SMAで探る星形成

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SMA (Submillimeter Array)とは

- SMAとはハワイ、マウナケア山頂に建設された、世界最初のサブミリ波イメージングアレイ。
- SAOとASIAAの共同プロジェクト。
- 口径6メートルの電波望遠鏡8機からなる。
- 180-900 GHzの周波数帯をカバー。
- ASIAAはアンテナ2機（電気系、受信機システムを含む）を作成（SMARTプロジェクト）。これにより、干渉計の観測効率が2倍。
- ALMAのプロトタイプ的役割。

SMAの仕様

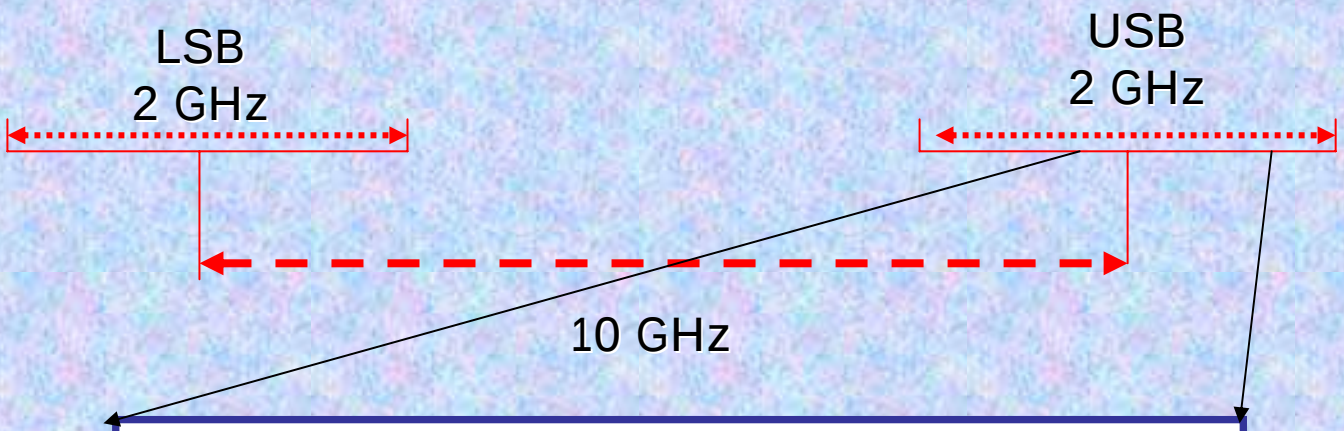
Antenna	Eight reflectors, 6-m in diameter Carbon Fiber backup structure Machined cast aluminum panels Primary reflector f/0.4, surface 12 μm rms
Baseline	8 to 505 meters
configurations	4 rings, 24 pads, up to 8 antennas per ring
resolution	0.5 to 0.1 arcsec
Field of View	70 to 14 arcsec
Receivers	Up to 8 per cryostat (2 bands simultaneously)
Correlators	Flexible Hybrid analog-digital design Up to 2 GHz bandwidth, 2 receivers, 8 stations
Pointing error	~1” rms

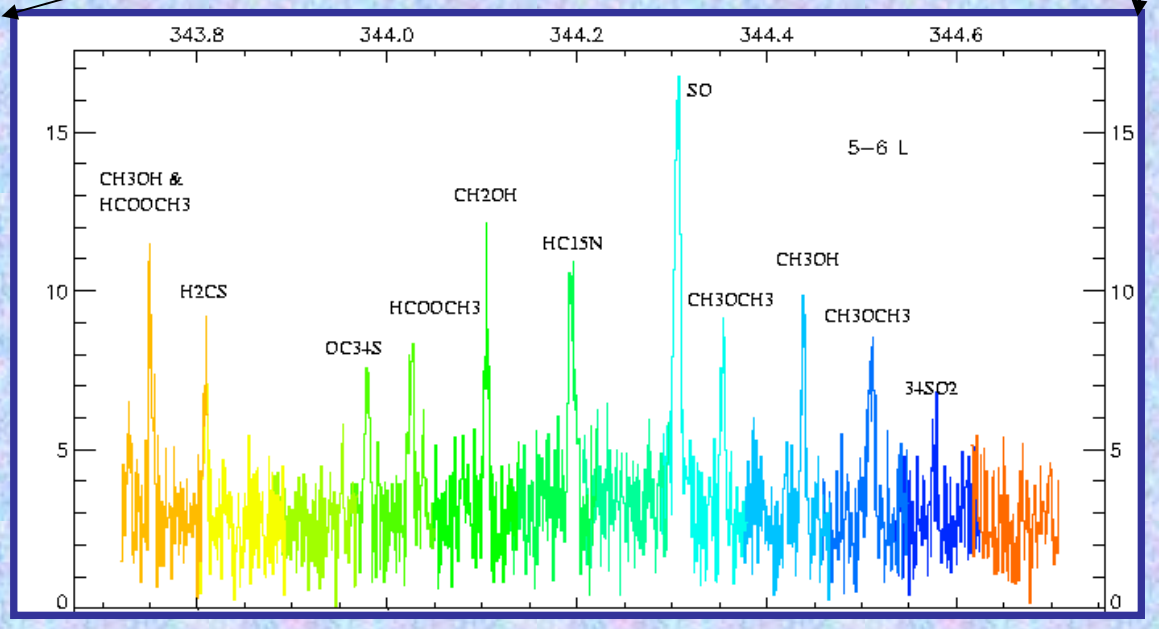
SMAの現状

	Goal	Current
Antennas		
6m dishes	8	8
Receivers		
230 GHz	8	8
345 GHz	8 x 2 polarization	8
460 GHz	8	0
690 GHz	8	6
820 GHz	8	0
Correlator		
Bandwidths	2 GHz (dual band)	2 GHz (single band)
Resolution	0.1 MHz	0.2 MHz

SMA Correlator

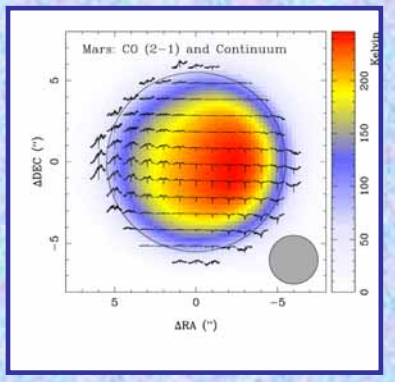
Very Flexible: Process Multiple Lines with Different Resolution

