The Spectral Legacy Survey: a spectral imaging survey with JCMT

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Helen Roberts
+ SLS Collaboration

http://www.jb.man.ac.uk/research/sls

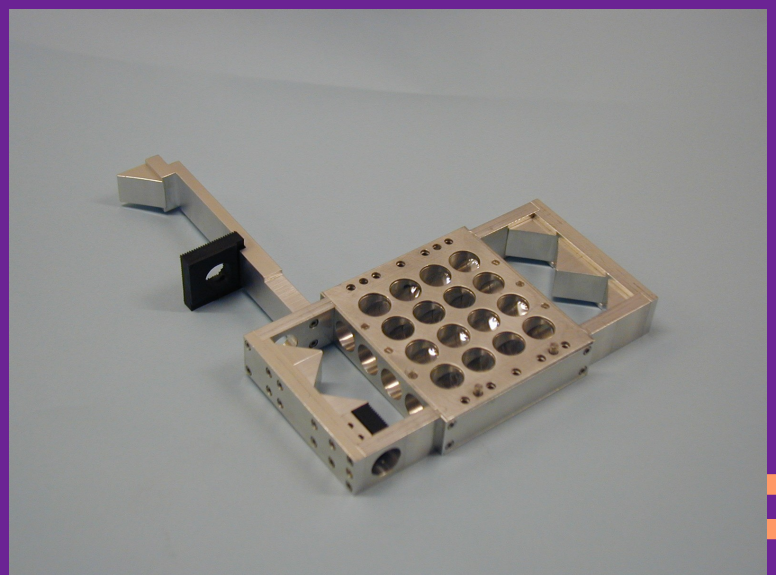
New JCMT Instrument: HARP-B/ACSIS

HARP-B:

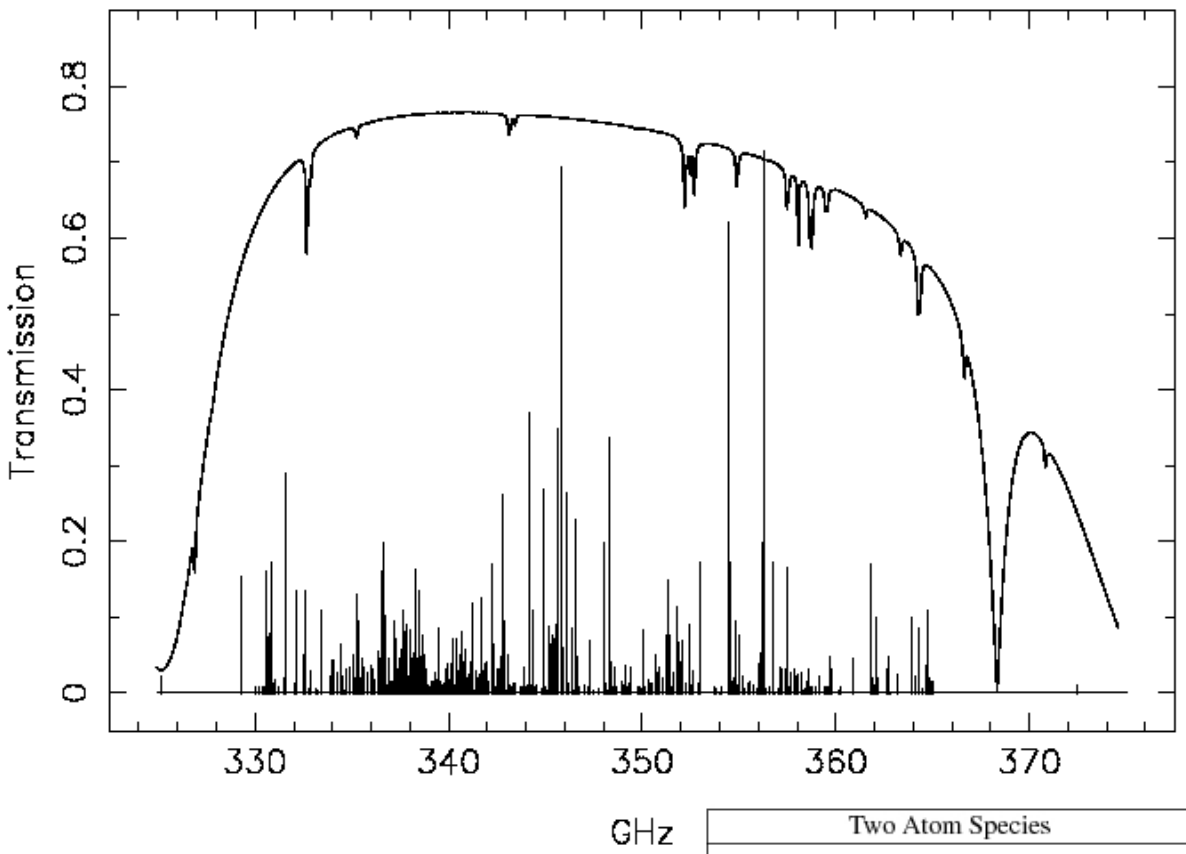
- 325-375 GHz heterodyne camera
- 4x4 pixels - 30'' separation - 2'x2' field of view - footprint
- T_{rx}~120 K, T_{sys}~320 K (grade 3 weather, tau(225GHz)~0.12)

ACSIS:

- 16 IF autocorrelator
- 2GHz per IF, 1MHz (0.9 km/s) channels



The 345 GHz Window



Lovas (2004)

- 866 transitions
- 82 species

Two Atom Species	Three Atom Species	Four Atom Species
CO ^{13}CO C^{17}O C^{18}O CS C^{34}S C^{33}S CN CO$^+$ NO NS SiO ^{29}SiO ^{30}SiO SiS Si33S Si34S 29SiS 30SiS SO 33SO S18O 34SO SO$^+$ SO2 ^{34}SO2	OCS OC^{34}S O^{13}CS HNC HN^{13}C H^{15}NC HCO+ H^{13}CO+ HC^{18}O+ DCO$^+$ HCN H^{13}CN HC^{15}N DCN H2O HDO HCO$^+$ SiC$_2$ HDS C$_2$H HNO HCS$^+$ HCO H$_2$D$^+$	CCCS H$_2$CS HDCO HNCO H3O+ NH2D NHD2 H$_2$CO H$_2$C^{18}O H$_2^{13}$CO D$_2$CO
Five Atom Species	**Six or More Atom Species**	
HCCCN HCC^{13}CN HC^{13}CCN H^{13}CCCN HCOOH HCOOD CH2CO NH2CN CH2NH c-C3H2	CH2CHCN CH3CCH CH3CH2CN CH3OCHO CH3CN ^{13}CH3CN	CH3OH ^{13}CH3OH NH2CHO t-CH3CH2OH CH3OCH3

Important spectral band: ALMA DRSP: >30% of observing time in this band

But poorly explored...

