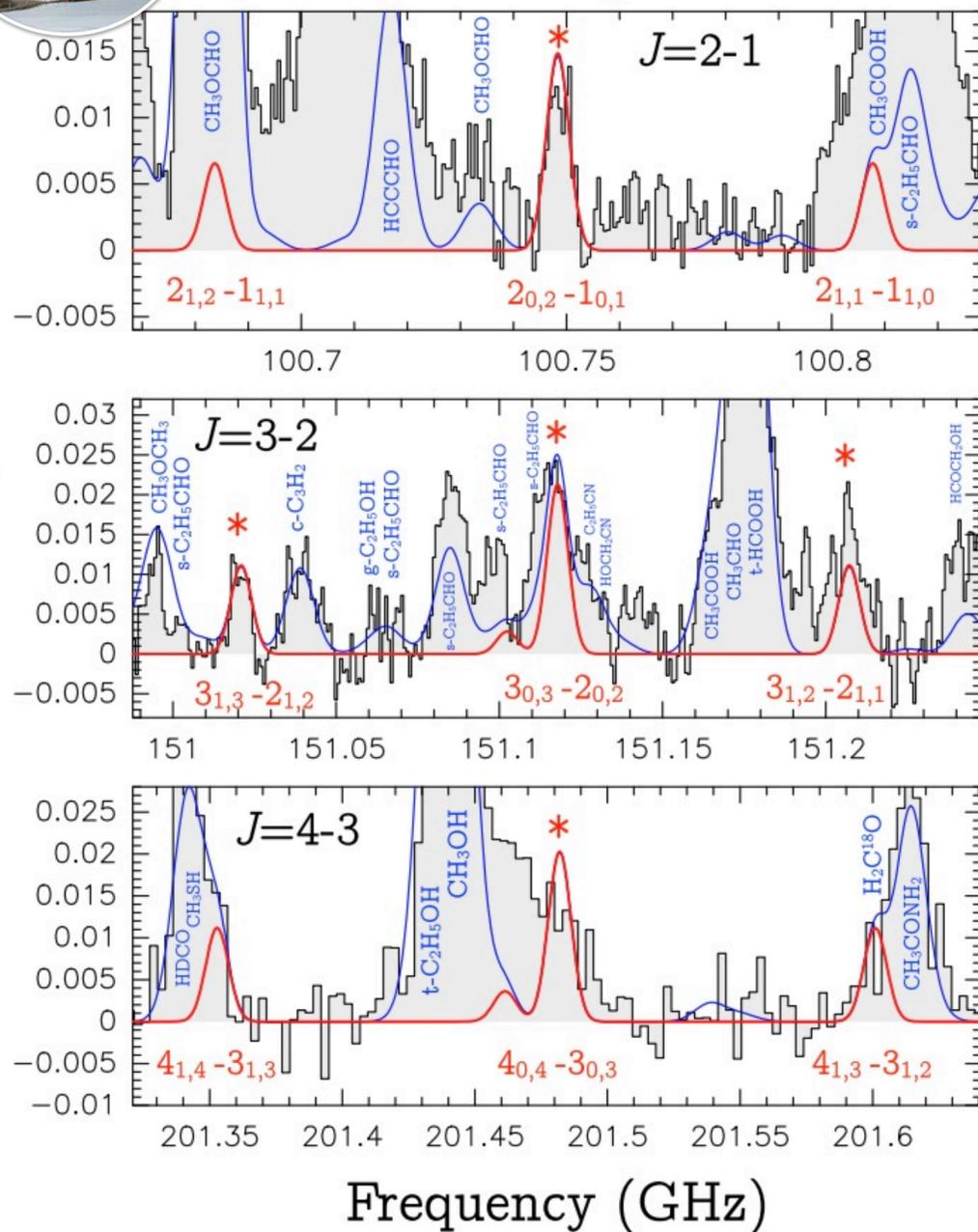
Becker et al., Science (2019)



# First detection of hydroxylamine (NH<sub>2</sub>OH) in the ISM

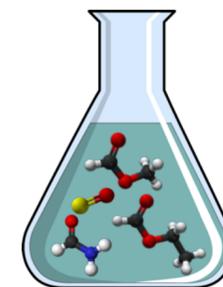


Rivilla et al. (2020b)

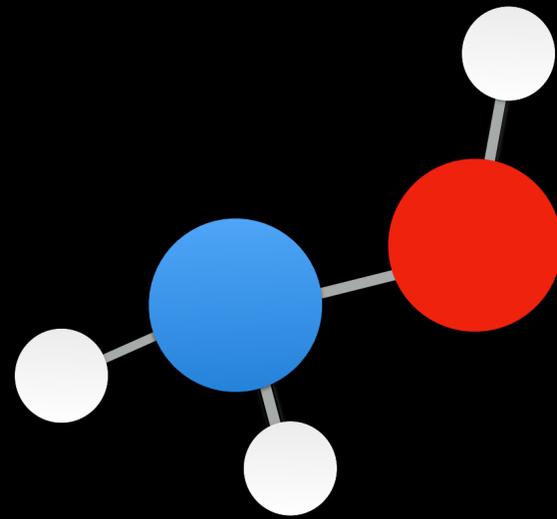


**RNA WORLD**

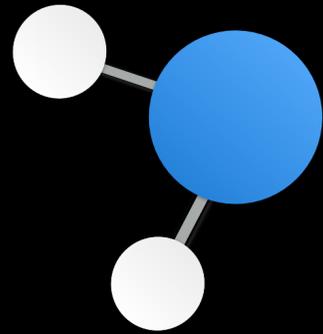
Becker et al., Science (2019)



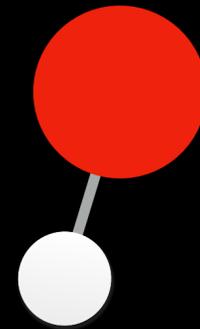
**NH<sub>2</sub>OH**

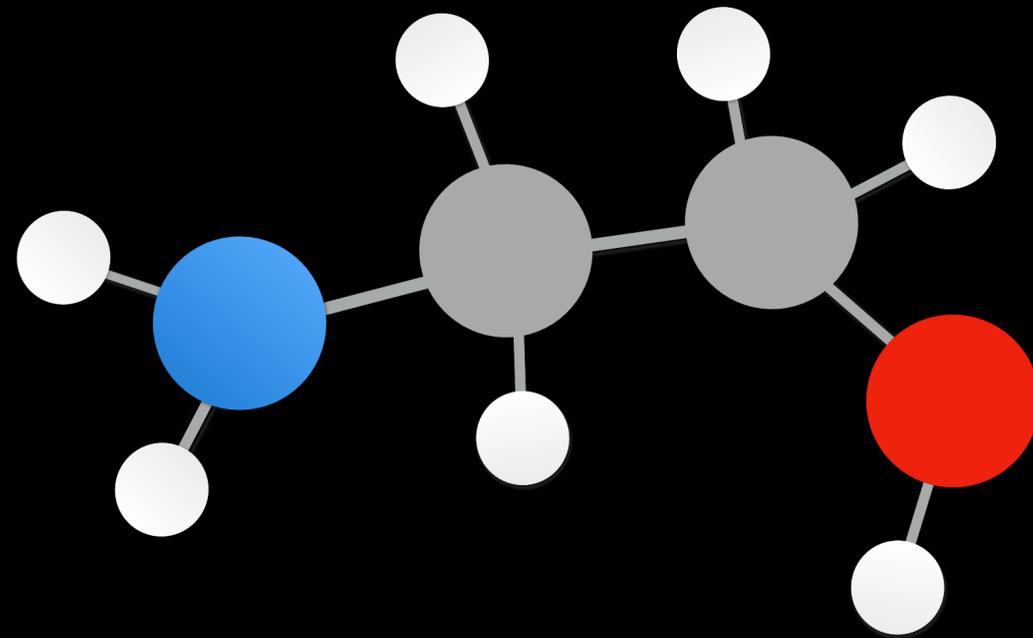


**NH<sub>2</sub>**

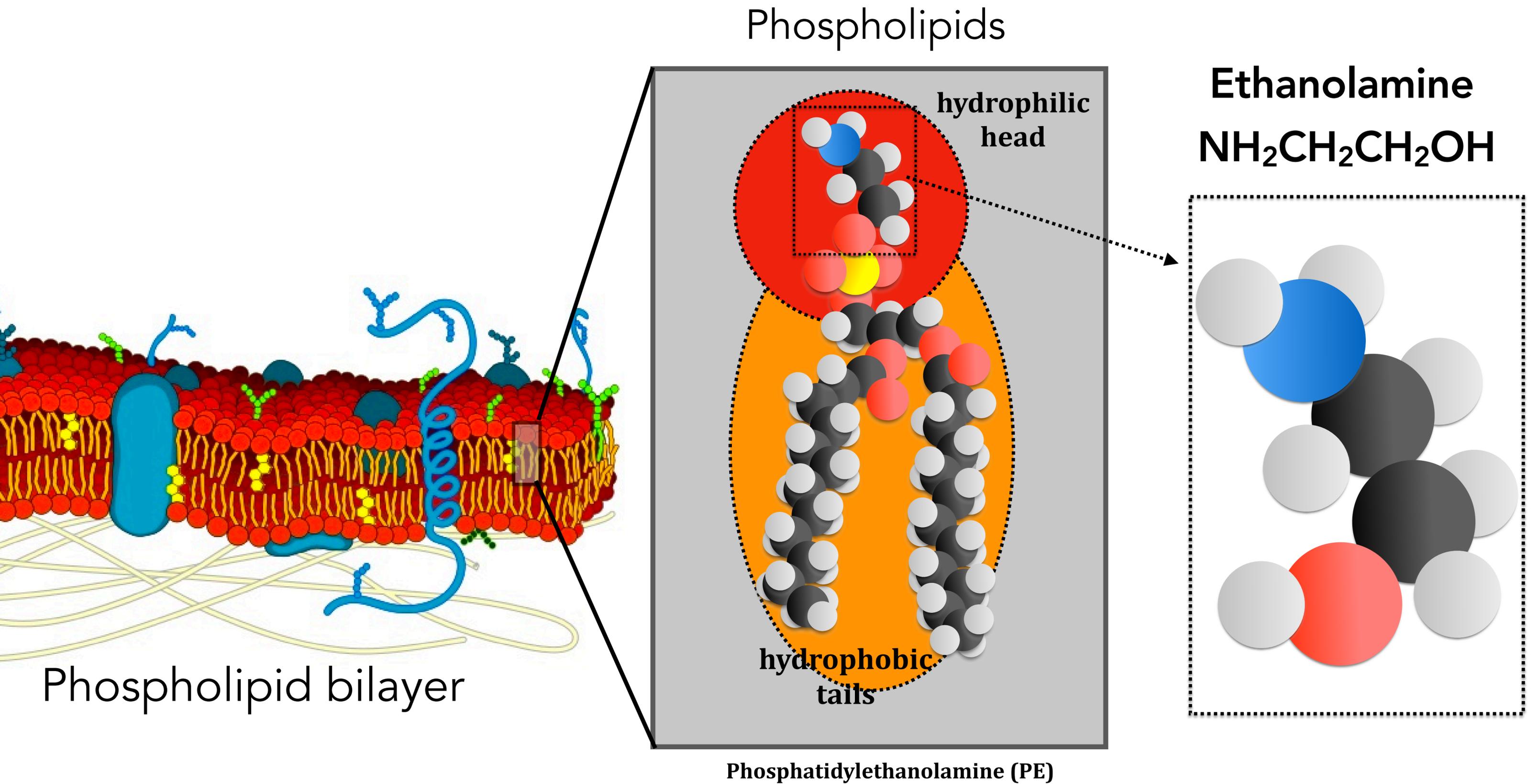


**OH**





**Ethanolamine**



# First detection of $\text{NH}_2\text{CH}_2\text{CH}_2\text{OH}$ in the ISM

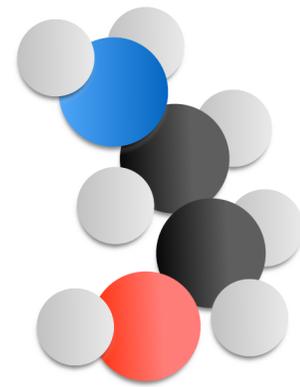
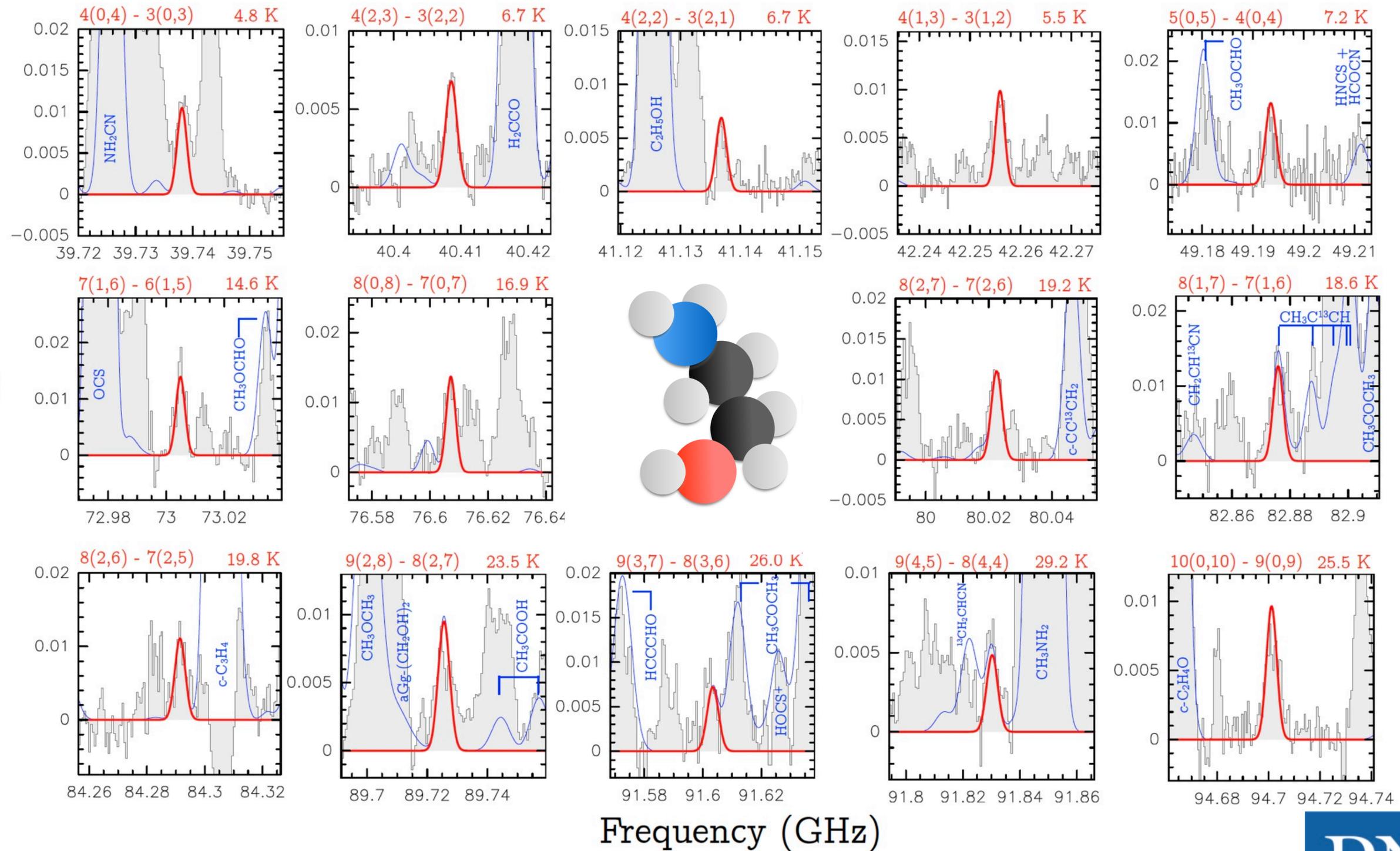


Yebes 40m

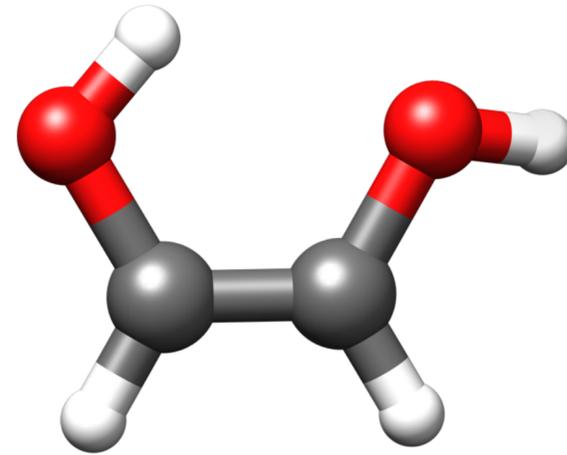
$T_A^*$  (K)



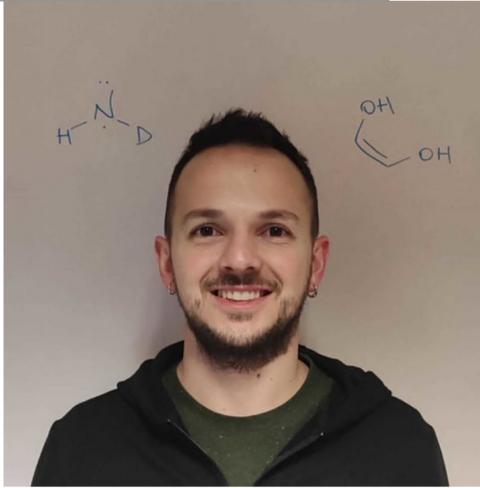
IRAM 30m



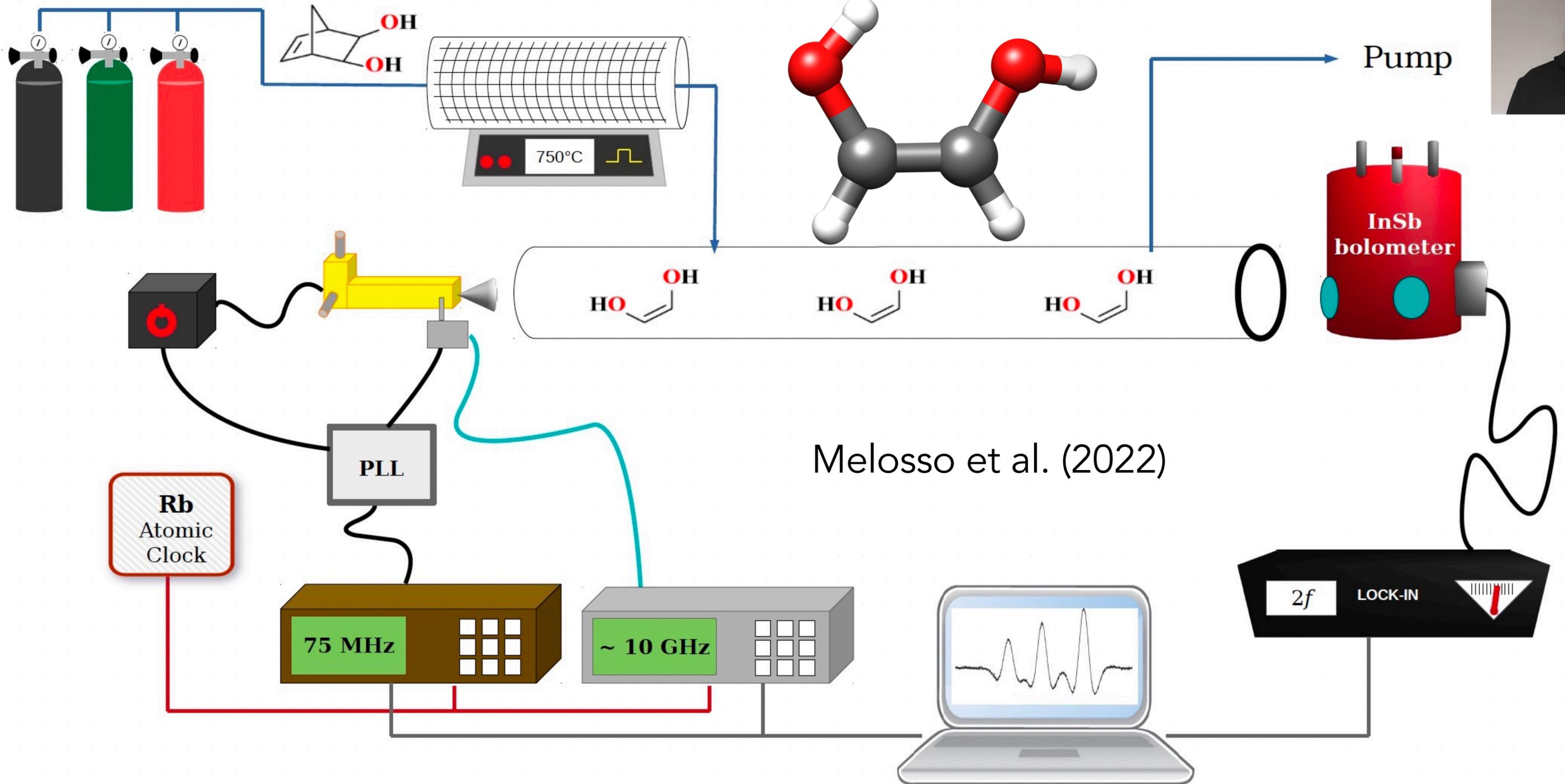
# 1,2-ethenediol



# 1,2-ethenediol

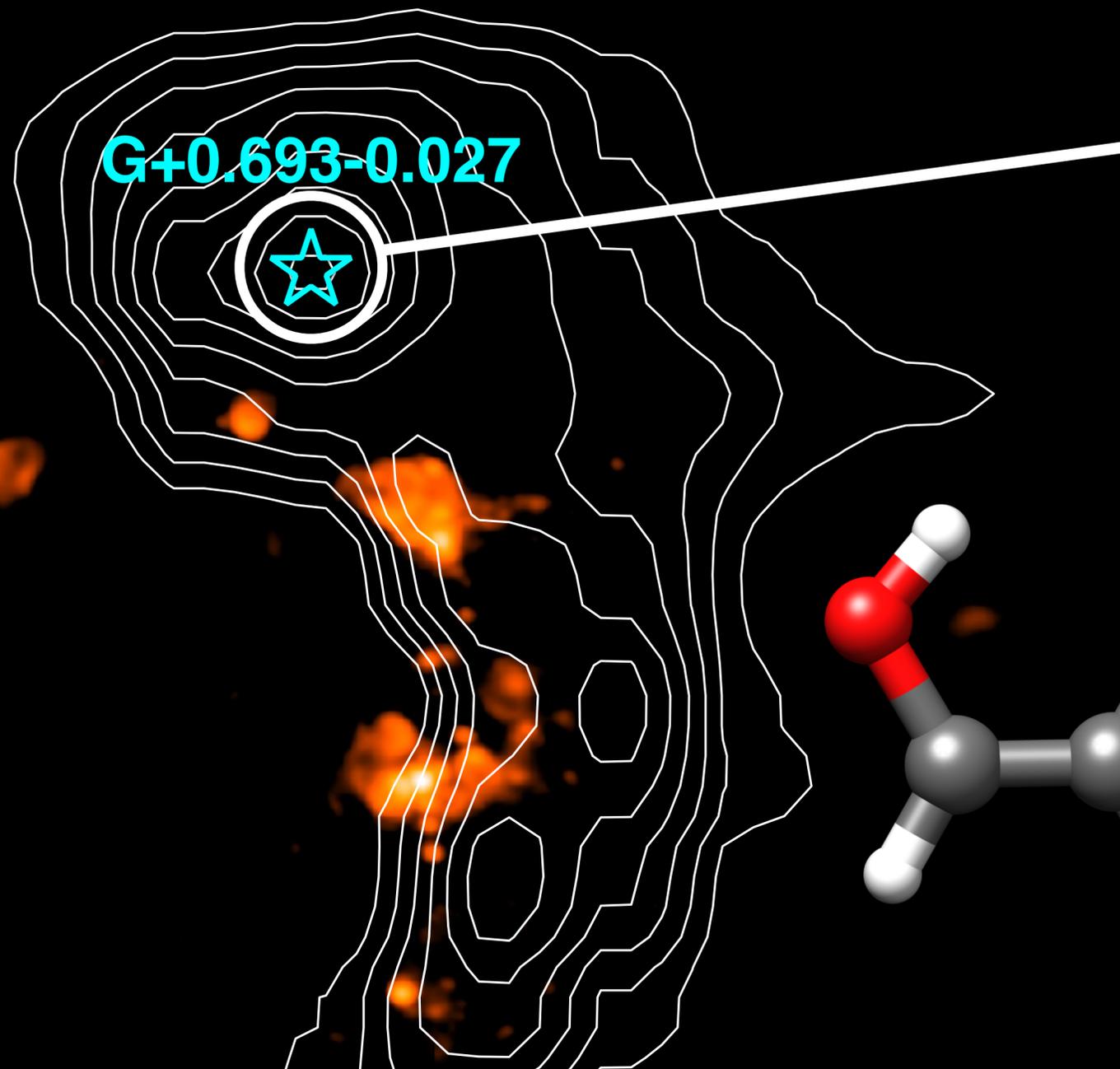


Mattia Melosso

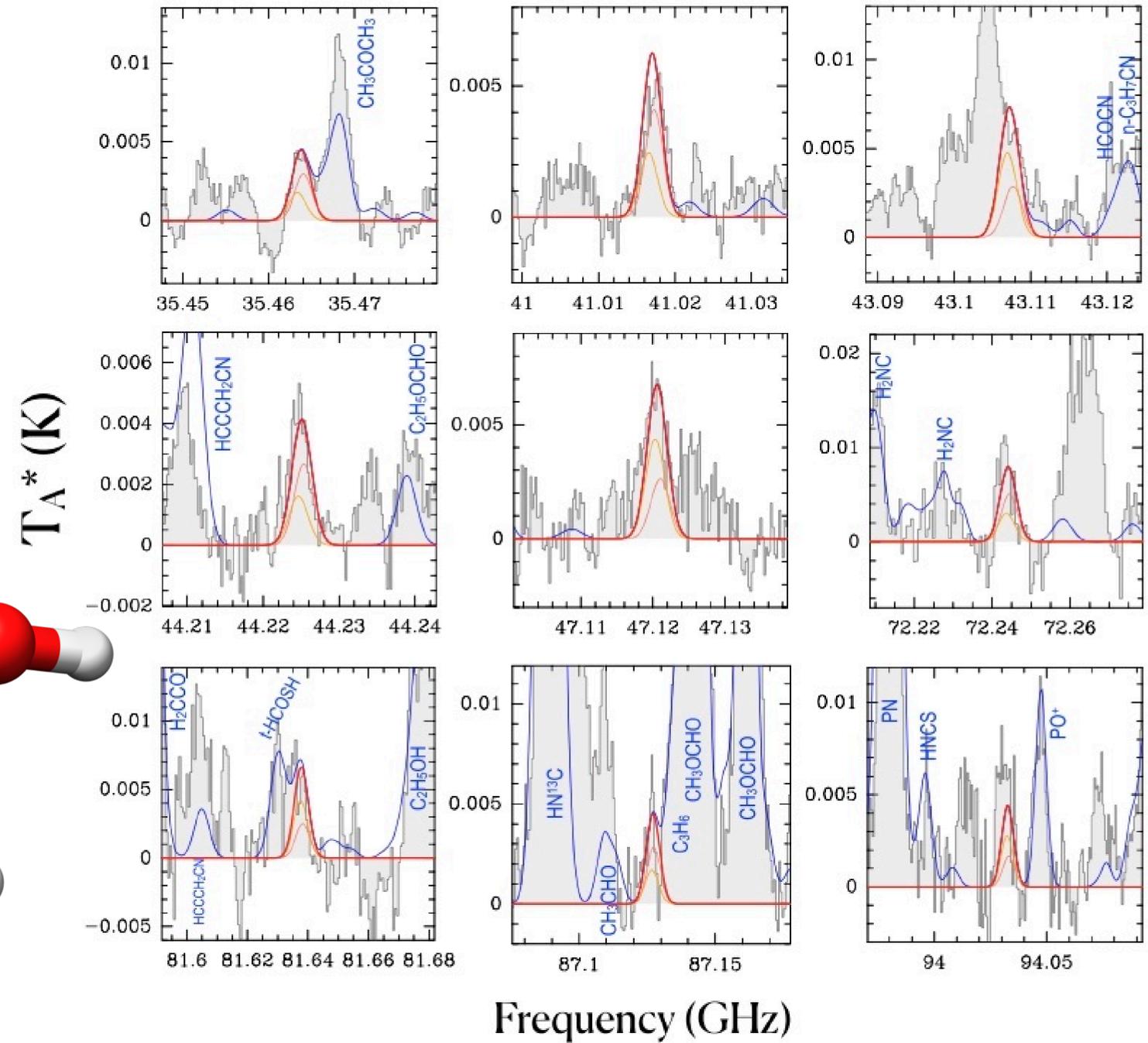


Mellosso et al. (2022)

