

Hunting Accretion Disks around Massive Young Stars in the Milky Way

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Harvard-Smithsonian Center for
Astrophysics



May 2026

Arcetri

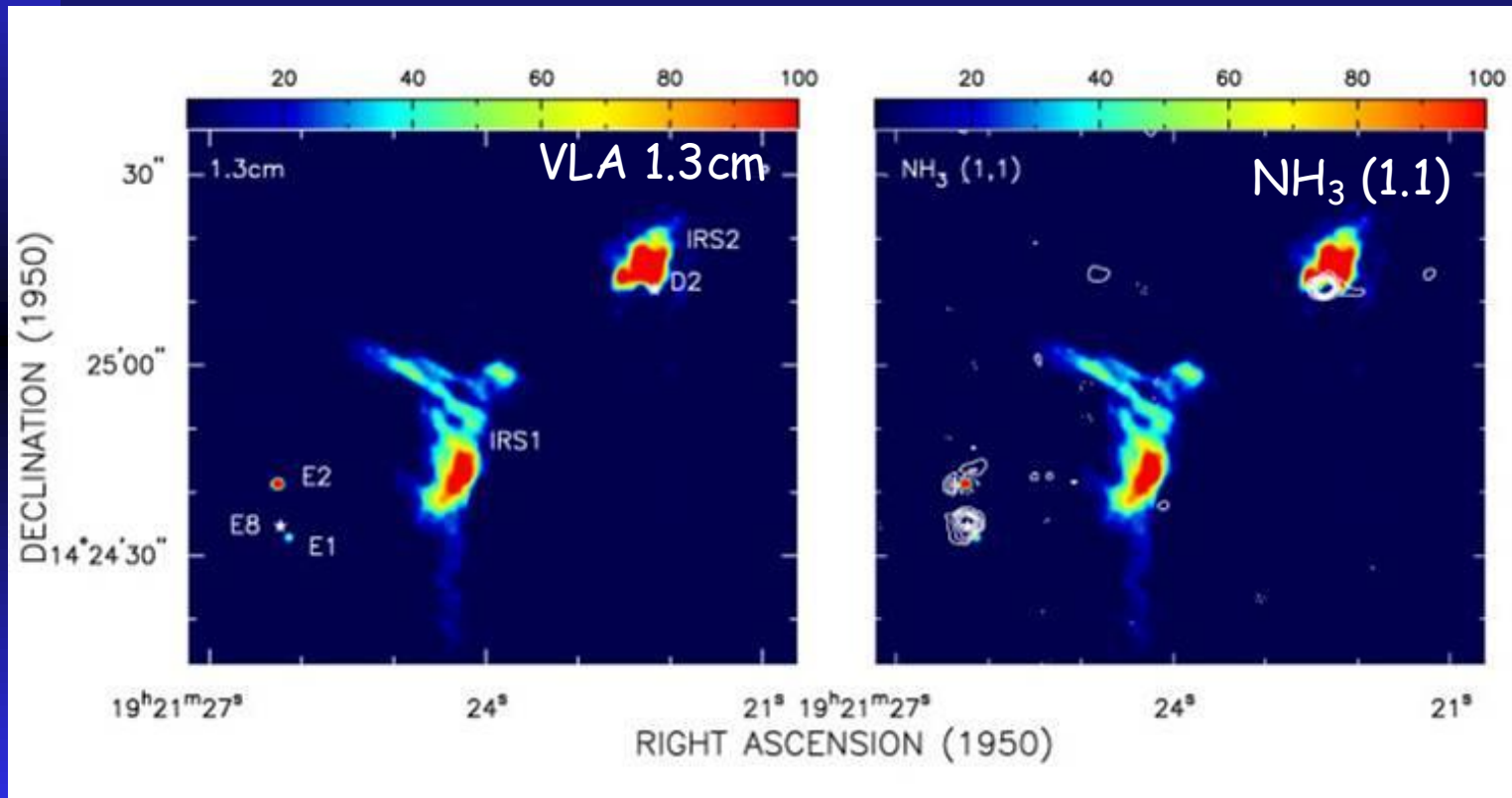
CENTER FOR **ASTROPHYSICS**

HARVARD & SMITHSONIAN

1

Infall in W51

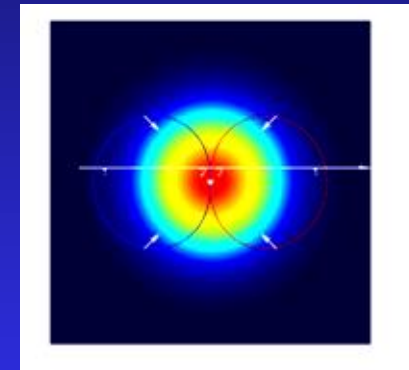
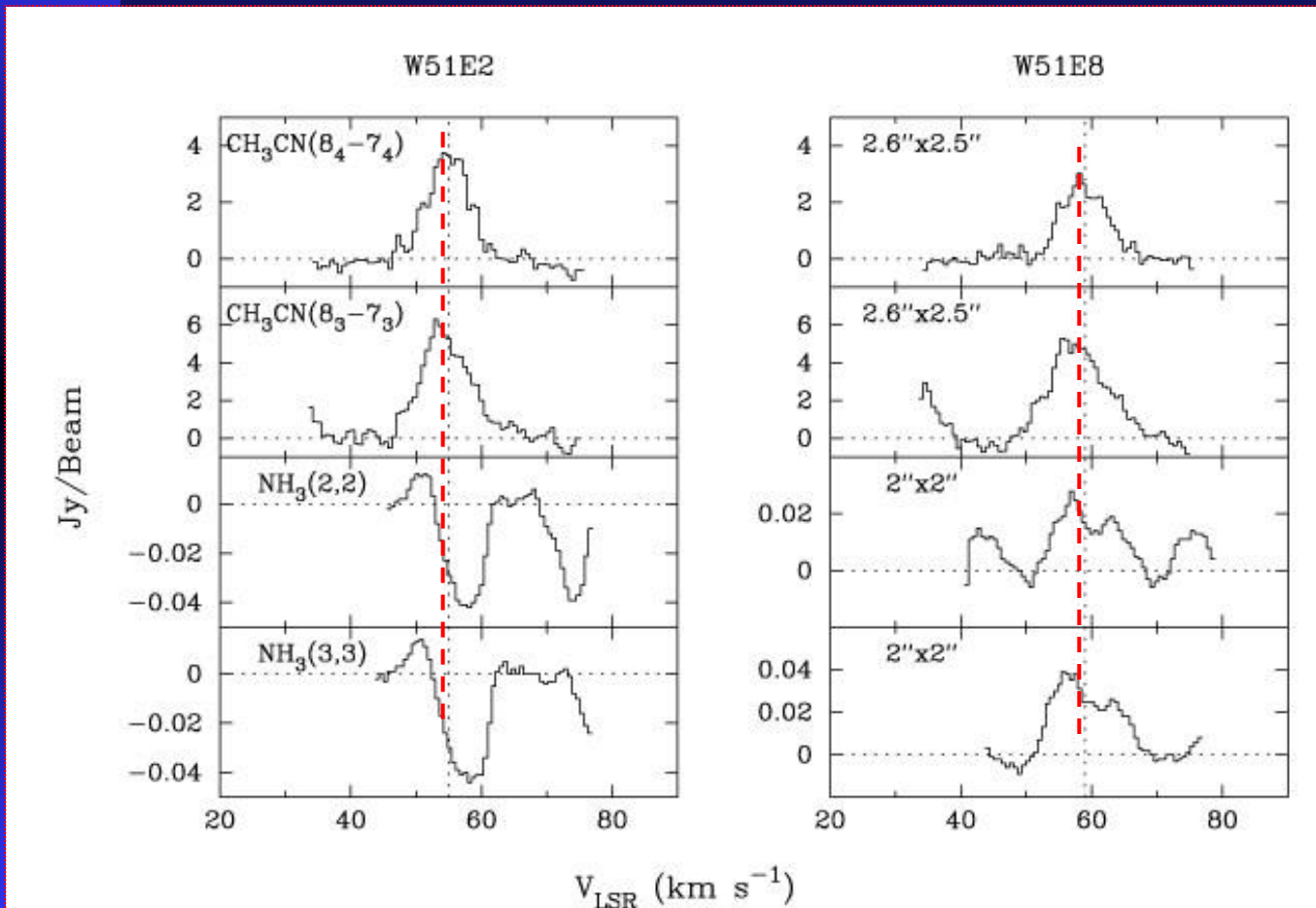
$L \sim 3 \times 10^6 L_{\text{sun}}$



