International Centre for Radio Astronomy Research

Curtin University of Technology

The University of Western Australia
Achieving International Excellence

ICRAR is a partnership between Curtin University of Technology and The University of Western Australia

Search for Molecules at Low Frequency using the MWA

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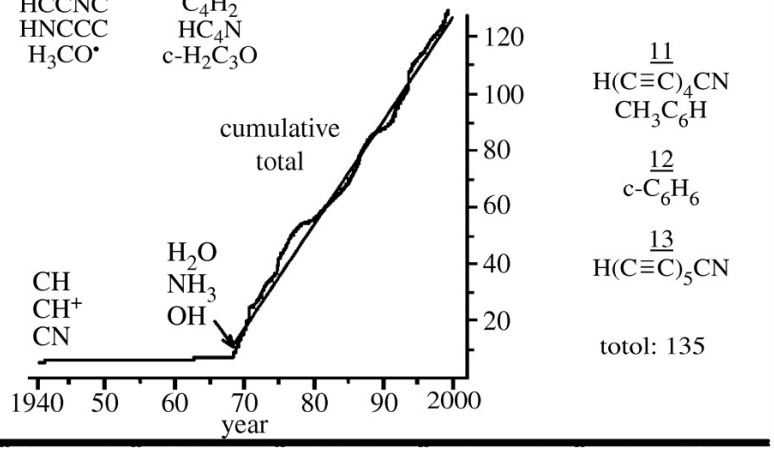
Search for Interstellar Molecules

known interstellar and circumstellar molecules (Jan 2006)

number of atoms

2	3	4	5	6	7	8	9
H_2	H_2O	NH_3	SiH_4	CH_3OH	CH_3CHO	$HCOOCH_3$	CH_3CH_2OH
OH	H_2S	H_3O^+	CH_4	NH_2CHO	CH_3NH_2	CH_2OHCHO	$(CH_3)_2O$
SO	SO_2	H_2CO	CHOOH	CH_3CN	CH_3CCH	CH_3C_2CN	CH_3CH_2CN
SO^+	HN_2^+	H_2CS	$HC \equiv CCN$	CH_3NC	CH_2CHCN	C_7H	$H=(C\equiv C)_3CN$
SiO	HNO	HNCO	CH_2NH	CH_3SH	HC_4CN	H_2C_6	$CH_3(C\equiv C)_2H$
SiS	SiH_2	HNCS	NH_2CN	C_5H	C_6H	HC_6H	C_8H
NO	NH_2	CCCN	H_2CCO	HC_2CHO	c-CH_2OCH_2	CH_3CO_2H	
NS	H_3^+	HCO_2^+	CH_2	$CH_2{=}CH_2$	CH_2CHOH_2	H_2C_3HCN	10
HCl	NNO	CCCH	c-C_3H_2	H_2CCCC		CH_2CHCOH	CH_3COCH_3
NaCl	HCO	c-CCCH	CH_2CN	$HC_3NH^\bullet$			$CH_3(C\equiv C)_2CN$
AlCl	OCS	CCCS	SiC_4	HC_4H			$HOCH_2CH_2OH$
AlF	CCH	HCCH	H_2CCC	C_5S			CH_2CH_2CHO
PN	HCS^+	$HCNH^+$	HCCNC	C_4H_2			
SiN	c-SiCC	HCCN	HNCCC	HC_4N			11
NH	CCO	H_2CN	$H_3CO^\bullet$	c-H_2C_3O			$H(C\equiv C)_4CN$
SH	CCS	c-SiC_3					CH_3C_6H
HF	C_3	CH_3					12
CN	MgNC	CH_2D^+					c-C_6H_6
CO	NaCN	AlNC					13
CS	CH_2						$H(C\equiv C)_5CN$
C_2	MgCN						
SiC	HOC^+						totol: 135
CP	HCN						
CO^+	HNC						
CH^+	CO_2						
CH	SiCN						
N_2	AlCN						
	SiNC						
	KCN						