Source	Frequency Range (GHz)	Noise (K)	Reference
High Mass Sources			
Orion KL	325 - 360	0.15	Schilke et al. 1997, Jewell et al. 1996
G34.3+0.15	330 - 365	0.05	Macdonald et al. 1996, Thompson et al. 1999
G5.89-0.39	330 - 360	0.06	Thompson & Macdonald 1999
W3 IRS5, IRS4, OH	334 - 365	0.03	Helmich & van Dishoeck 1997
Sgr B2	330 - 355	0.06	Sutton et al. 1991
IRAS 23385-6053	330 - 360 (incomplete)	0.03	Thompson & Macdonald 2003
Low Mass Sources			
IRAS 16293-2422	330 - 365	0.018	Caux et al. in progress

- Complete census of species
- Comparison of species
- Trace range of excitation and environments
- New/unexpected species
- Define the continuum

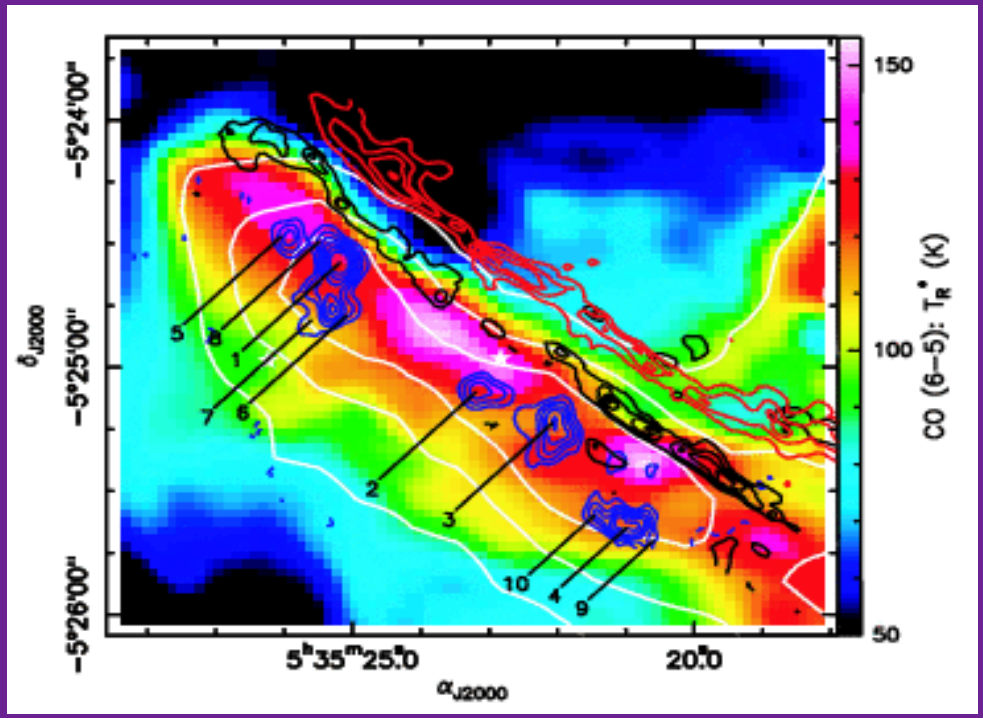
All current surveys are at single positions
BUT none of the sources are isolated point sources
→ Need imaging

SLS: An imaging spectral survey

- Goals
  - understand the molecular inventory and its evolution
  - probe a range of star formation environments
- Five target sources
  - Chosen to span range of star forming environments and evolutionary stages

Photon Dominated Region : Orion Bar

- Dense gas exposed to 10^4 G_o
- Dense clumps ~10^6 cm^{-3}
- Inter-clump ~10^4 cm^{-3}
- No (internal) star formation

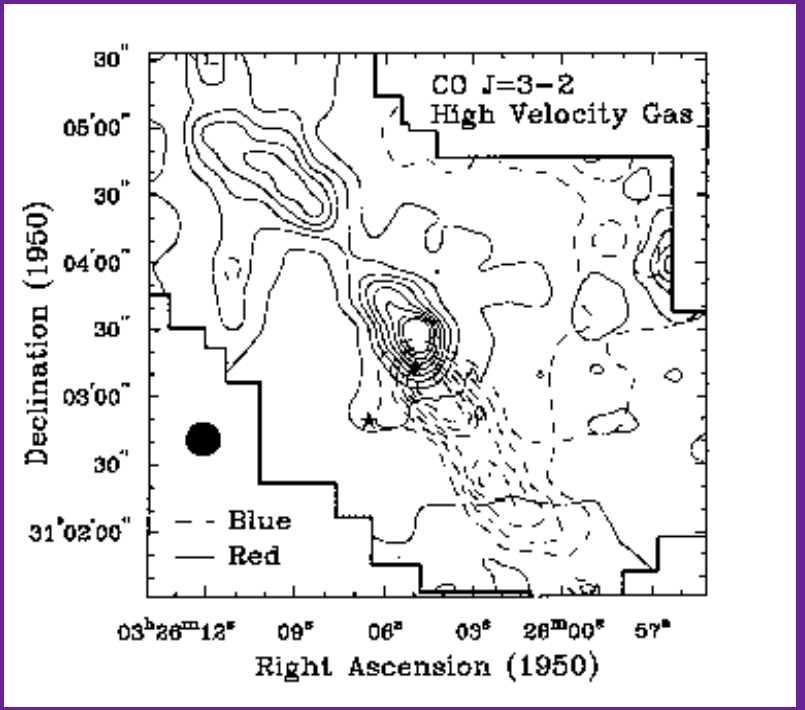


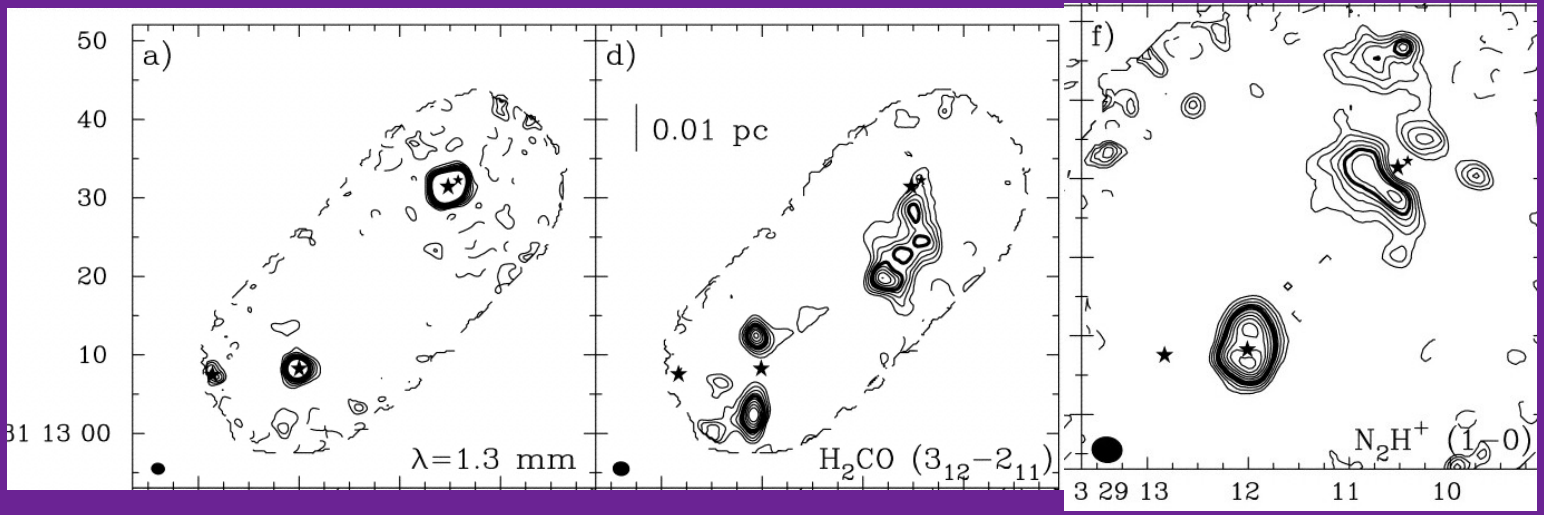
(Lis & Schilke 2003)