Zhang & Ho 1997

Infall motions in W51 e2/e8

Line asymmetry arises from gas motions/varying opacity/excitations



Zhang & Ho 1997; Zhang, Ho & Ohashi 1998

Early interactions with Riccardo

Hot ammonia towards compact HII regions^{*}

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A MASSIVE YOUNG EMBEDDED OBJECT ASSOCIATED WITH THE UC H II
REGION G31.41 + 0.31

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Survey of Outflows and Search for ‘Disks’

- IRAS color bases selection: Precursors of HII regions
 - ◆ Massive ‘Protostellar’ Candidates I: Molinari et. al. 1996
 - ◆ Massive ‘Protostellar’ Candidates II: Sridharan et. al. 2002
- Finishing up my PhD in 1996, and thinking about new projects during Jansky fellowship at NRAO
- Proposing to VLA (for NH₃) and NRAO 12m (for CO outflows) in 1997

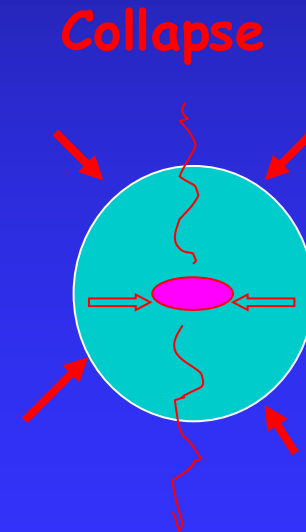
Radiation Pressure: The “10 M_⊙ Limit” & Why Disk Helps ?

- Force balance implies maximum luminosity to mass ratio

$$\frac{P_R}{F_G} = \frac{\kappa L}{4\pi GM}$$

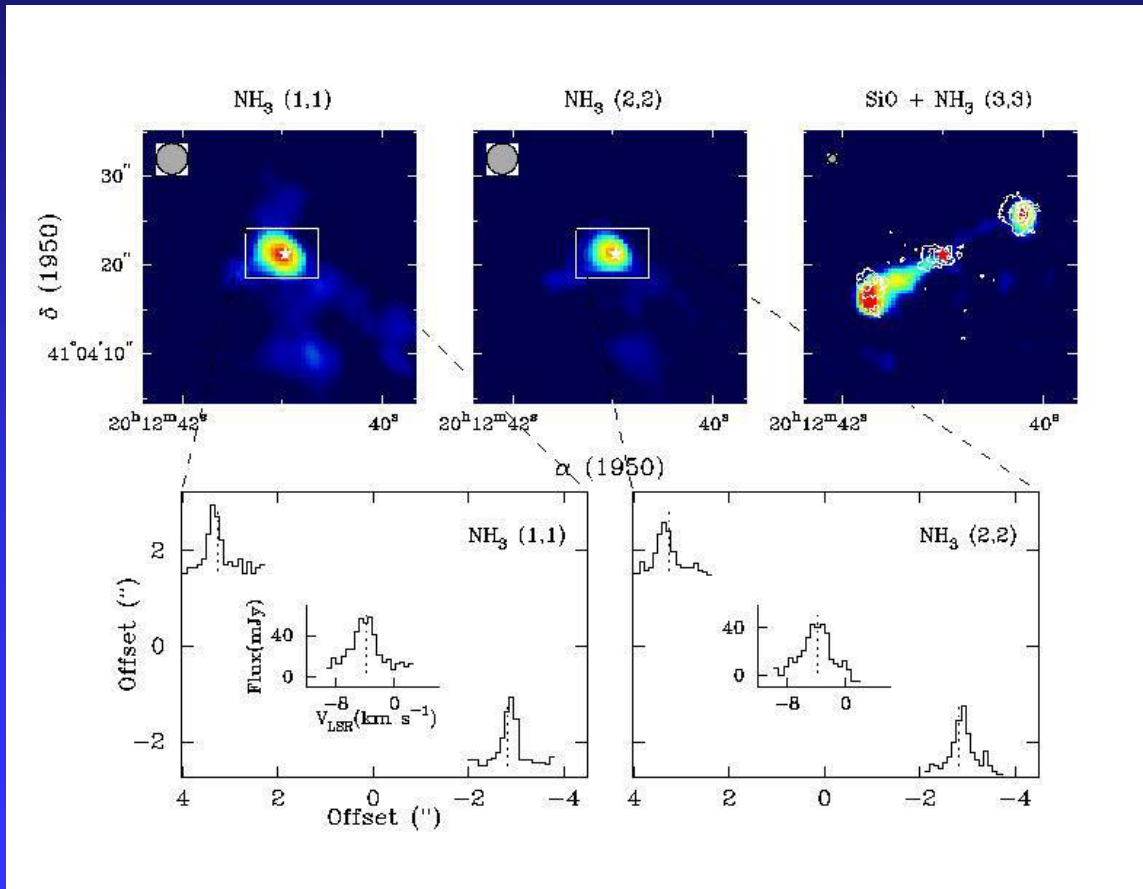
- Mean opacity at radiation T of star
 - ◆ $\kappa \sim 100 \text{ cm}^2 \text{ g}^{-1}$
 - ◆ $L/M \sim 2500$
 - ◆ Spectral type \sim Early B Stars

Radiation Leaks out in Polar Axis



Search for Disks: IRAS20126+4104

NH₃ (1,1), (2,2), (3,3) + SiO



Zhang et al. 1998;
1999

Cesaroni et al. 1997,
1999

Search for disks: IRAS 20126+4104

The disk-outflow system around the high-mass (proto)star IRAS 20126+4104

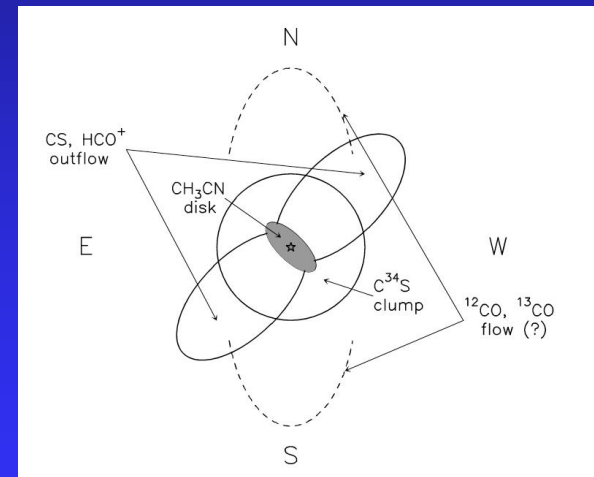
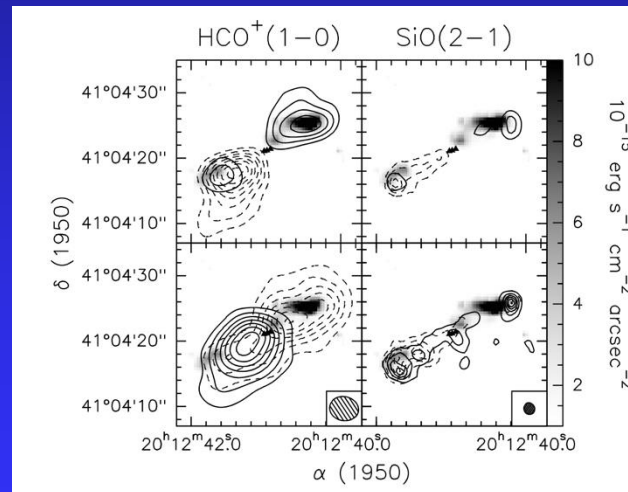
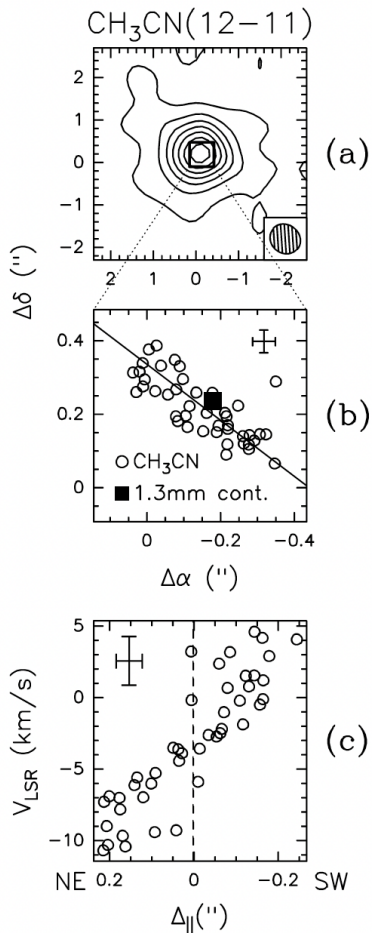
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¹ Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy