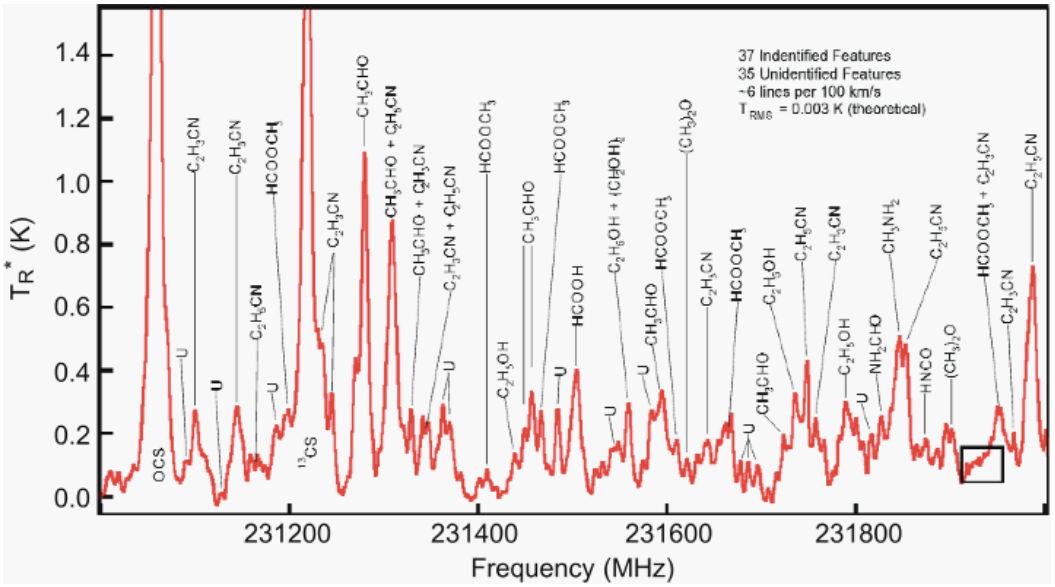


P. Thaddeus, 2006

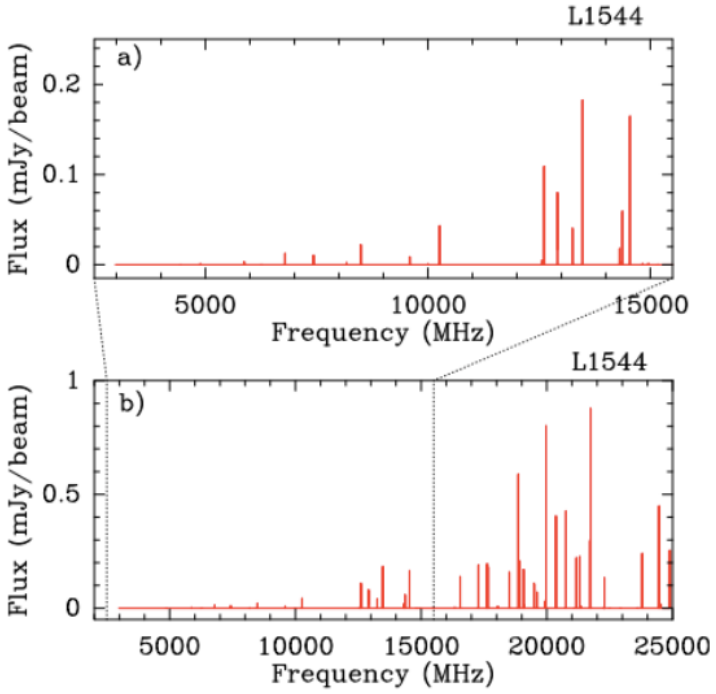
Over 200 interstellar molecules have been detected with many of them organic and quite complex

Why Go Low?

Reason 1:Low Frequency radio allows for a decrease in line confusion



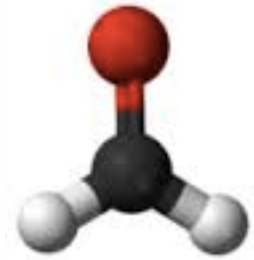
Ziurys et al. 2006



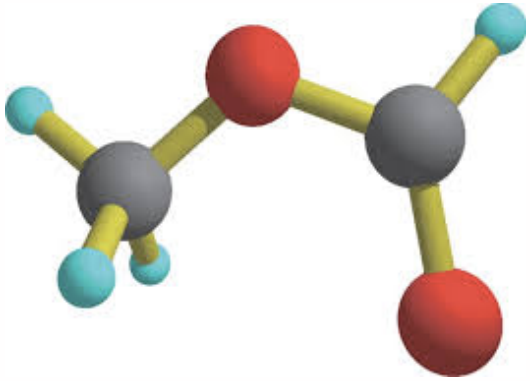
Codella et al. 2014

Why Go Low?

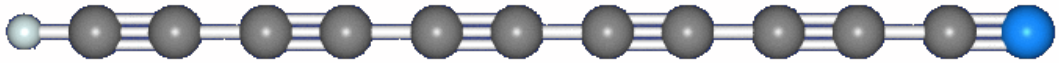
Reason 2: The low energy transitions of large molecules reside at low frequencies.



Formaldehyde



Methyl Formate



$HC_{13}N$

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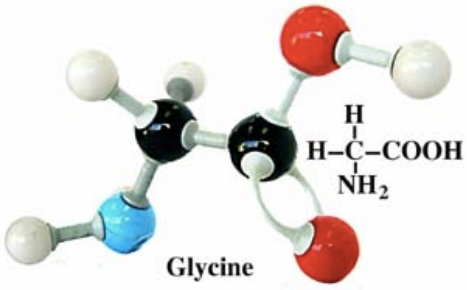
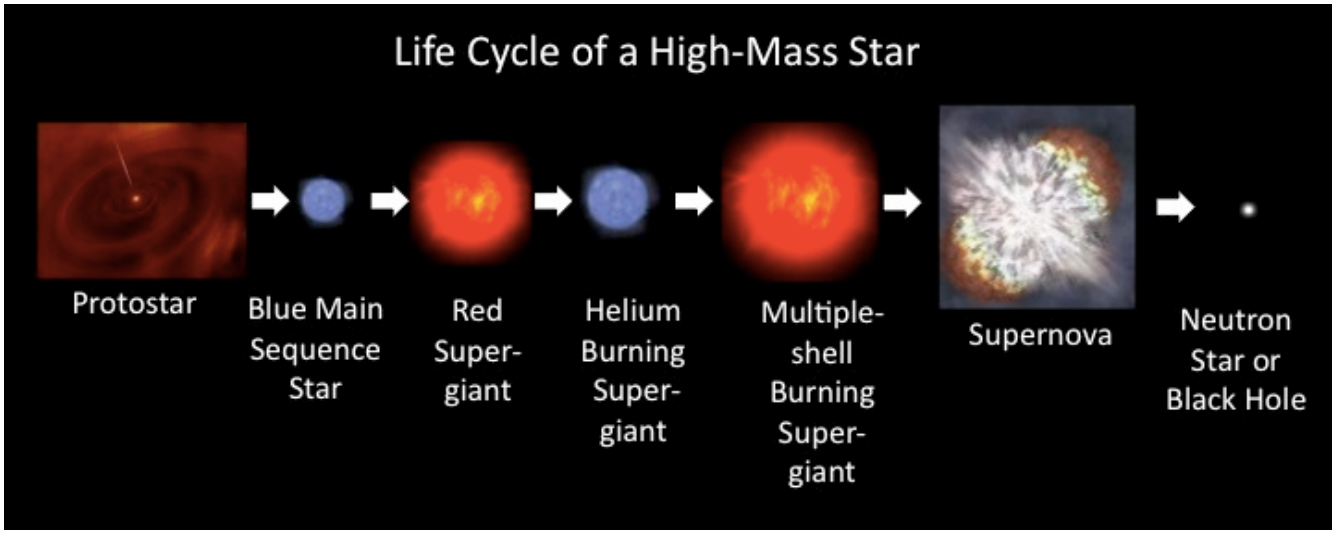
Why Go Low?