Low Mass Protostar: NGC1333 IRAS4

(Blake et al. 1995)

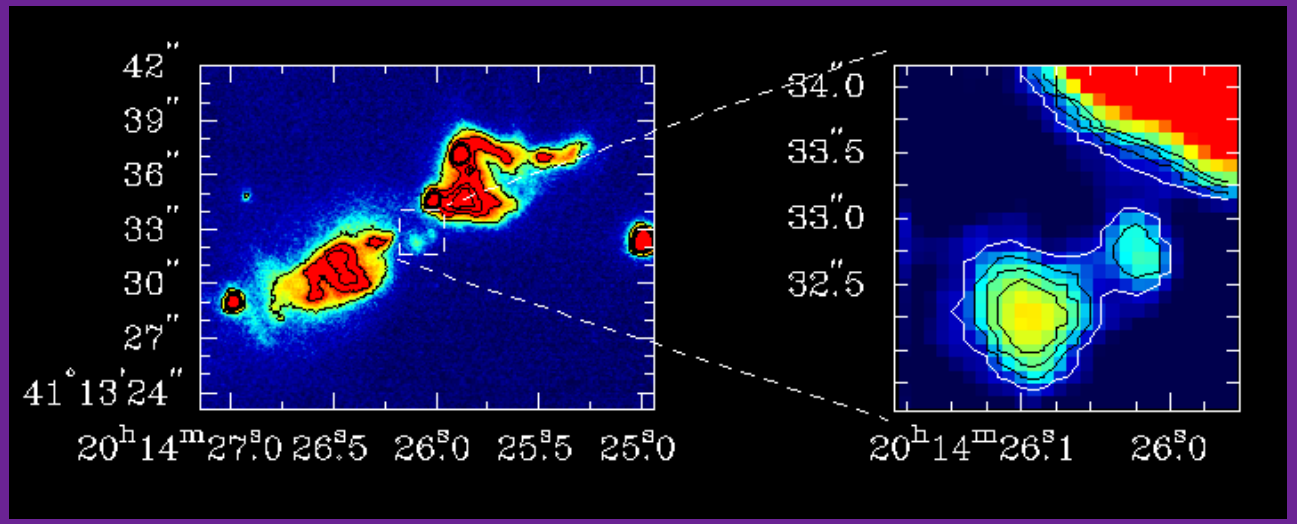
- 30'' binary – resolved and imaged
- Class 0 sources – infall, outflow, rotation
- Differences between components
- Depletion, high deuterium fractionation
- (L1157, L1544)





(Di Franesco et al. 2001)