# First detection of 1,2-ethenediol in the ISM



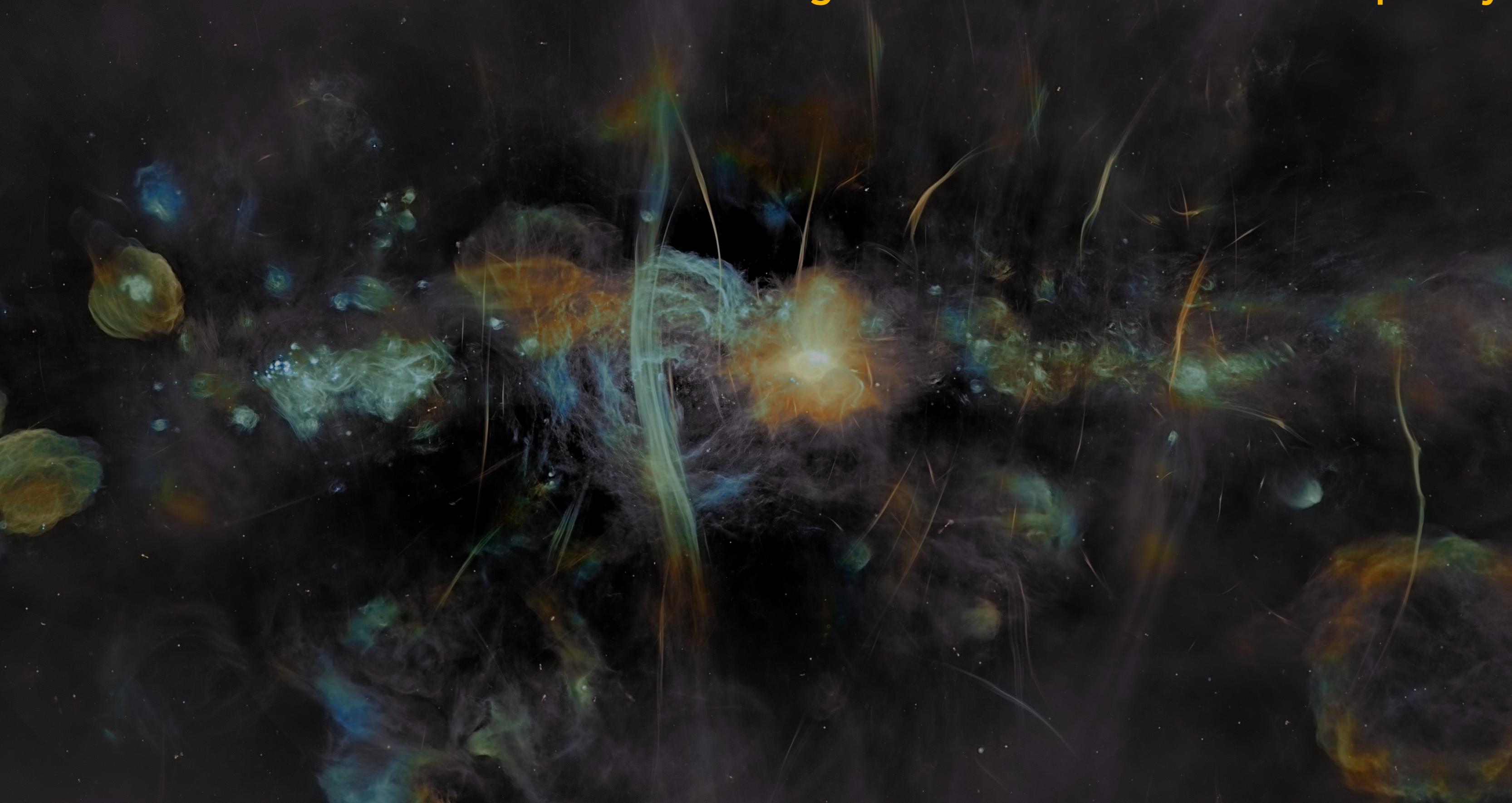
Rivilla et al. (2022a)





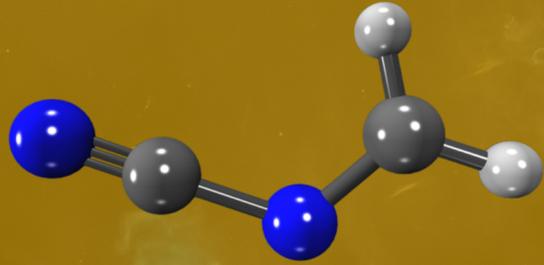


**G+0.693-0.027 molecular cloud** Pushing the limits of interstellar complexity



# G+0.693-0.027 molecular cloud Pushing the limits of interstellar complexity

N-cyanomethanimine



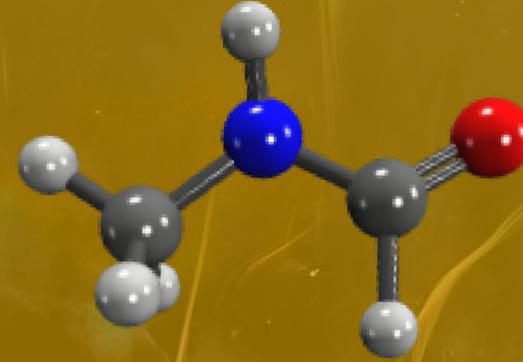
H2CNCN

New HCN dimer

San Andrés et al. (2024)

High-energy  
structural  
isomers

cis N-methyl formamide



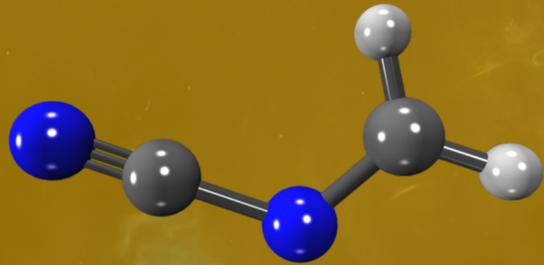
CH3NHCHO

Zeng et al. (2025)



# G+0.693-0.027 molecular cloud Pushing the limits of interstellar complexity

N-cyanomethanimine



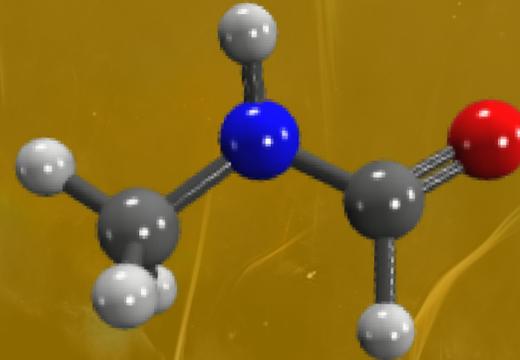
H2CNCN

New HCN dimer

San Andrés et al. (2024)

High-energy  
structural  
isomers

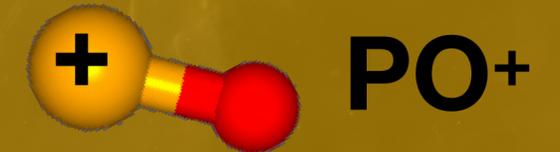
cis N-methyl formamide



CH3NHCHO

Zeng et al. (2025)

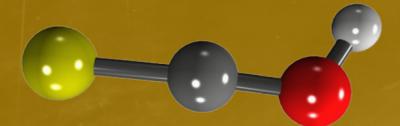
New cations



PO+

Rivilla et al. (2022b)

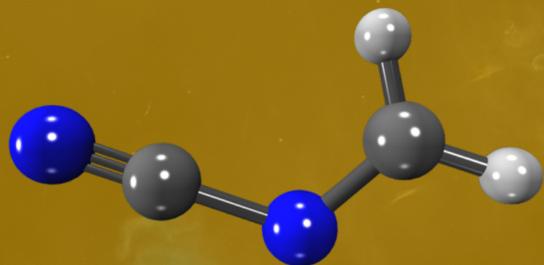
HOCS+



Sanz-Novo et al. (2024a)

# G+0.693-0.027 molecular cloud Pushing the limits of interstellar complexity

N-cyanomethanimine



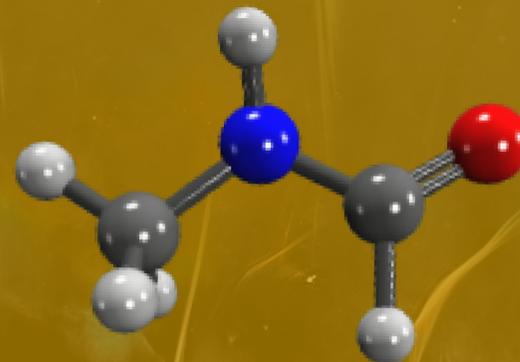
H2CNCN

New HCN dimer

San Andrés et al. (2024)

High-energy structural isomers

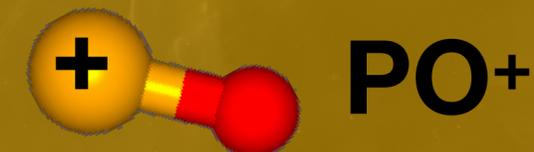
cis N-methyl formamide



CH3NHCHO

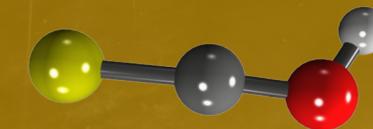
Zeng et al. (2025)

New cations



Rivilla et al. (2022b)

HOCS+

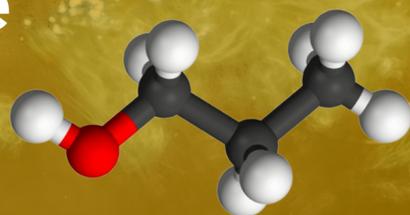


Sanz-Novo et al. (2024a)

Climbing the complexity ladder



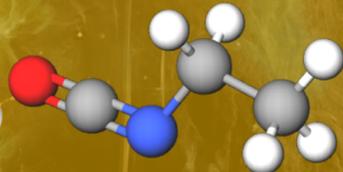
Alcohols



CH3CH2CH2OH

Jiménez-Serra et al. (2022)

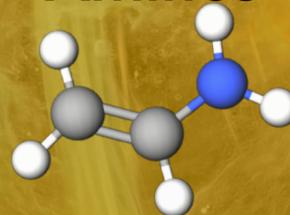
Isocyanates



CH3CH2NCO

Rodríguez-Almeida et al. (2021b)

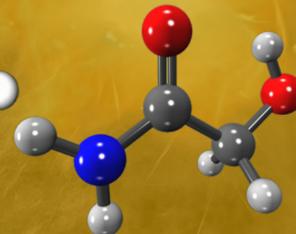
Amines



CH2CHNH2

Zeng et al. (2021)

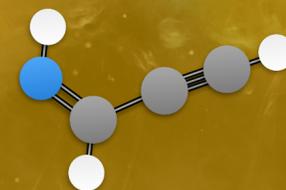
Amides



NH2COCH2OH

Rivilla et al. (2023)

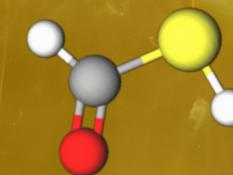
Imines



HCCCHNH

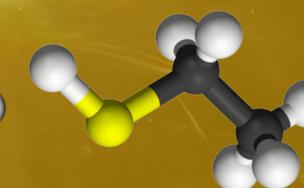
Bizzochi et al. (2020)

S-bearing species

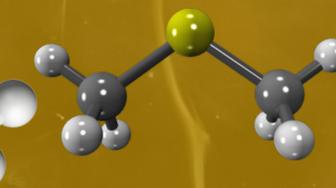


HCOSH

Rodríguez-Almeida et al. (2021a)



CH3CH2SH

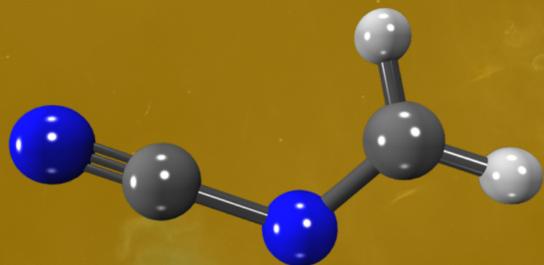


CH3SCH3

Sanz-Novo et al. (2025a)

# G+0.693-0.027 molecular cloud Pushing the limits of interstellar complexity

N-cyanomethanimine

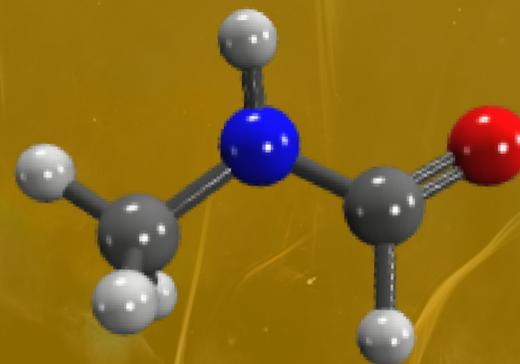


H2CNCN

New HCN dimer

San Andrés et al. (2024)

cis N-methyl formamide

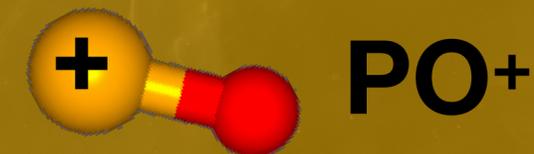


CH3NHCHO

Zeng et al. (2025)

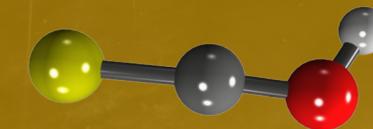
High-energy structural isomers

New cations



Rivilla et al. (2022b)

HOCS+

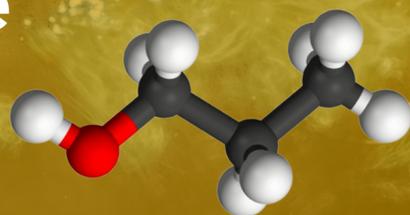


Sanz-Novo et al. (2024a)

Climbing the complexity ladder



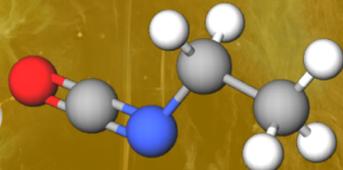
Alcohols



CH3CH2CH2OH

Jiménez-Serra et al. (2022)

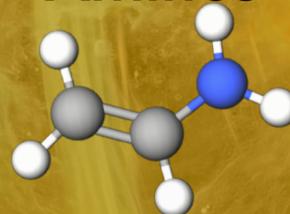
Isocyanates



CH3CH2NCO

Rodríguez-Almeida et al. (2021b)

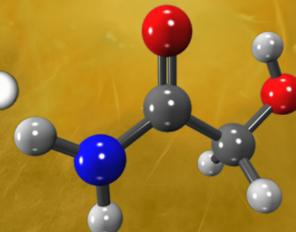
Amines



CH2CHNH2

Zeng et al. (2021)

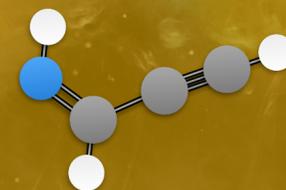
Amides



NH2COCH2OH

Rivilla et al. (2023)

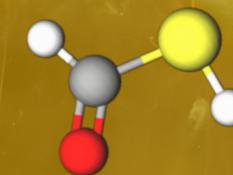
Imines



HCCCHNH

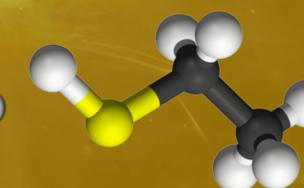
Bizzochi et al. (2020)

S-bearing species

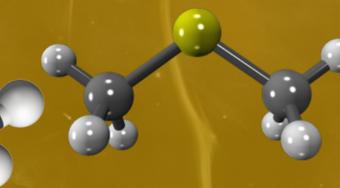


HCOSH

Rodríguez-Almeida et al. (2021a)



CH3CH2SH



CH3SCH3

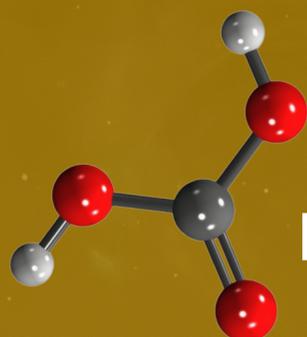
Sanz-Novo et al. (2025a)

New complexity frontiers

Carbonic acid

HOCOOH

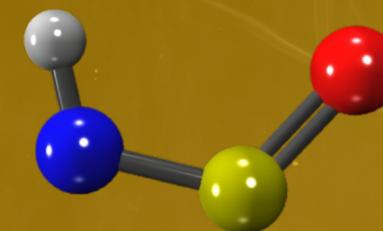
First interstellar molecule with 3 oxygen atoms



HNSO

Sanz-Novo et al. (2024b)

First interstellar molecule with N, S and O





# Rings in the Galactic Center



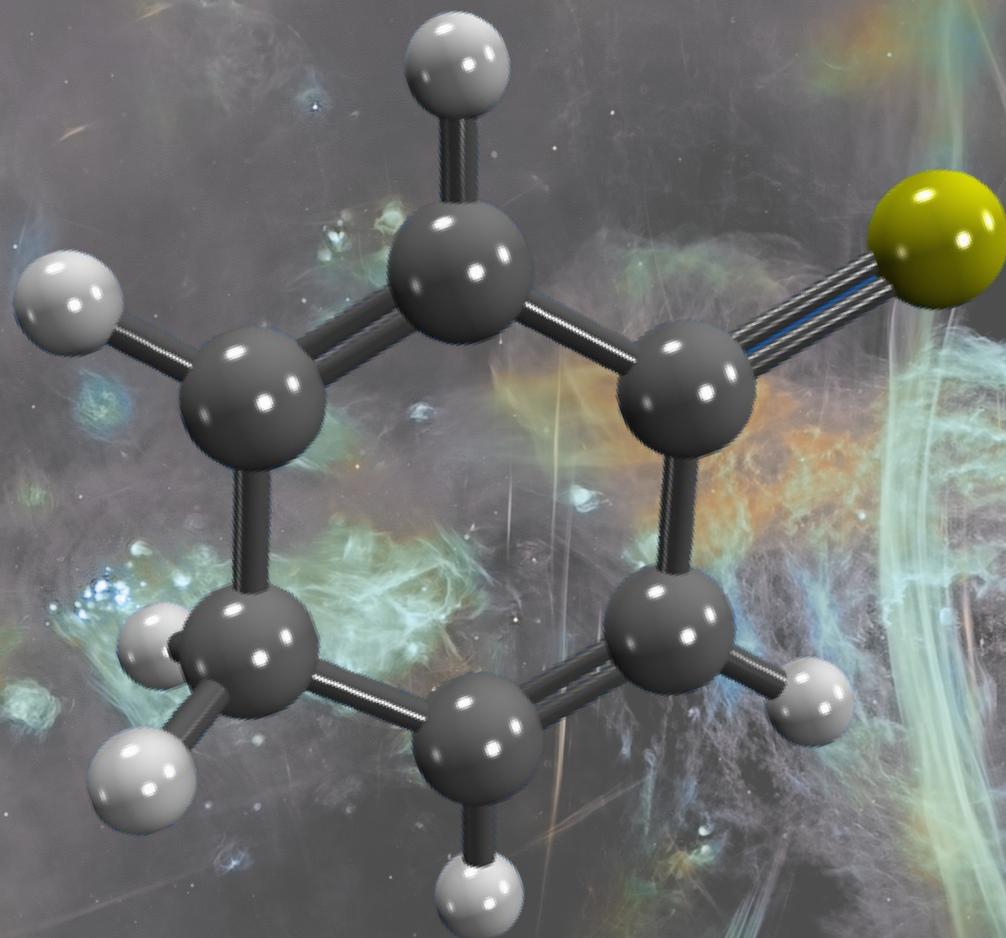


# Rings in the Galactic Center

**2,5-cyclohexadien-1-thione (c-C<sub>6</sub>H<sub>6</sub>S)**

Araki, Sanz-Novo et al. (2026), Nat. Astro.

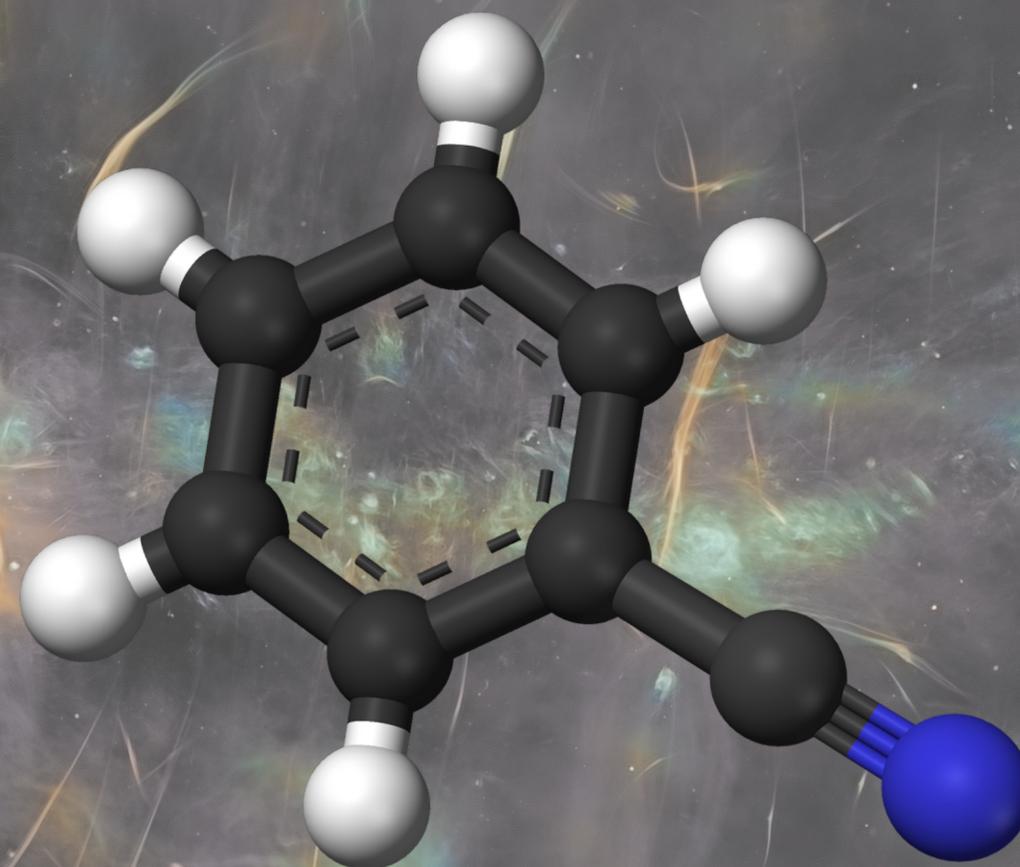
**First detection in the ISM**



**Benzonitrile (c-C<sub>6</sub>H<sub>5</sub>CN)**

Rivilla et al. (in prep.)