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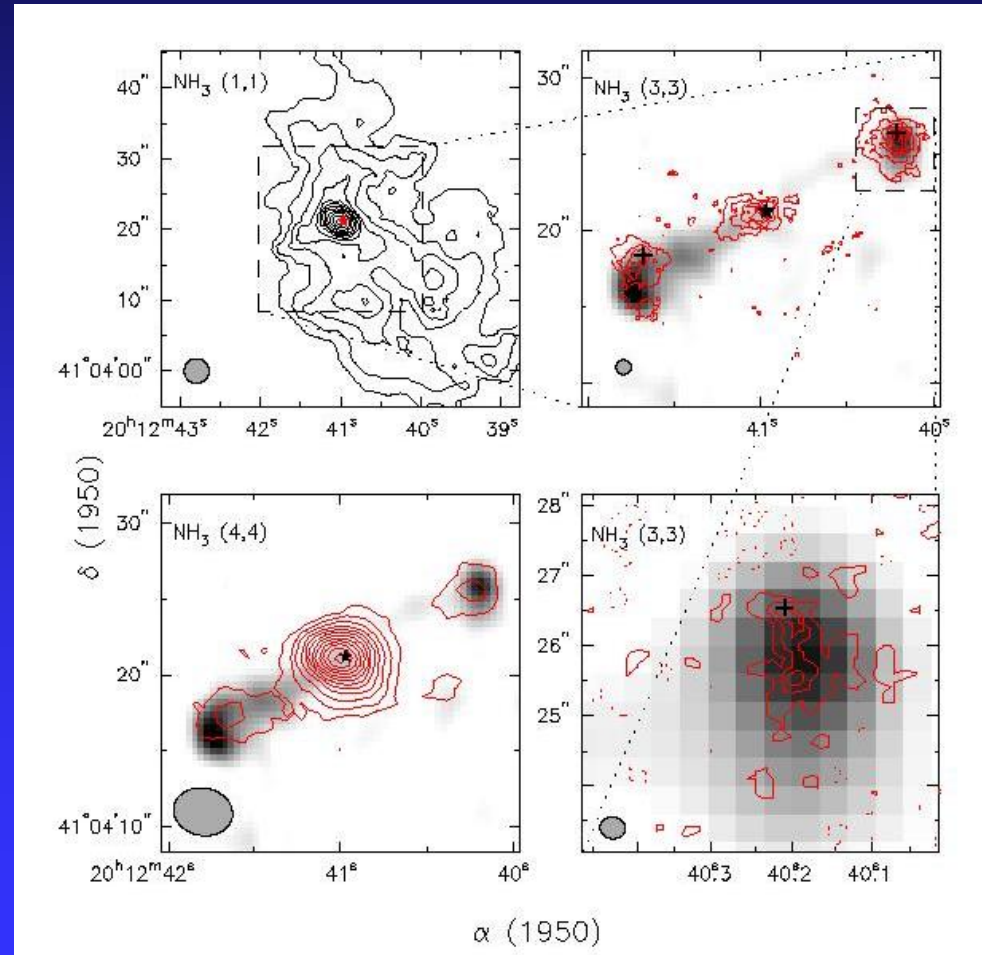
³ I. Physikalisches Institut der Universität zu Köln, Zùlpicherstrasse 77, D-50937 Köln, Germany

⁴ Cornell University, NAIC, Arecibo Observatory, P.O. Box 995, Arecibo, P.R. 00613



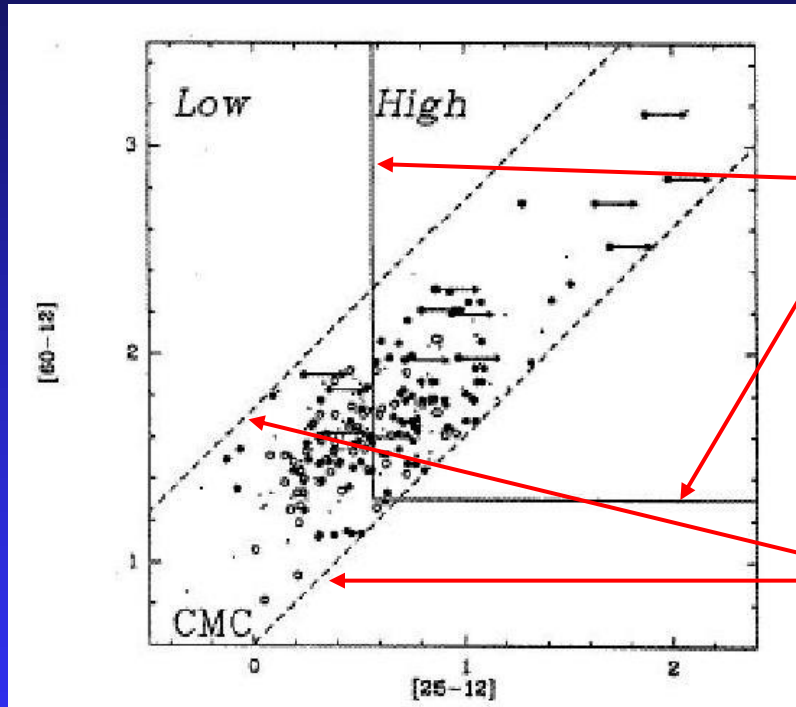
Search for Disks: IRAS20126+4104

Zhang et al. 1999



Survey of Outflows: Sample

IRAS Point Sources



Wood & Churchwell Criteria
(Wood & Churchwell 1989)

IRAS Colors of Compact Molecular
Cloud (Richards et al. 1987)

Palla et al. 1991

Molinari et al. 1996

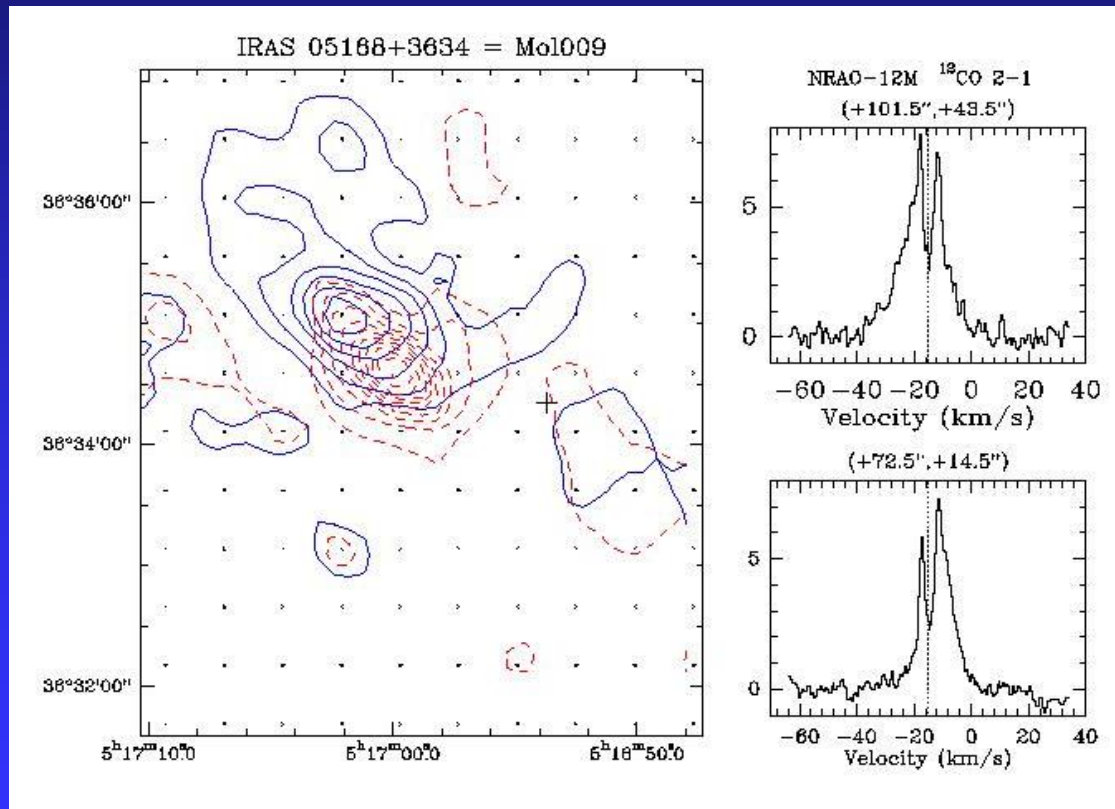
Survey of Outflows

- 69 high-mass protostellar candidates;
- NRAO 12m telescope;
- CO 2-1, 30'' resolution.