An Intermediate Mass Protostar: IRAS20126+4104

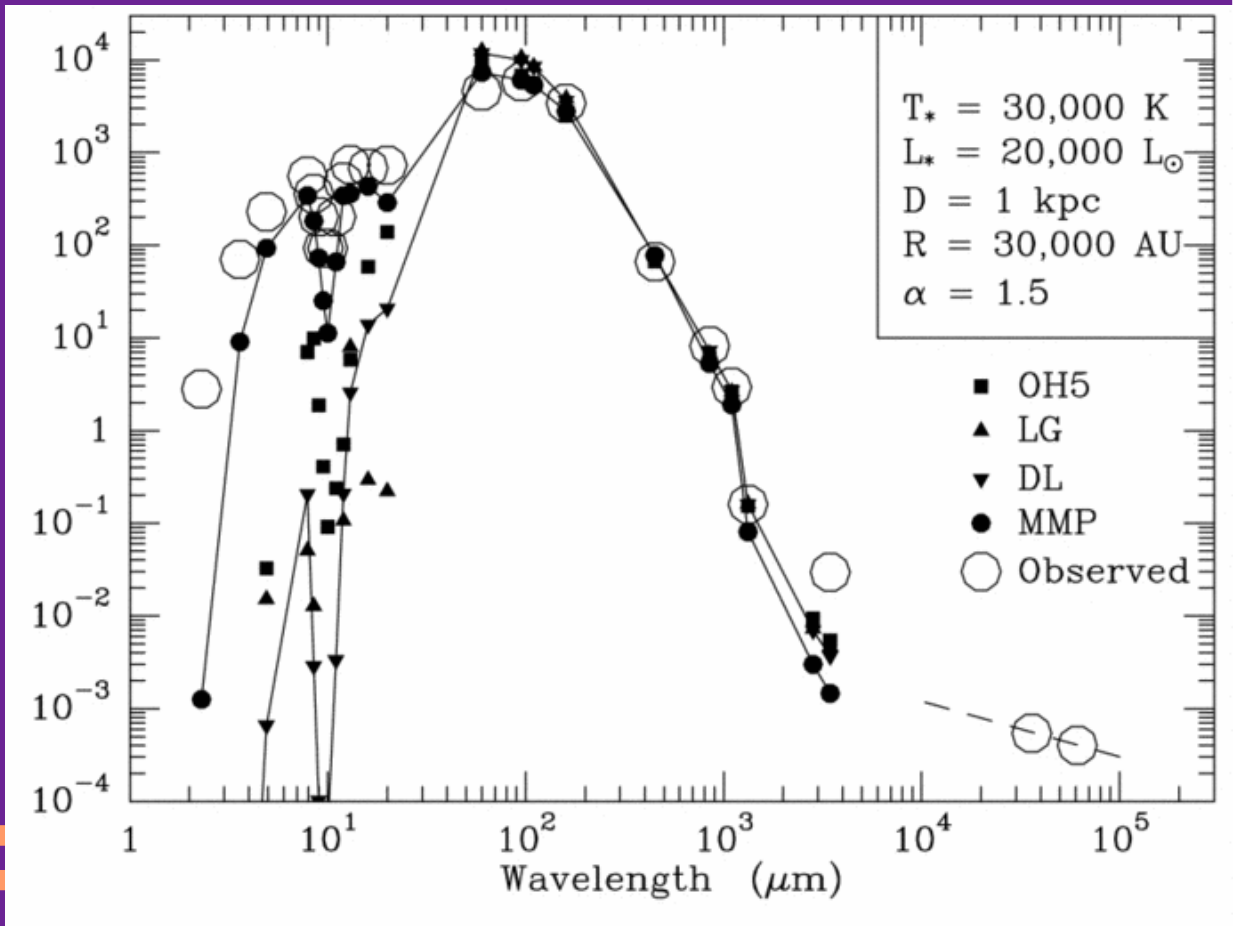


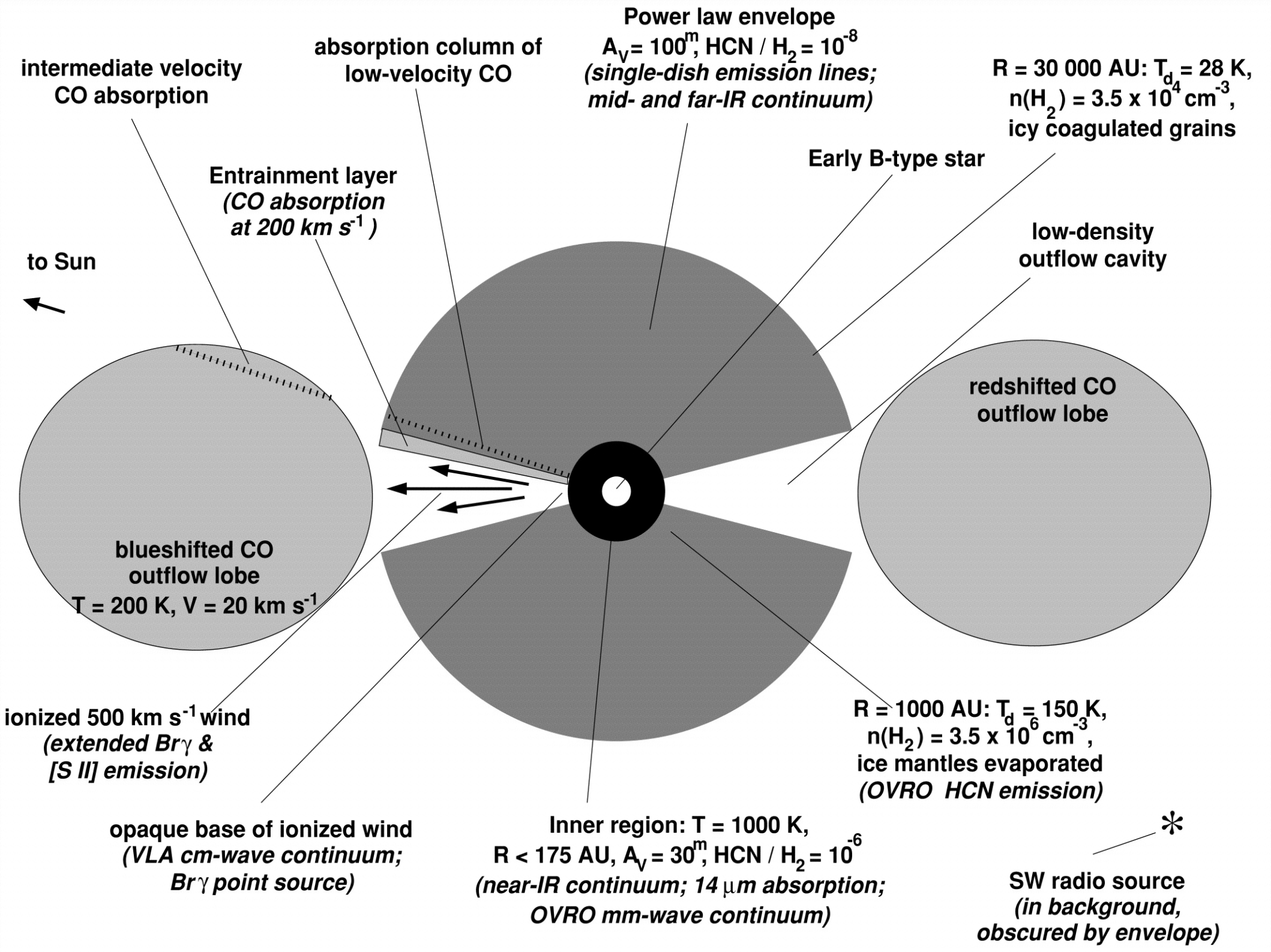
2μm image
(Sridharan, Williams & Fuller 2005)

- Embedded young 10^4 $L_\odot$ source at 1.7 kpc
- 5-7 $M_\odot$ central source in 200$M_\odot$ core
- Keplerian disk, 5000 AU in radius – CH_3CN, OH masers
- Outflow – CH_3OH, SiO, H_2O masers - precessing?
- Target for HIFI on Herschel

A massive protostar: AFGL 2591

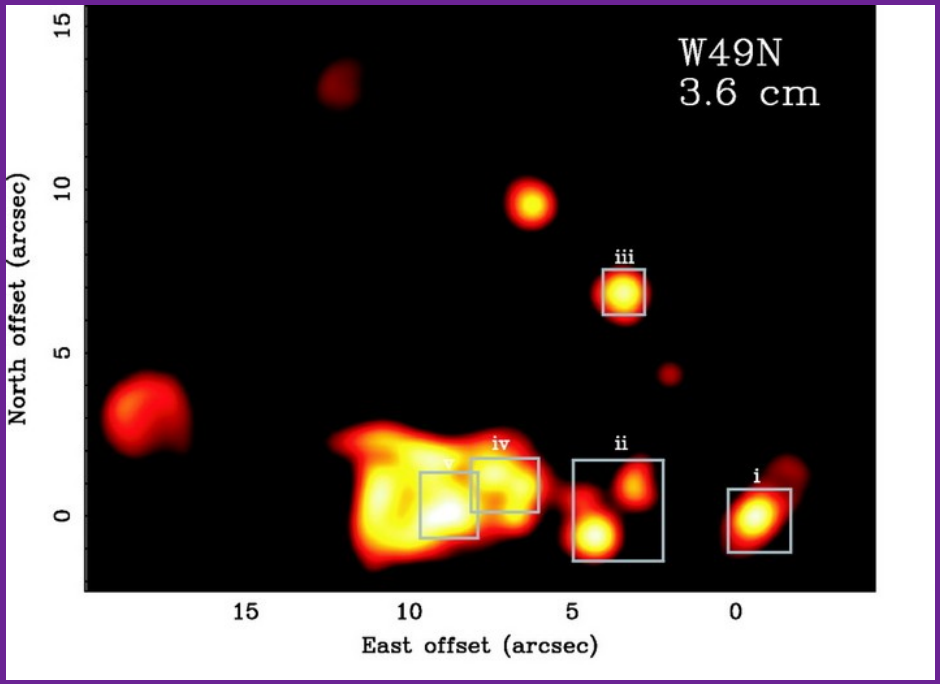
- $2x10^4$ Lo at 1 kpc
- Infrared bright
- Very well studied
- Rich molecular spectrum
- Source structure well characterized (van der Tak et al 1999)




intermediate velocity CO absorption
absorption column of low-velocity CO
Power law envelope
$A_V = 100^m$, HCN / $H_2 = 10^{-8}$
(single-dish emission lines; mid- and far-IR continuum)
R = 30 000 AU: T_{d4} = 28 K, $n(H_2) = 3.5 \times 10^4$ cm^{-3}, icy coagulated grains
Early B-type star
Entrainment layer *(CO absorption at 200 km s^{-1})*
low-density outflow cavity
to Sun
redshifted CO outflow lobe
blueshifted CO outflow lobe
T = 200 K, V = 20 km s^{-1}
ionized 500 km s^{-1} wind *(extended Brγ & [S II] emission)*
R = 1000 AU: T_d = 150 K, $n(H_2) = 3.5 \times 10^6$ cm^{-3}, ice mantles evaporated *(OVRO HCN emission)*
opaque base of ionized wind *(VLA cm-wave continuum; Brγ point source)*
Inner region: T = 1000 K, R < 175 AU, $A_V = 30^m$, HCN / $H_2 = 10^{-6}$ *(near-IR continuum; 14 μm absorption; OVRO mm-wave continuum)*
SW radio source *(in background, obscured by envelope)*

A Galactic Starburst: W49

- Distant: 11.4 kpc
- Luminous: 10^7 L_o
- Cluster of UCHII regions embedded in 10^5 M_o cloud



(De Pree et al. 2003)