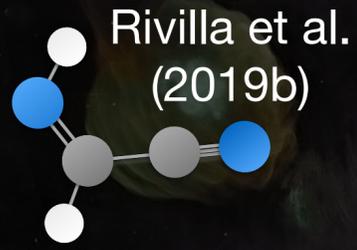
**First detection(s) beyond dark clouds**



New interstellar species discovered by our group including species with the 6 key chemical elements for life:



**Z-cyanomethanimine**

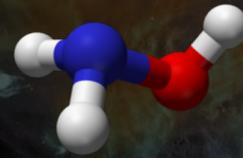


**Propargylimine**



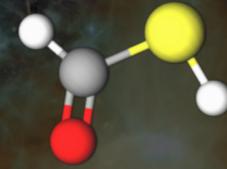
**Hydroxylamine**

Rivilla et al. (2020c)



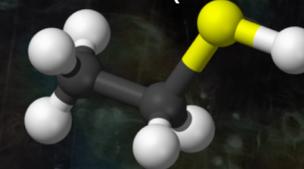
**Thioformic acid**

Rodríguez-Almeida et al. (2021a)



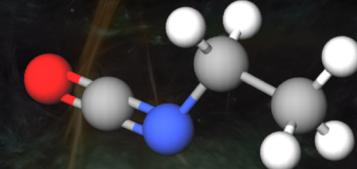
**Ethyl mercaptan**

Rodríguez-Almeida et al. (2021a)



**Ethyl isocyanate**

Rodríguez-Almeida et al. (2021b)



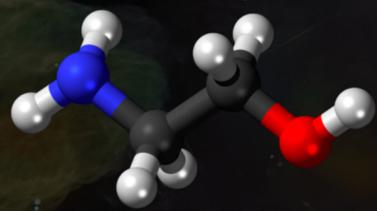
**Cyanomidyl**

Rivilla et al. (2021b)



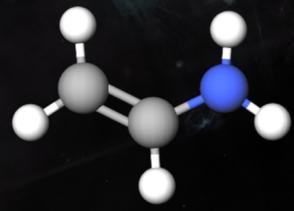
**Ethanolamine**

Rivilla et al. (2021a)



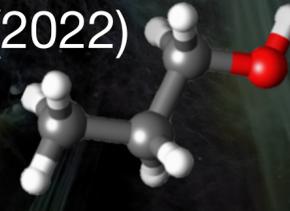
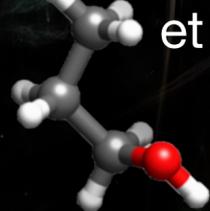
**Vinyl amine**

Zeng et al. (2021)



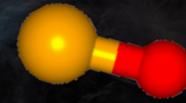
**n-propanol**

Jiménez-Serra et al. (2022)



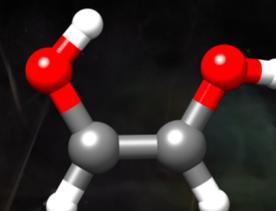
**Phosphorus oxide cation**

Rivilla et al. (2022b)



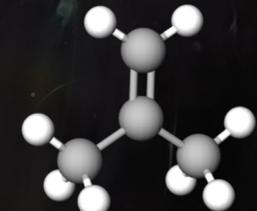
**Z-1,2-ethenediol**

Rivilla et al. (2022a)



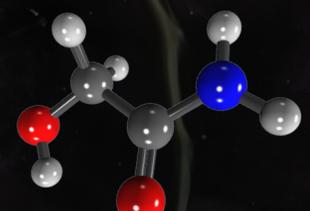
**Isobutene**

Fatima et al. (2023)



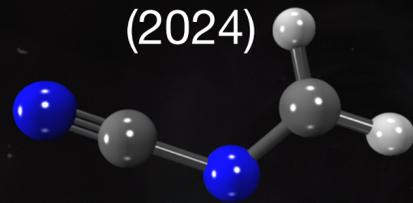
**Glycolamide**

Rivilla et al. (2023)



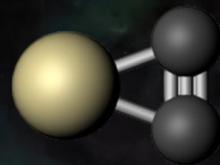
**N-cyanomethanimine**

San Andrés et al. (2024)



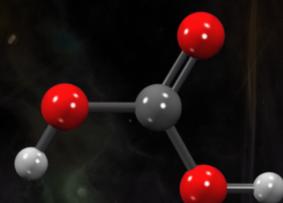
**Silacyclopropynylidene**

Massalkhi et al. (2023)



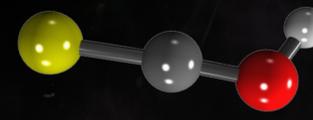
**Carbonic acid**

Sanz-Novo et al. (2023)



**Protonated carbonyl sulphide**

Sanz-Novo et al. (2024a)



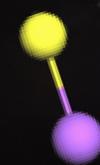
**Thionylimide**

Sanz-Novo et al. (2024b)

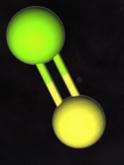


**Magnesium sulfide**

Rey-Montejo et al. (2024)

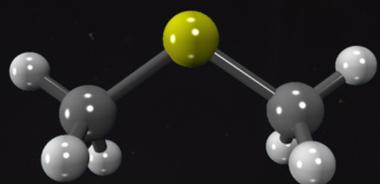


**Sodium sulfide**



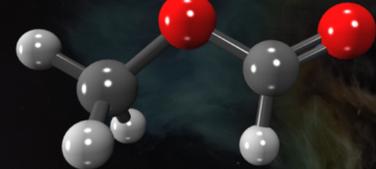
**Dimethyl sulfide**

Sanz-Novo et al. (2025a)



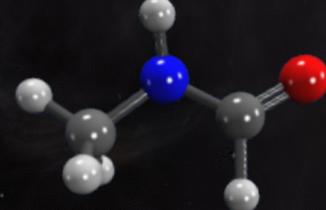
**Trans methyl formate**

Sanz-Novo et al. (2025b)



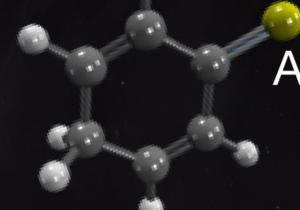
**Cis N-methyl formamide**

Zeng et al. (2025)



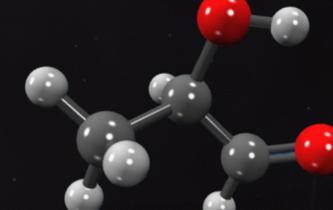
**2,5-cyclohexadien-1-thione**

Araki et al. (2026)

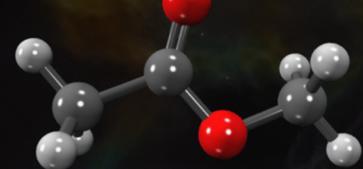


**Lactaldehyde**

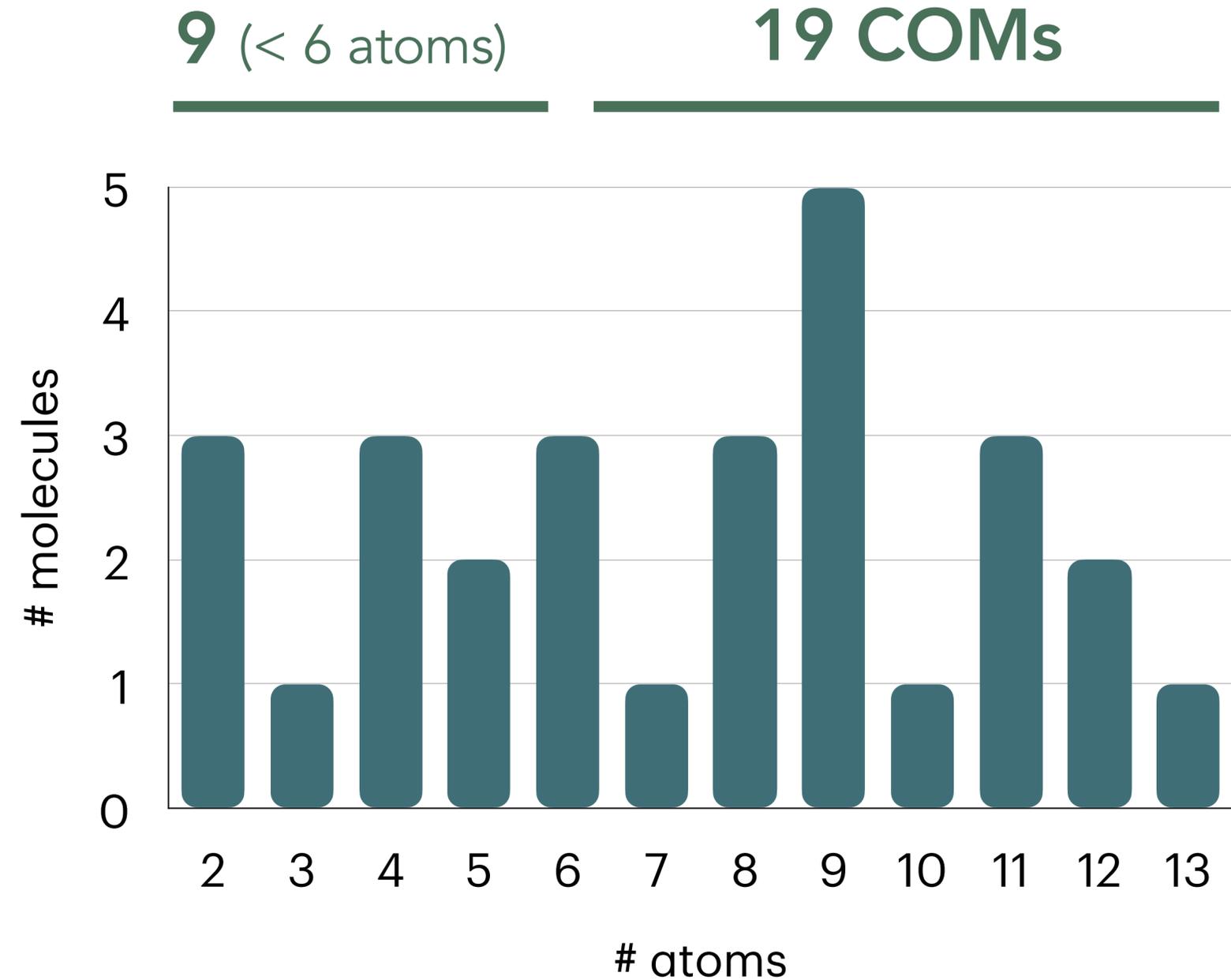
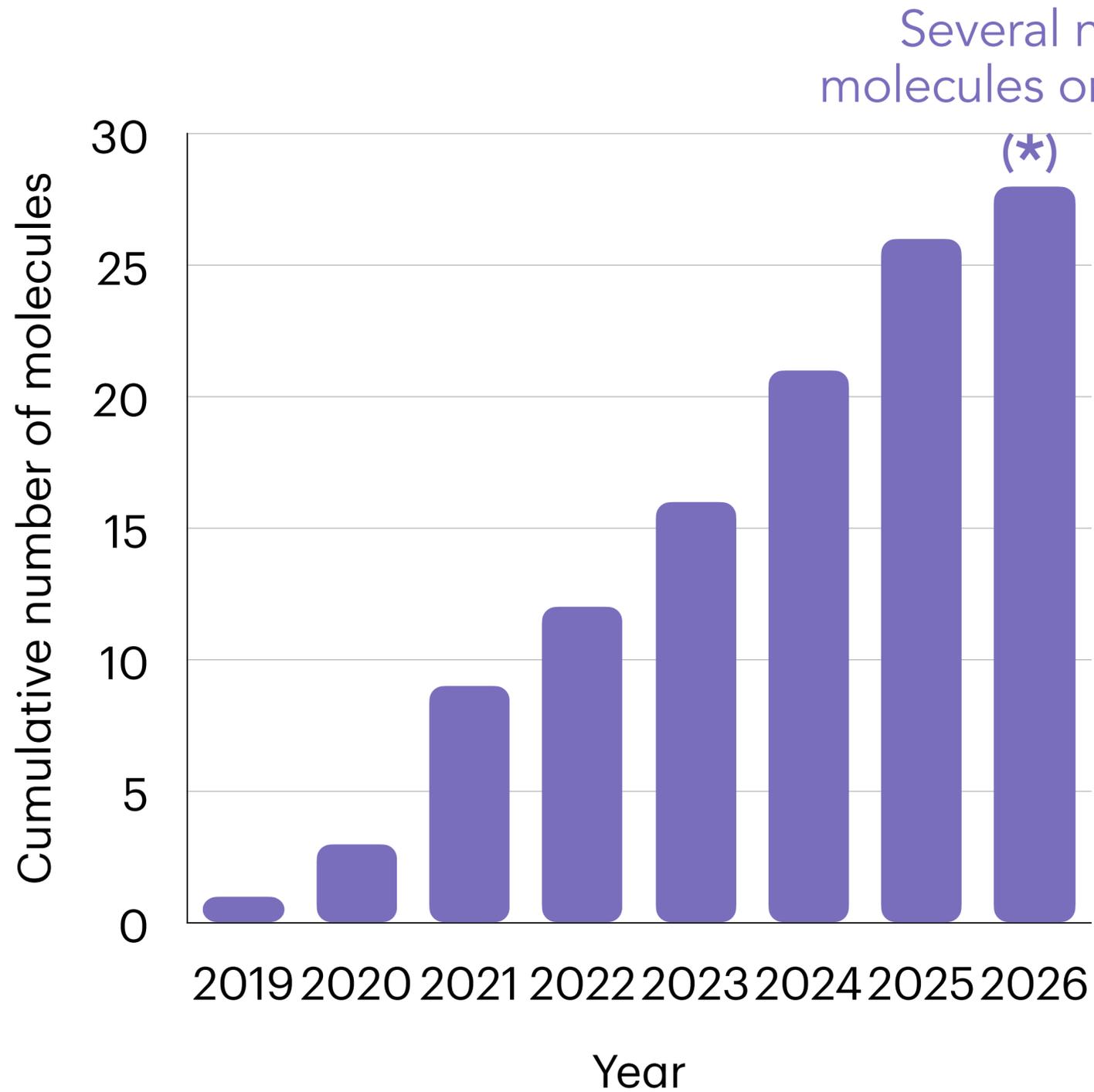
Sanz-Novo et al. (2026)



**Methoxacetaldehyde**

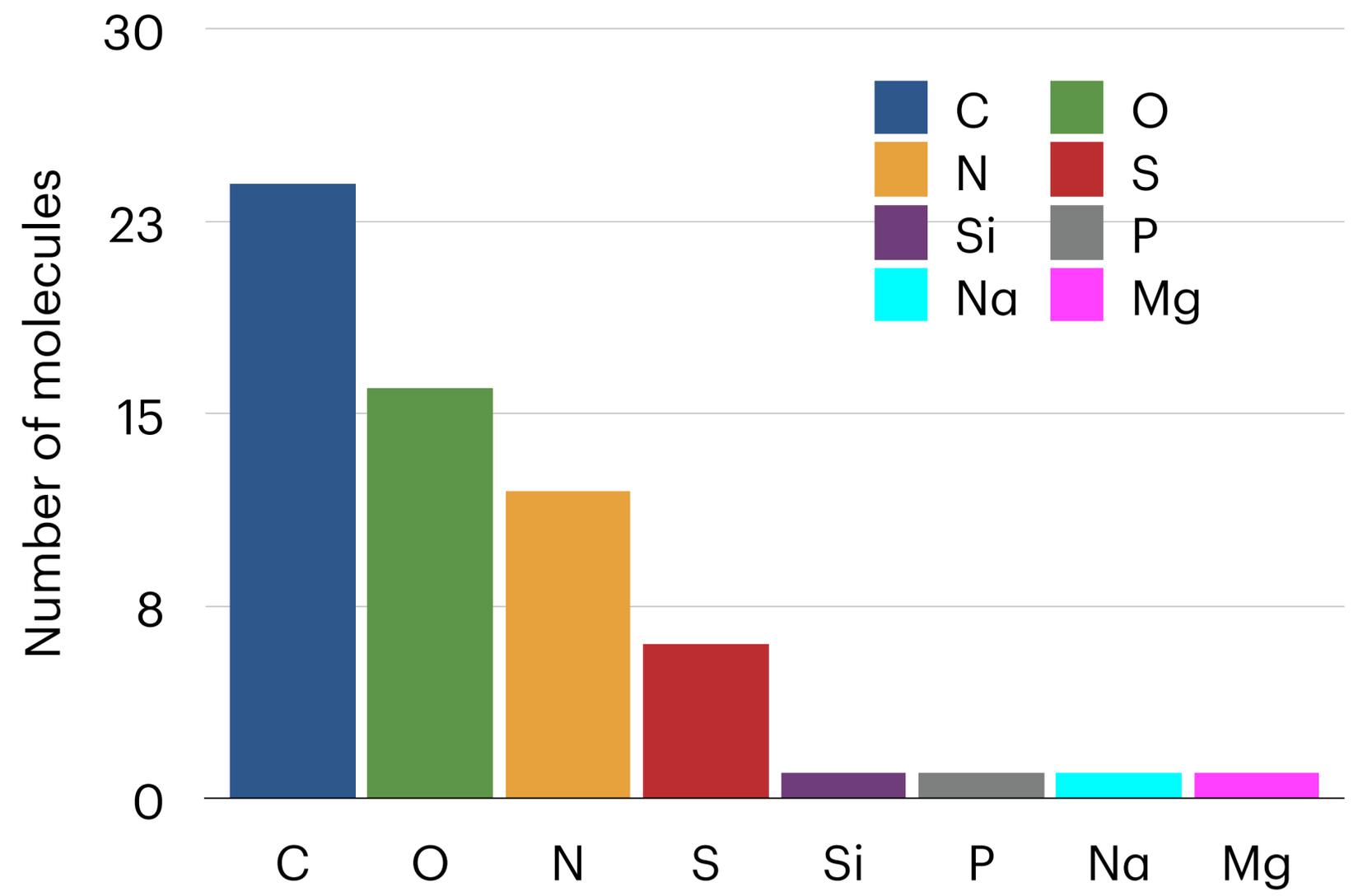
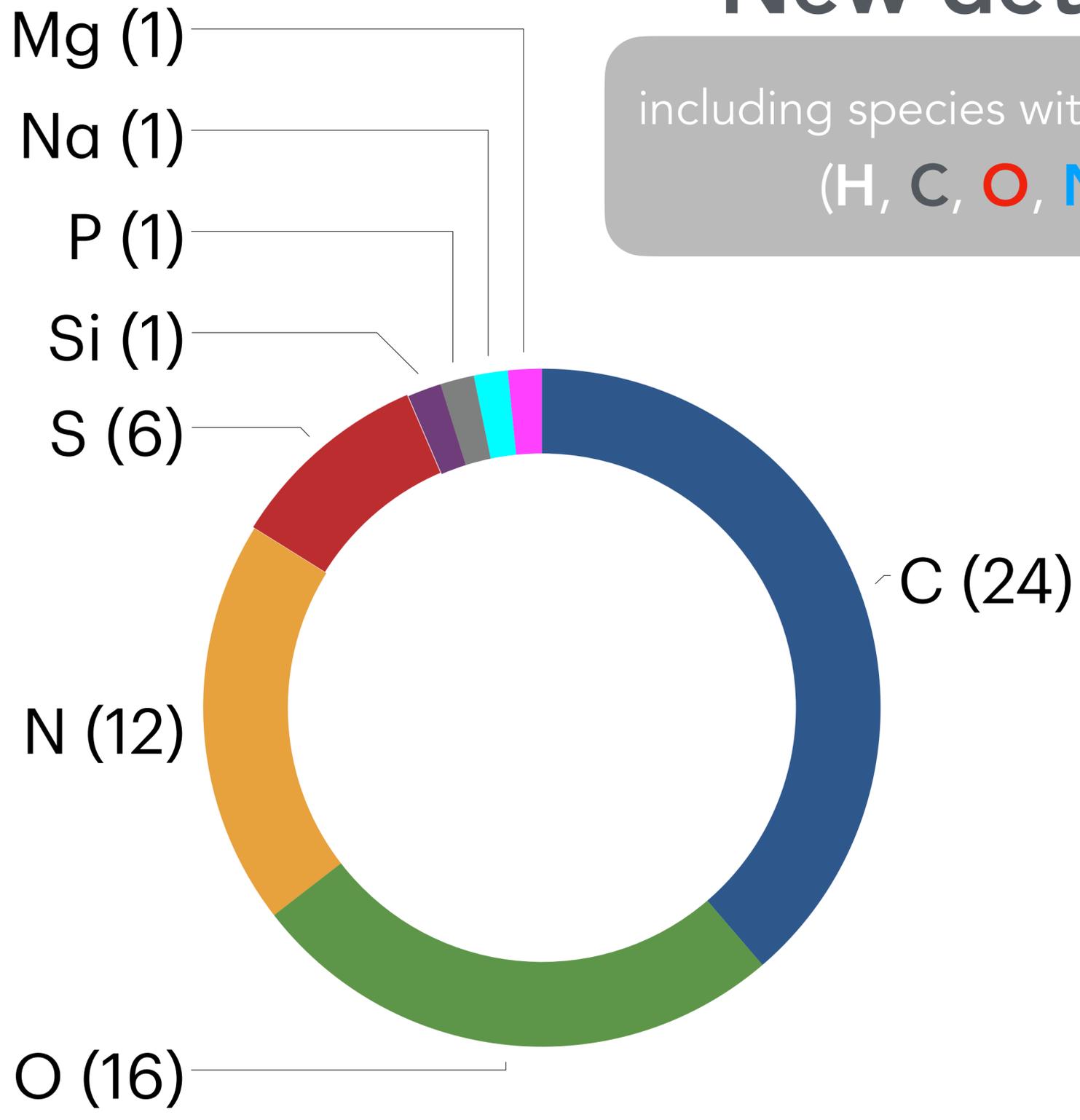


# 28 new detections in G+0.693



# New detections in G+0.693

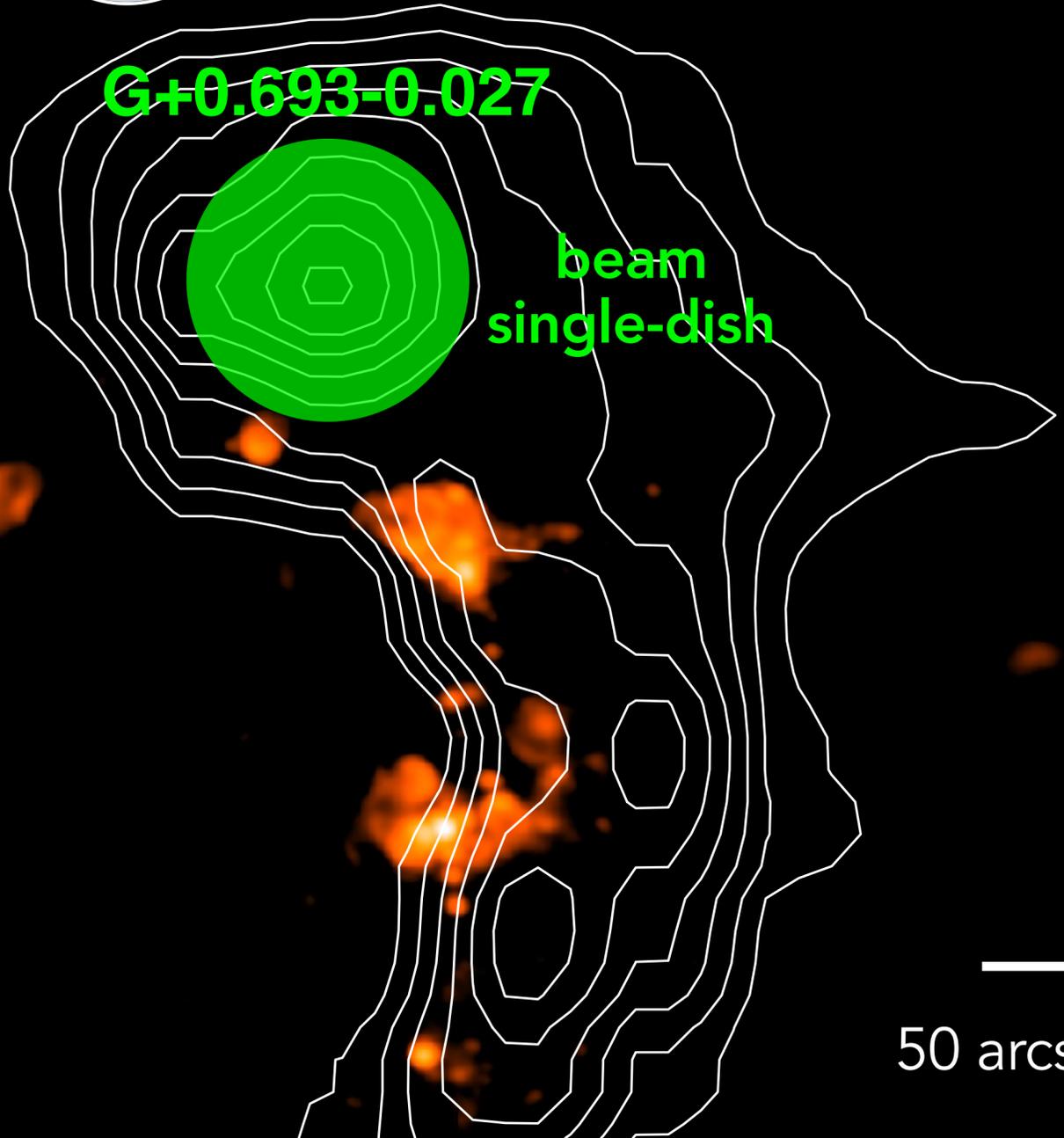
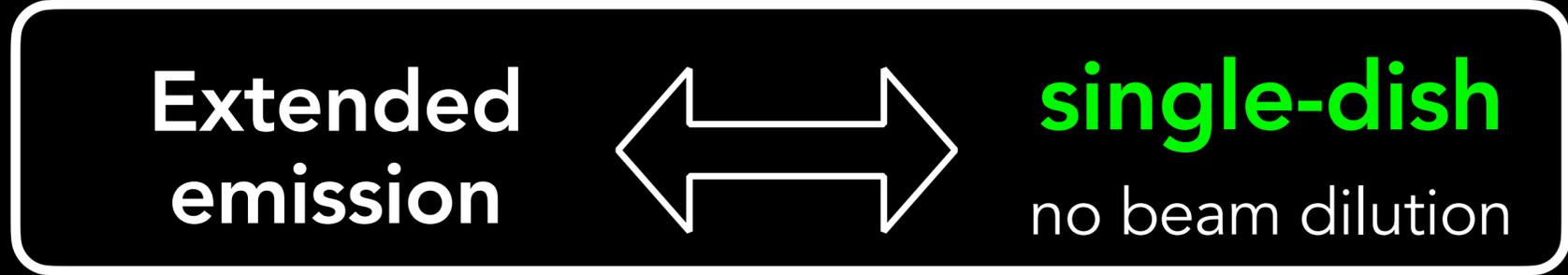
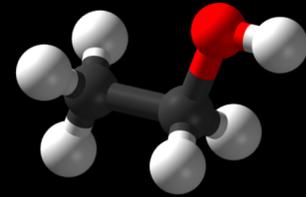
including species with the 6 key chemical elements for life:  
(H, C, O, N, S y P) + Si + Mg + Na



# The G+0.693-0.027 molecular cloud



Ethanol  
(CH<sub>3</sub>CH<sub>2</sub>OH)