It is anticipated that observations at low frequencies will be best for detecting pre-biotic molecules

Molecules can help our understanding of formation of high mass stars.



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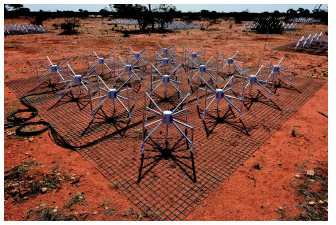
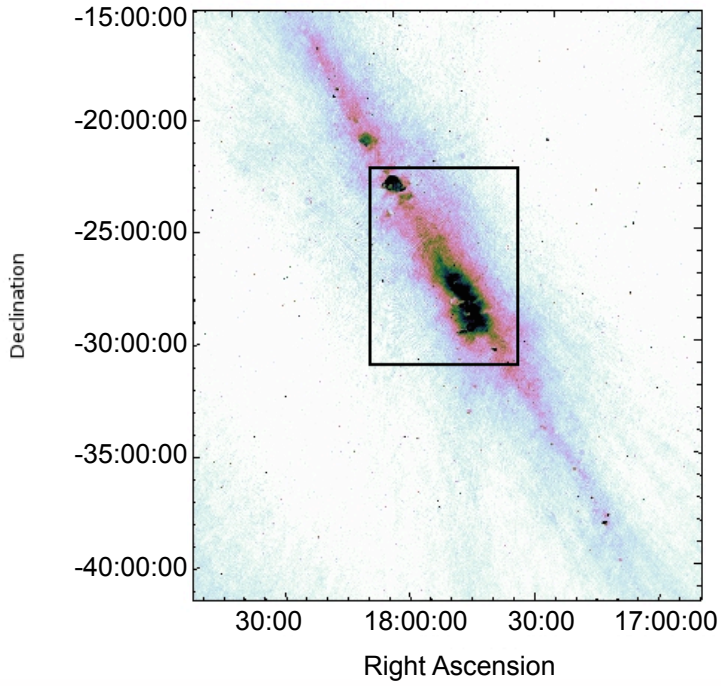
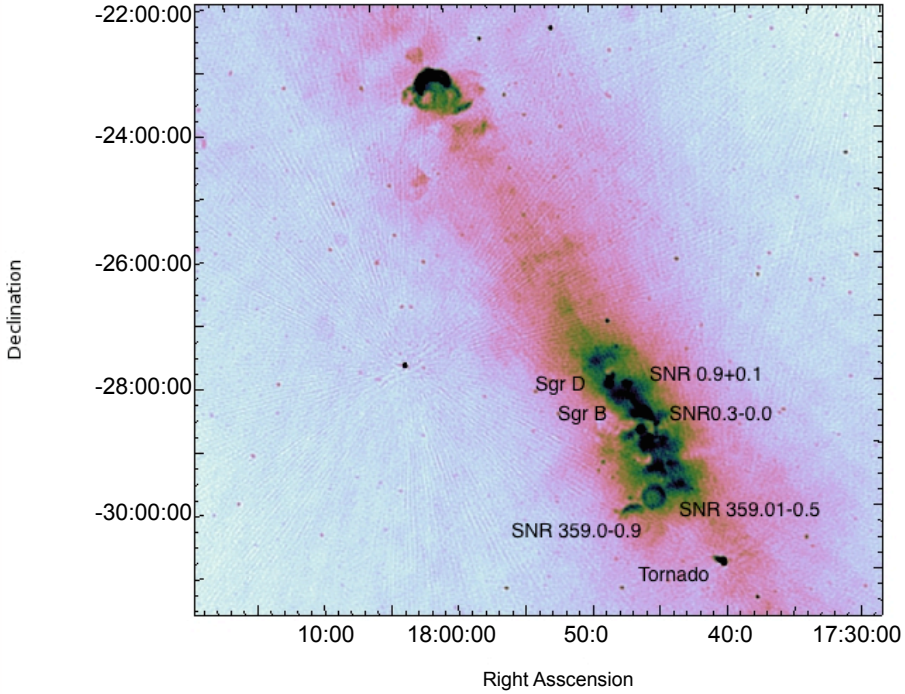
Murchison Widefield Array



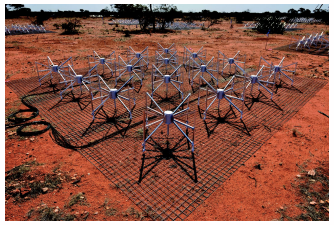
» Look at the Galactic Centre at 103-133MHz

- 2 arcminute synthesised beam
- 576 sq degree field of view
- Bandwidth of 30.72MHz with 10kHz (26km/s) frequency resolution