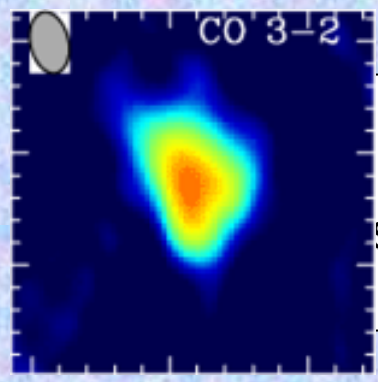


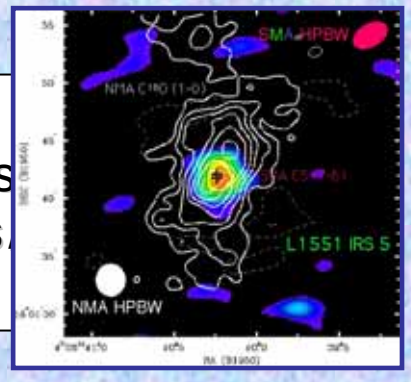


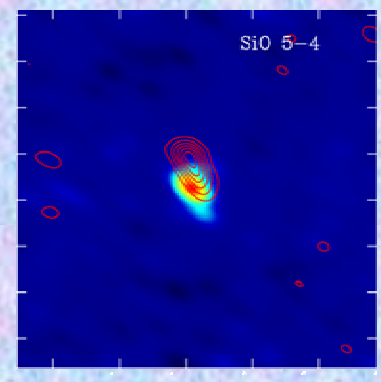
0.8MHz
/Chan

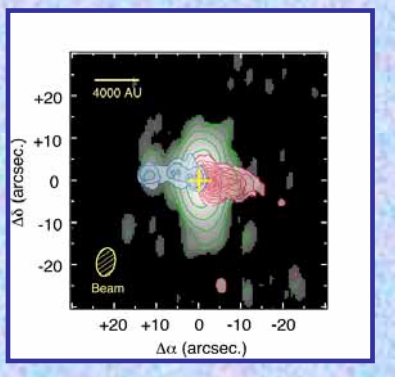
SMA Initial Science: 7 Projects

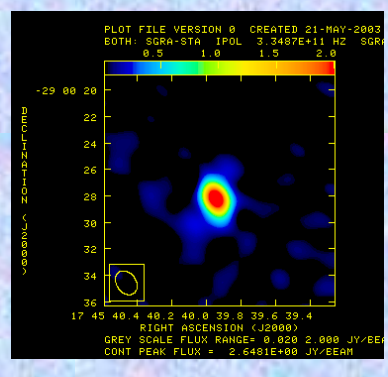


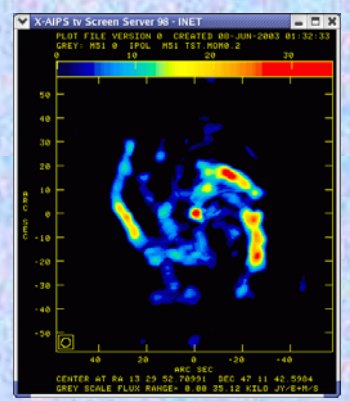


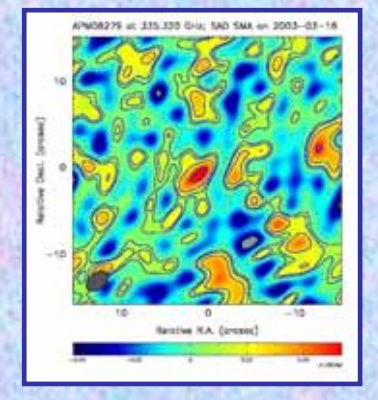










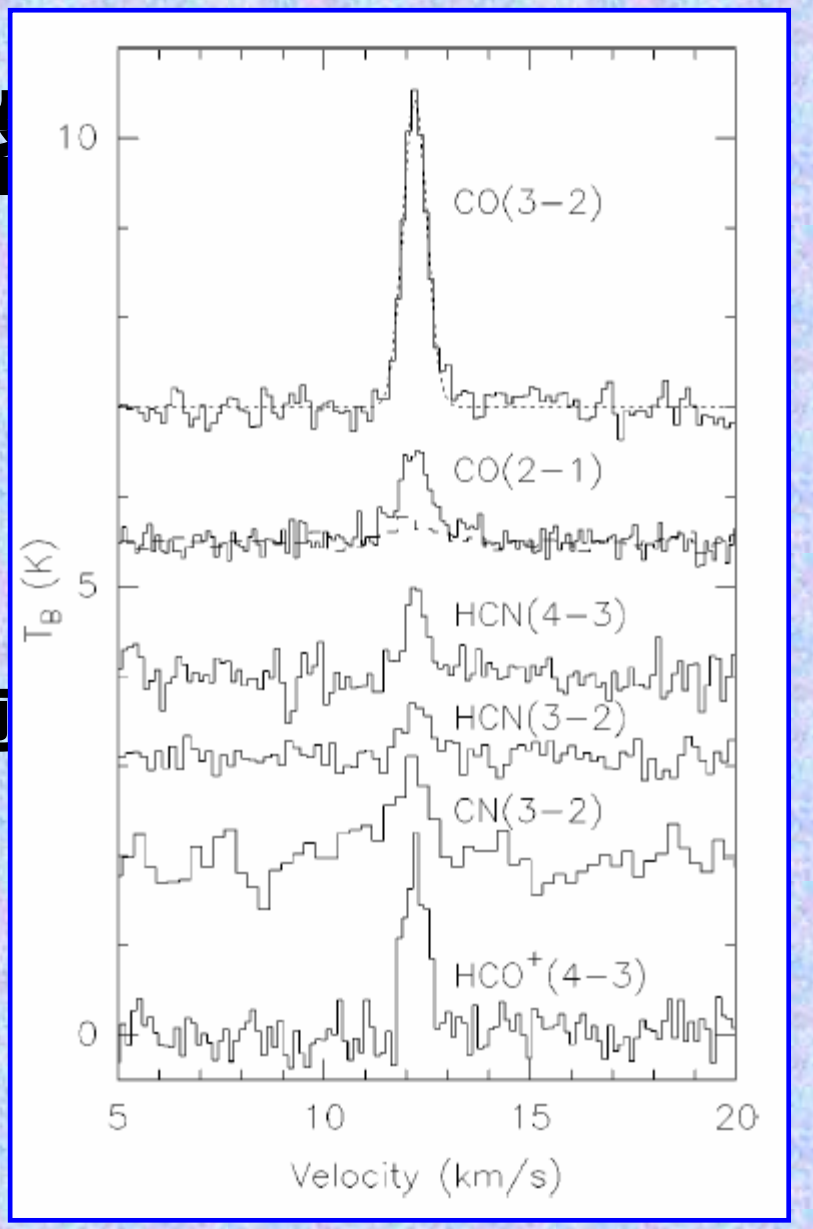


SMAで探る星形成

- **原始惑星系円盤、**Debris disks
  - TW Hya
- **原始星エンベロープ、アクリーション、アウトフロー**
  - L1551 IRS5
- High mass young stars
  - Hot core