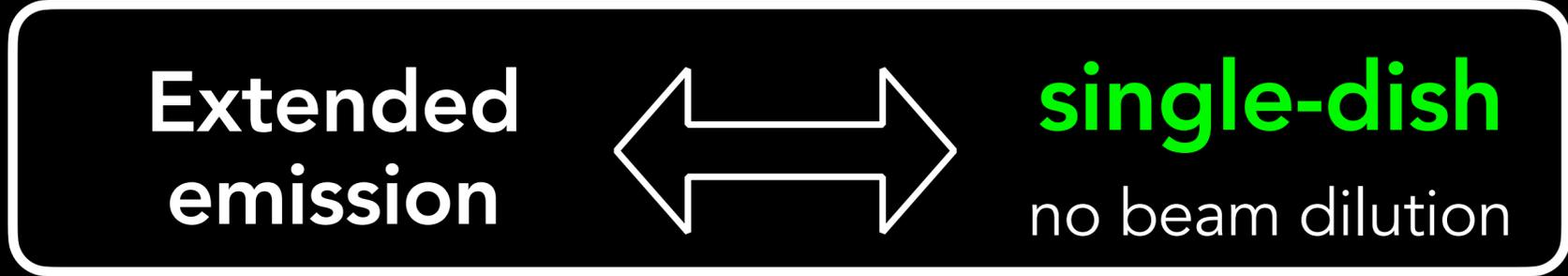
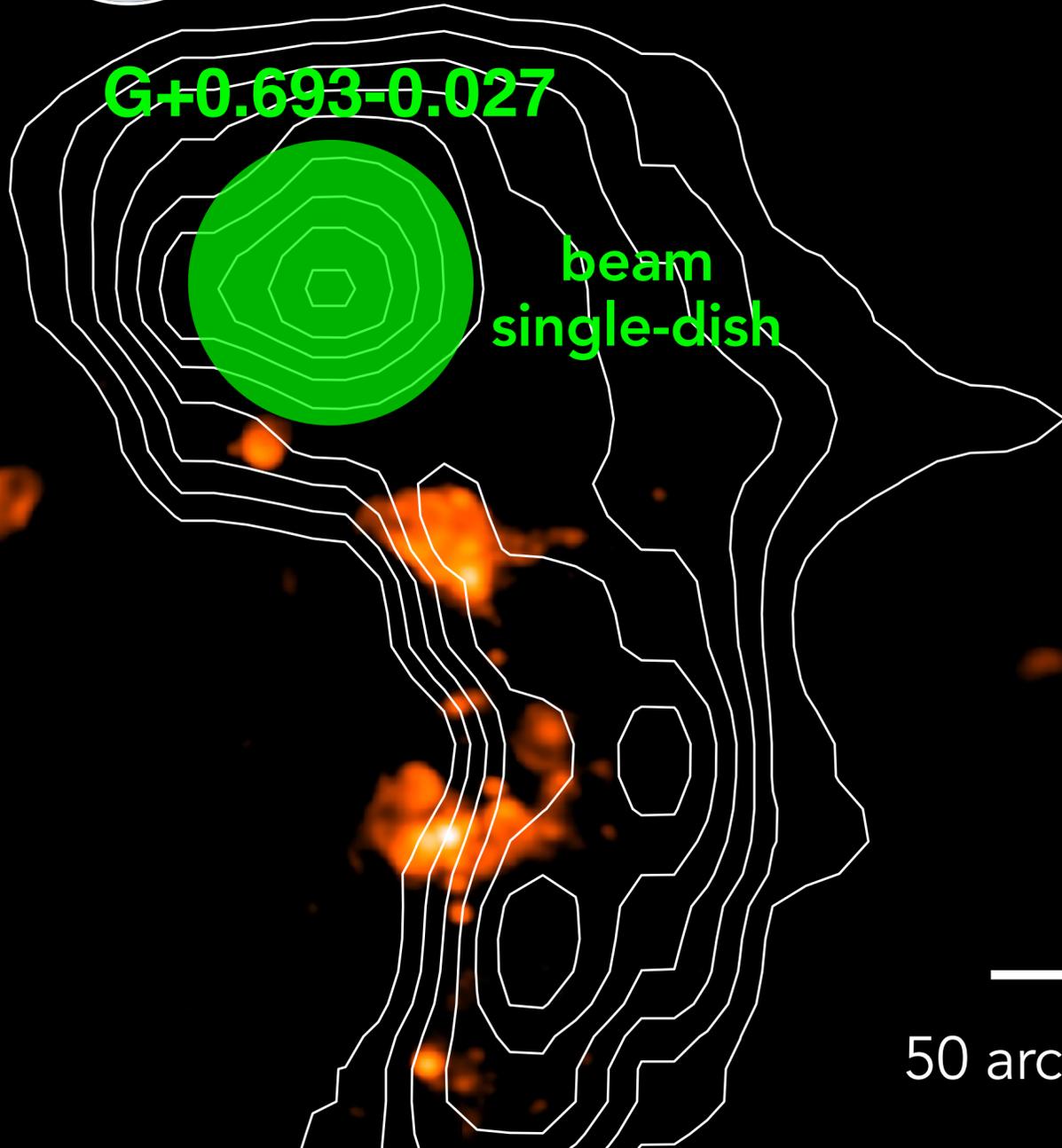
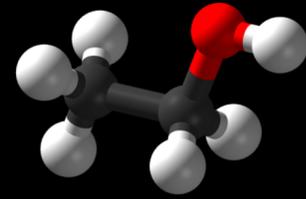


50 arcsec ~2 pc

# The G+0.693-0.027 molecular cloud



Ethanol  
(CH<sub>3</sub>CH<sub>2</sub>OH)



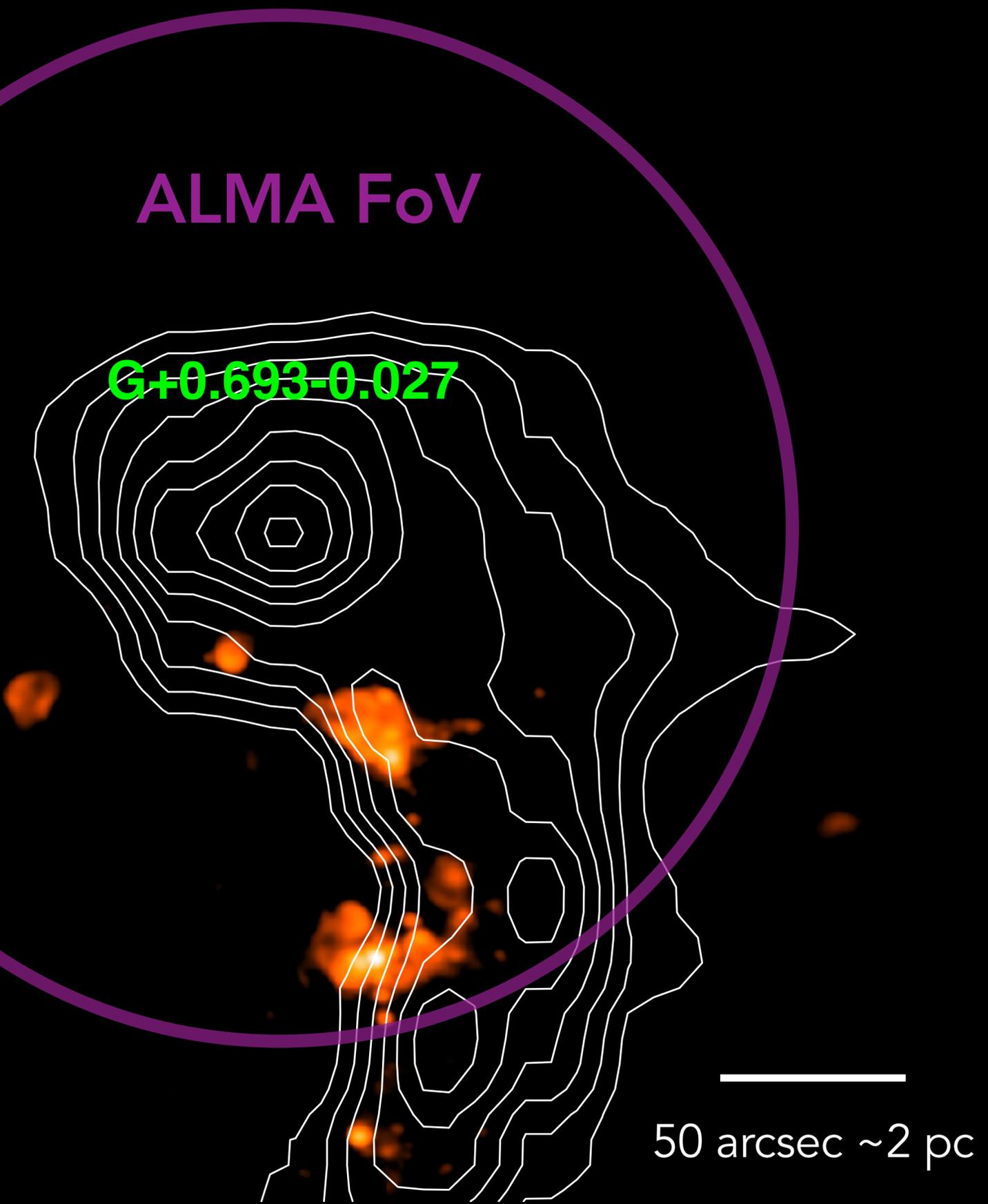
But we lack **SPATIAL INFORMATION**



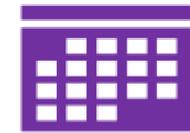
# ALMA BAND 1 OBSERVATIONS

ALMA FoV

G+0.693-0.027



2023.1.00038.S  
(PI: Sergio Martín)



Mar, Apr & Sep 2024  
(18 days of CYCLE 10)



ALMA 12m array



~ 19 h on source



~ 4.8x3.4 arcsec



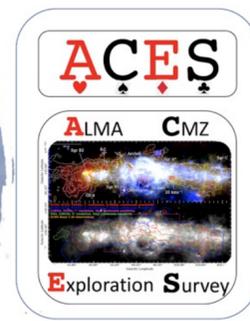
Band 1  
~ 44 – 50 GHz



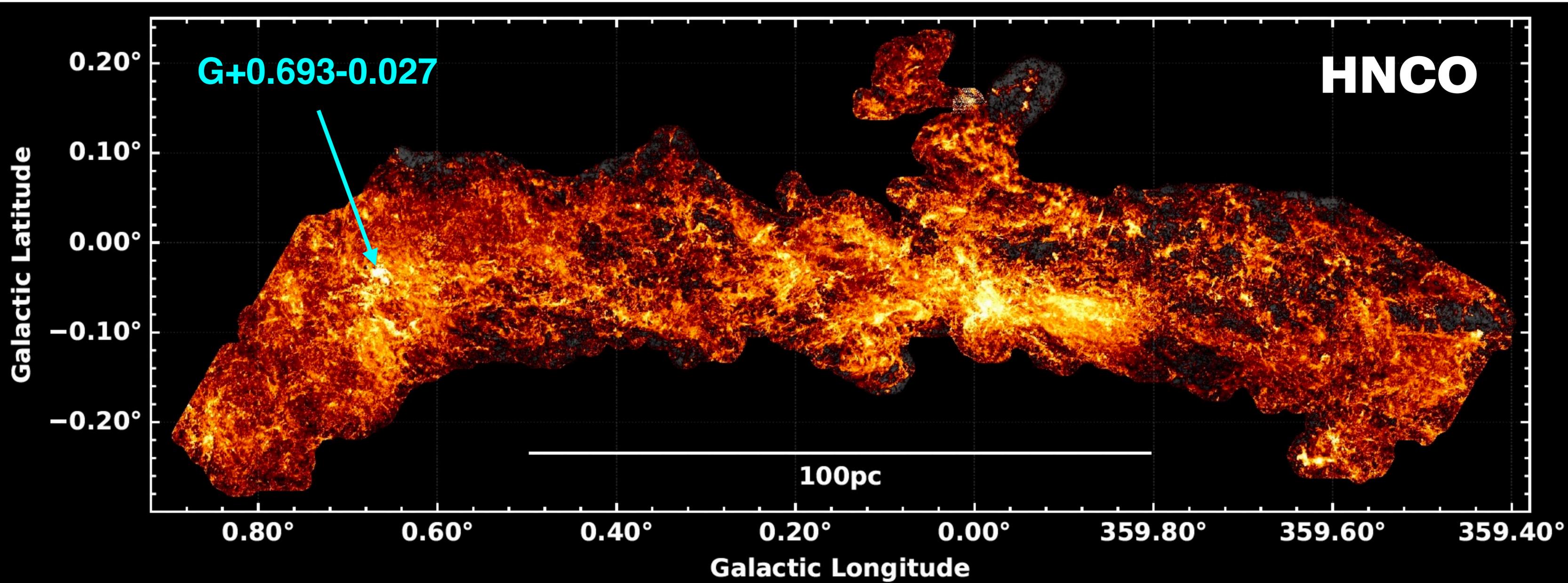
~ 0.3 mJy (~ 8.5 mK)



Sergio Martín and David San Andrés



# ACES ALMA Large Program



Longmore et al. (2026): arXIV:2602.20340 + 5 other publications

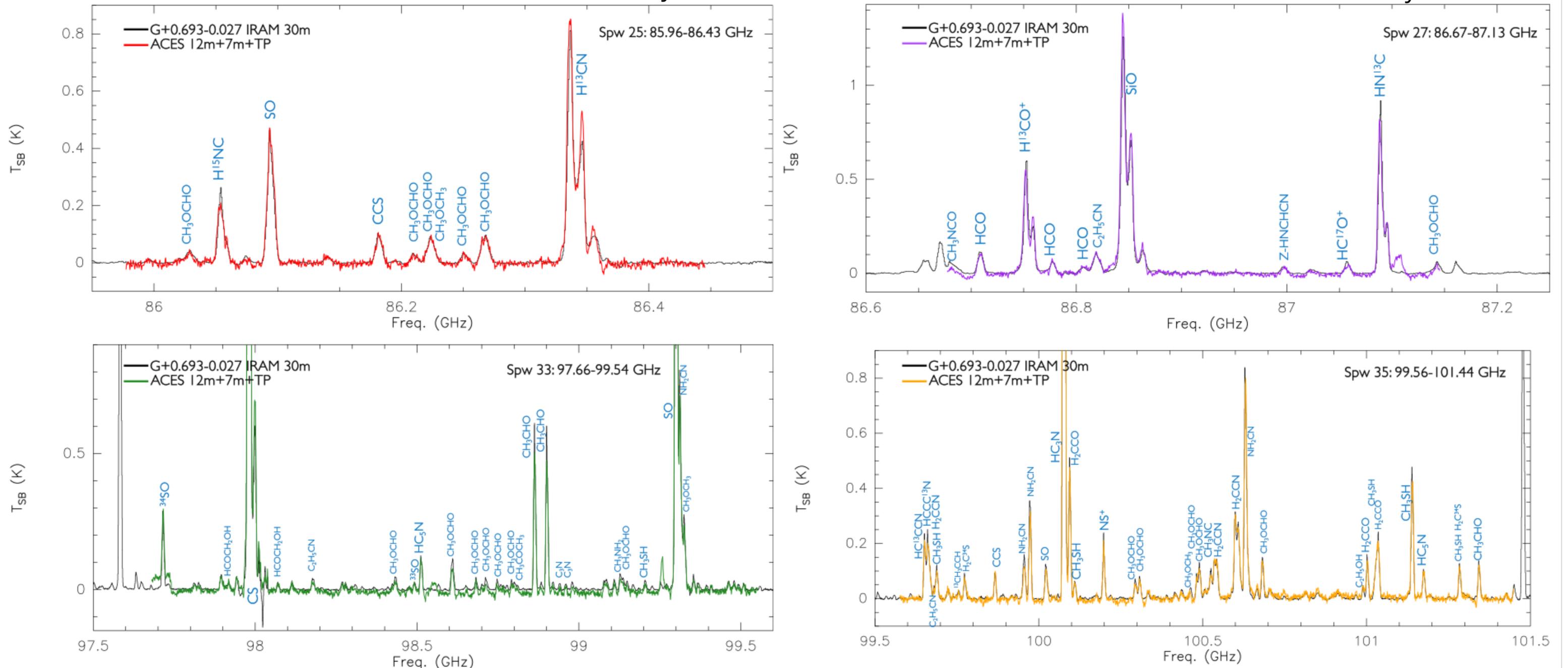


# ACES Band 6 vs. IRAM 30m



12m-array + ACA + TP recover all the flux

Courtesy of L. Colzi



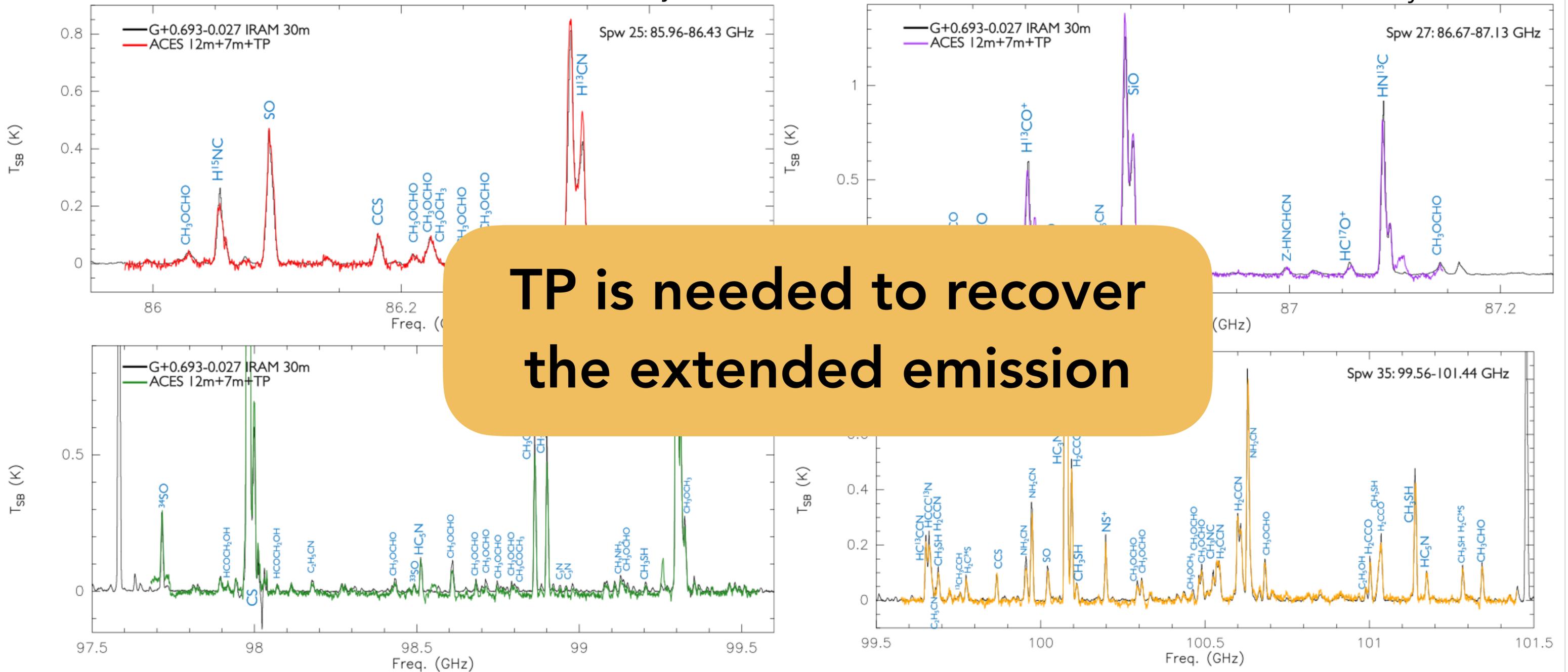


# ACES Band 6 vs. IRAM 30m



12m-array + ACA + TP recover all the flux

Courtesy of L. Colzi



**TP is needed to recover the extended emission**

**Star-forming regions??**



**Only 2 of them have been detected in star-forming regions !!**

**Z-cyanomethanimine**

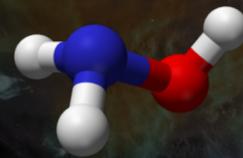


**Propargylimine**



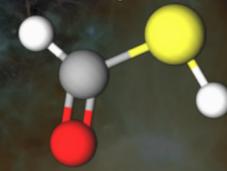
**Hydroxylamine**

Rivilla et al. (2020c)



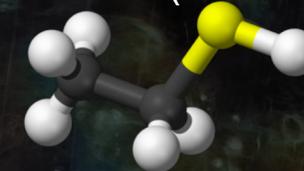
**Thioformic acid**

Rodríguez-Almeida et al. (2021a)



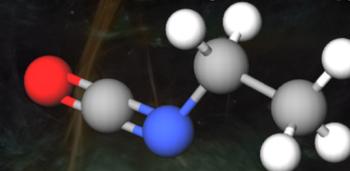
**Ethyl mercaptan**

Rodríguez-Almeida et al. (2021a)



**Ethyl isocyanate**

Rodríguez-Almeida et al. (2021b)



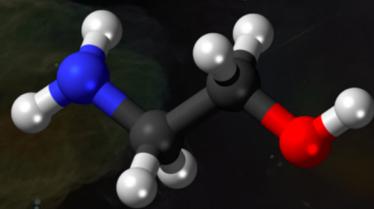
**Cyanomidyl**

Rivilla et al. (2021b)



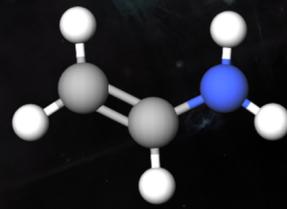
**Ethanolamine**

Rivilla et al. (2021a)



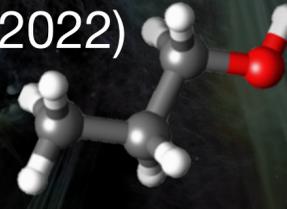
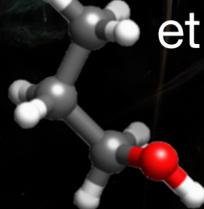
**Vinyl amine**

Zeng et al. (2021)



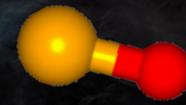
**n-propanol**

Jiménez-Serra et al. (2022)



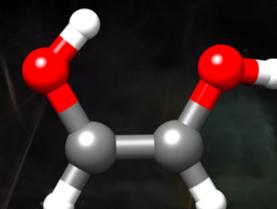
**Phosphorus oxide cation**

Rivilla et al. (2022b)



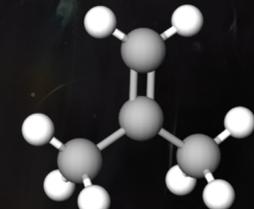
**Z-1,2-ethenediol**

Rivilla et al. (2022a)



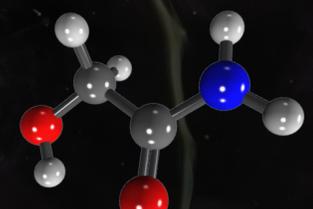
**Isobutene**

Fatima et al. (2023)



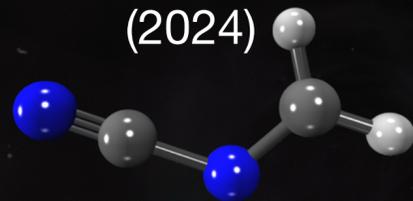
**Glycolamide**

Rivilla et al. (2023)



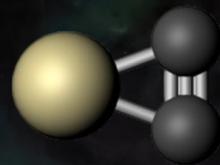
**N-cyanomethanimine**

San Andrés et al. (2024)



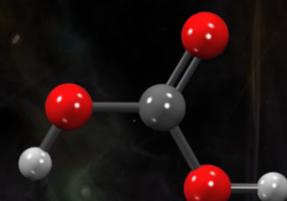
**Silacyclopropynylidene**

Massalkhi et al. (2023)



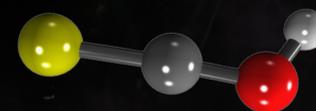
**Carbonic acid**

Sanz-Novo et al. (2023)



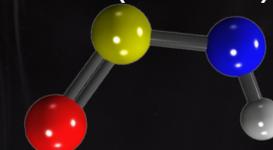
**Protonated carbonyl sulphide**

Sanz-Novo et al. (2024a)



**Thionylimide**

Sanz-Novo et al. (2024b)

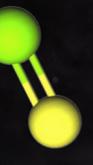


**Magnesium sulfide**

Rey-Montejo et al. (2024)

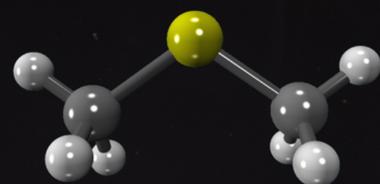


**Sodium sulfide**



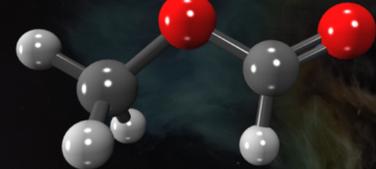
**Dimethyl sulfide**

Sanz-Novo et al. (2025a)



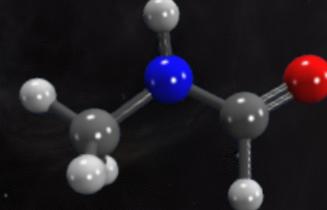
**Trans methyl formate**

Sanz-Novo et al. (2025b)



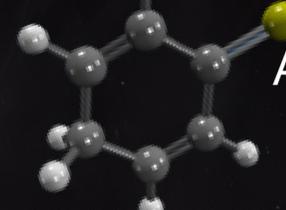
**Cis N-methyl formamide**

Zeng et al. (2025)



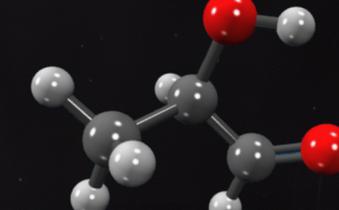
**2,5-cyclohexadien-1-thione**

Araki et al. (2026)

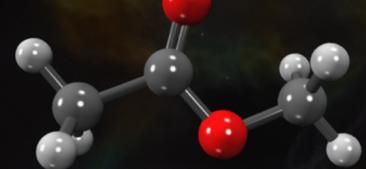


**Lactaldehyde**

Sanz-Novo et al. (2026)



**Methoxacetaldehyde**



# ALMA Band 2 SV



Atacama Large Millimeter/submillimeter Array  
In search of our Cosmic Origins

[About](#)[Science](#)[Proposing](#)[Observing](#)[Data](#)[Processing](#)[Tools](#)[Documentation](#)[Help](#)

## Announcement of Intent to Release Science Verification Data in Band 2

19 February 2026

A new release of Science Verification data is planned late February. The data release for Band 2 will consist of the following targets:

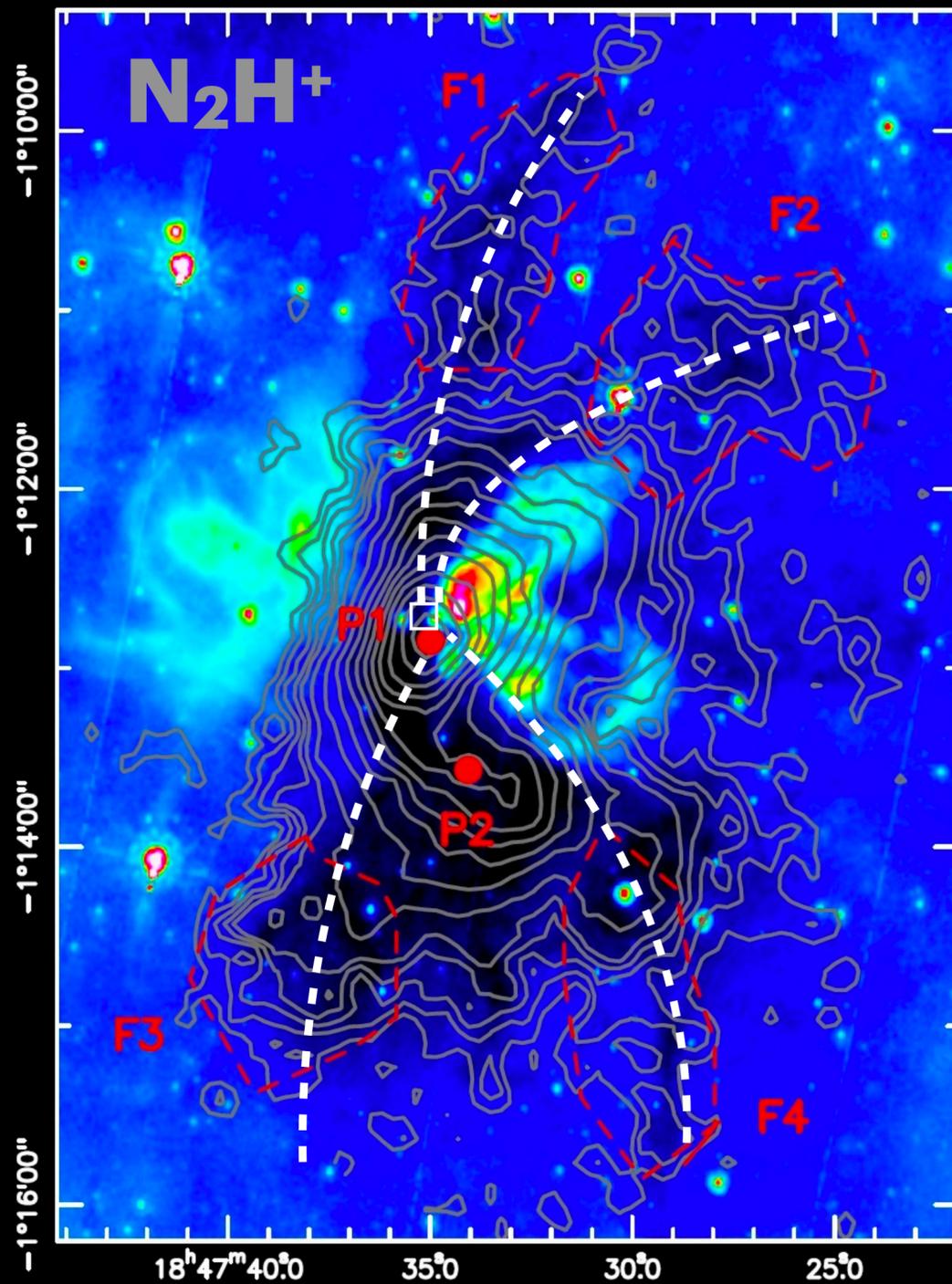
- G31.41+0.31: spectral scan in Band 2
- SPT 0027-50: spectral scan in Band 2
- HR 5907: full polarization in Band 2



Details of the targets will be listed on [the Science Verification web page](#). There will be a separate announcement once the data are released.