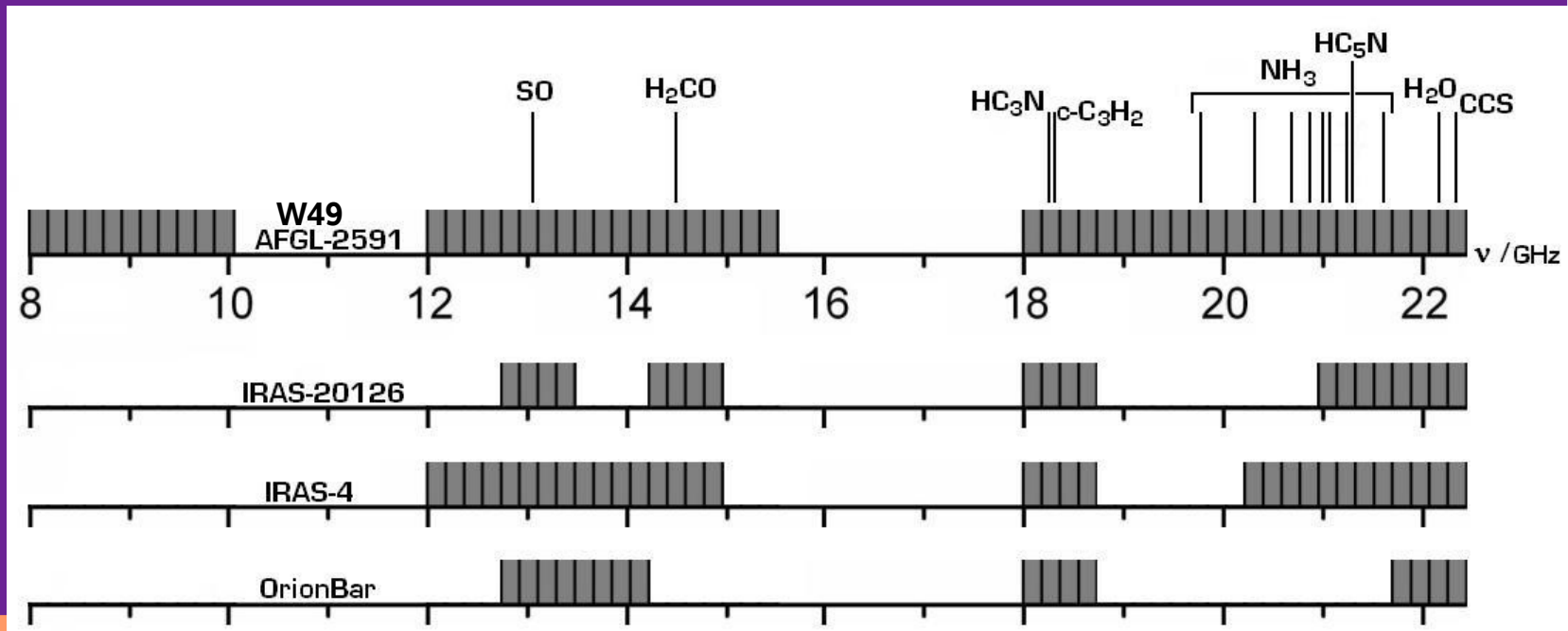
Stepping stone to extragalactic star formation regions

SLS: The parameters

- Five sources
  - Orion Bar
  - NGC1333 IRAS4
  - IRAS20126+4104
  - AFGL2591
  - W49
- Noise levels (in 2.5 km/s channels)
  - 25mK
  - Low mass source: 9mK
- Allocation
  - 187 Hours (in grade 4 weather)
- Coverage
  - 330 GHz – 363 GHz
  - 2GHz (1.6GHz) per observation, 1 km/s channels
  - Single footprint (2'x2')

Extensions

- High frequency
  - SLS extension from 363 GHz to 375 GHz
- 230 GHz
  - Imaging of important transitions
- GBT
  - 8 – 22.6 GHz – complete W49, AFGL2591
  - Would like to extend up to 45 GHz