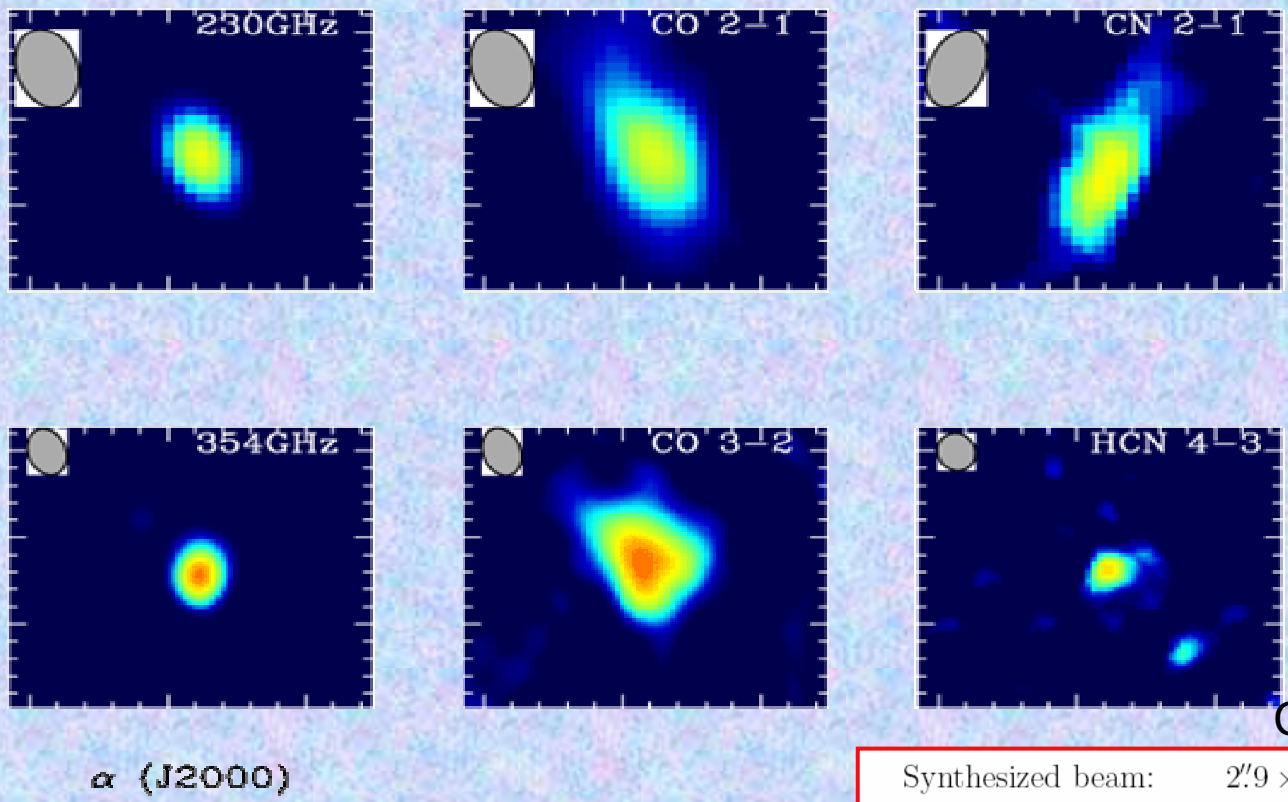
原始惑星系円盤

- 最も近傍(56 pc)のCTTS。
- ダスト円盤 (質量~5x10^{-3} Mo)が付随。
- CO, HCN, CN, HCO+, DCO+等の分子ガスが付随することがシングルディッシュの観測により示唆。
- 南天(-34度)にあるため干渉計観測が困難。



Kastner et al. 1997

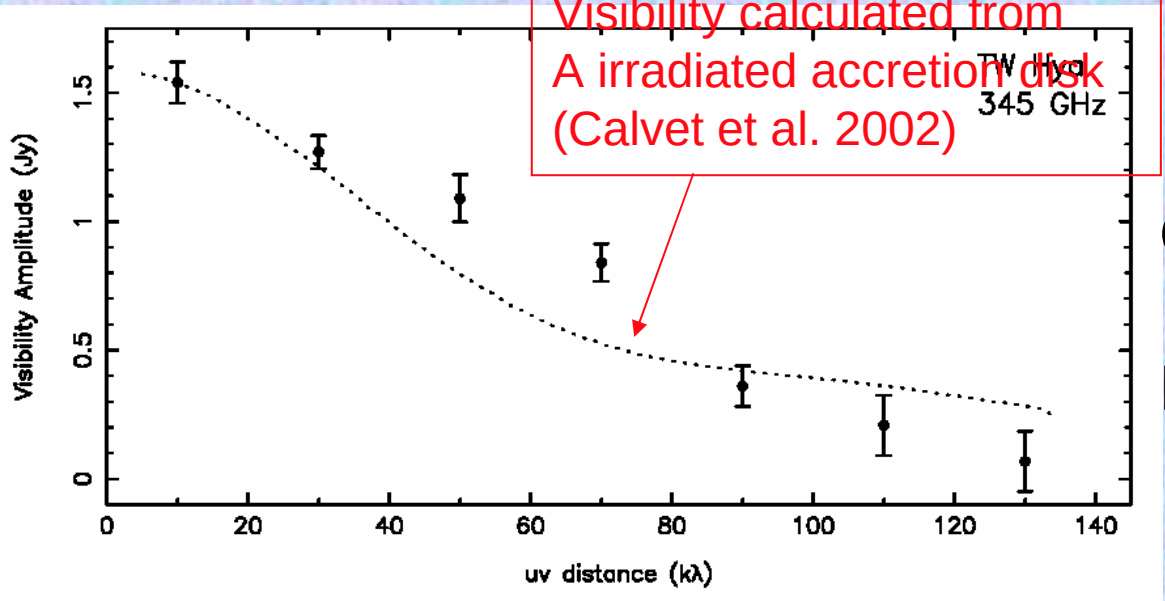
CO 3-2 & 2-1 & Continuum Observations of TW Hya



Qi et al. 2004

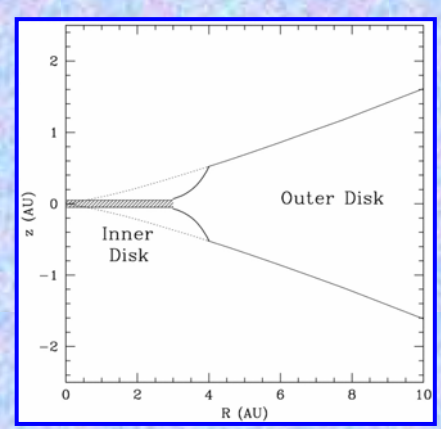
	CO 3-2	CO 2-1
Synthesized beam:	$2\farcs9 \times 2\farcs1$ PA 3.4°	$4\farcs7 \times 2\farcs7$ PA 9.9°
R.M.S[a] (continuum):	35 mJy/beam	6.8 mJy/beam
Dust flux:	1.46 ± 0.04Jy	0.57 ± 0.02Jy
Channel spacing:	0.18 km s^{-1}	0.26 km s^{-1}
R.M.S.[a] (line):	1.1 Jy/beam	0.28 Jy/beam
Integrated intensity	23.7 K km s^{-1}	10.6 K km s^{-1}
Peak intensity	25.9 K	14.7 K
ΔV[b]	0.86 km s^{-1}	0.73 km s^{-1}