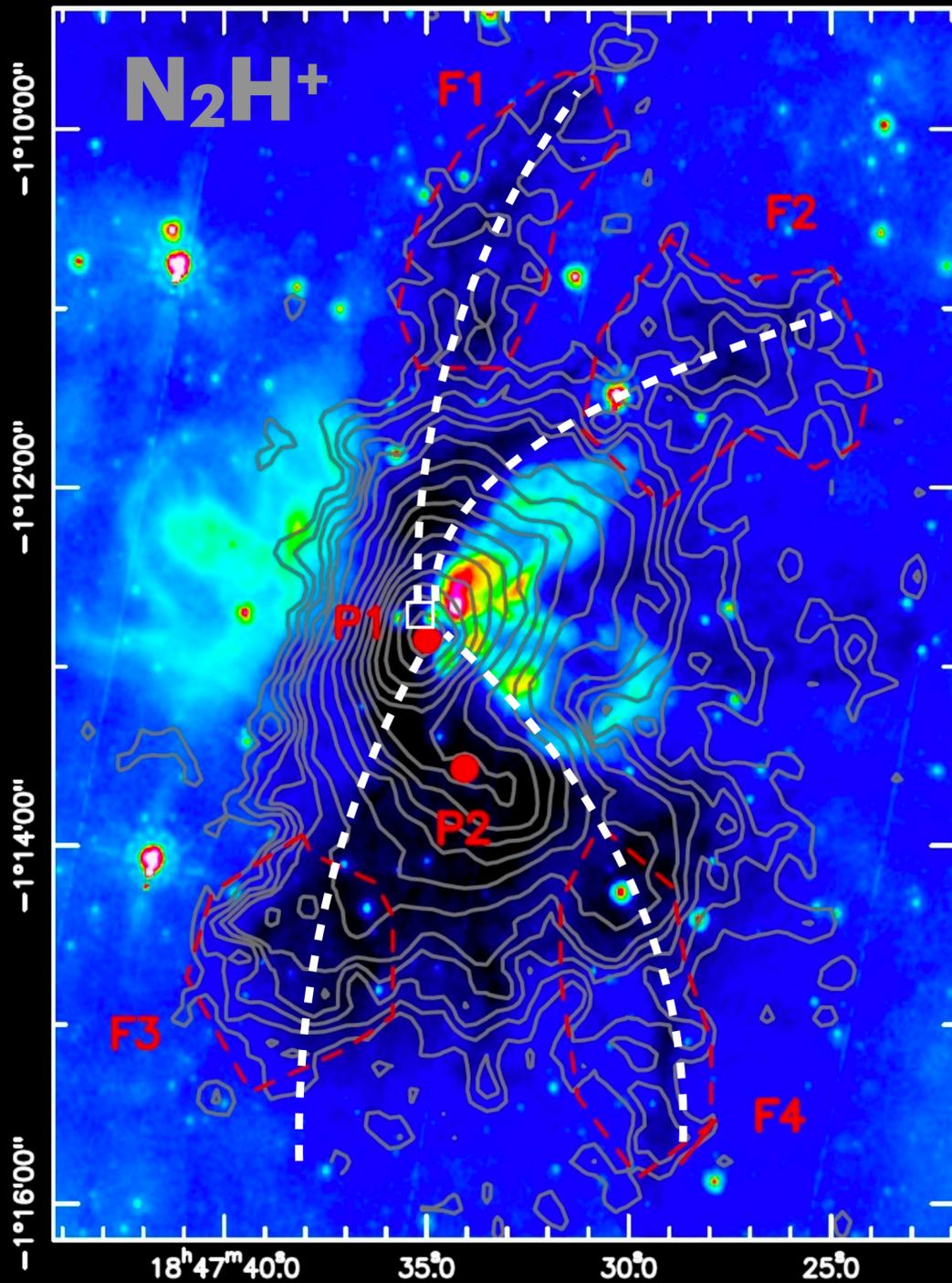
# The G31.41+0.31 massive star-forming region

IR Spitzer 8microns image

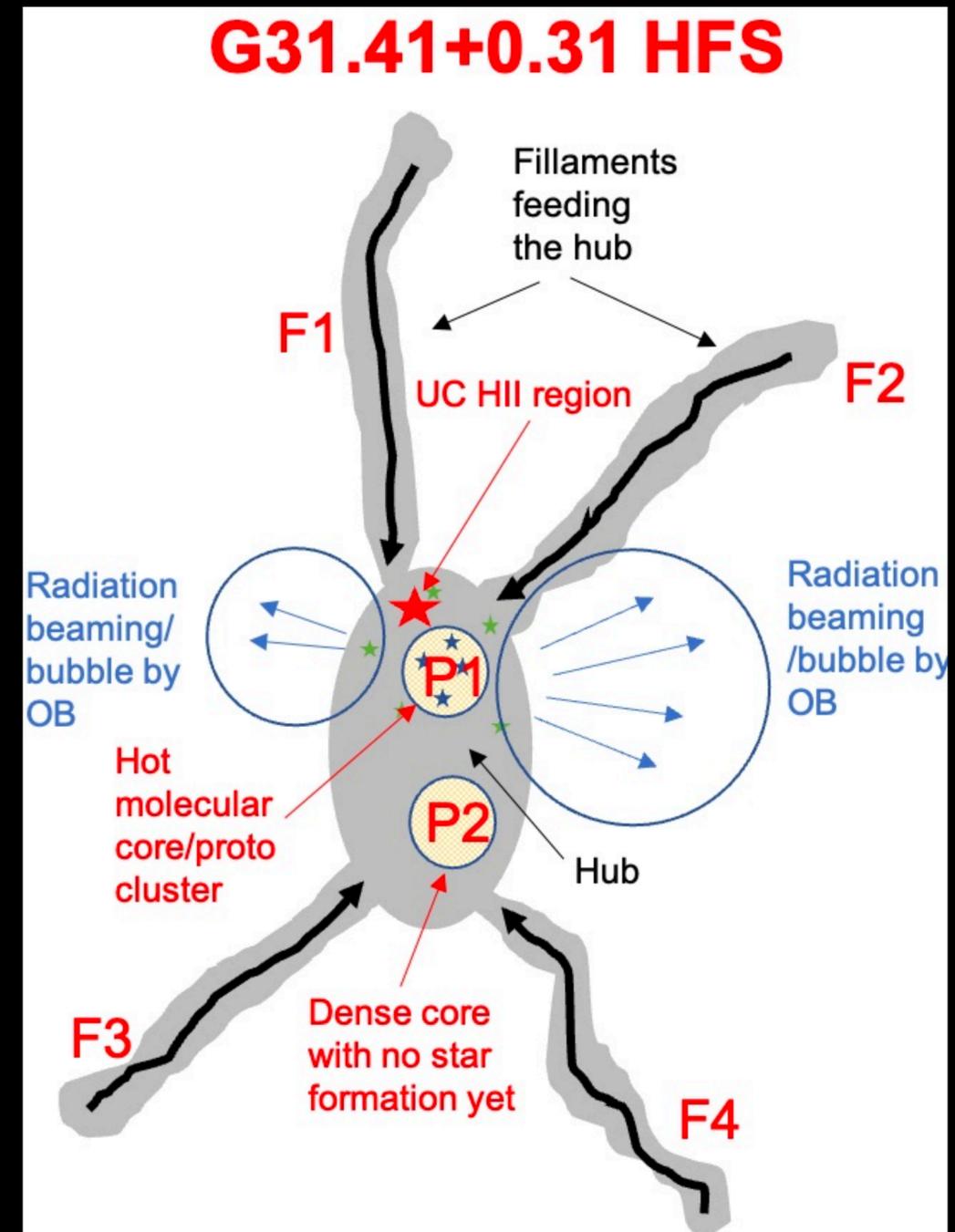


# The G31.41+0.31 massive star-forming region

IR Spitzer 8microns image

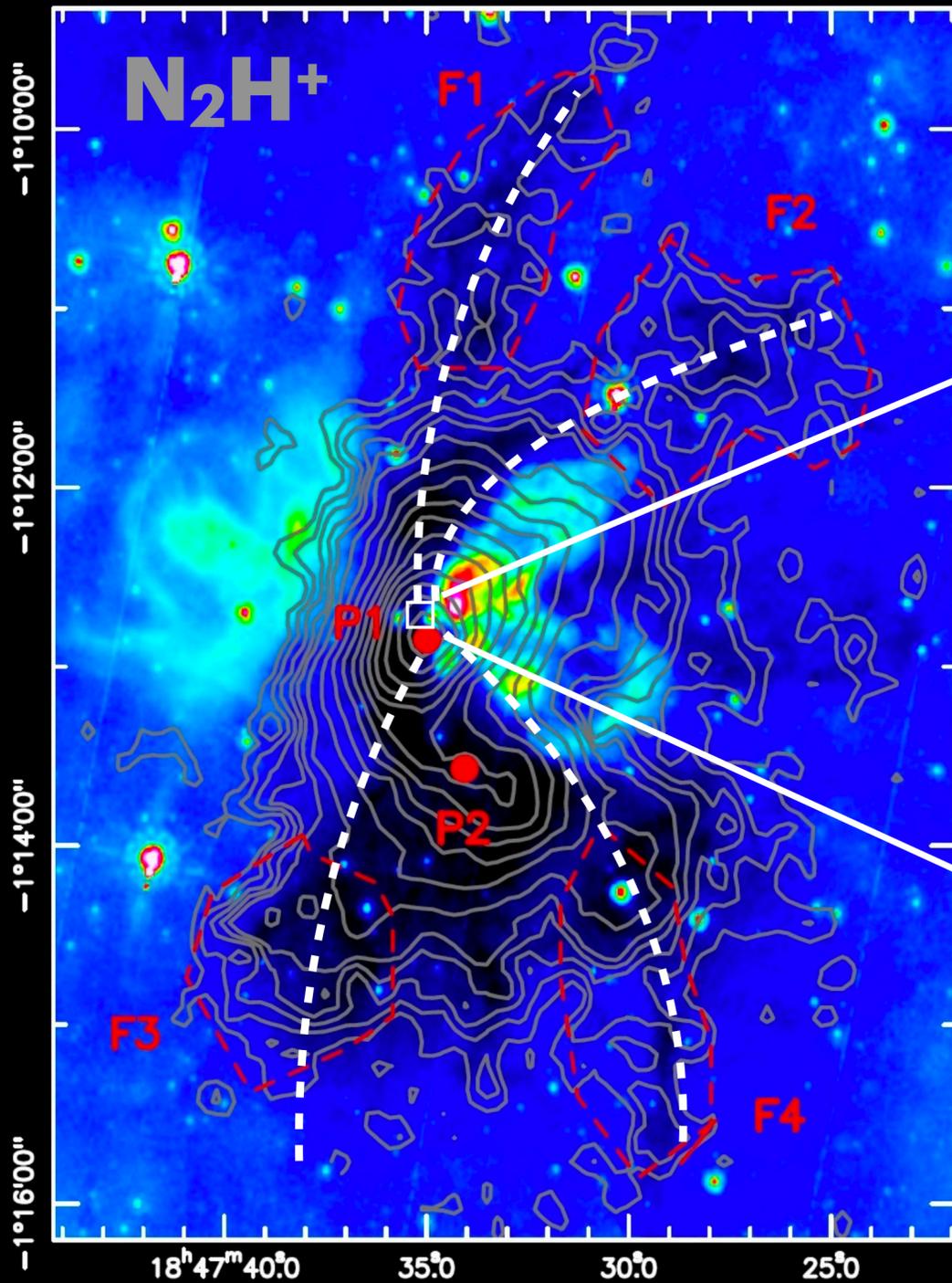


Beltrán et al. (2022)



# The G31.41+0.31 massive star-forming region

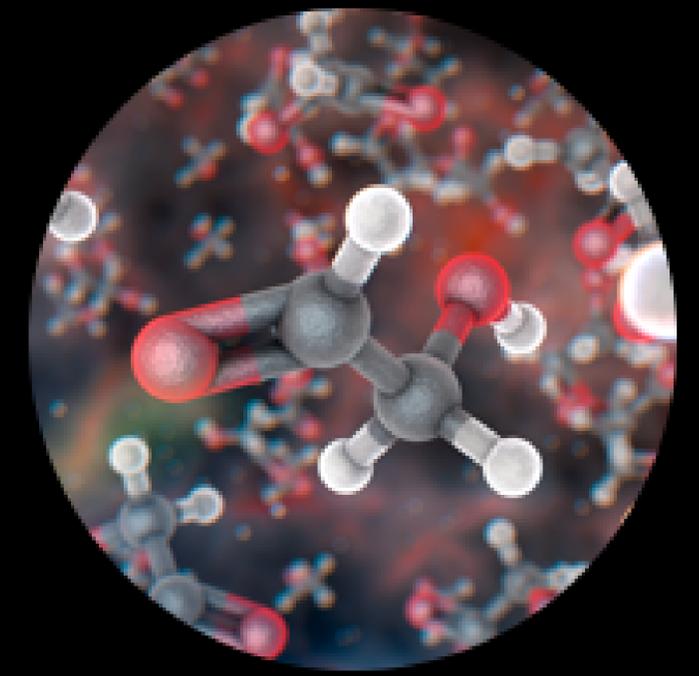
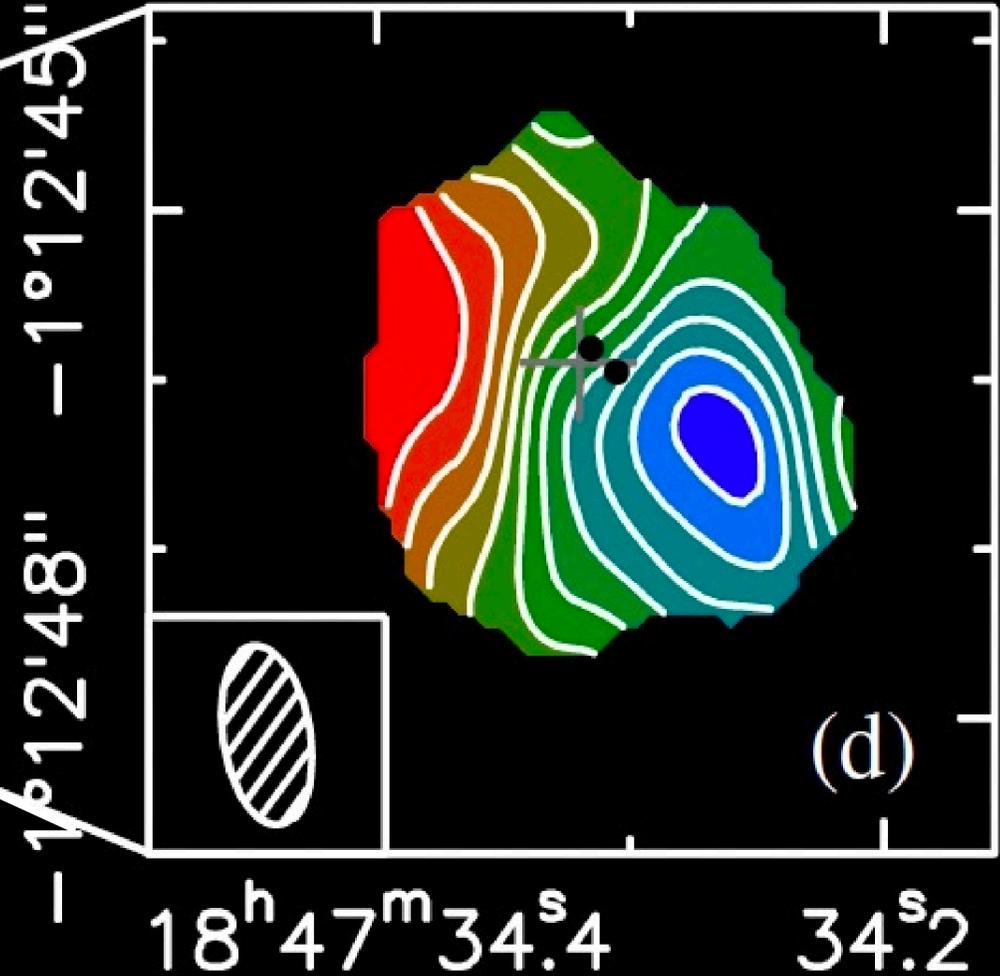
IR Spitzer 8microns image



THE ASTROPHYSICAL JOURNAL, 690:L93–L96, 2009 January 10  
 © 2009. The American Astronomical Society. All rights reserved. Printed in the U.S.A.  
 doi:10.1088/0004-637X/690/2/L93

FIRST DETECTION OF GLYCOLALDEHYDE OUTSIDE THE GALACTIC CENTER\*

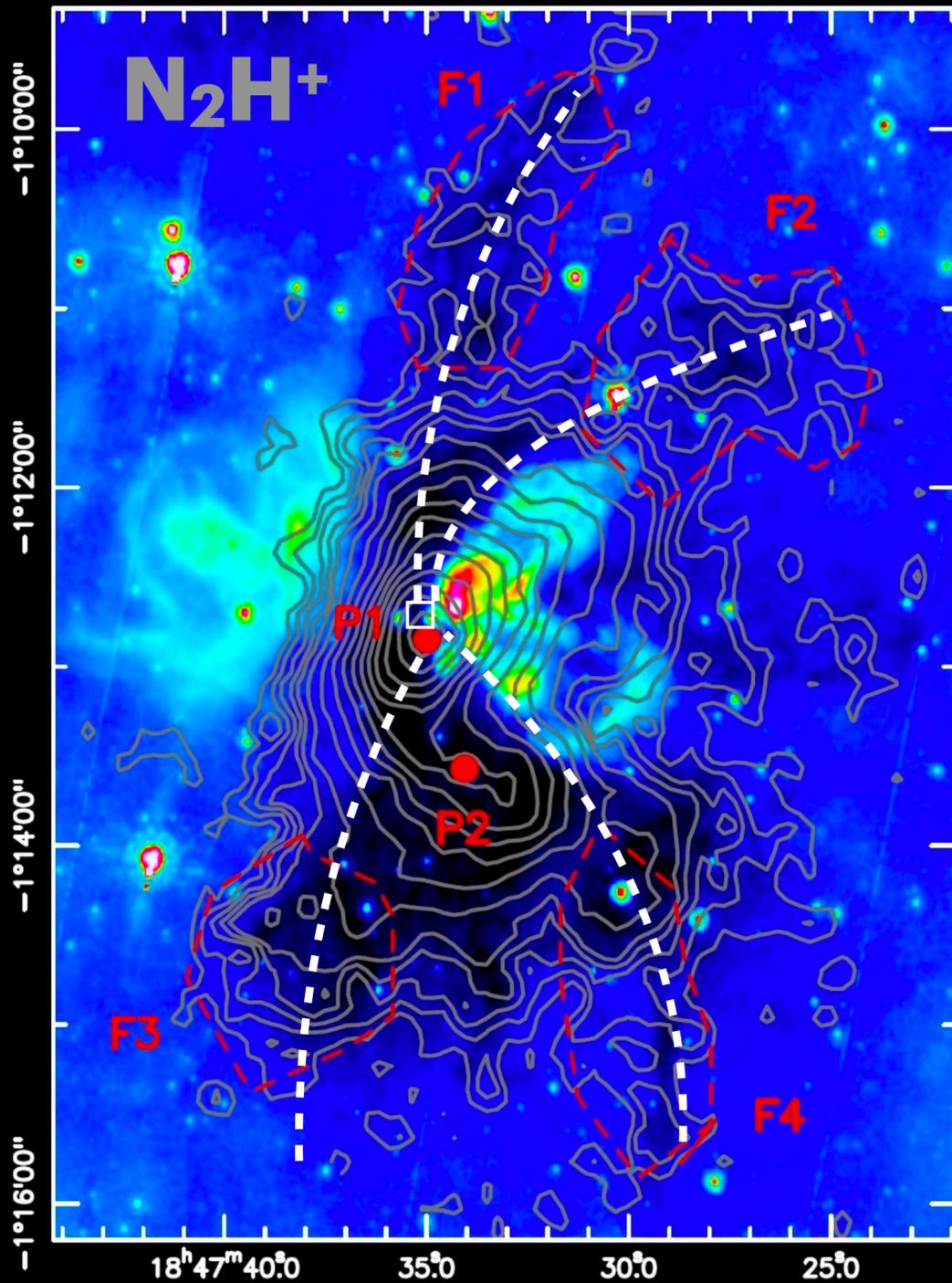
M. T. BELTRÁN<sup>1</sup>, C. CODELLA<sup>2</sup>, S. VITI<sup>3</sup>, R. NERI<sup>4</sup>, AND R. CESARONI<sup>5</sup>



Beltrán et al. (2009)

# The G31.41+0.31 massive star-forming region

IR Spitzer 8microns image

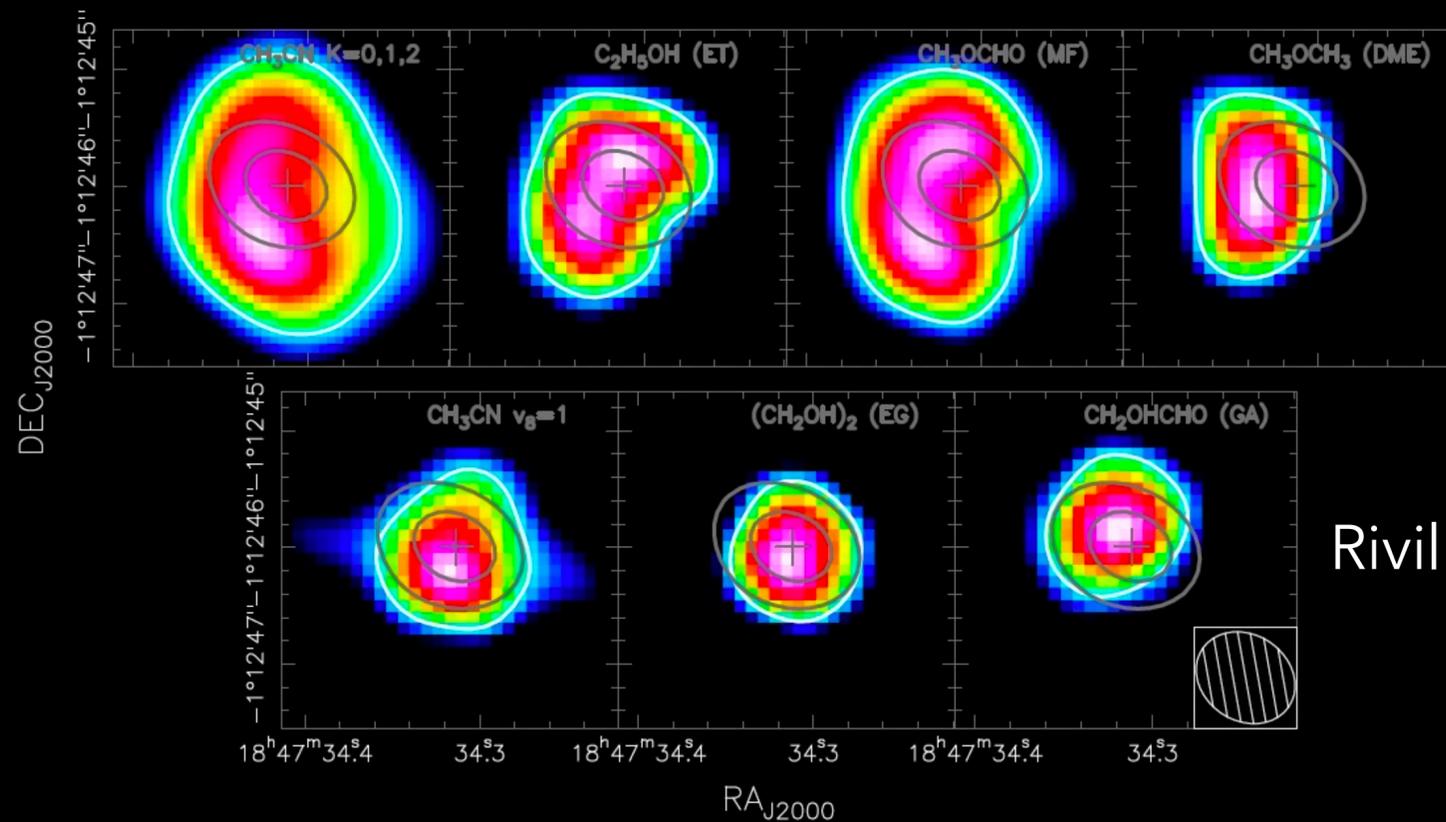


A&A 598, A59 (2017)  
 DOI: 10.1051/0004-6361/201628373  
 © ESO 2017

**Astronomy  
&  
Astrophysics**

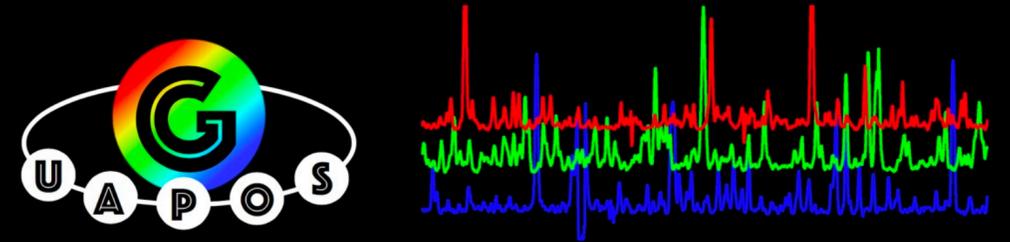
## Formation of ethylene glycol and other complex organic molecules in star-forming regions<sup>★</sup>

V. M. Rivilla<sup>1</sup>, M. T. Beltrán<sup>1</sup>, R. Cesaroni<sup>1</sup>, F. Fontani<sup>1</sup>, C. Codella<sup>1</sup>, and Q. Zhang<sup>2</sup>