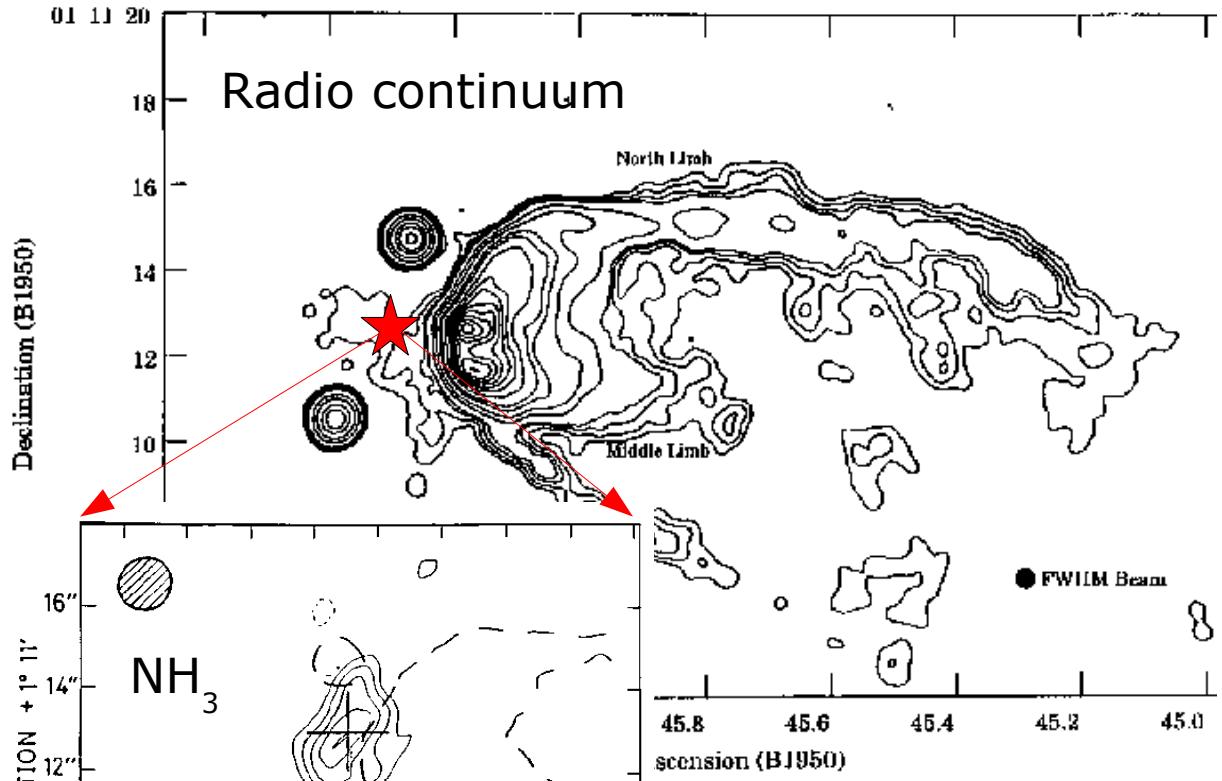


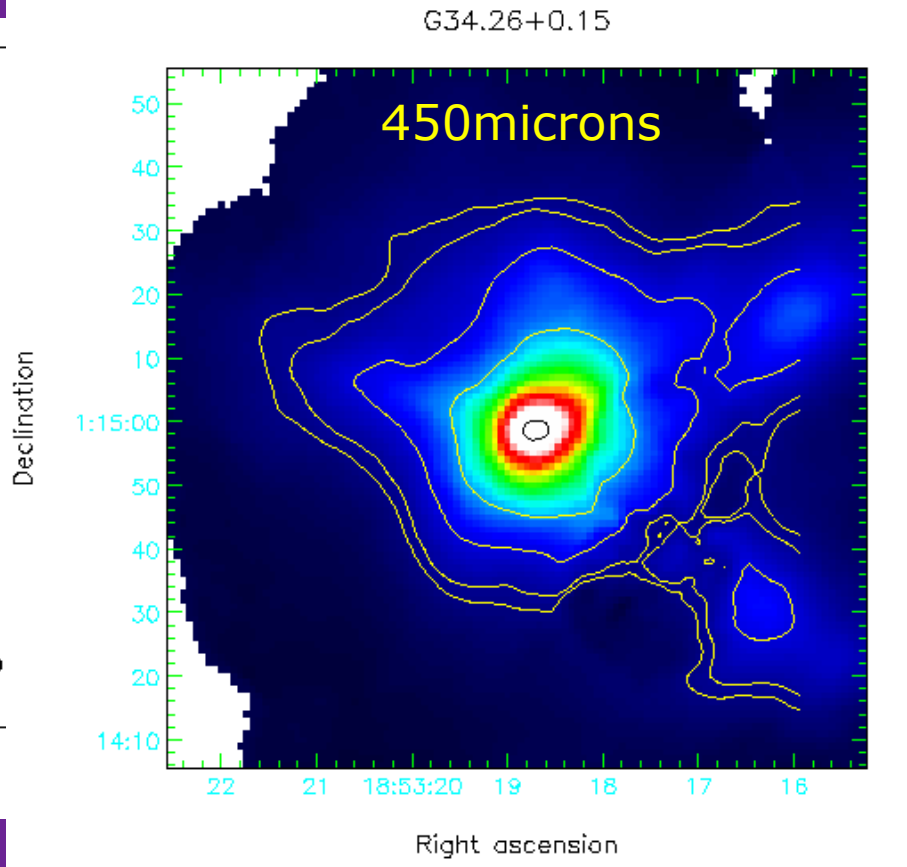
Status of the survey

- SLS started Nov 2007. Blocks every month.
  - But currently little data
  - Reduction evolving
- High frequency extension: Started in 06B. Ongoing. More time allocated
- 230GHz observations: Started in 05B, ongoing. More time allocated.

A Demonstration Case: G34.26+0.15

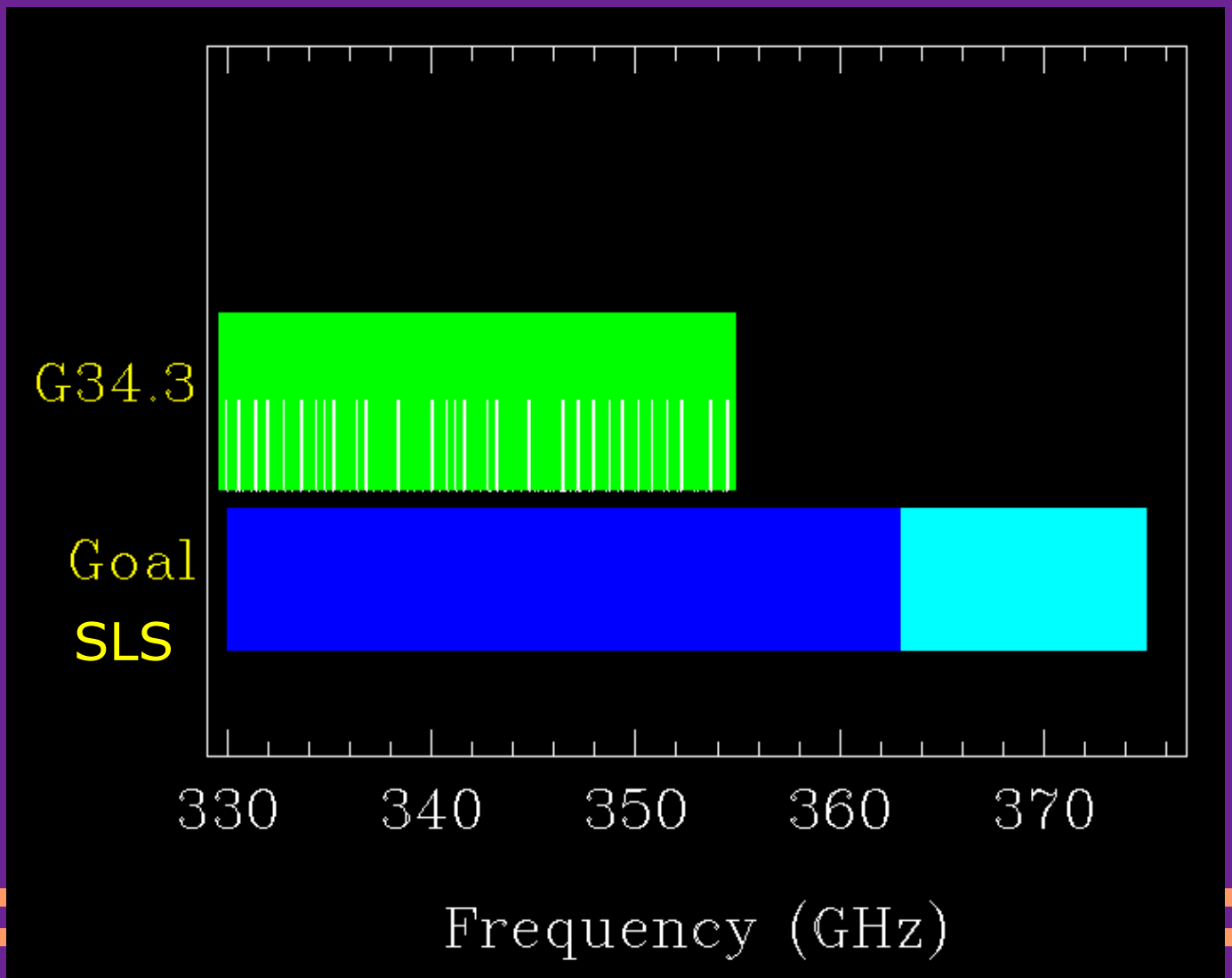
- Classical hot core: ~0.01pc, 300K, 10^7 cm^{-3}, 10^{24} cm^{-2}
- Single point survey by Macdonald et al. (1996)
  - 35 species, 19 isotopologues, 70 U lines
- Multipoint chemical model by Millar et al. (1997)
- Survey of envelope by Thompson et al. (1999)