Continuum Visibility of TW Hya

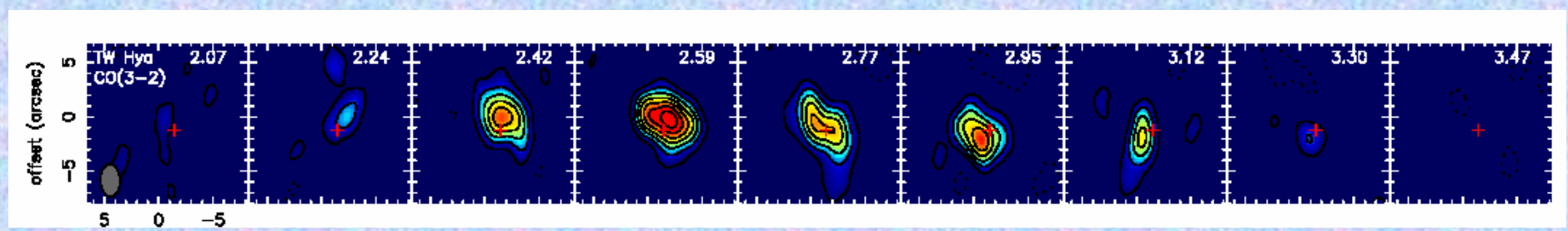


Calvet et al. (2002)**の** Irradiated accretion disk Model**でよく説明できる。**

Calvet's model



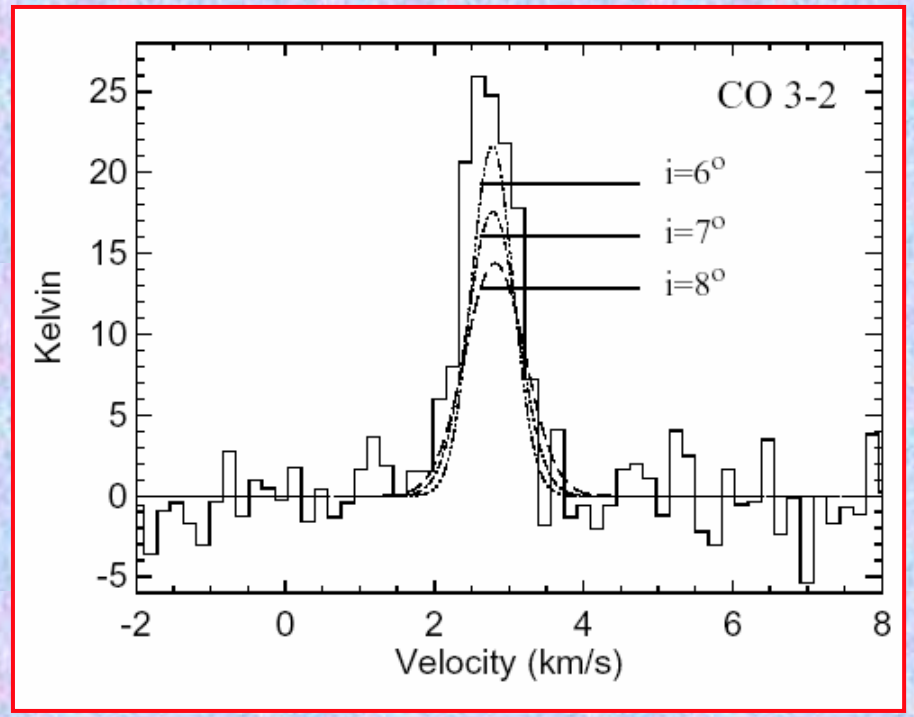
CO Channel Maps of TW Hya

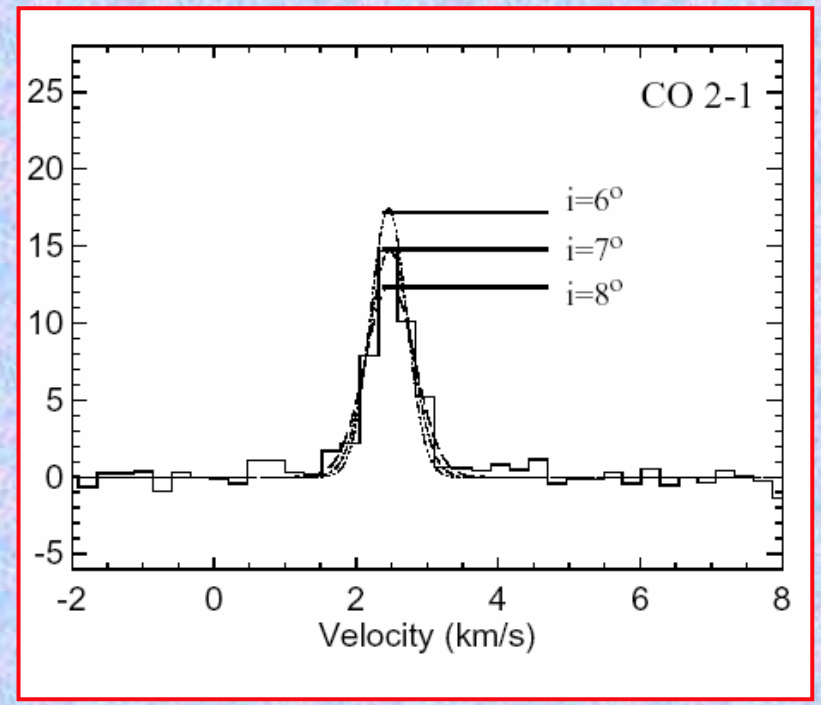


Use a two-dimensional accelerated Monte Carlo model (Hogerheijde & van der Tak 2000), and calculate the radiative transfer and molecular excitation.

	Parameters
Physical Structure	Irradiated accretion disk (Calvet et al. 2002)
Stellar Mass	0.6 $M_\odot$
Disk Size	R_{in} 4 AU, R_{out} 196 AU
Disk PA	45°
Inclination Angle	7°
Turbulent Velocity	0.05 km s^{-1}
Depletion Factor	10× (100× for T≤22 K)