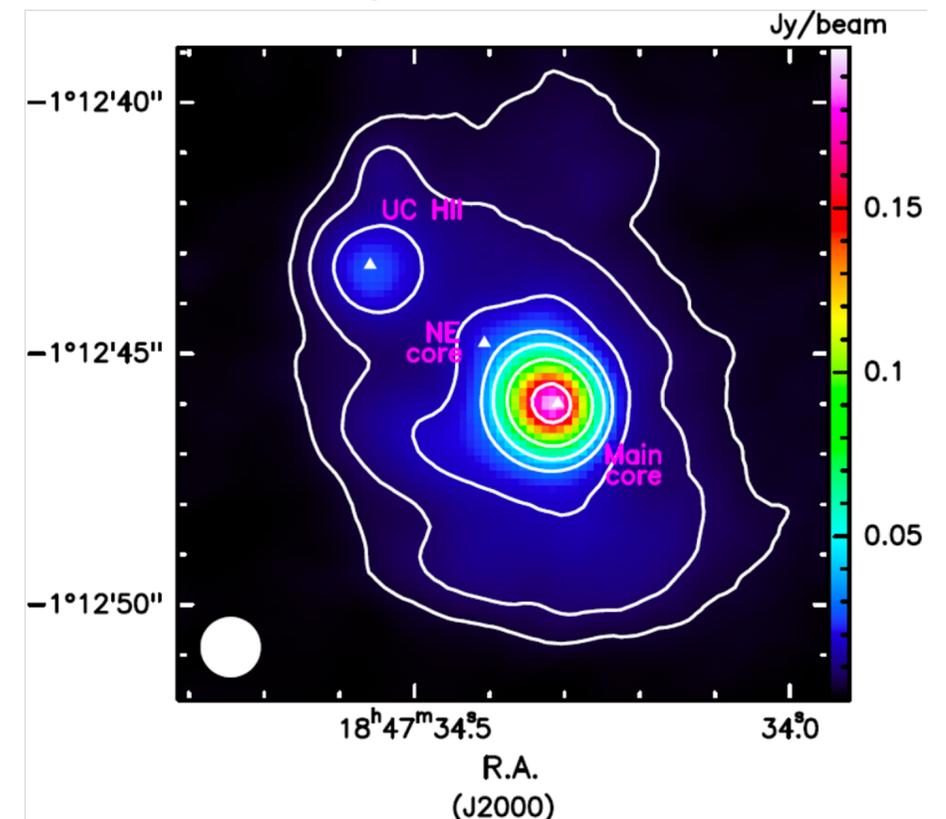


Rivilla et al. (2017a)

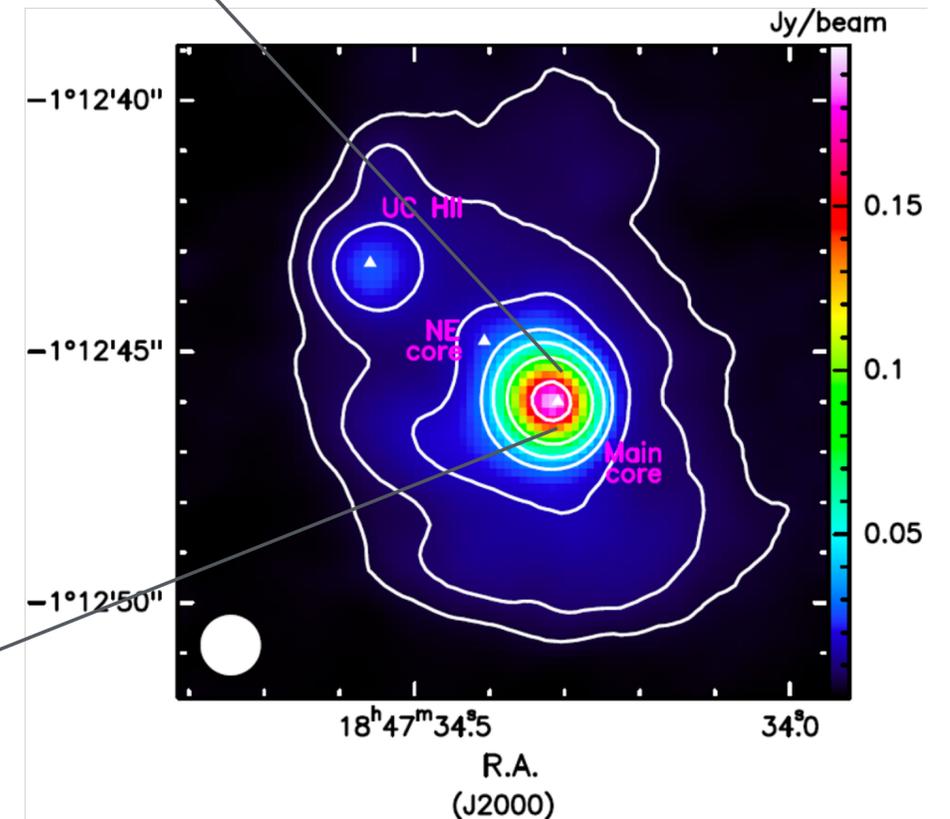
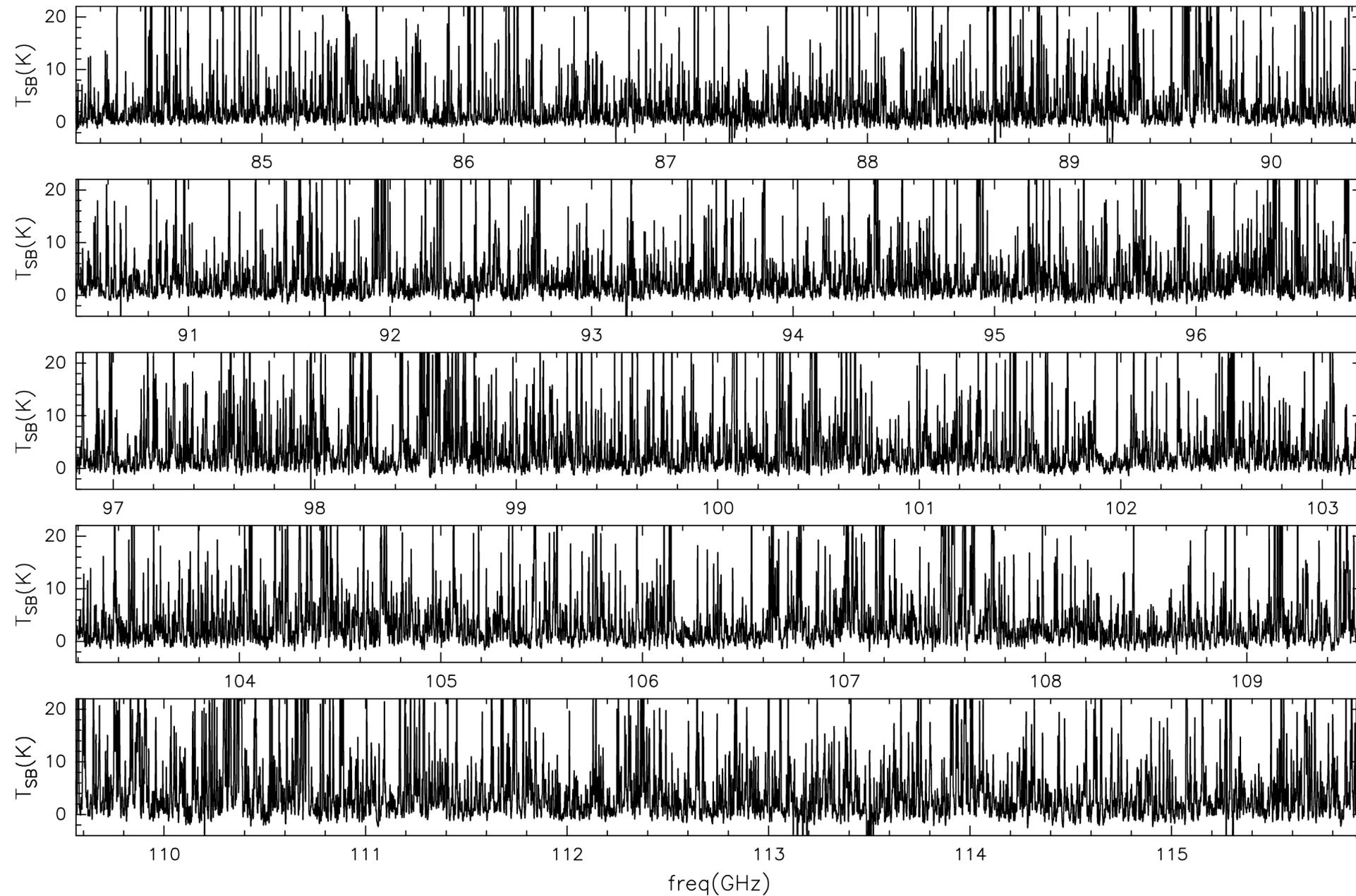
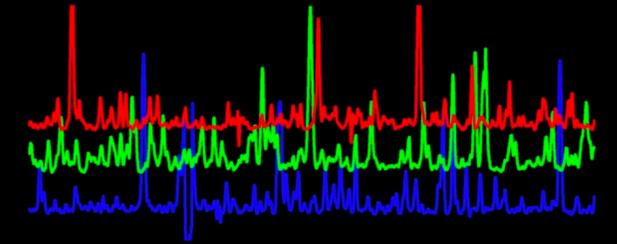
# GUAPOS: G31.41+0.31 Unbiased ALMA sPectral Observational Survey



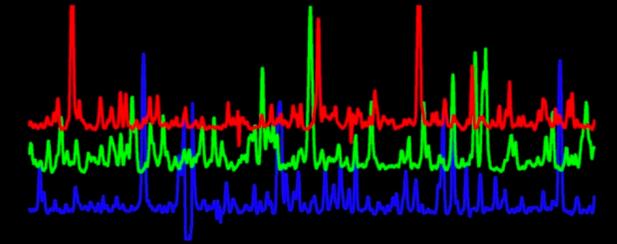
- PI: Maite Beltrán
- Target: G31.41+0.31 hot molecular core
- Spectral resolution ( $\sim 0.5$  MHz) = 1.2-1.7 km/s
- Final spatial resolution 1.2'' (about 4500 au).
- rms = 0.5 - 1.9 mJy/beam.



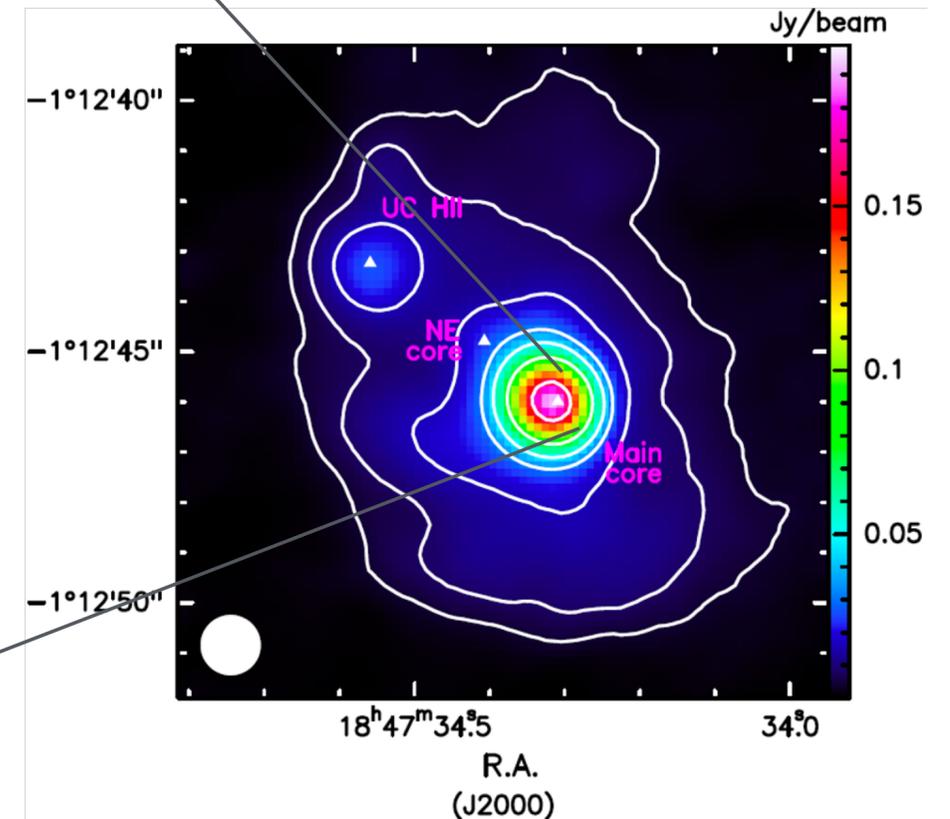
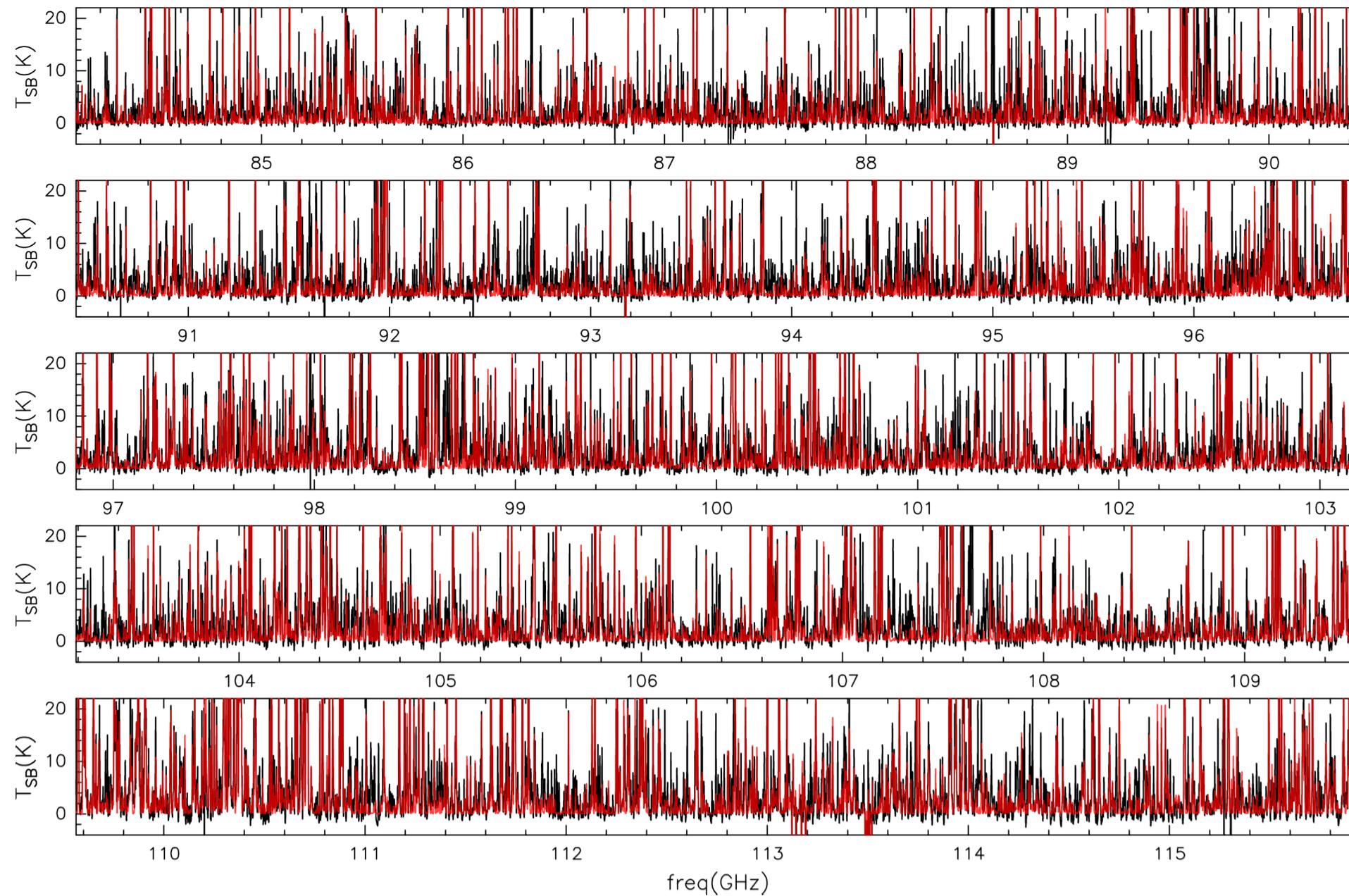
# GUAPOS: G31.41+0.31 Unbiased ALMA sPectral Observational Survey

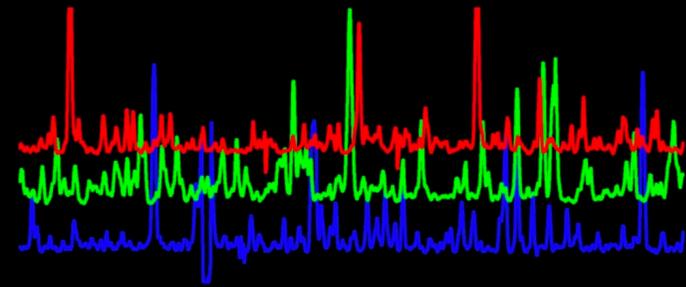


# GUAPOS: G31.41+0.31 Unbiased ALMA sPectral Observational Survey



LTE modelling considering all species identified





NH <sub>3</sub>	Ammonia	C <sub>2</sub> H <sub>3</sub> CN	Vinyl cyanide
HCN	Hydrogen cyanide	C <sub>2</sub> H <sub>5</sub> CN	Ethyl cyanide
CO	Carbon monoxide	CH <sub>3</sub> NCO	Methyl Isocyanate
H <sub>2</sub> CO	Formaldehyde	C <sub>2</sub> H <sub>5</sub> CHO	Propanal
CH <sub>3</sub> OH	Methanol	CH <sub>3</sub> COCH <sub>3</sub>	Acetone
CH <sub>3</sub> CCH	Propyne	CH <sub>3</sub> C(O)NH <sub>2</sub>	Acetamide
CH <sub>3</sub> CN	Methyl cyanide	CH <sub>3</sub> NHCHO	N-Methylformamide
CH <sub>3</sub> NC	Methyl isocyanide	OCS	Carbonyl sulphide
NH <sub>2</sub> CN	Methyl isocyanide	CH <sub>3</sub> OCHO	Methyl formate
HNCO	Isocyanic acid	CH <sub>2</sub> OHCHO	Glycolaldehyde
CH <sub>3</sub> CHO	Acetaldehyde	CH <sub>3</sub> COOH	Acetic acid
c-C <sub>2</sub> H <sub>4</sub> O	Ethylene oxide	aGg'-((CH <sub>2</sub> OH) <sub>2</sub> )	aGg'- Ethylene glycol
CS	Carbon monosulphide	gGg'-((CH <sub>2</sub> OH) <sub>2</sub> )	gGg'- Ethylene glycol
NH <sub>2</sub> CHO	Formamide	CH <sub>3</sub> OCH <sub>2</sub> OH	Methoxymethanol
H <sub>2</sub> CS	Thioformaldehyde	SO <sub>2</sub>	Sulphur dioxide
C <sub>2</sub> H <sub>5</sub> OH	Ethanol		
CH <sub>3</sub> OCH <sub>3</sub>	Dimethyl ether		
t-HCOOH	Formic acid		
HONO	Nitrous acid		
CH <sub>3</sub> SH	Methyl mercaptan		
SO	Sulphur monoxide		
HC <sub>3</sub> N	Cyanoacetylene		

**GUAPOS I** (Mininni et al. 2020)

**GUAPOS II** (Colzi et al. 2021)

**GUAPOS III** (Mininni et al. 2022)

**GUAPOS IV** (Fontani et al. 2023)

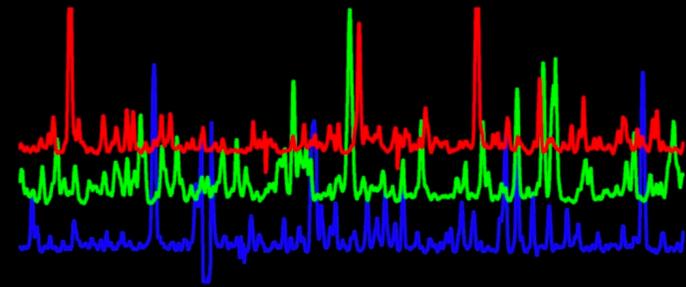
**GUAPOS V** (Lopez-Gallifa et al. 2024)

**GUAPOS VI** (López Gallifa et al. 2025)

**GUAPOS VII** (Cesaroni et al. 2026)

García de la Concepción et al. (2023)

Cesaroni et al. (1994)



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**GUAPOS IV** (Fontani et al. 2023)

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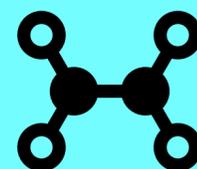
**GUAPOS VI** (López Gallifa et al. 2025)

**GUAPOS VII** (Cesaroni et al. 2026)

García de la Concepción et al. (2023)

Cesaroni et al. (1994)