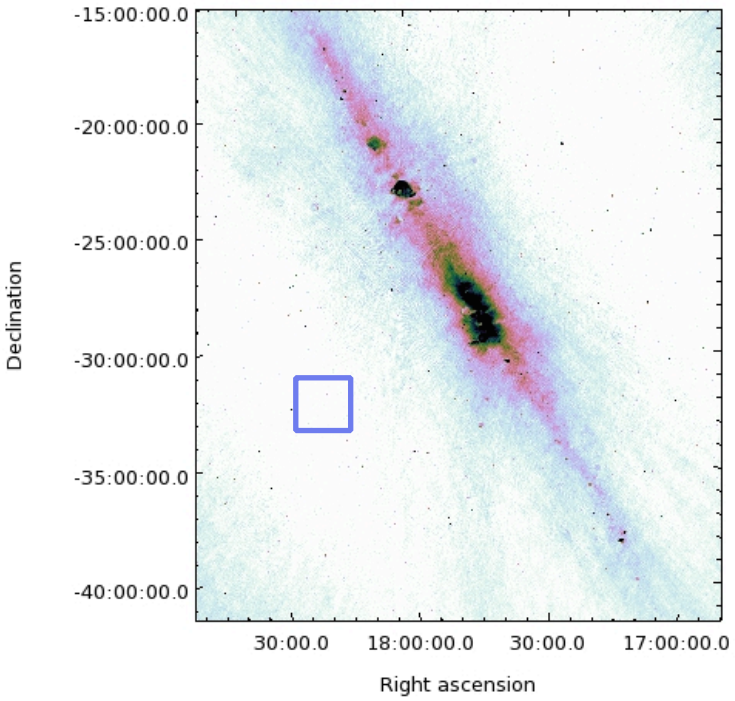
Pilot Survey with the MWA

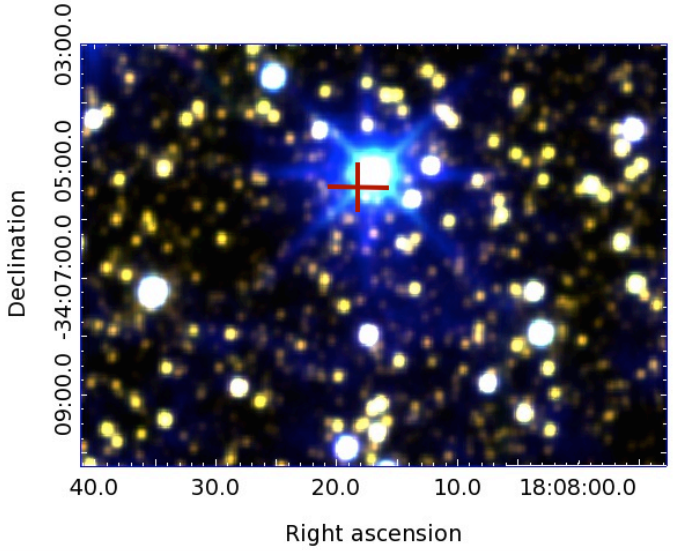


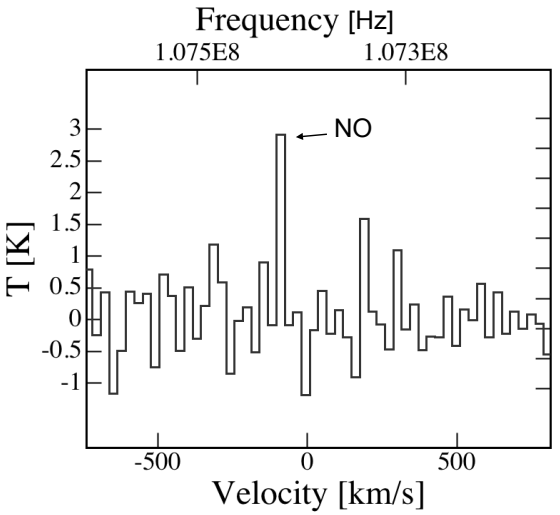
- Pilot survey
  - 4 sigma detection (2Jy/beam)
  - within 1 channel of the rest frequency
  - cross matched with Simbad

CH_2CO	$H_2{}^{13}CO$	NO
$CH_3O^{13}CHO$	H_2CCCH_2	$N^{15}O$
$CH_3{}^{18}OH$	H_2C_2S	^{15}NO
l-C_3H	H_2SO_4	$N^{17}O$
DCOOH	$HCCCH_2OH$	$N^{18}O$
DNO_3	HCOOD	$^{15}N^{17}O$
cis-$H^{13}COO$	HDCO	SH
cis-HCOOD	$NH_2CH_2CH_2OH$	c-SiC_3