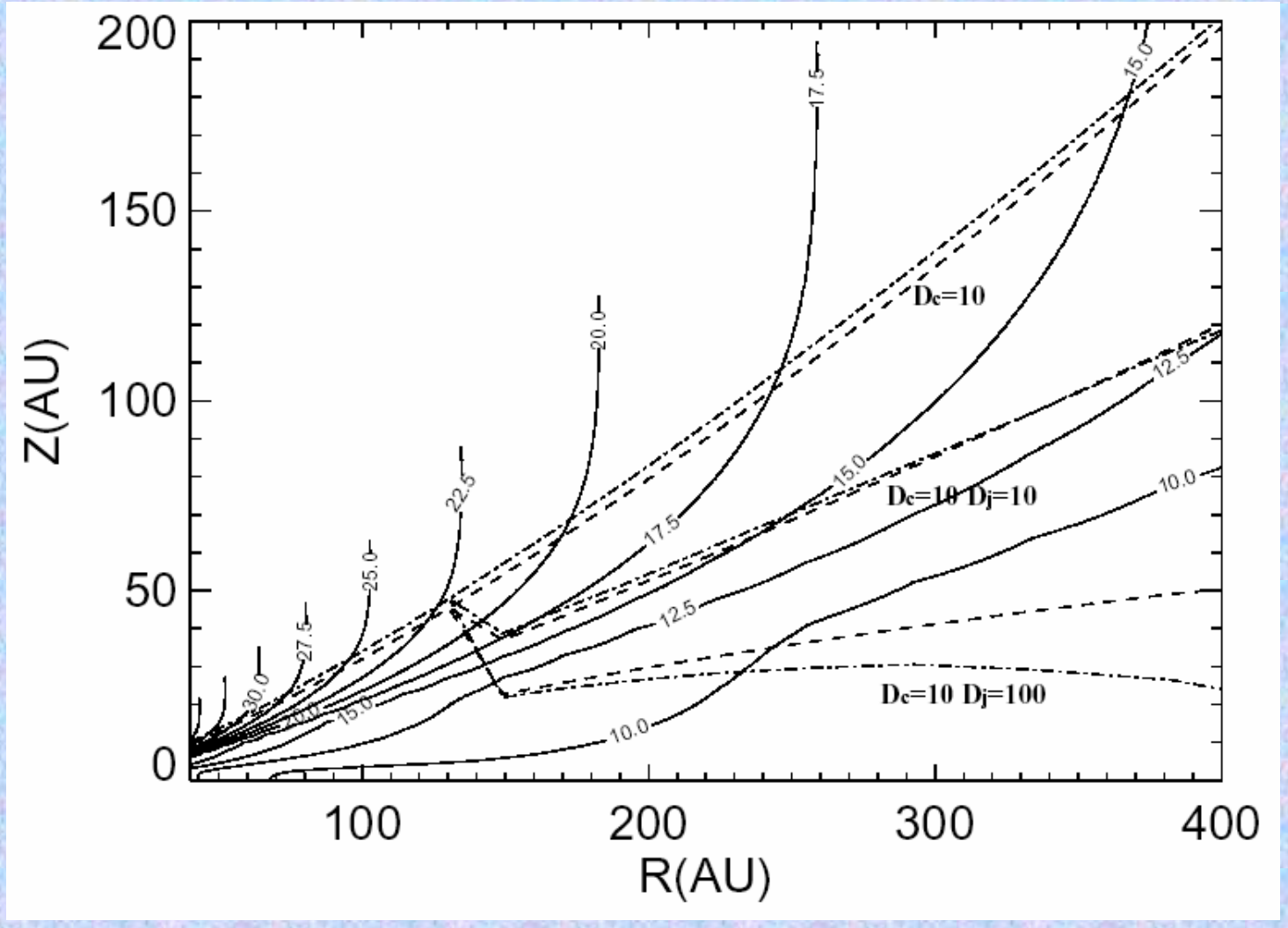
CO Spectra of TW Hya





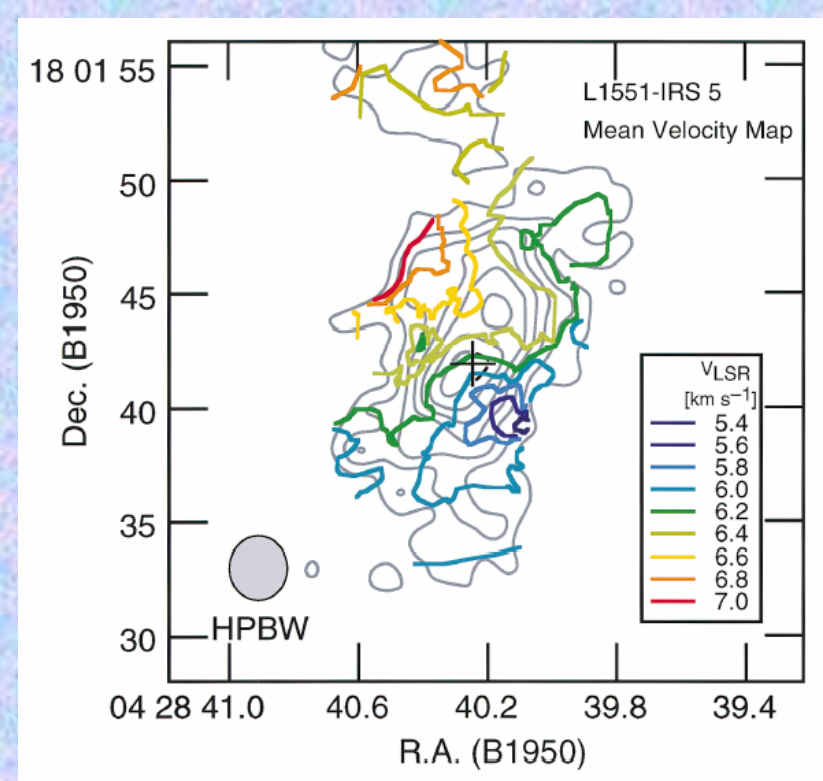
Disk inclination angle ~ 7 deg.

Vertical Structure of the CO disk?



L1551 IRS5

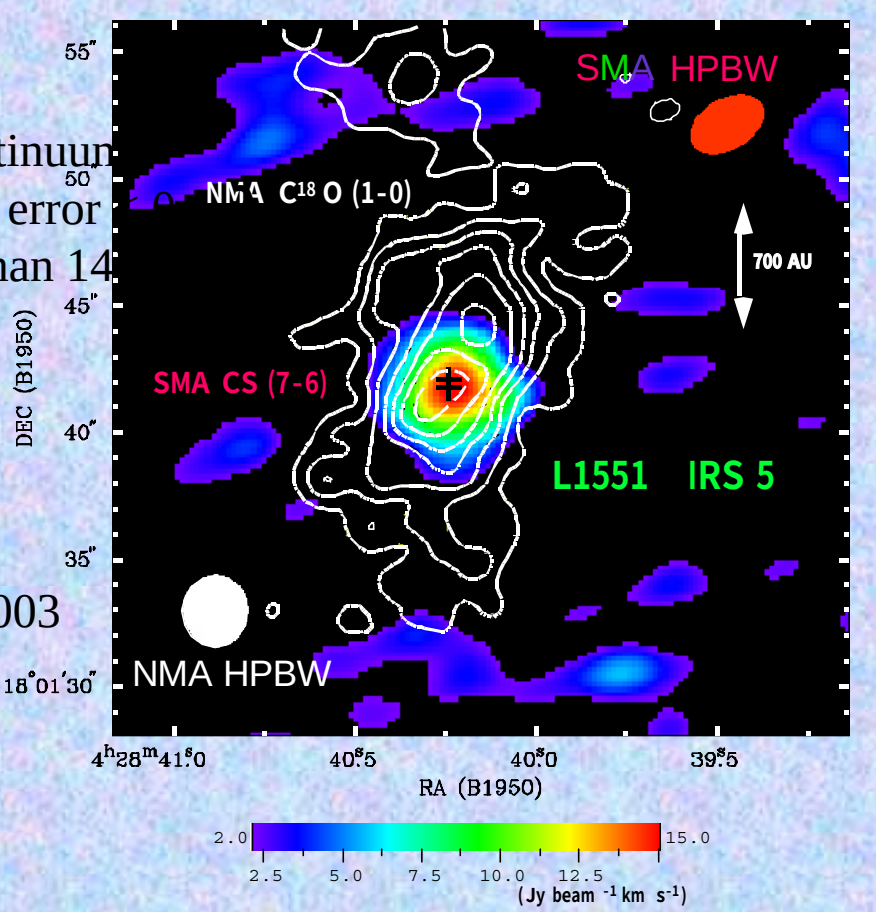
- Taurusで最も明るい原始星。
- バイナリー。
- Flattened-envelopeを伴う。
- Envelopeの運動はインフォール＋回転で説明。