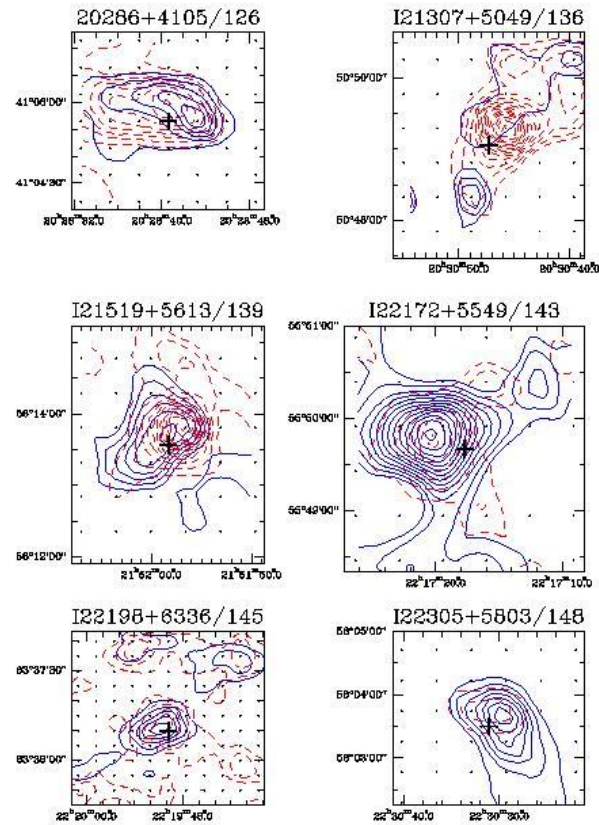


Survey of Outflows: Mol 109

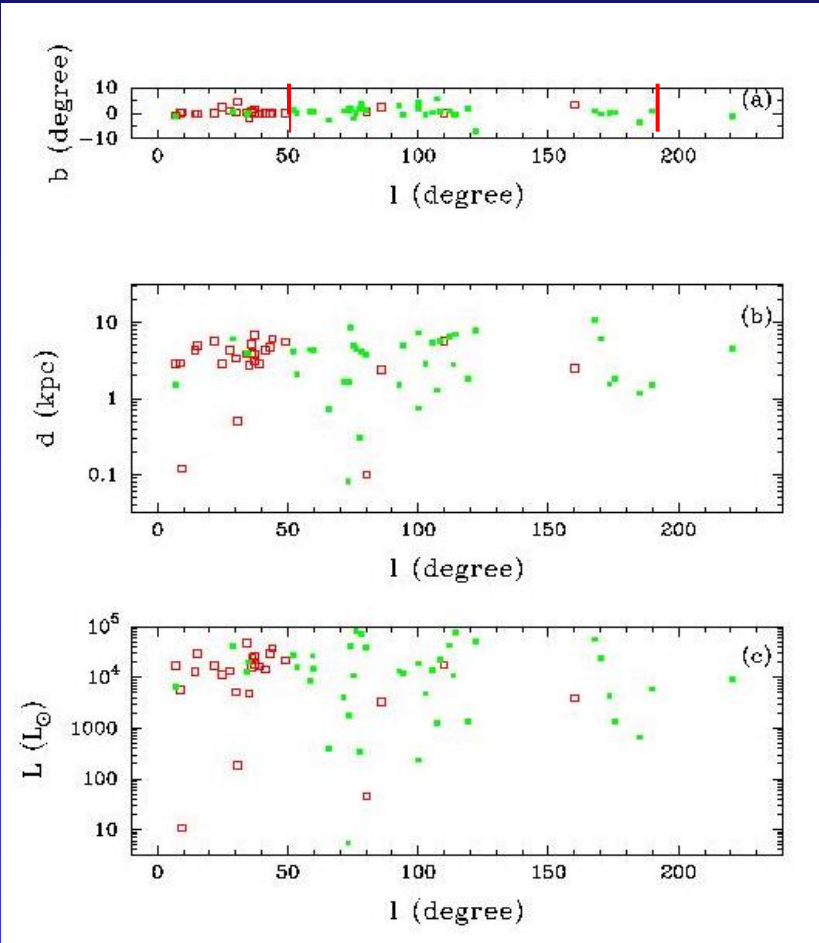
An example



Survey of Outflows: Maps



Survey of Outflows: Summary



Zhang et al. 2001, 2015

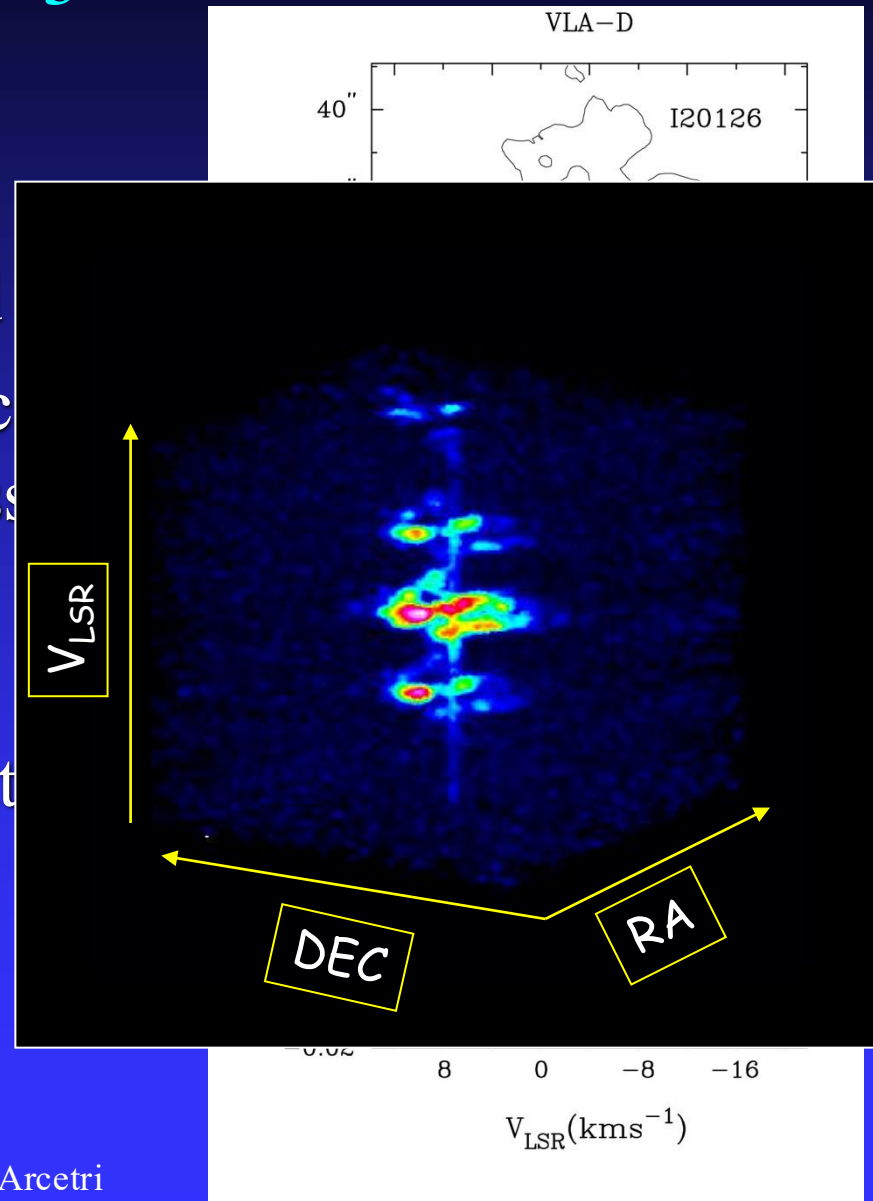
90% high-mass young stars have outflows

→ Disk accretion

See also Beuther+ 2024

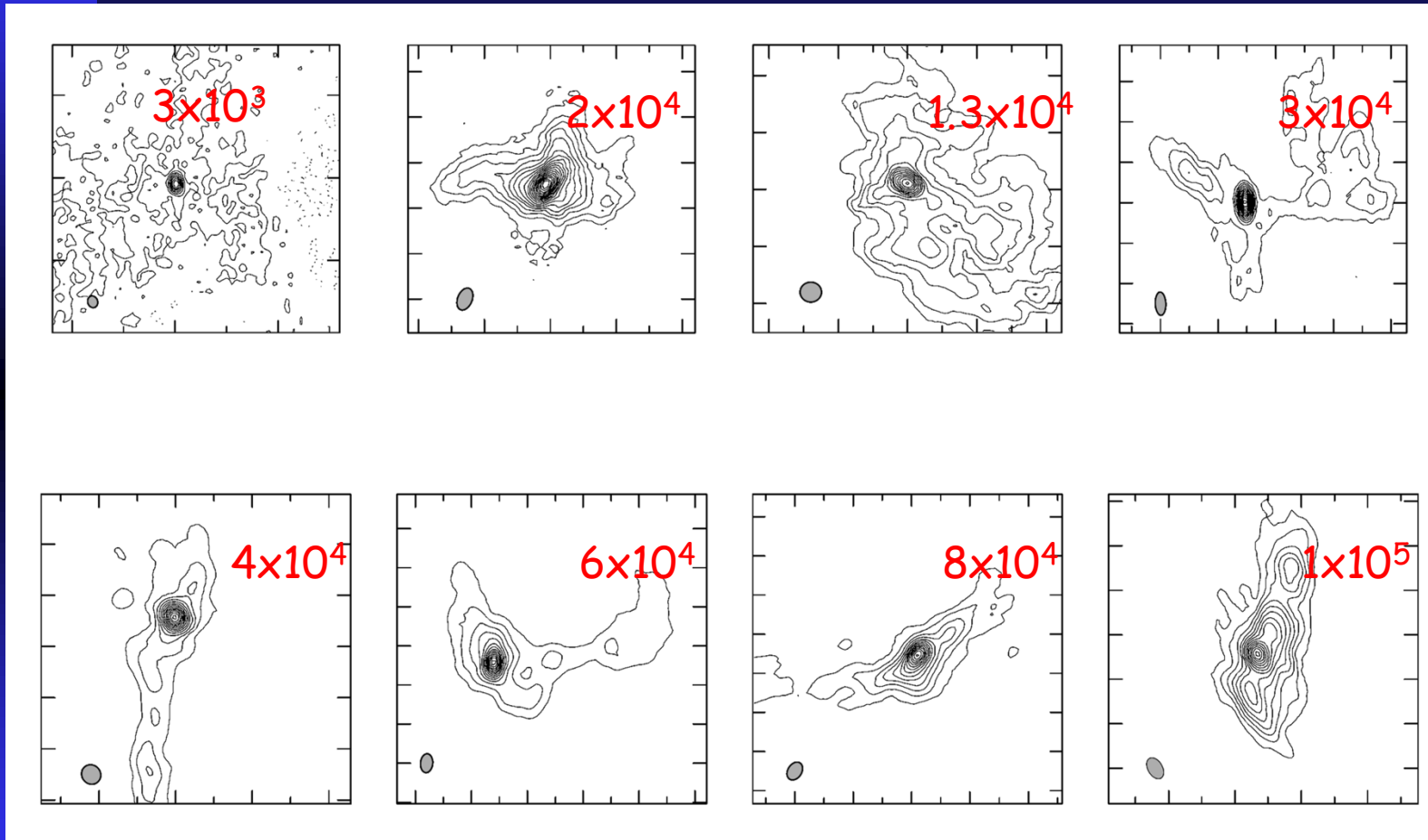