Galactic Centre Results



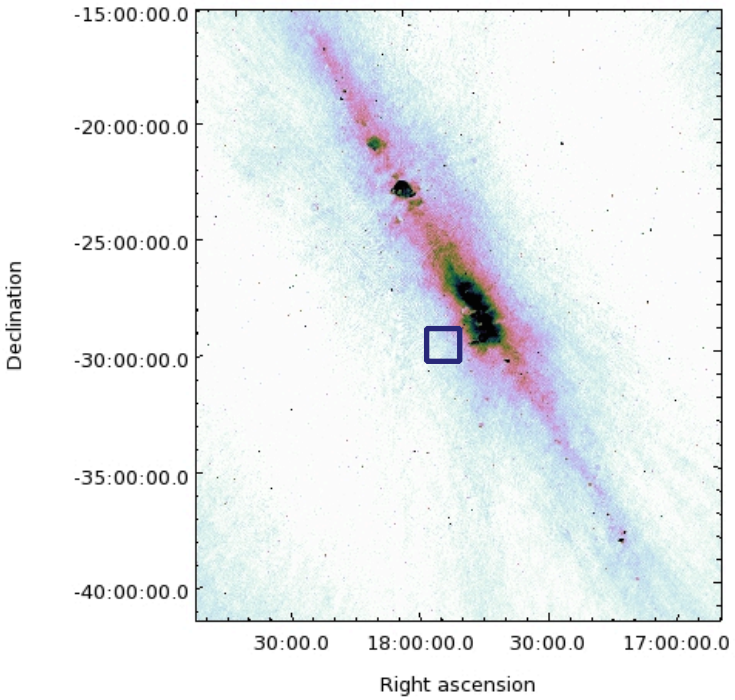


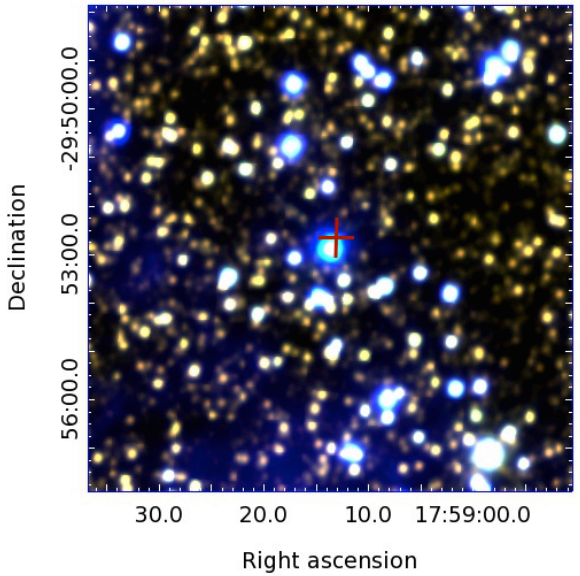


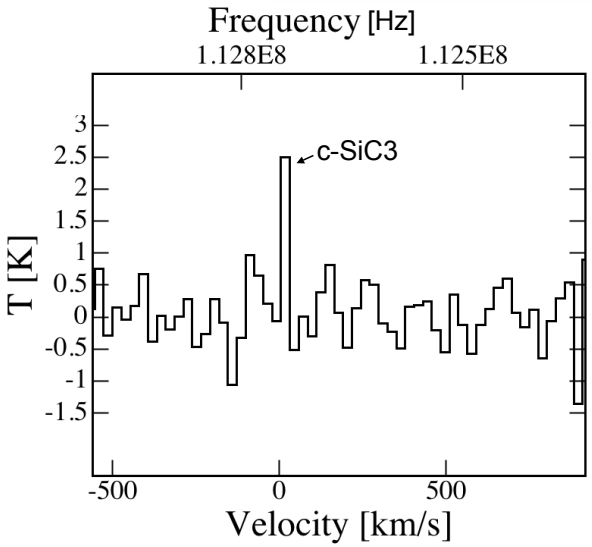
Nitric Oxide

Tremblay et al., 2015, submitted

Galactic Centre Results







3-Silanetetrayl-1,2-Propadienylidene ($c\text{-}SiC_3$)

Tremblay et al., 2015, submitted

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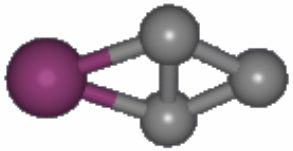
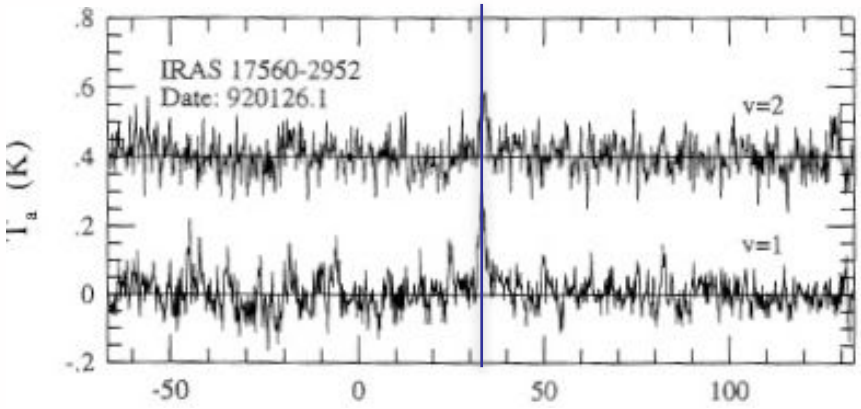
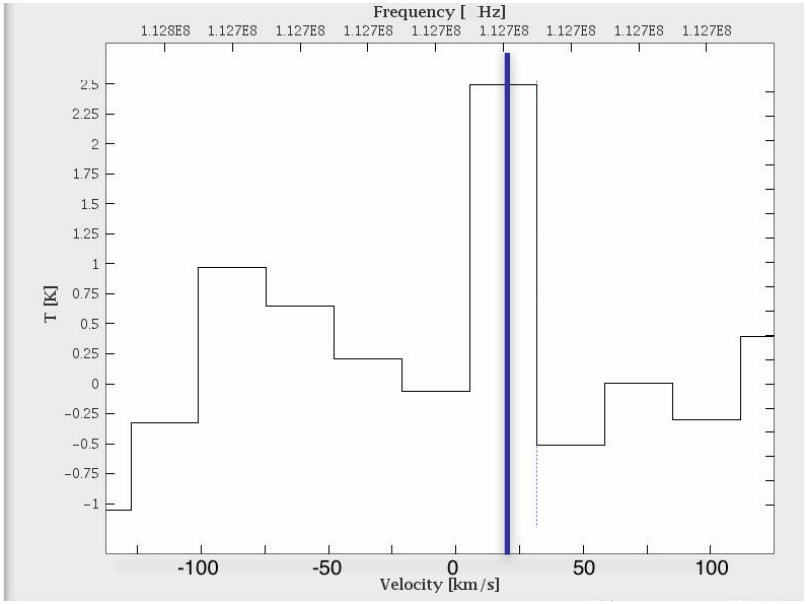
Galactic Centre Results





SiO Maser Izumiura et al. 1995



c-SiC_3 Tremblay et al. submitted 2015

Both molecules at the same velocity.