Momose et al. 1998

CS J=7-6 Observations of 1551 IRS5

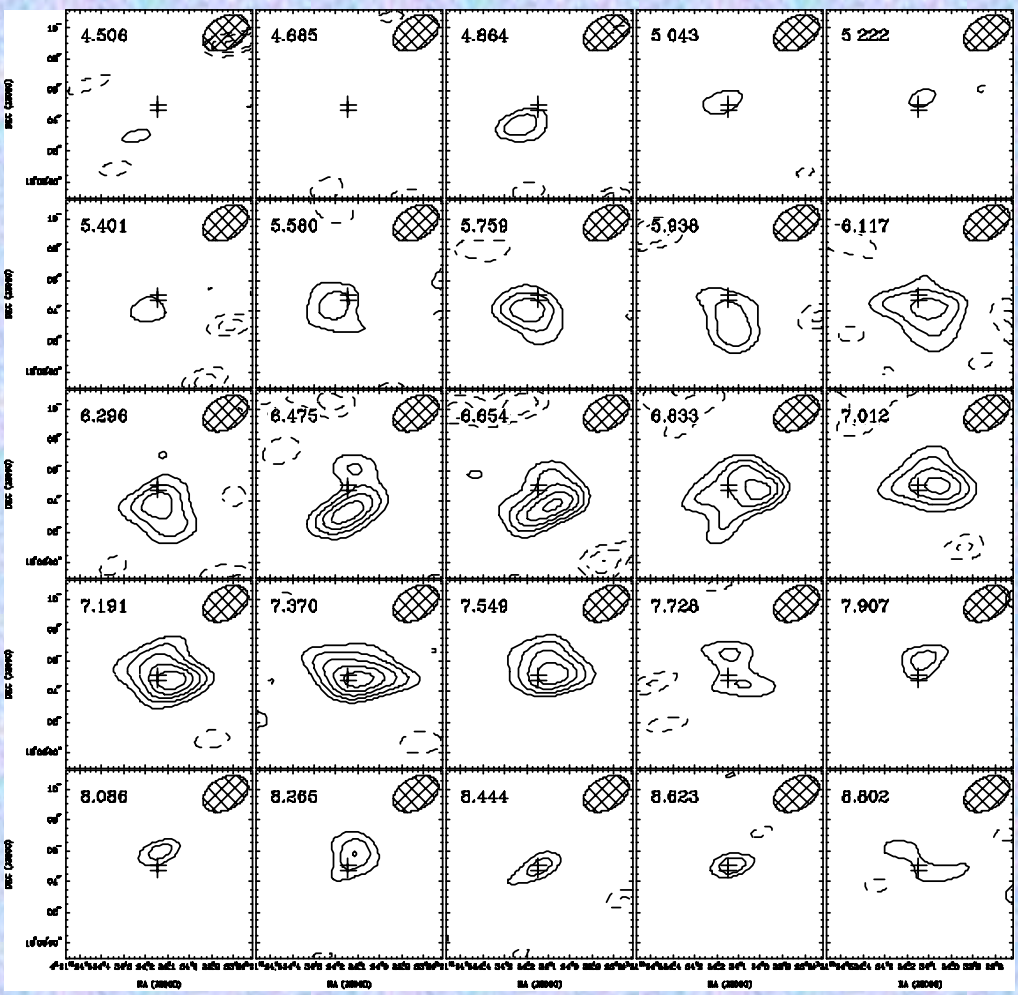
Line : CS (J=7-6; 342.88295 GHz) + Continuum
Baseline : 10-Baselines (5 antennas), baseline error
: Insensitive to the structure greater than 14
Beam : 3.2 ×2.0 arcsec (P.A.=-60 °)
Field of View : ~ 40 arcsec
Spectral Res. : 203 kHz
Gain Cal. : 0423-013 (7.8 --> 7.2 Jy)
Passband Cal.: Saturn, Jupiter
Date : December 18, 2002, March 13, 2003