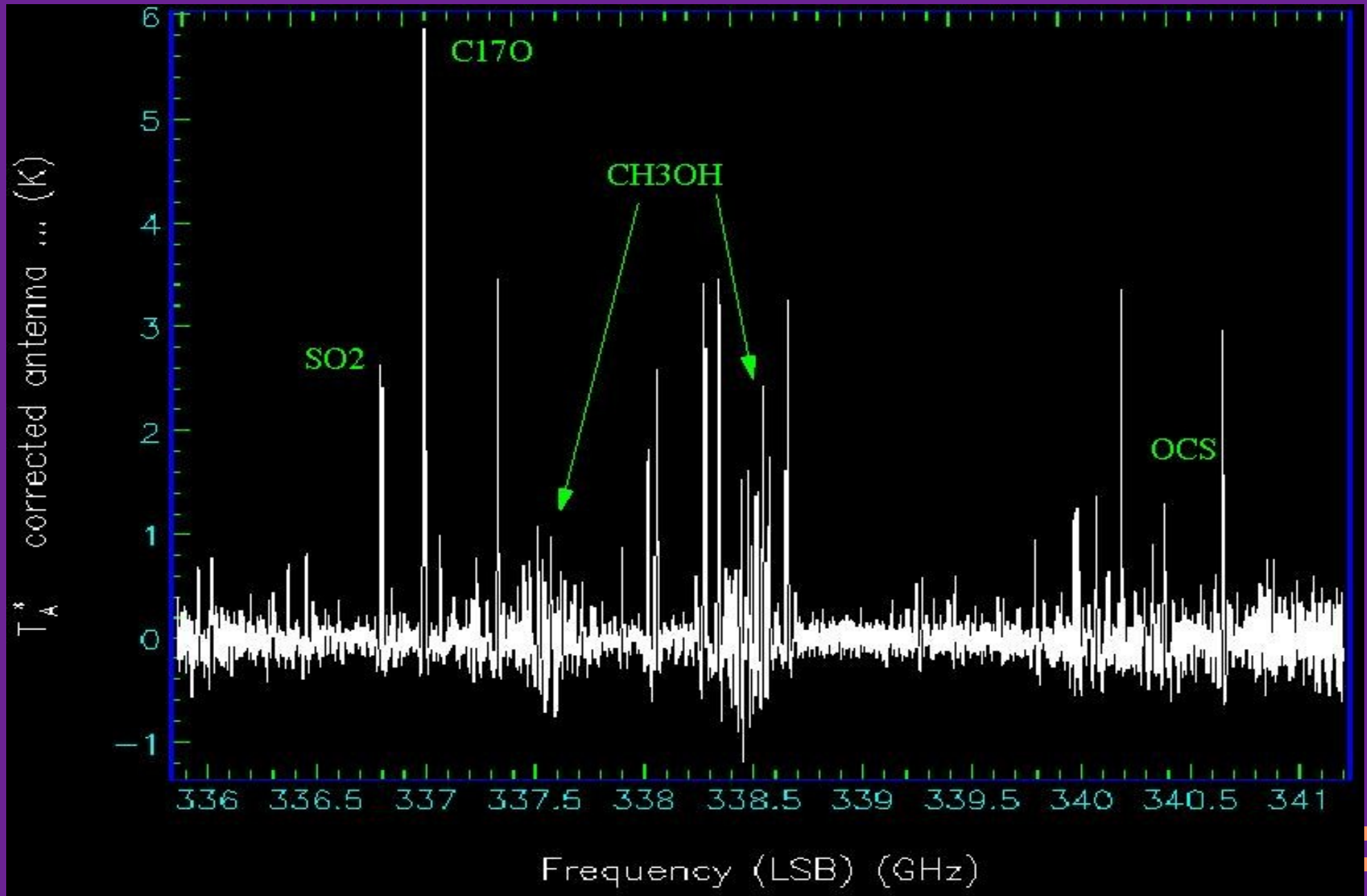


G34.3 Frequency coverage

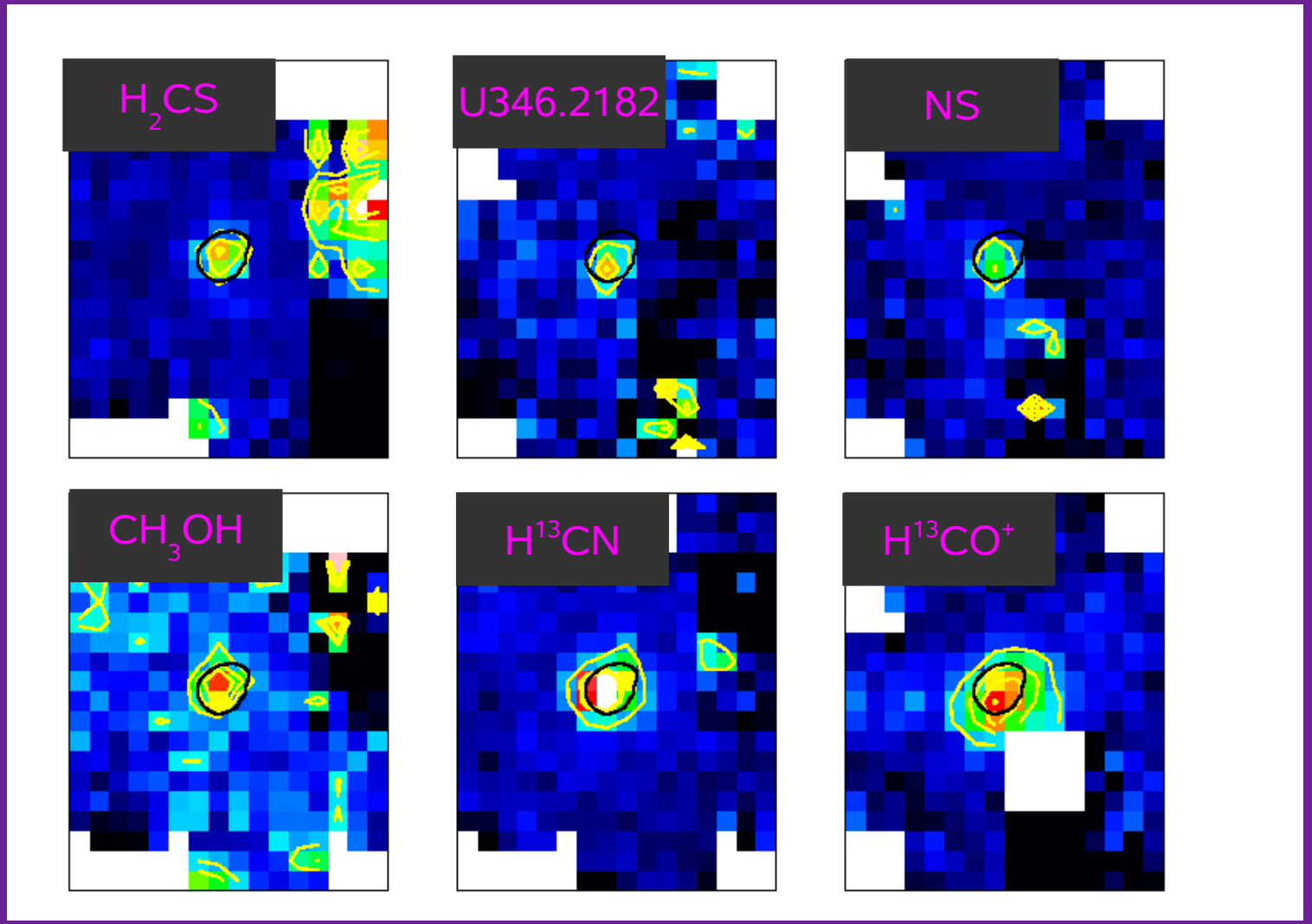
- Short integrations
  - Coverage not to SLS depth