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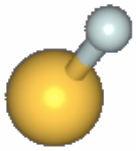
Mercapto Radical

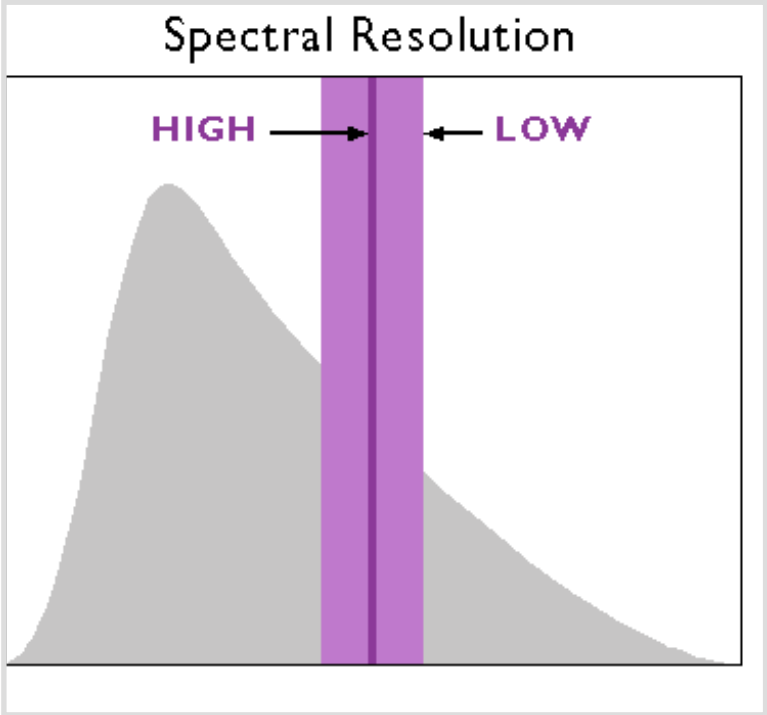


- SH at low frequencies has analogous transitions to those of OH at 1.7GHz. Therefore, may be seen as masers
- Total species of sulfur molecules only accounts for 1/4 of the total interstellar sulfur.
- The relatively low SH/H_2S ratio (~0.13) suggests that reaction is fast

$$SH + H_2 \longrightarrow H_2S + H$$

Molecule	Column density (10^{12} cm^{-2})	Abundance relative to H_2	Fraction of solar	
SH	4.6	6.9×10^{-9}	0.026%	Neufeld et al. 2012
H_2S	35	5.2×10^{-8}	0.20%	Gerin et al. 2012
SH^+	2.6	3.9×10^{-9}	0.015%	Godard et al. 2012
CS	12	1.8×10^{-8}	0.070%	Miyawaki et al. 1988
H_2O	60	9.6×10^{-8}	0.010%	Sonnentrucker et al. 2010
CH	58	9.0×10^{-8}	0.017%	Gerin et al. 2011

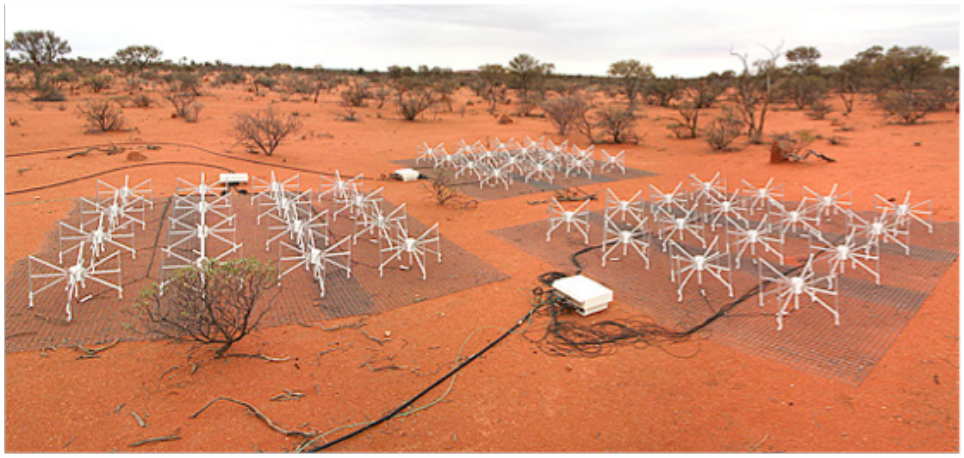
Confirmation of detection?