Signatures of NH_3 Disks

- Compact emission embedded in extended emission
- Broad line width associated with the compact emission indicating systematic motions;
- Associated with jet/outflow



SMA Search for Rotating Disks/Envelopes

VLA NH₃ 'disks' + G31/G24

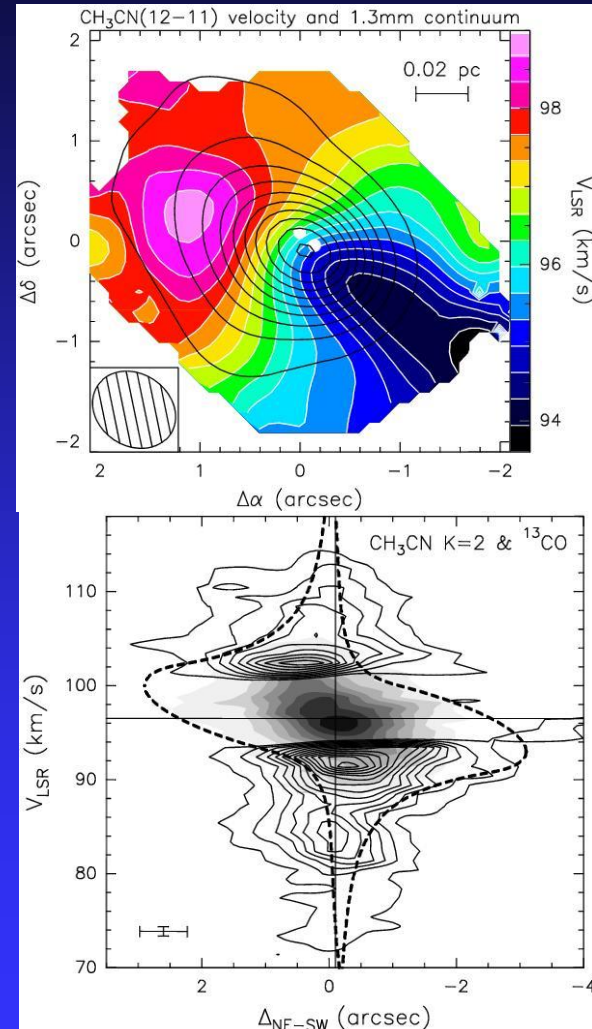
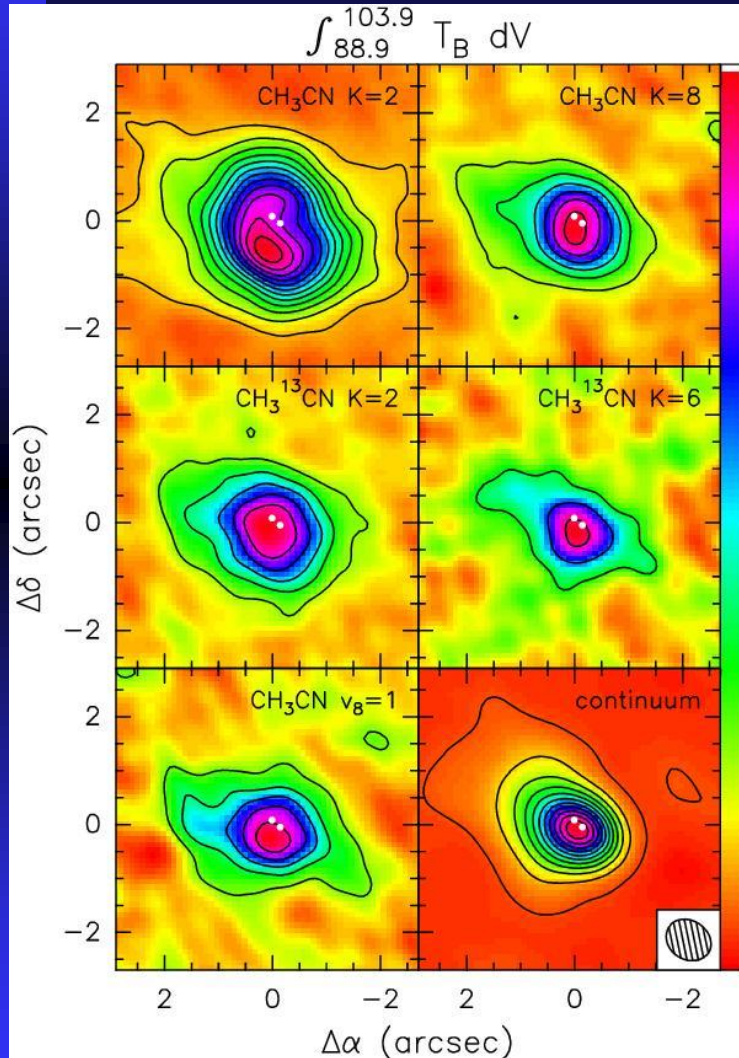