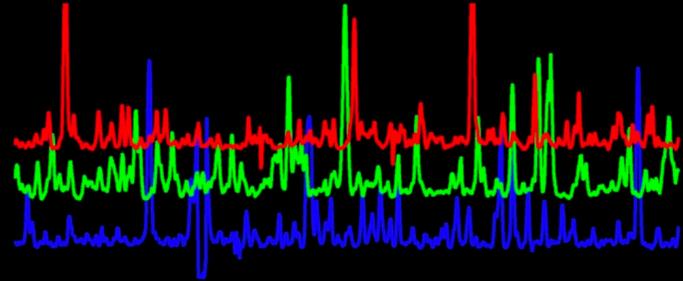
MOLECULAR SAMPLE



• **51 different species**

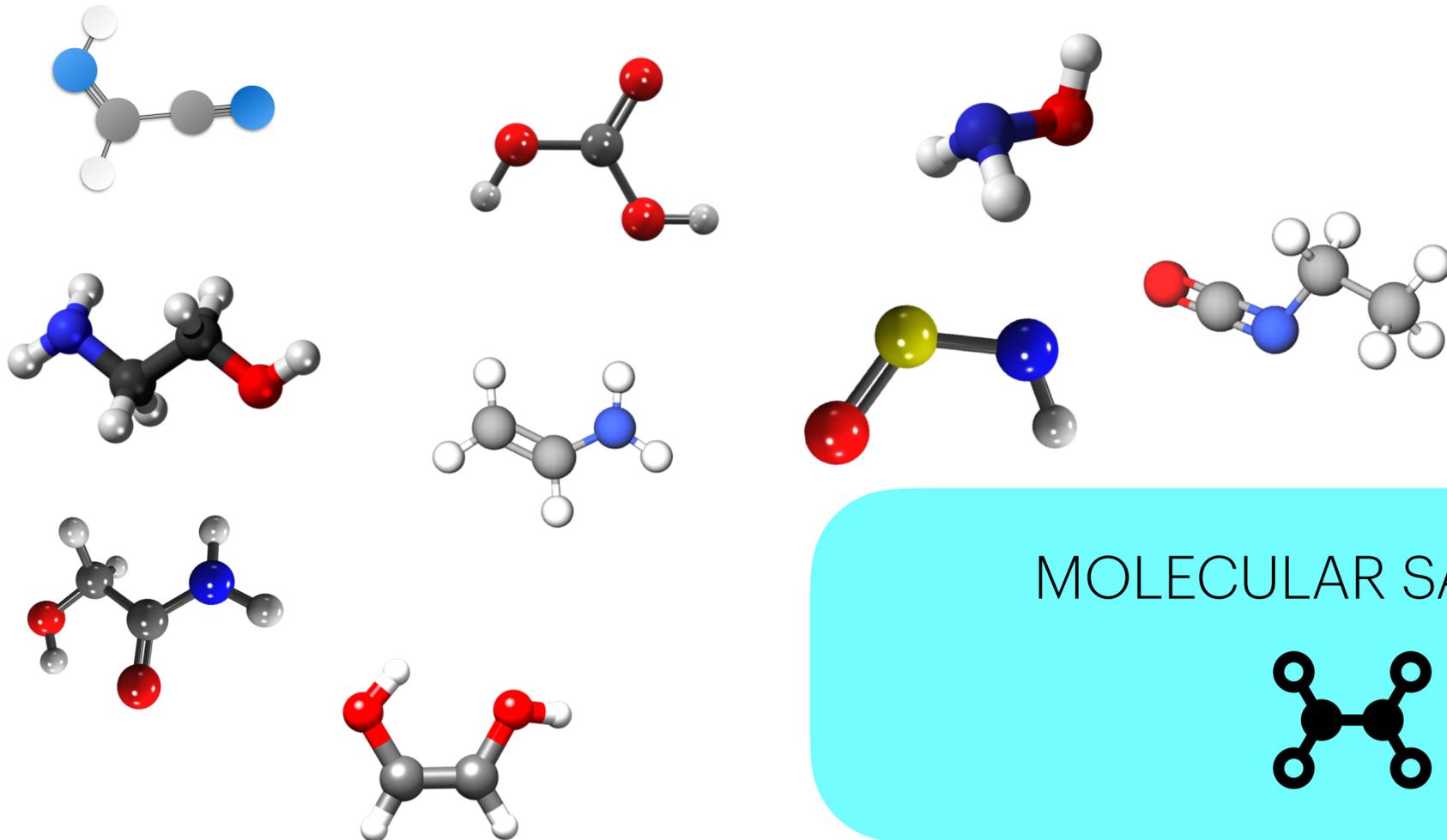
• **42 isotopologues**

• **23 COMs (> 5 atoms)**

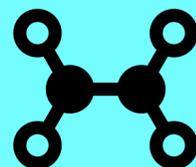


**BUT...**

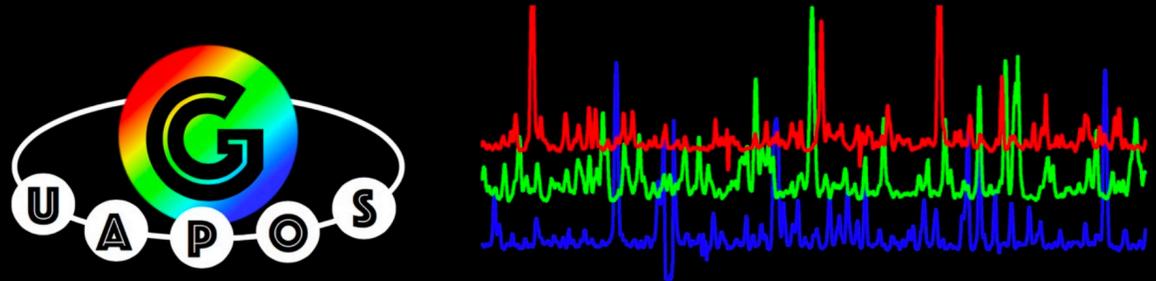
**none of these are detected**



MOLECULAR SAMPLE

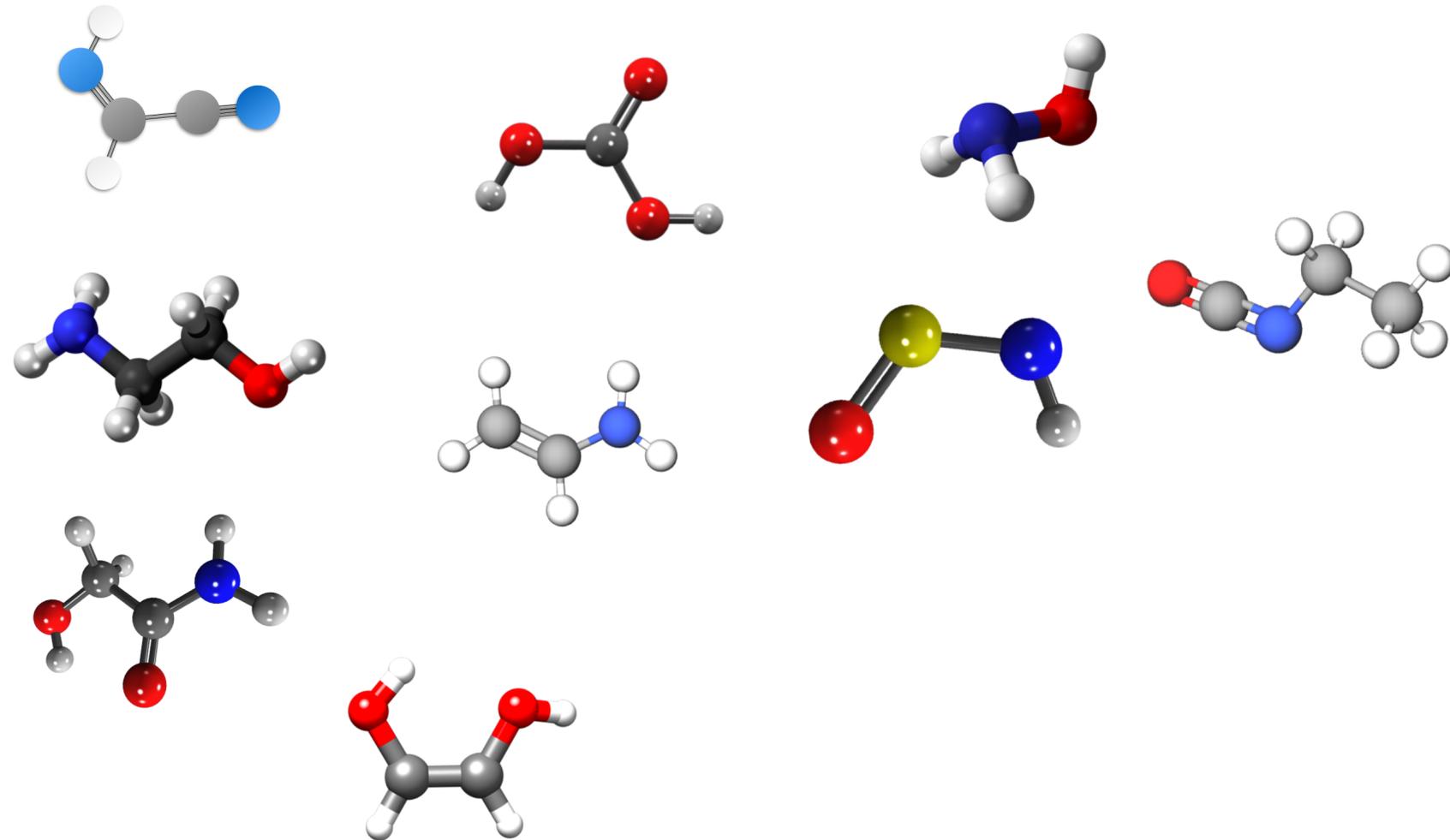


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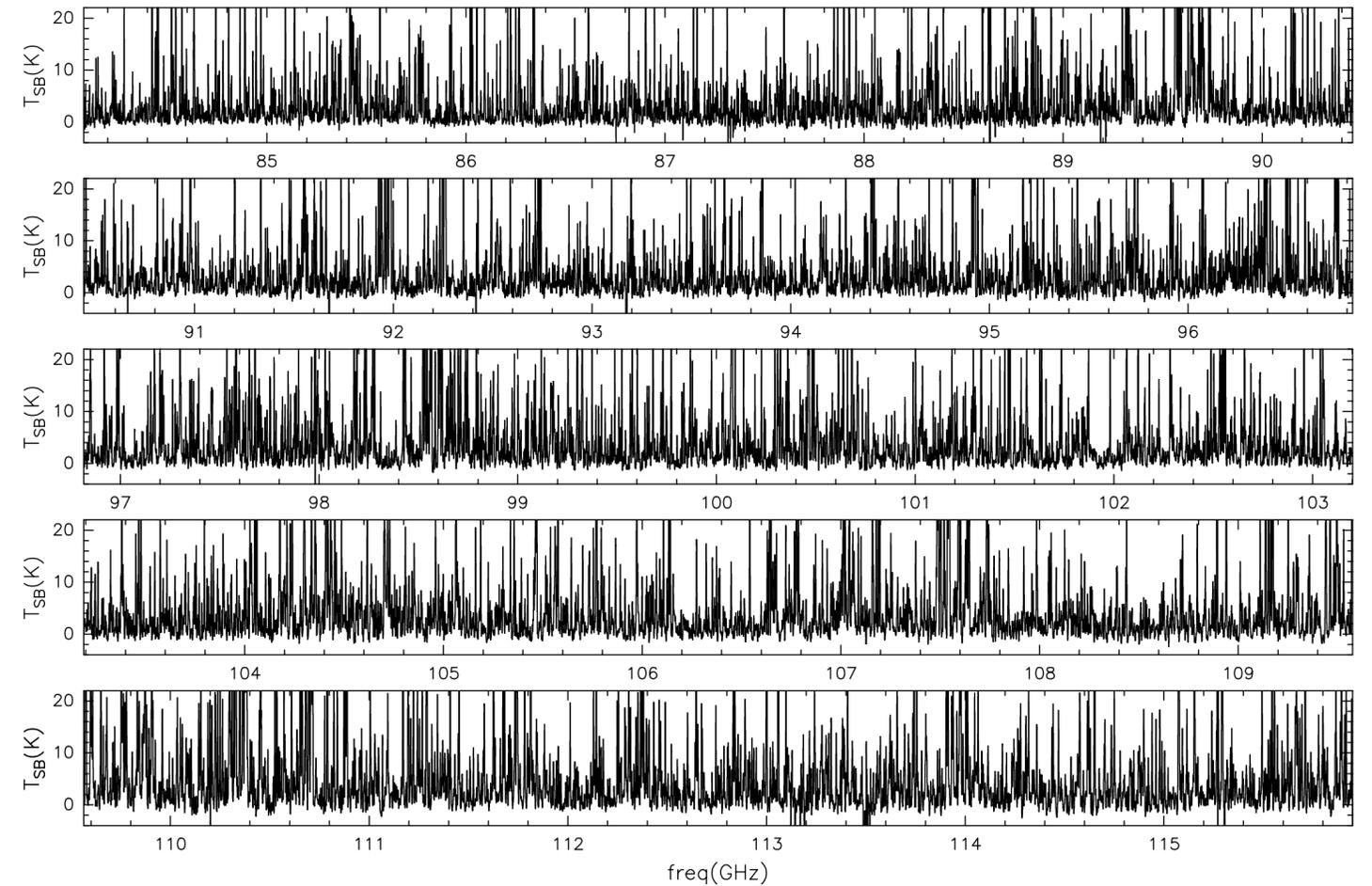


**BUT...**

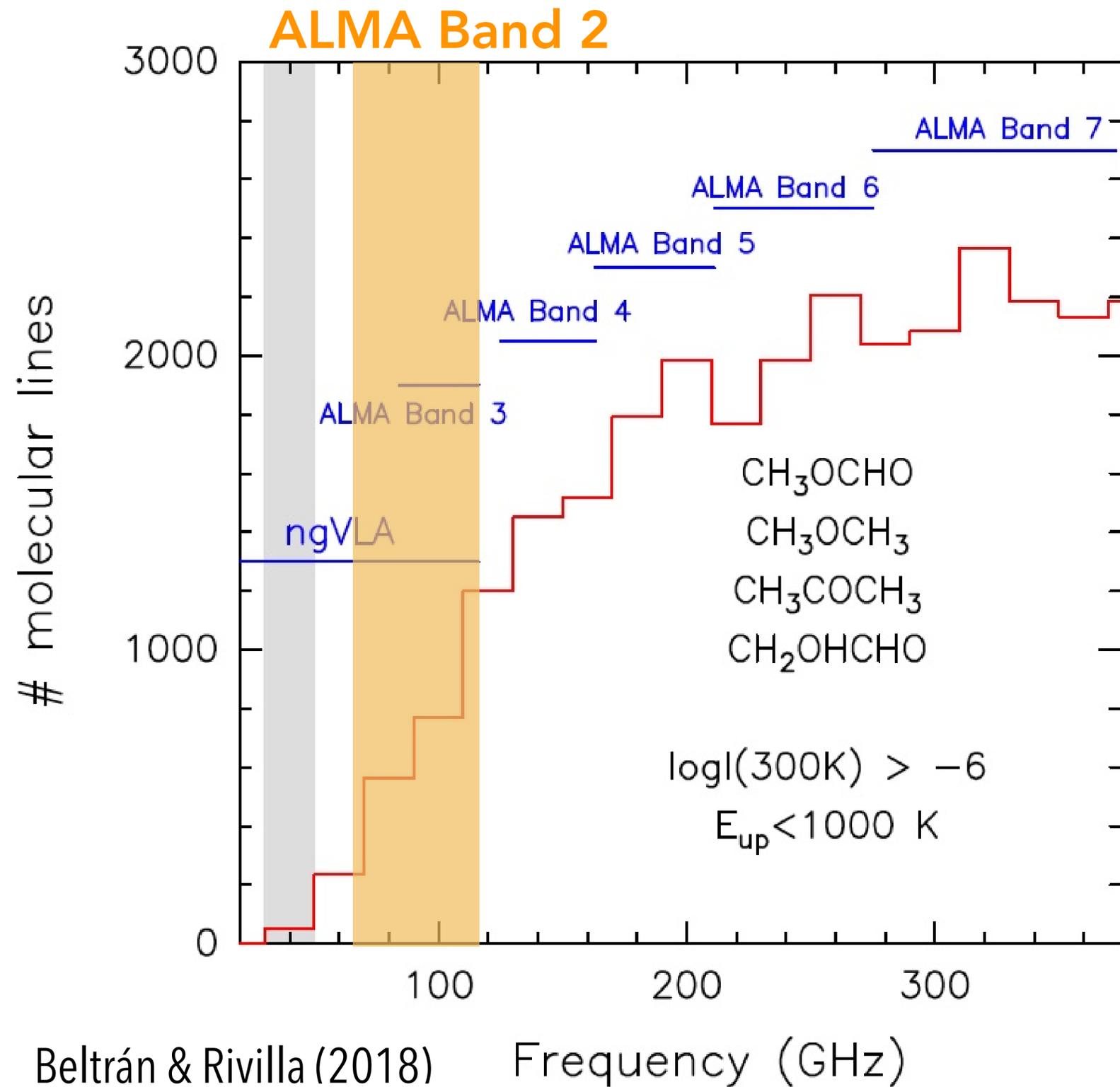
**none of these are detected**



**Line confusion**



# ALMA Band 2 (and 1)



**Significantly lower line density**

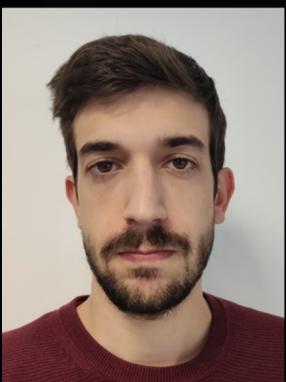
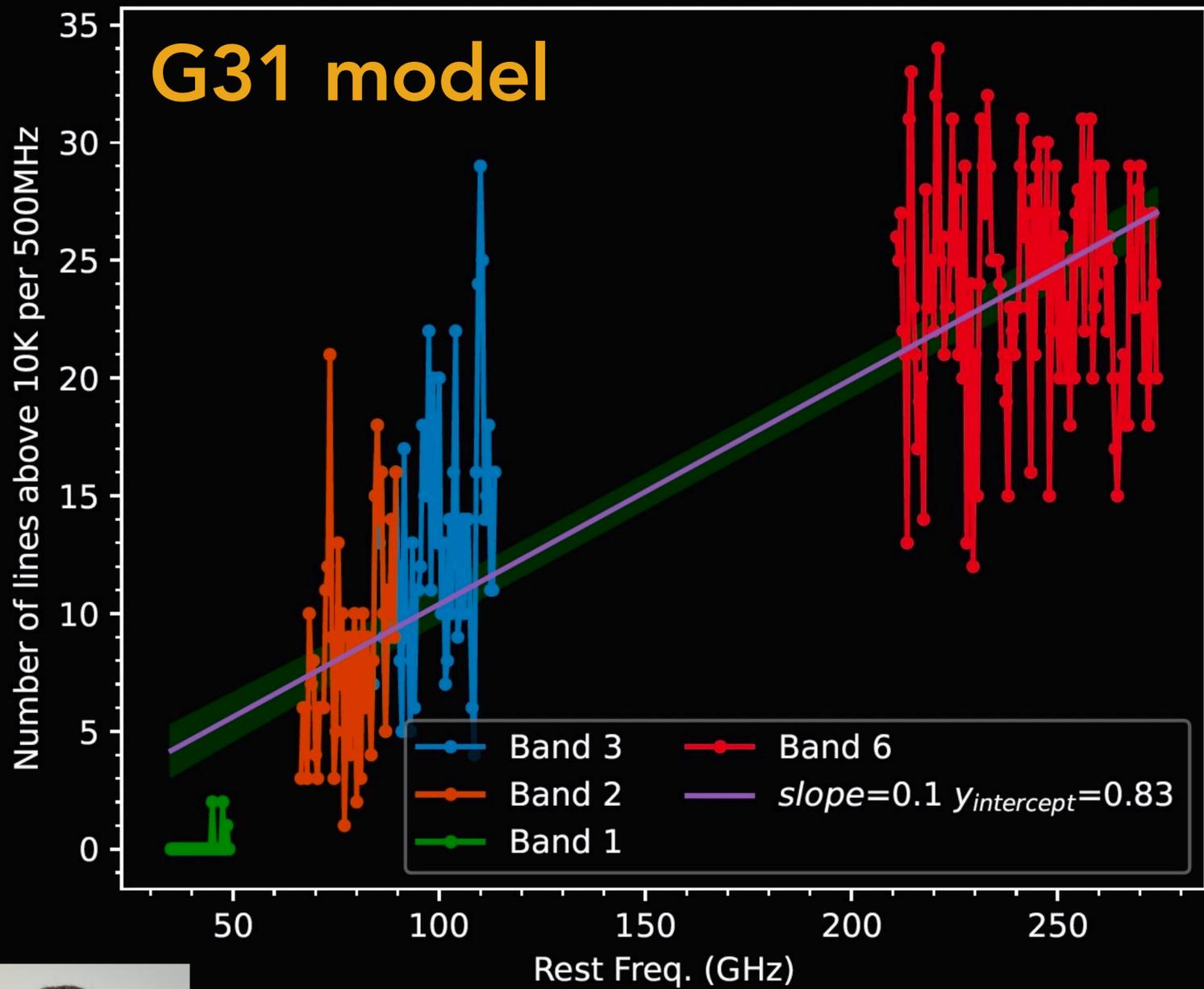


**Line blending mitigation**



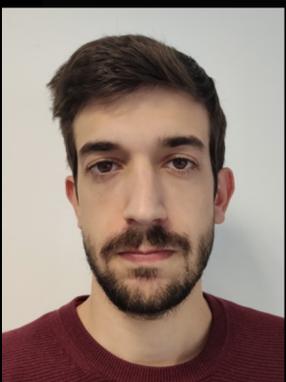
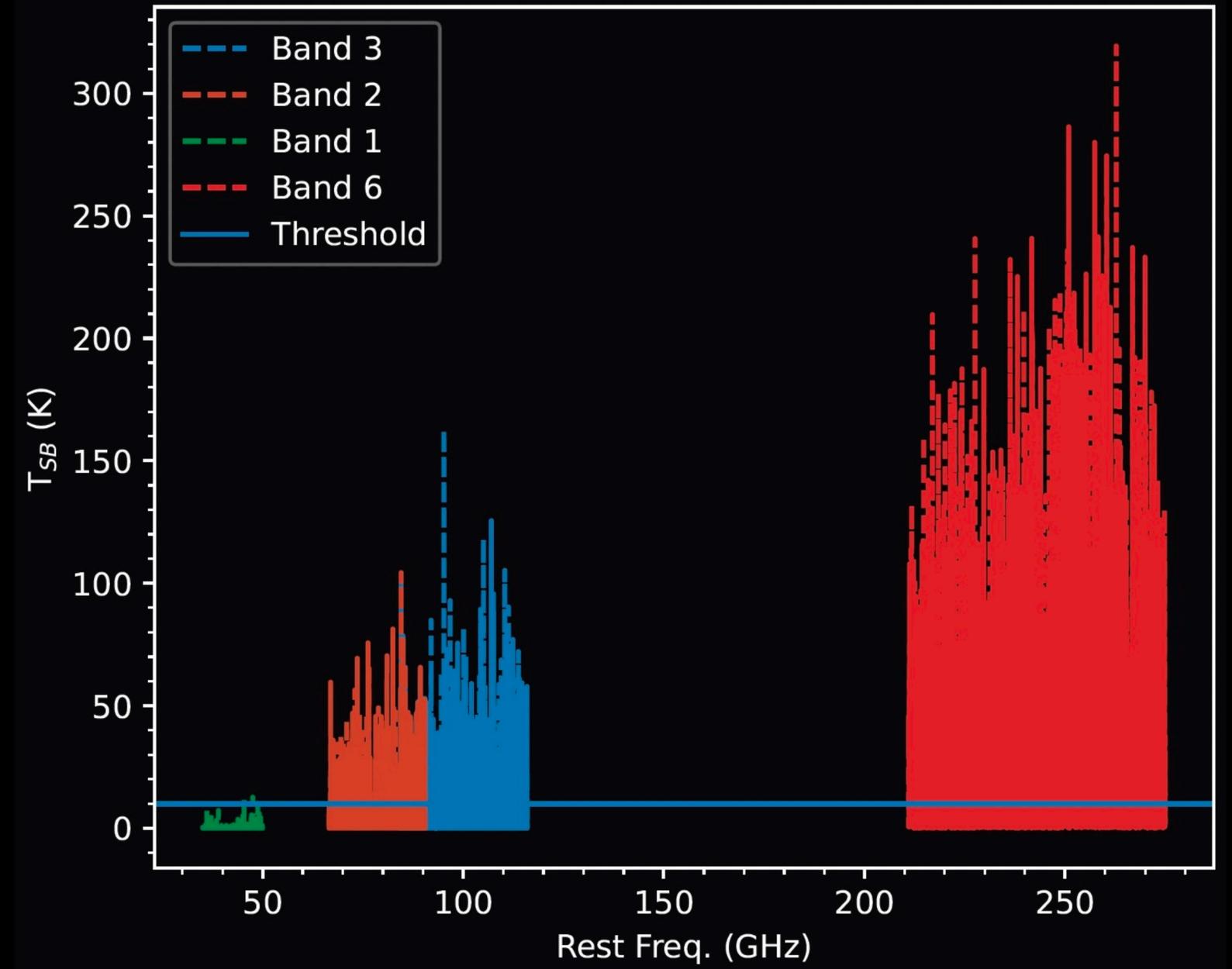
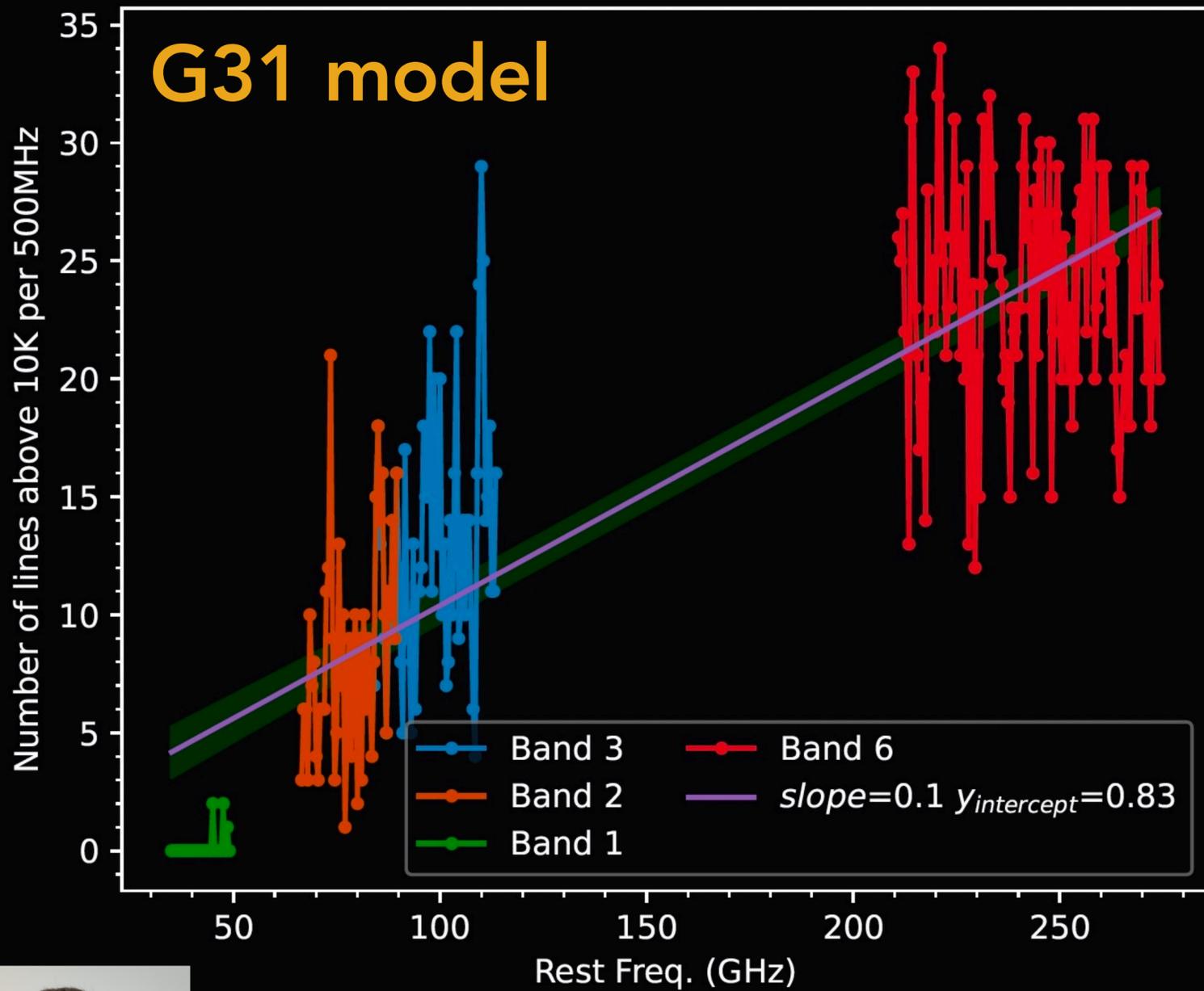
**New detections**

# Line density decreases with frequency



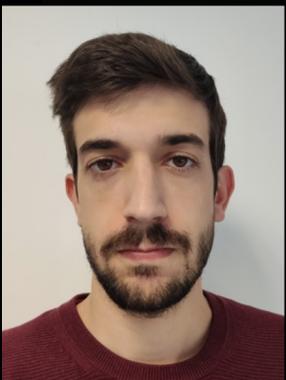
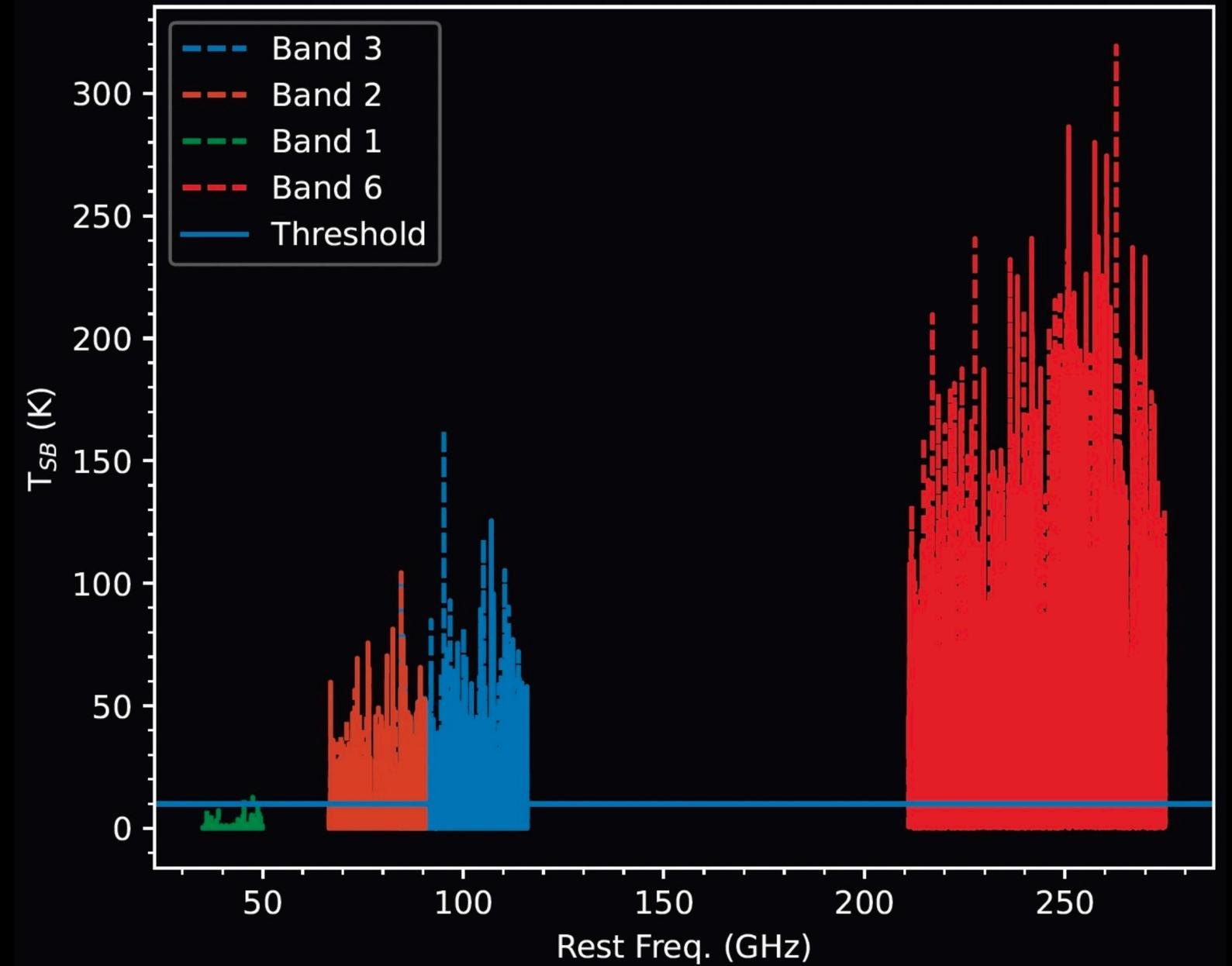
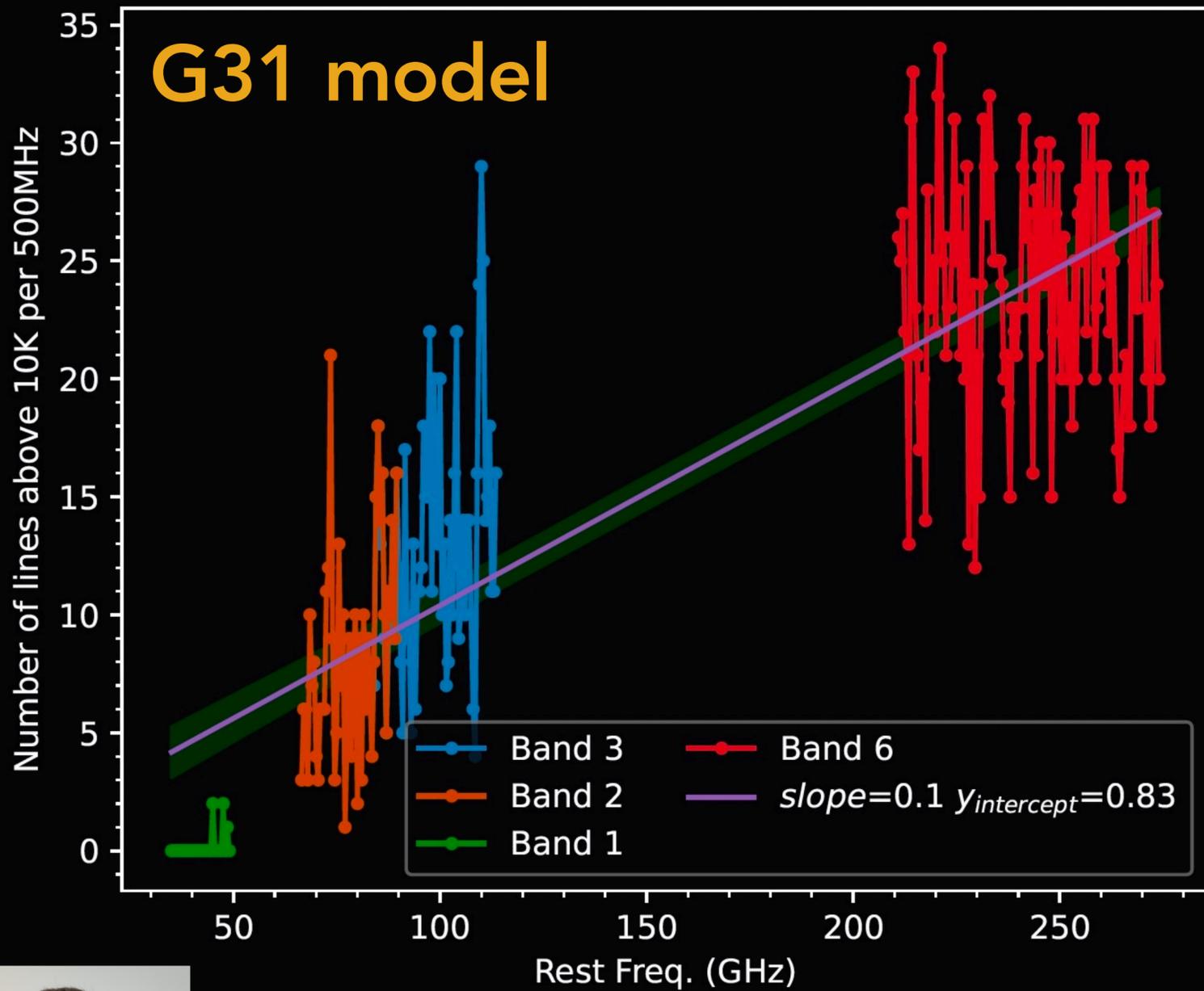
Line density decreases with frequency