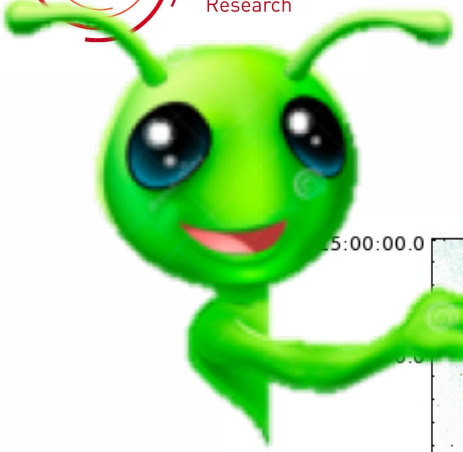
100us → ~0.3 kHz

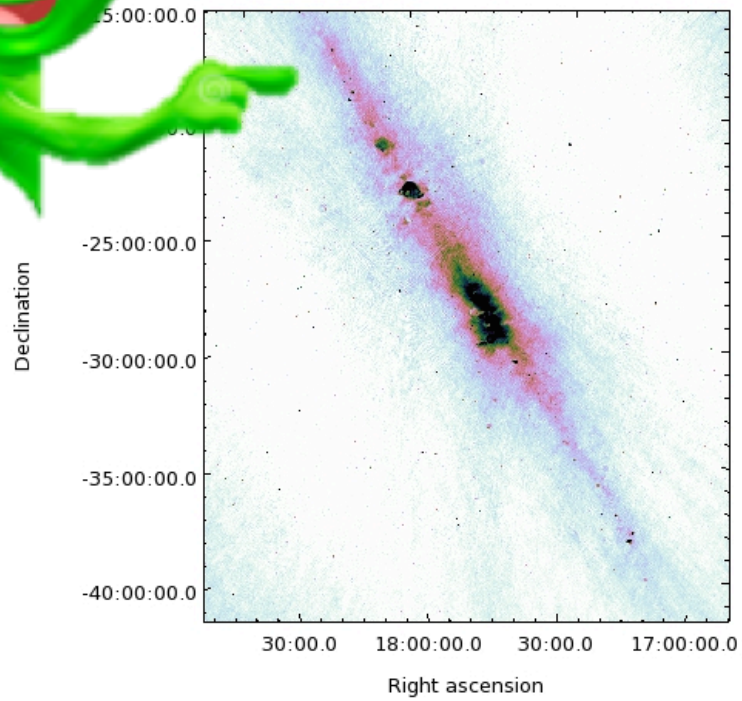
Higher Resolution

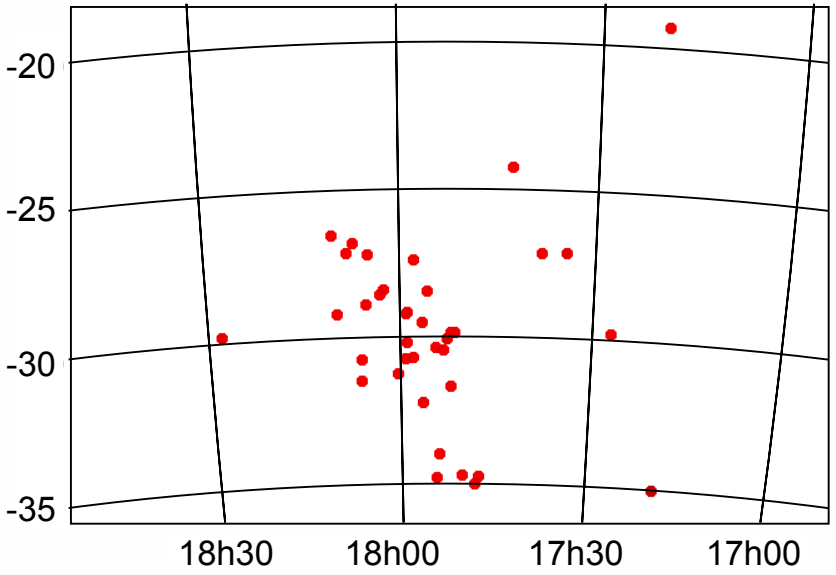
- Use the voltage capture system (VCS) to obtain better than 10kHz resolution



Galactic Centre SETI Search







# System	RA	Dec	RMS (mJy/beam)	Dist. (pc)	P (10^{14} W)
GJ 667 C	259.7451	-34.9968	416.447	6.8	< 2
HD 156846	260.1429	-19.3337	361.667	49	$< 10^2$
HD 164604	270.7789	-28.5606	399.954	37.98	< 70
HD 169830	276.9562	-29.8169	374.033	36.32	< 60

Tingay, Tremblay et al. Pending

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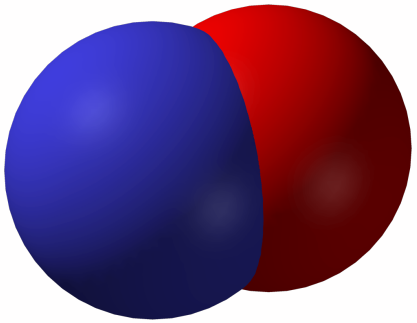
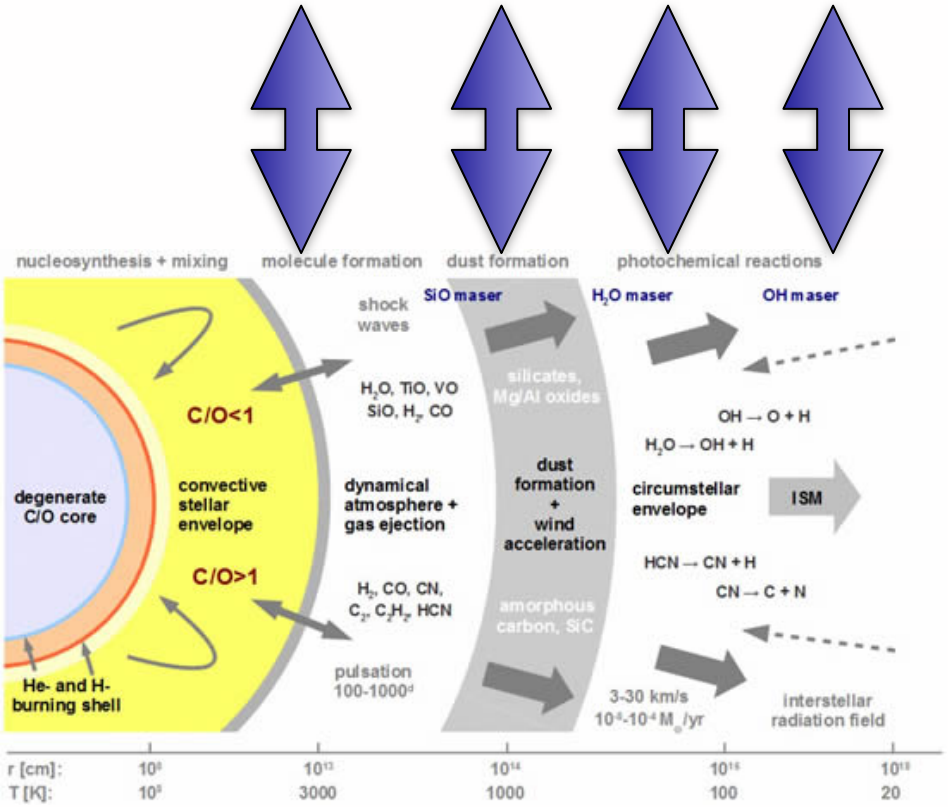
Thank you.