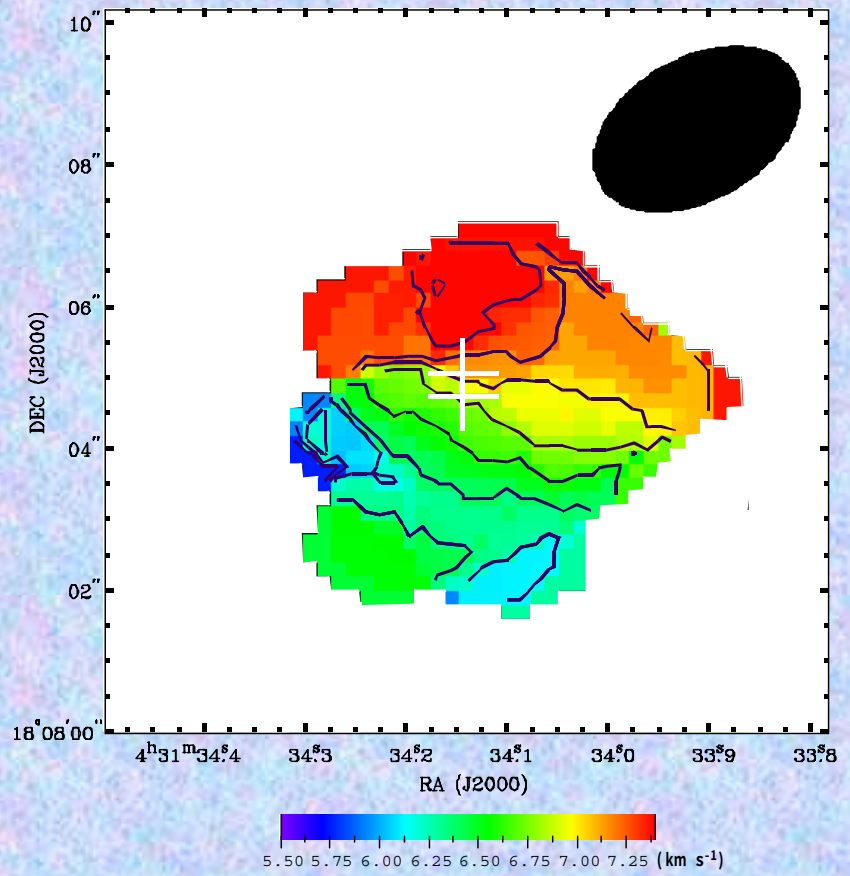
Takakuwa et al. 2004

Velocity Structures of the CS 7-6

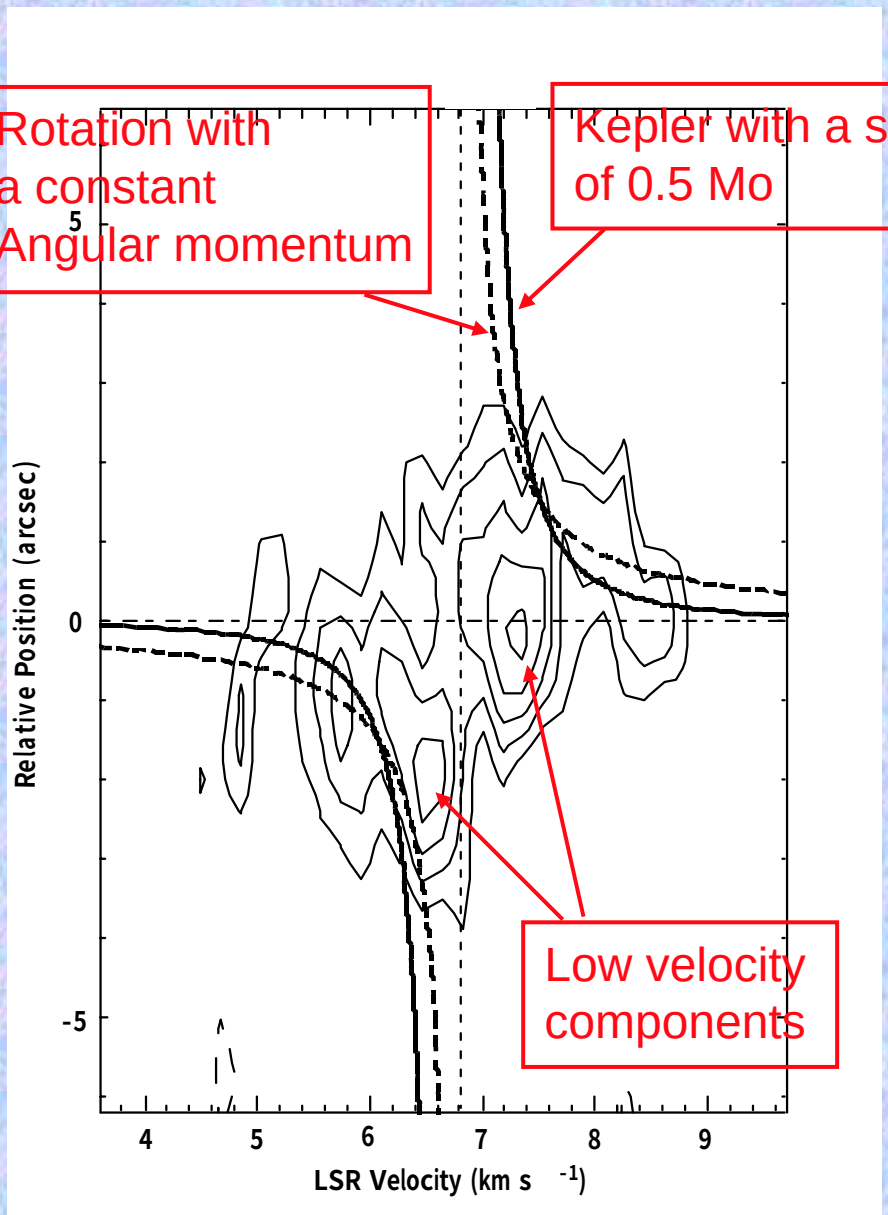
CS channel maps

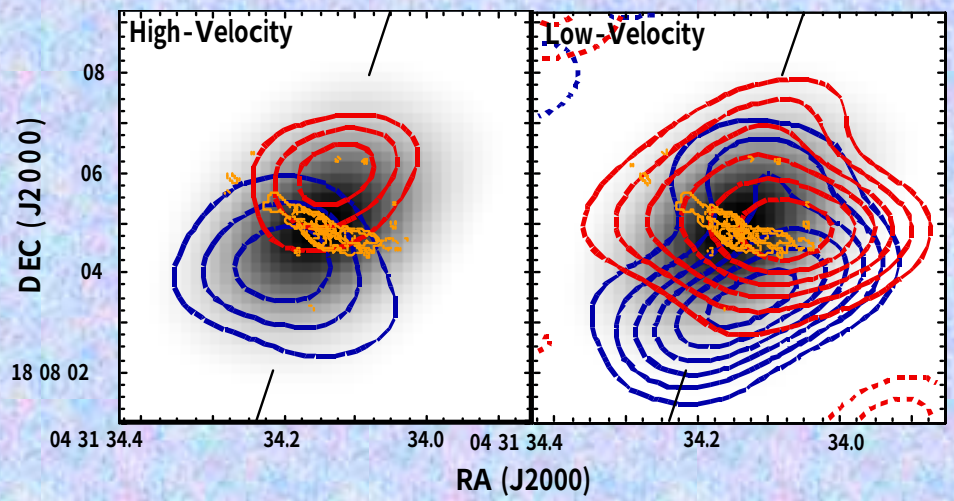


CS mean velocity map



Rotation of the CS envelope?



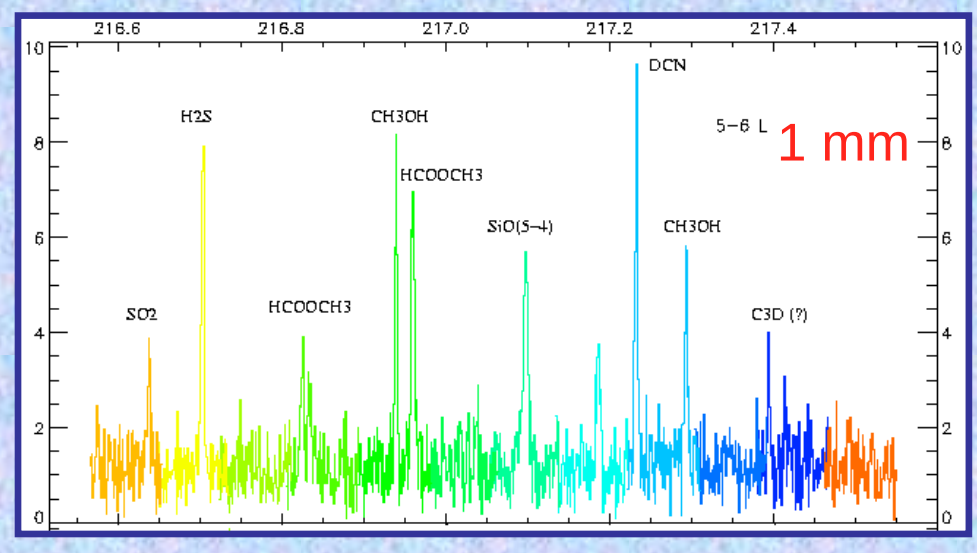


The low velocity components
Are related the outflow?

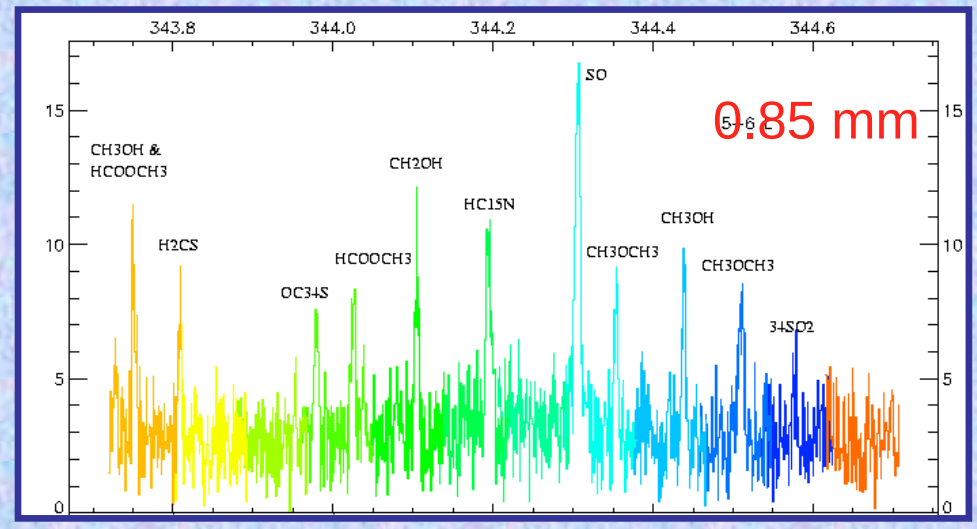
Hot Core: IRAS 18089-1732

- A part of a sample of 69 High-Mass Protostellar Objects (HMPO) cataloged by Sridharan et al. (2002).
- Distance ~ 3.6 kpc.
- Hot core?: CH3CN and CH3OH were detected (Sridharan et al. 2002)
- Rich Chemistry?