... but also line intensity



Line density decreases with frequency

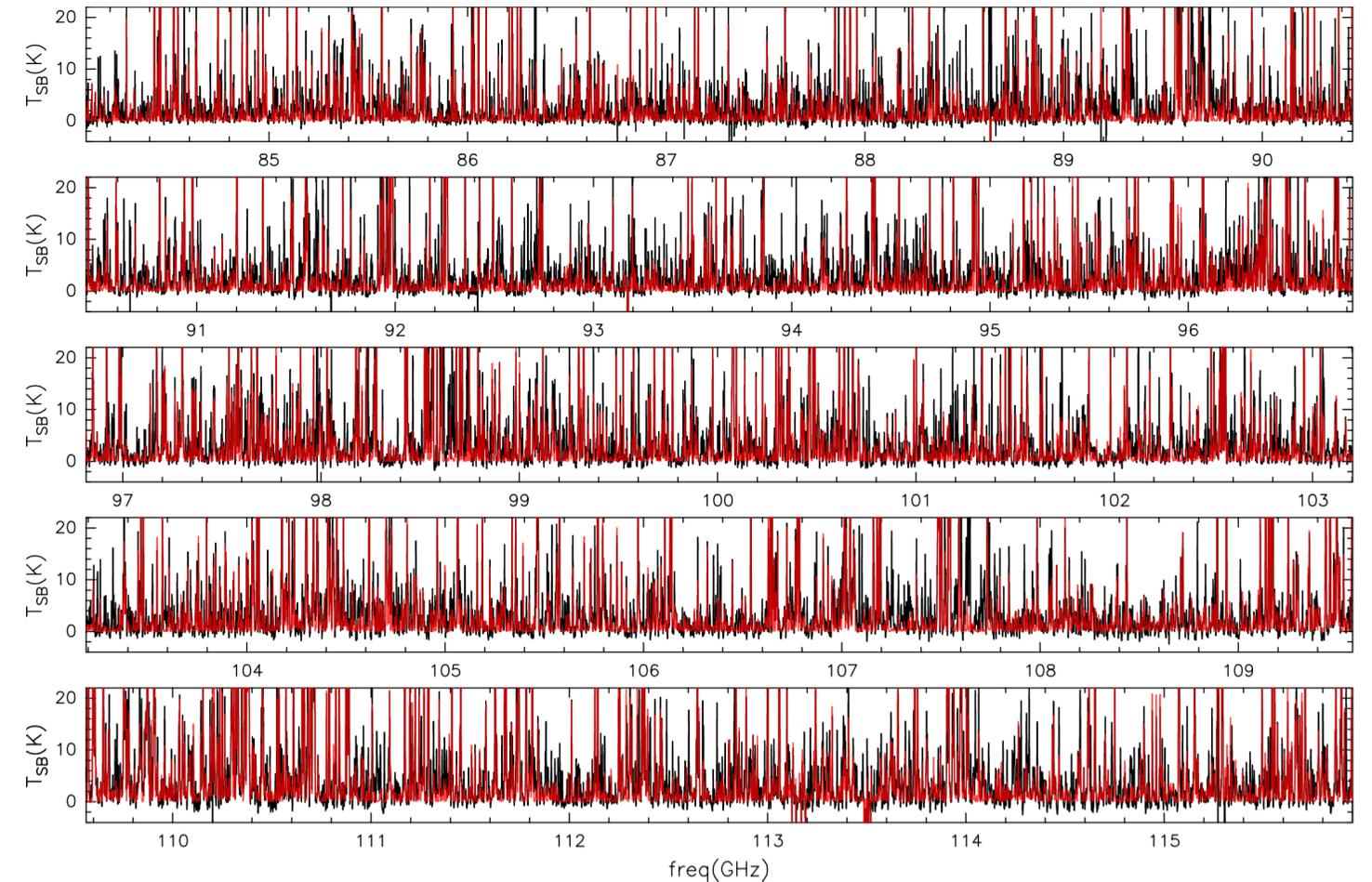
... but also line intensity



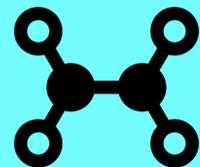
**ALMA Band 2 can provide a good compromise**

# G31.41+0.31 in Band 2

## Band 3 (GUAPOS)



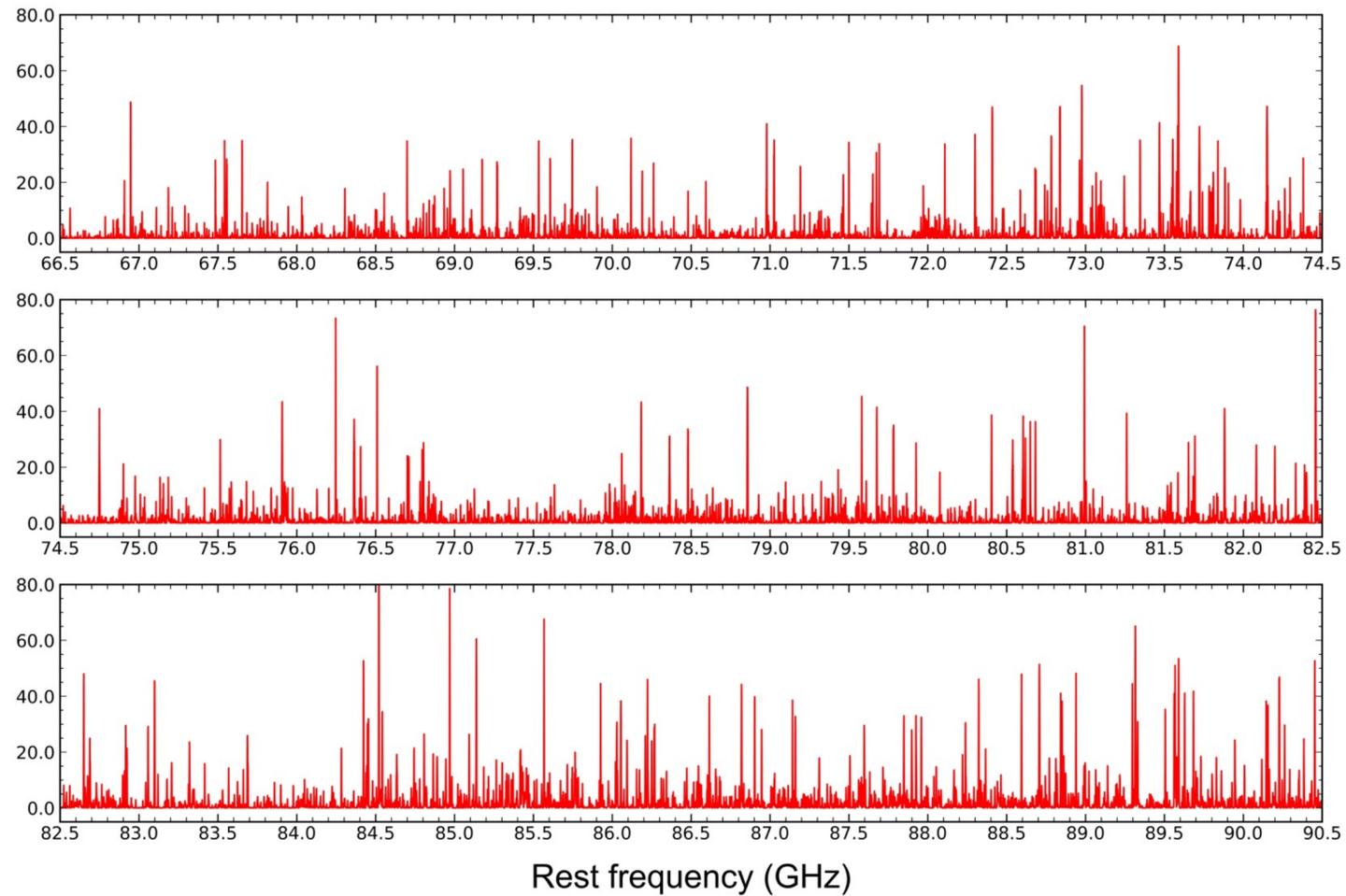
MOLECULAR SAMPLE



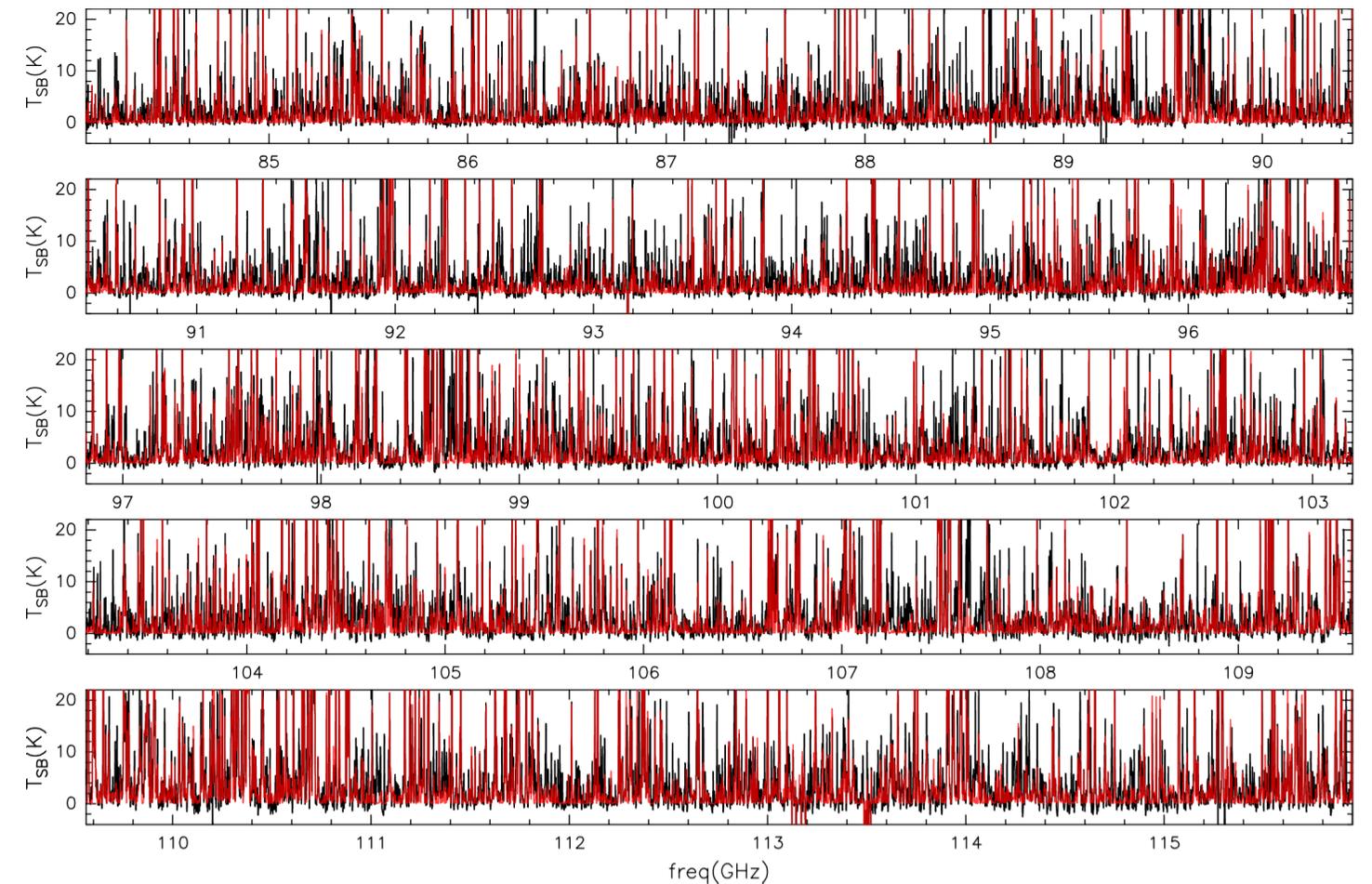
- **51 different species**
- **42 isotopologues**
- **23 COMs (> 5 atoms)**

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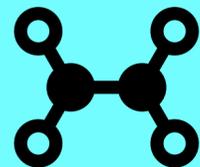
## Band 2



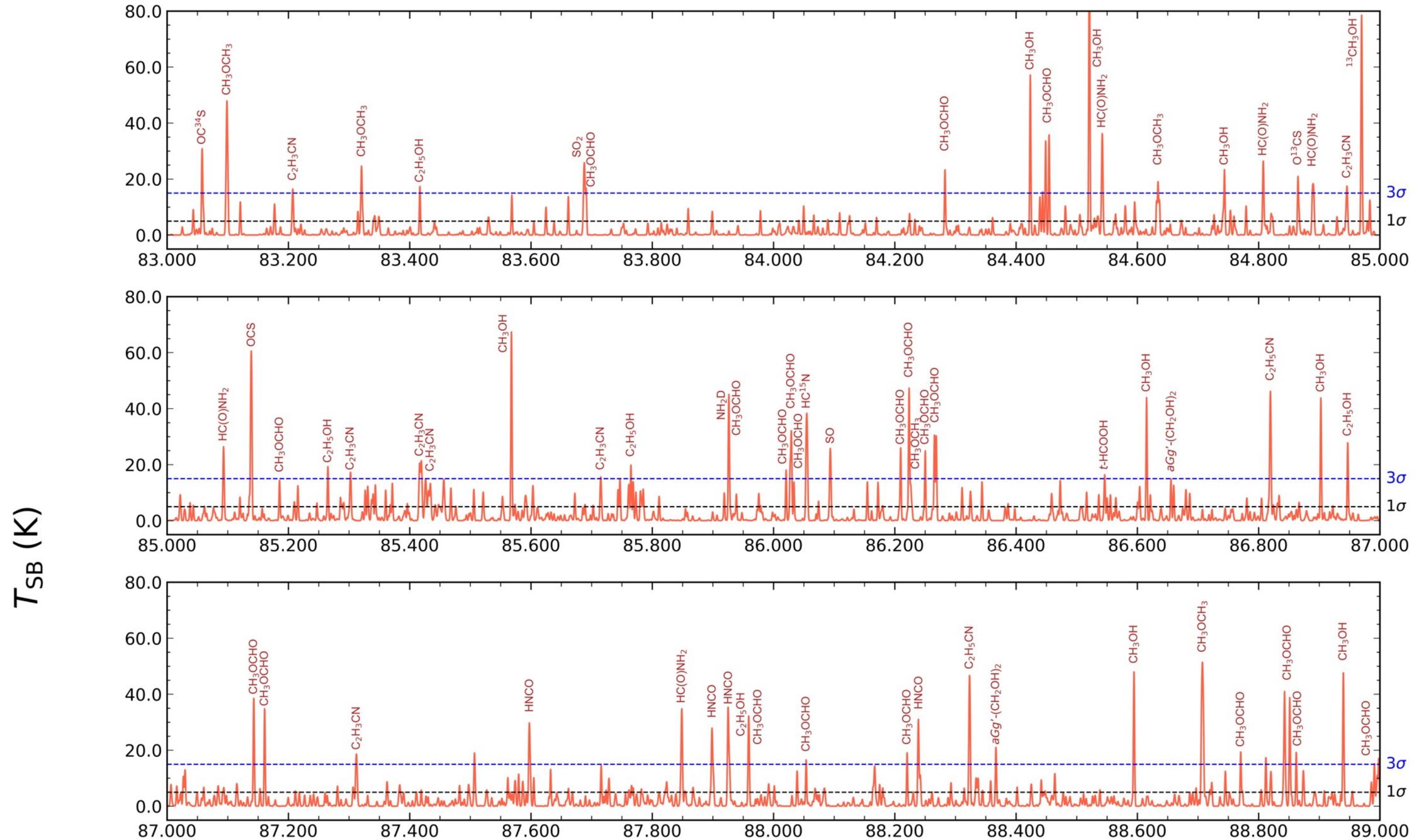
## Band 3 (GUAPOS)



MOLECULAR SAMPLE



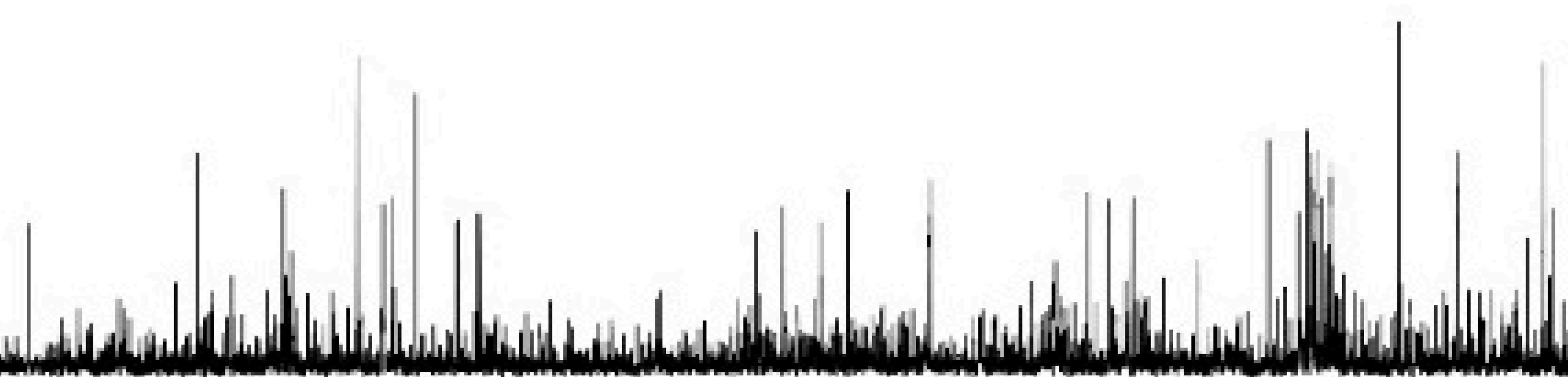
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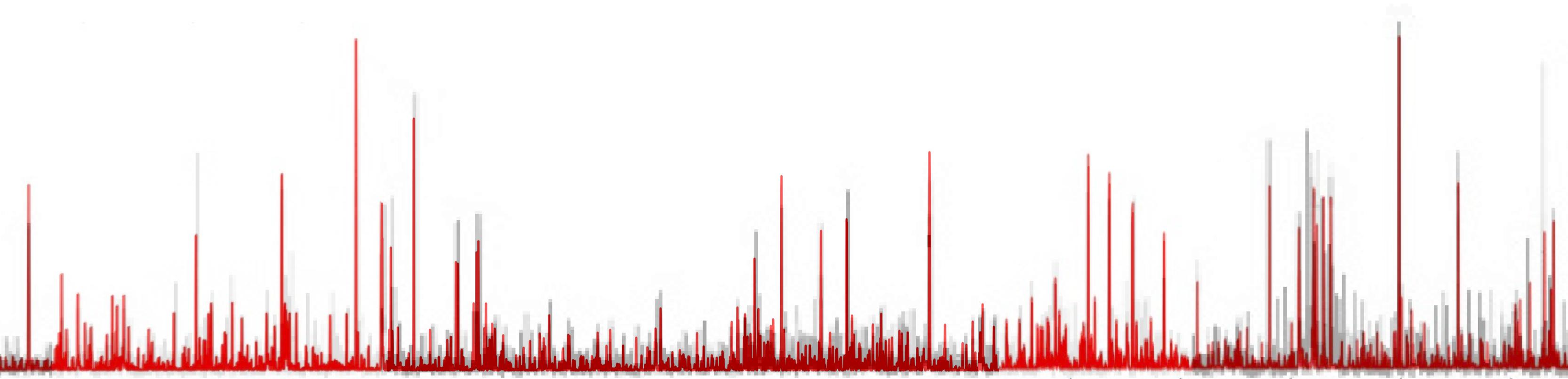
## # of lines expected in the range 67-90.5 GHz

- 1863 lines above 2 K
- 883 lines above 5K
- 406 lines above 10 K

- **ALMA Band 2 SV (spectra from María Díaz Trigo's talk yesterday)**



- ALMA Band 2 SV (spectra from María Díaz Trigo's talk yesterday)
- LTE modelling prediction from GUAPOS (Band 3)



# Take away messages: chemical complexity in the ISM

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Ultra-sensitive broadband spectral surveys

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Ultra-sensitive broadband spectral surveys



Cold galactic disk clouds

Galactic Center clouds

# Take away messages: chemical complexity in the ISM

Ultra-sensitive broadband spectral surveys



Cold galactic disk clouds

Galactic Center clouds

Band 1 (Q-band)



Emission  
extended

# Take away messages: chemical complexity in the ISM

Ultra-sensitive broadband spectral surveys



Cold galactic disk clouds

Galactic Center clouds

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Emission extended



Spatial information

# Take away messages: chemical complexity in the ISM

Ultra-sensitive broadband spectral surveys



Cold galactic disk clouds

Galactic Center clouds

Band 1 (Q-band)



Emission extended



Spatial information



**TP needed !**

# Take away messages: chemical complexity in the ISM

## Ultra-sensitive broadband spectral surveys

 Cold galactic disk clouds  
Galactic Center clouds

 Star-forming regions

Band 1 (Q-band)



Emission extended



Spatial information

 **TP needed !**

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Ultra-sensitive broadband spectral surveys

 Cold galactic disk clouds  
Galactic Center clouds

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Emission extended



Spatial information

 **TP needed !**

Band 2



Compromise between line intensities and line blending

# Take away messages: chemical complexity in the ISM

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 Cold galactic disk clouds  
Galactic Center clouds

 Star-forming regions

Band 1 (Q-band)



Emission extended



Spatial information

 **TP needed !**

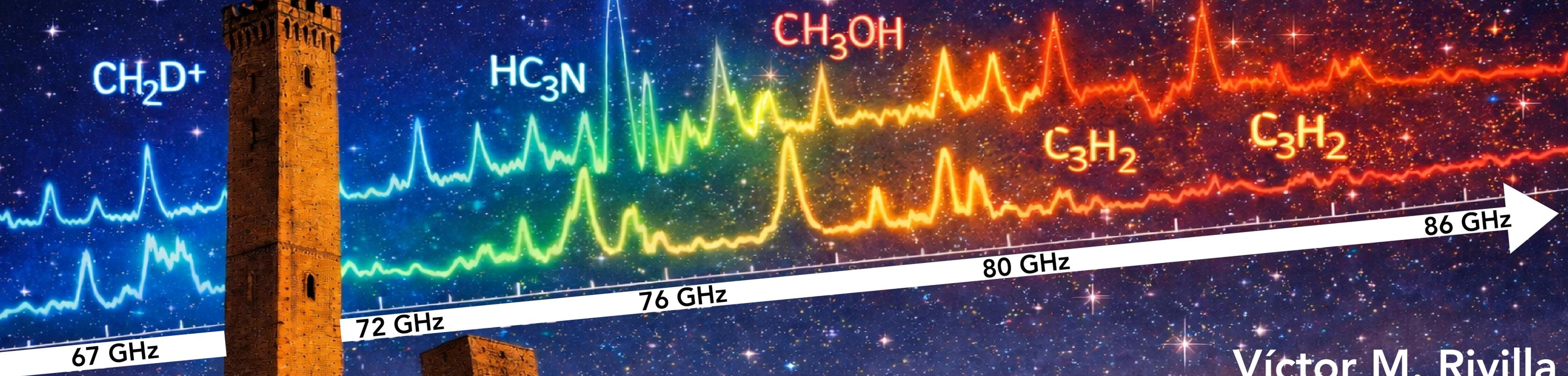
*Wideband Sensitivity Upgrade (WSU)*

Band 2



Compromise between line intensities and line blending

# Prebiotic molecules in ALMA Band 2



Víctor M. Rivilla

Centro de Astrobiología (CAB), CSIC-INTA, Madrid

Miguel-Sanz Novo, Álvaro López-Gallifa, David San Andrés, Laura Colzi, Chiara Mininni, Sandy Zeng, Francesco Fontani, Riccardo Cesaroni, Izaskun Jiménez-Serra, Maite Beltrán, Sergio Martín