Where do we find NO?





- It is unknown what region NO forms.
- Column densities are low compared to abundance of N and O in the ISM

Quintana-Lacaci et al., 2013

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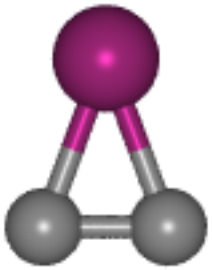
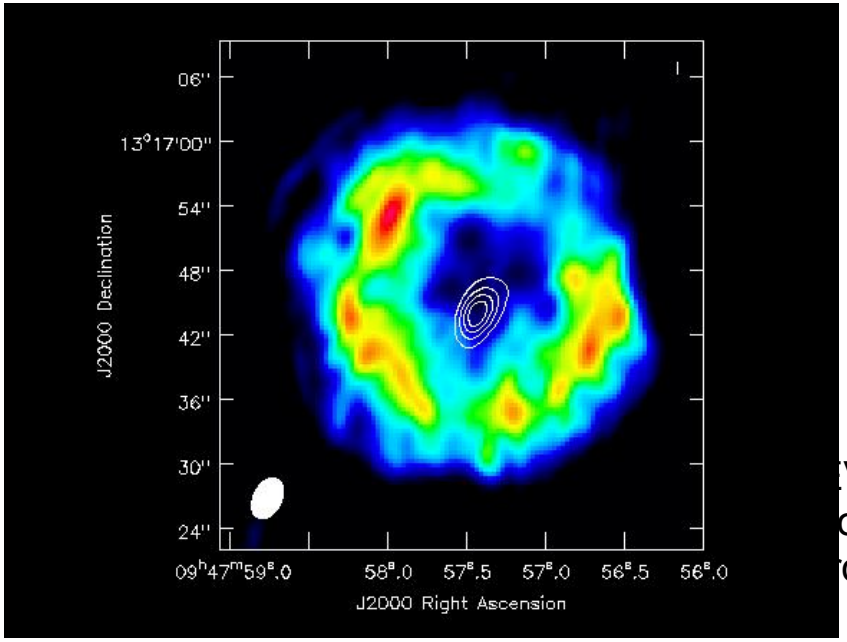
Where do we find these?



Silicon Carbide molecules have been detected in the outer edges of the circumstellar envelope.



IRC+10216

VLA SiS, HC3N and
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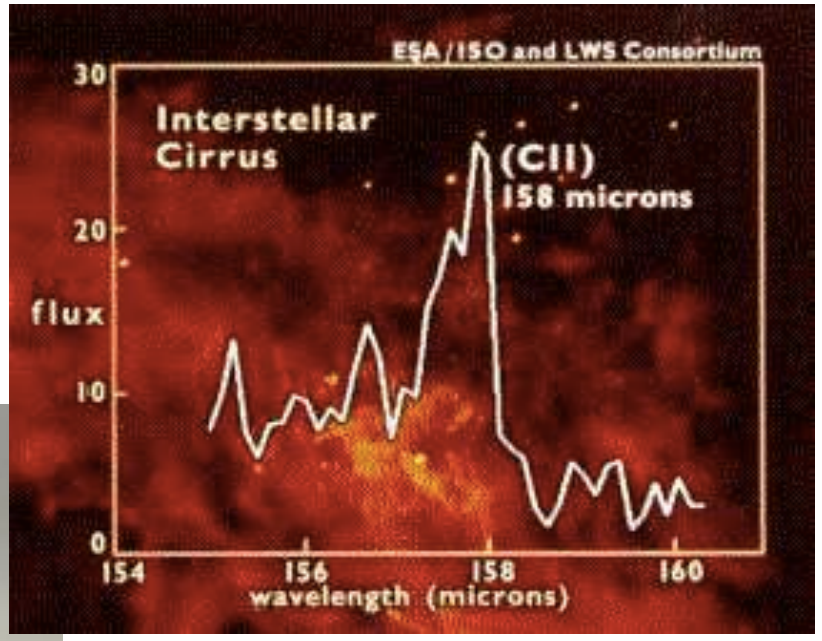
A History of Spectroscopy



This spectrometer made by W.Wilson of Tottingham, England and dates from the first half of the 20th century.