Lu, Zhang et al. 2014
May 2026

Arcetri

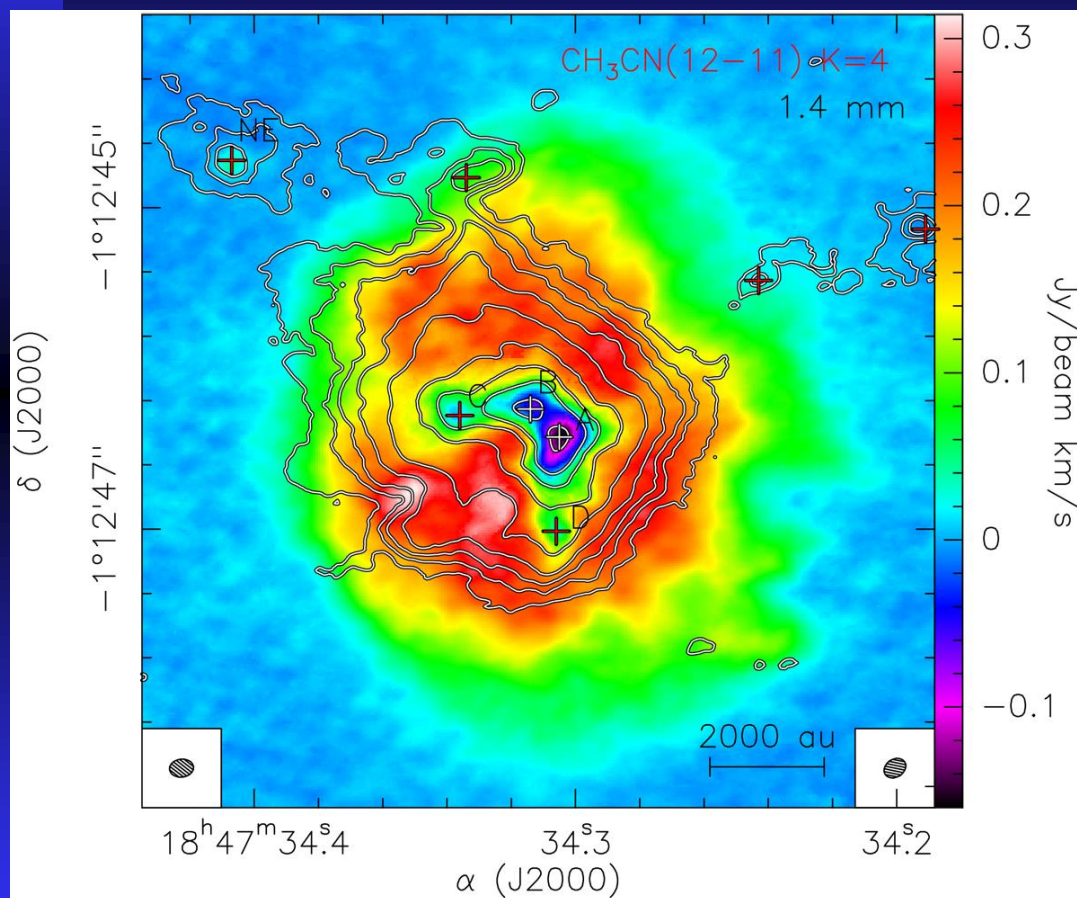
SMA Survey of Massive 'Disks' ~ 2008

G31.41 Cesaroni+ 2011



Toroid in G31.41 cluster with ALMA

Beltran+ 2022



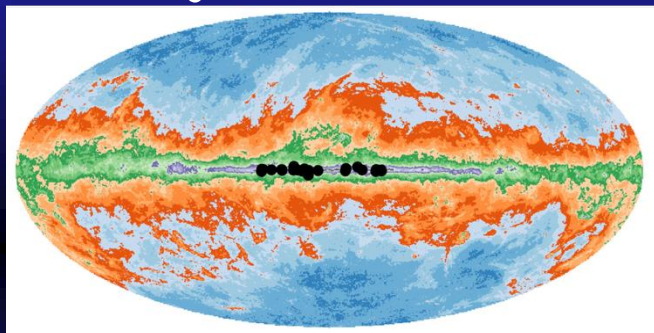
Four protostars,
multiple outflows

ALMA DIHCA Survey

Digging into the Interior of Hot Cores with ALMA
30 Targets selected from ATLASGAL

PI: Patricio Sanhueza

Project Overview:



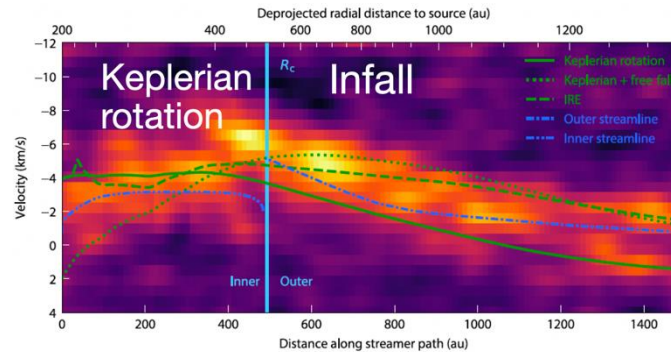
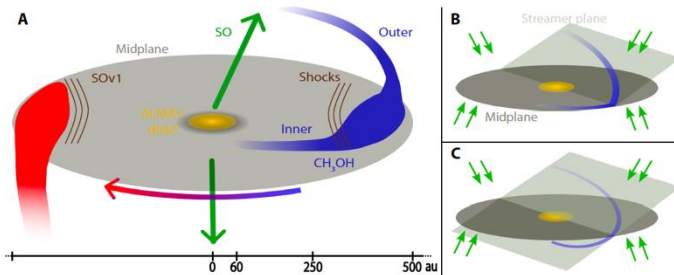
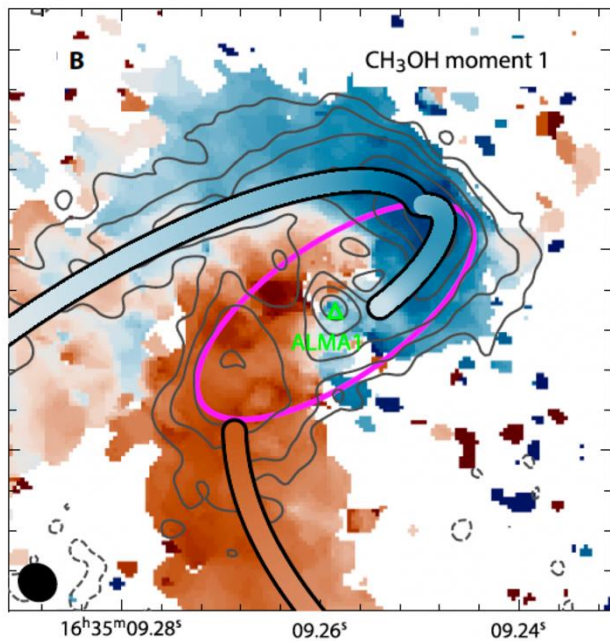
ALMA Observational Setup