Spectra of IRAS 1



1 mm

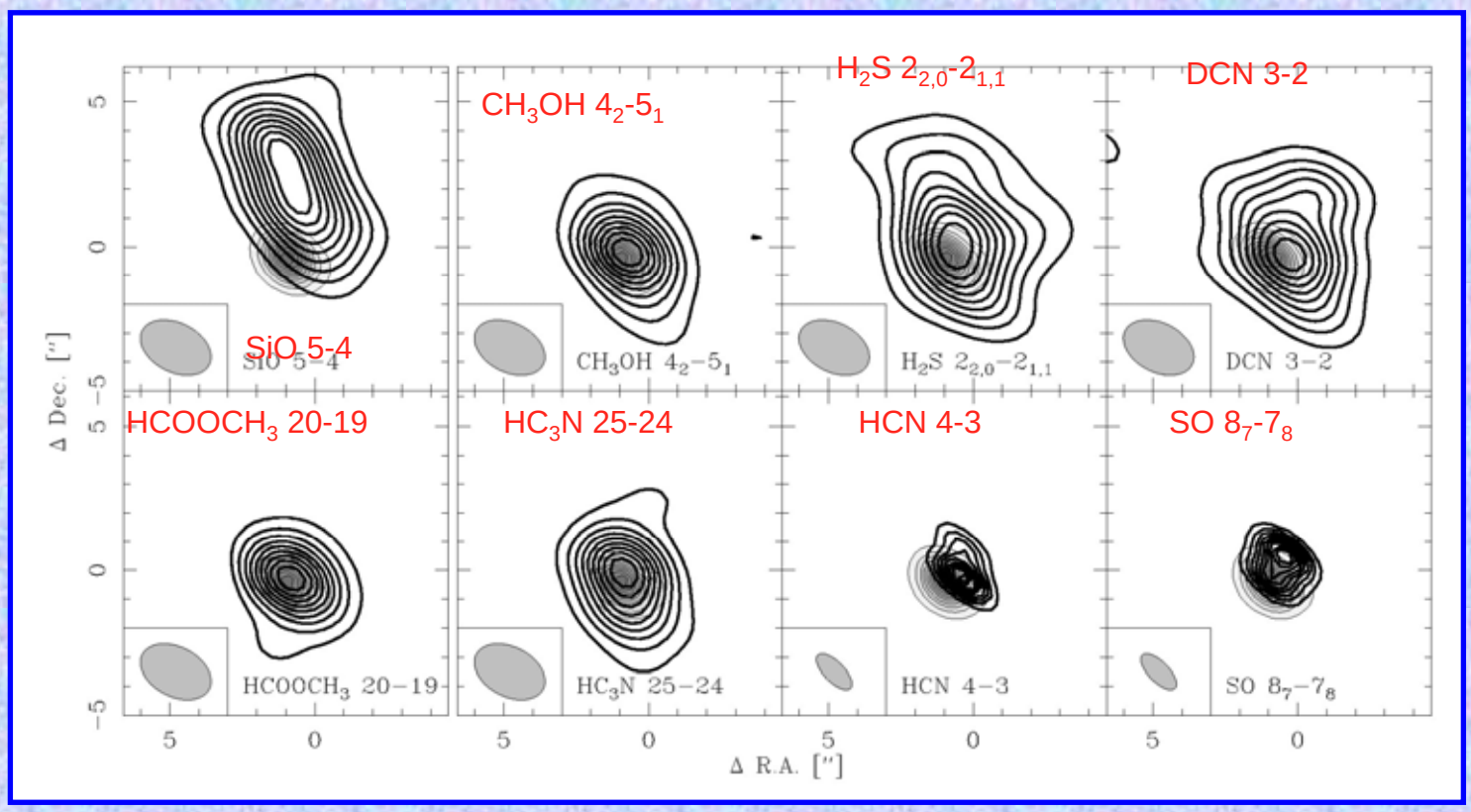


0.85 mm

Line	ν GHz	S^b_{peak} $\frac{Jy}{beam}$	$S^{b,c}$ Jy	Size^c $''$	$\frac{S}{S_{peak}}^d$
SO_2 $22_{2,20} - 22_{1,21}$	216.643				
H_2S $2_{2,0} - 2_{1,1}$	216.710	2.3	6.4	39.7	0.6
$HCOOCH_3$ 18–17	216.839				
CH_3OH $4_2 - 5_1$	216.946	2.0	2.8	20.5	0.3
$HCOOCH_3$ 20–19	216.966	2.1	2.3	15.9	0.2
SiO 5–4	217.105	1.0	2.6	31.9	0.6
UL[a]	217.193				
DCN 3–2	217.239	1.9	4.3	32.6	0.5
UL[a]	217.300				
UL[a]	217.400				
$HCOOCH_3$ 19–18 E	227.020				
$HCOOCH_3$ 19–18 A	227.028				
HC_3N 25–24	227.419	3.4	5.9	21.3	0.4
$HCOOCH_3$ 21–20	227.562				
UL[a]	227.815				
$HCOOCH_3$ 27–26 E	343.732				
CH_3OCH_3 17–16	343.753				
$HCOOCH_3$ 27–26 A	343.758				
H_2CS $10_{2,8} - 9_{2,7}$	343.811				
$OC^{34}S$ 29–28	343.983				
$HCOOCH_3$ 32–31	344.030				
CH_2OH-E	344.110				
$HC^{15}N$ 4–3	344.200				
SO $8_8 - 7_7$	344.311	2.4	4.2	5.6	1.5
CH_3OCH_3 19–18	344.358				
CH_3OH $19_{10,9} - 18_{10,8}$	344.445				
CH_3OCH_3 11–10	344.512				
$^{34}SO_2$ $19_{1,19} - 18_{0,18}$	344.581				
UL[a]	354.129				
$^{13}CH_3OH$ $4_3 - 3_2$	354.446				
HCN(0,1,0) 4–3	354.461				
HCN 4–3	354.506	2.2	3.1	4.9	1.3
$HCOOCH_3$ 33–32	354.608				
HC_3N 39–38	354.699				

H. Beuther et al. 2004

Maps of IRAS 18089-1732



Morphologicaally, most of molecular line maps show Significant contributions from the outflow.

まとめ

- 8素子SMAの完成。
- SMAを用いたサイエンス観測を開始。
- 今年の中旬にはプロポーザルをオープン。
- SMAを用いた共同研究を日本と促進？