G34.3 Spectrum



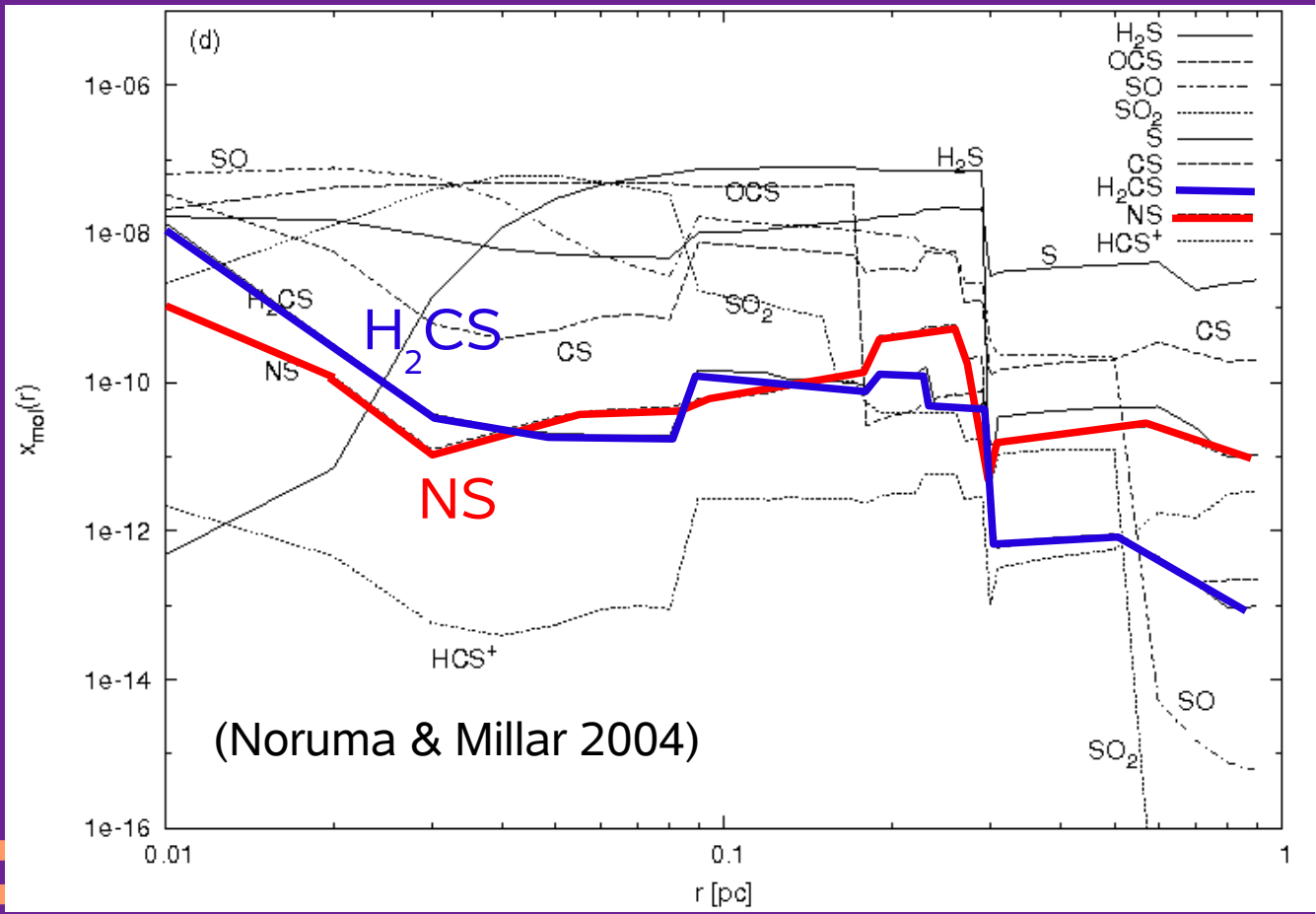
Many species in G34.26+0.15



Species:Colour + yellow contours - Black contour: Peak 450μm

Spatial Information

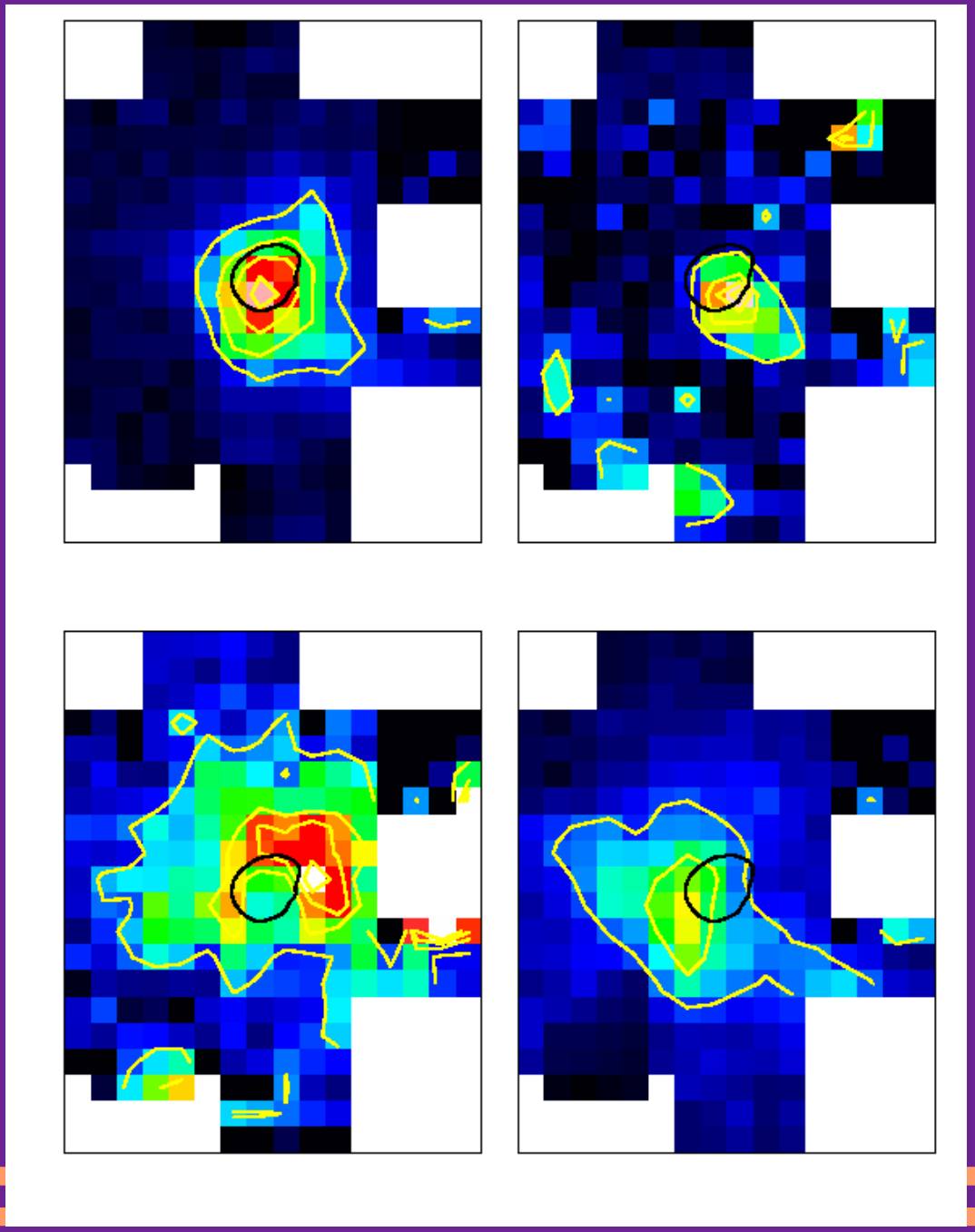
Species	Peak	Size (")
H_2CS	(0,+7.5")	7.8
CH_3OH	(0,+7.5")	7.3
$H^{13}CN$	(0,+7.5")	8.6
$H^{13}CO^+$	(0,0)	11
NS	(0,0)	8.3
U346.2186	(0,0)	5.7
H_2CO	(0,0)	10.4



Spatial and Velocity Structure

HCN

4 velocity ranges



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More information:

http://www.jb.man.ac.uk/research/sls

Plume, Fuller, van der Tak et al. 2007, PASP, 119, 102

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