Operating Frequency: Band-6 (226 GHz)
Configurations: Config 43-5, Config 43-8
Angular Resolution: 0.05 - 0.3 arcsec
Continuum sensitivity: 0.2-0.05mJy/beam
SPW windows: 217 -235 GHz

Distance: 1.3 -5.2 kpc

ALMA DIHCA Survey

Gas kinematics



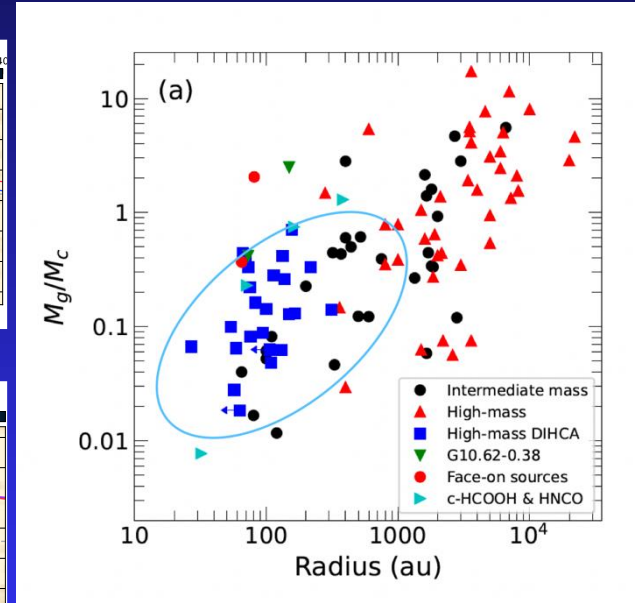
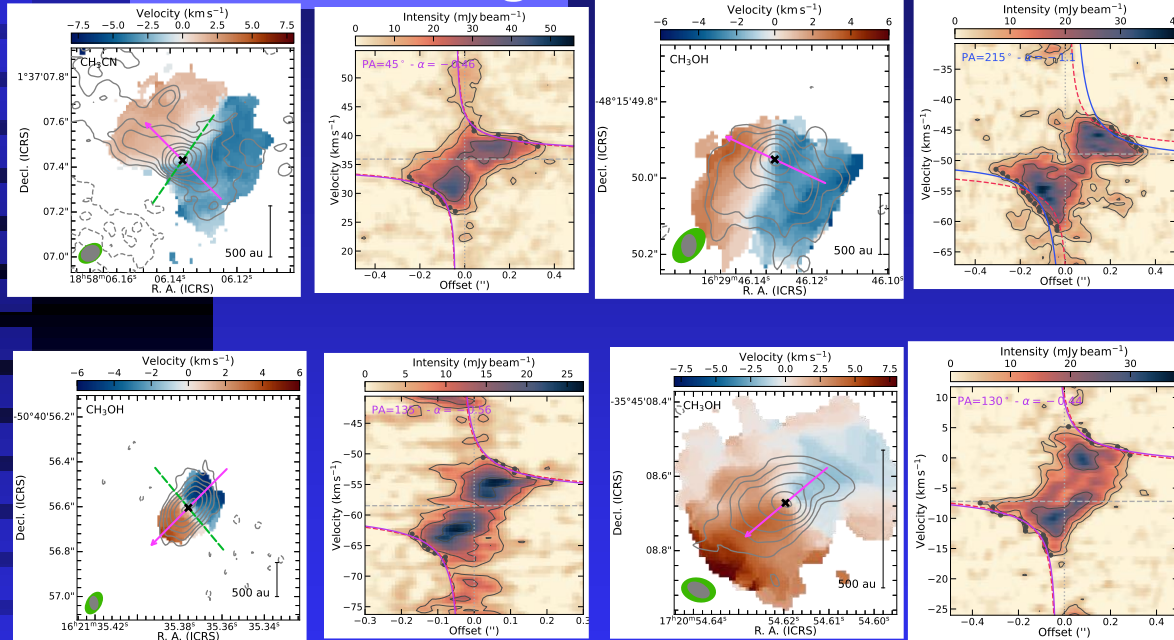
Streamers act as primary mass-delivery channels in high-mass star formation.

Streamers penetrate inside disk scales and feed the protostar directly

G336: Fernando et al. 2025

ALMA DIHCA Survey

Disk searching



Tracers: CH₃OH, CH₃CN, and tentative detections of HNCO and cis-HCOOH

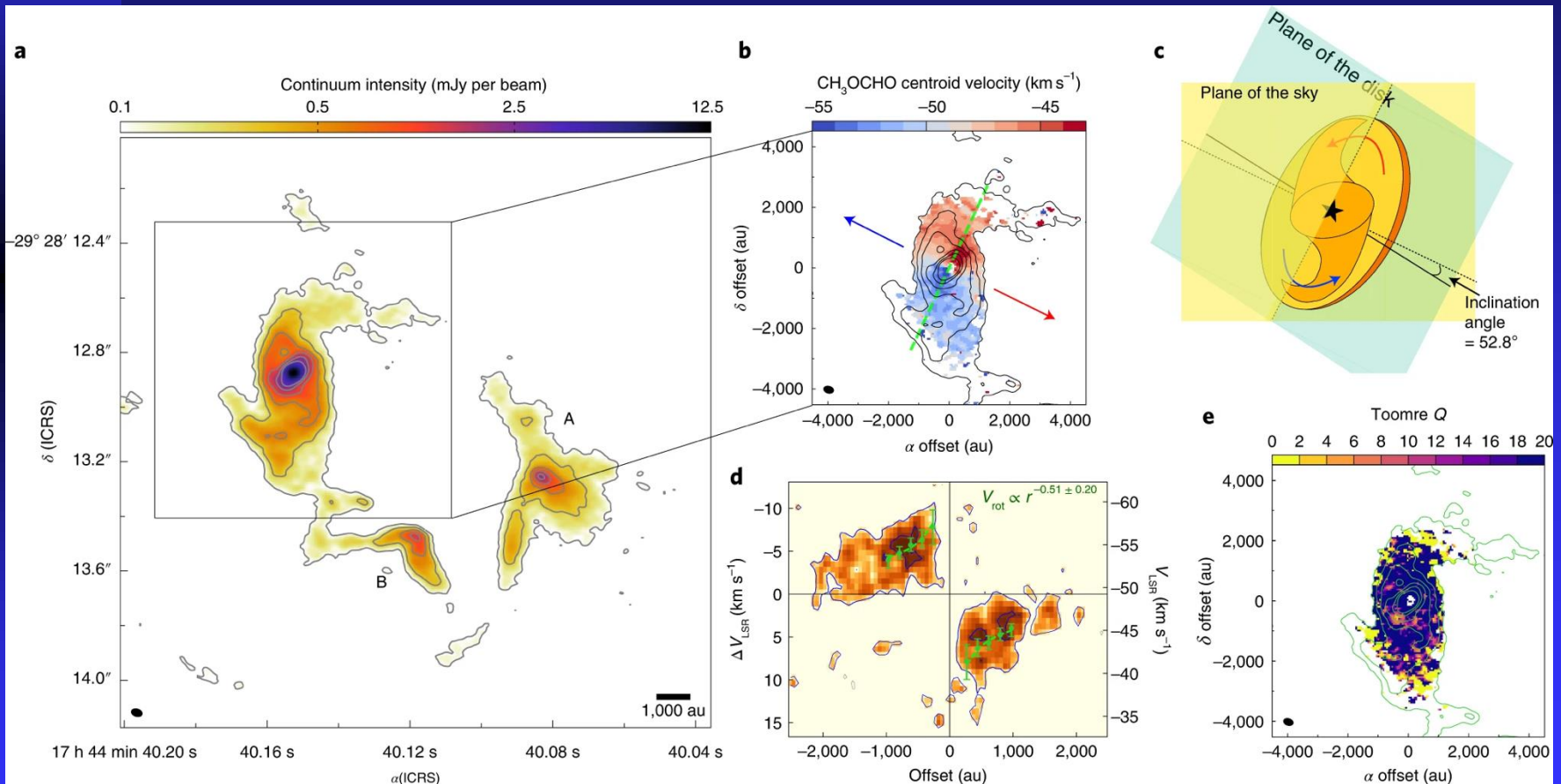
Fernando et al. 2026

32 disks have been with central stellar mass is $\sim 7-45 M_{\text{sun}}$, with a radius of ~ 200 au

A large disk in Sgr C

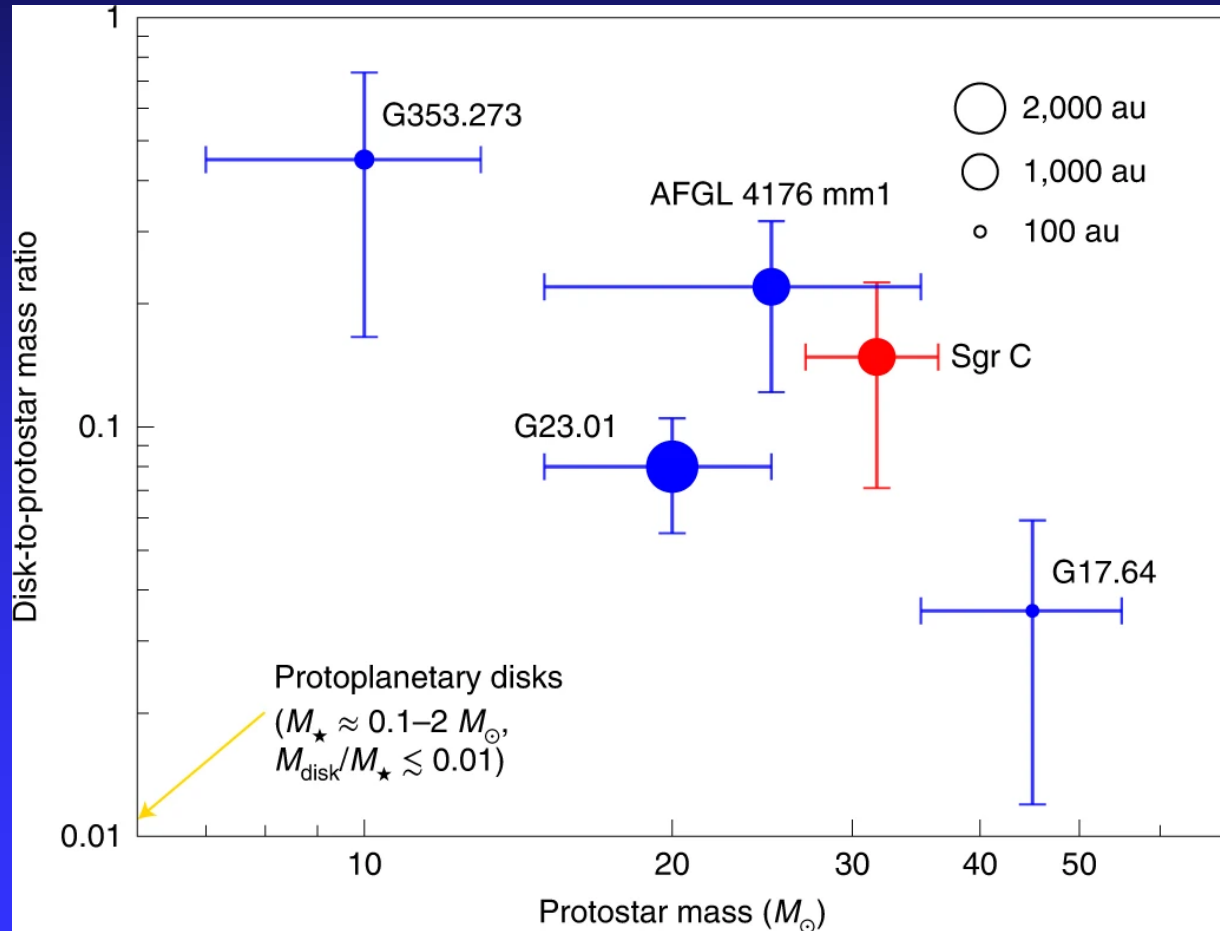
Mstar = 32 Msun
Md = 4.2 Msun
Rd = 1000 au

Lu, X et al. 2023; Weng et al. 2026



A large disk in Sgr C

Lu, X et al. 2023



Formation of most massive stars in galaxies

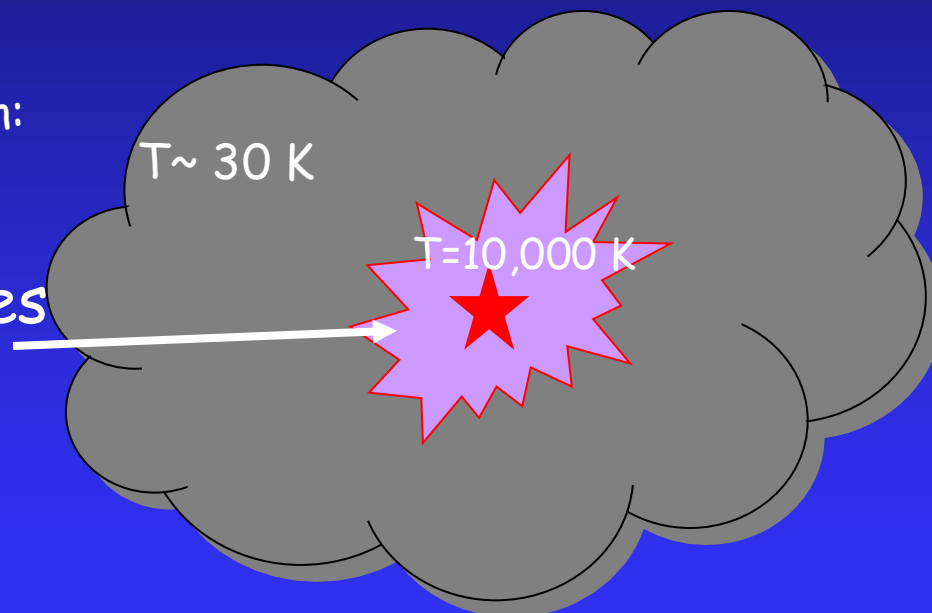


Bengt Stromgren

Problem with Ionization:

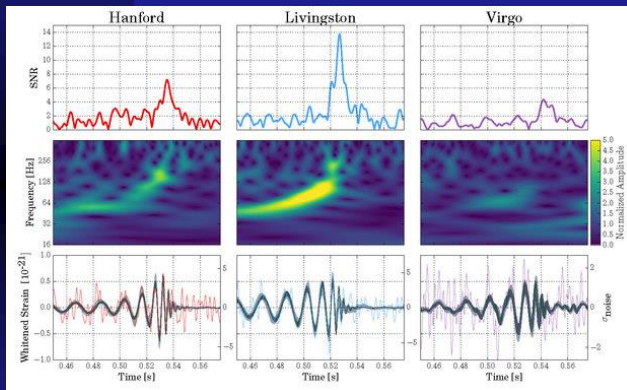
Classical Picture of HII region:

HII region undergoes
free expansion

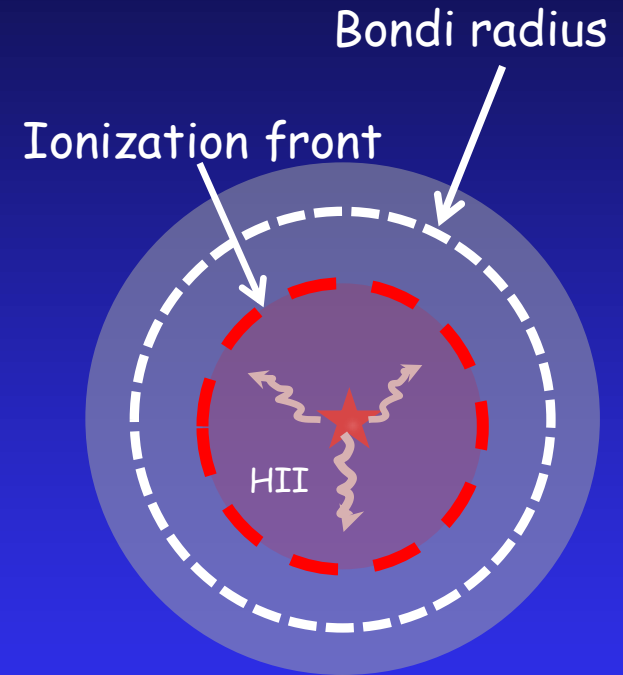
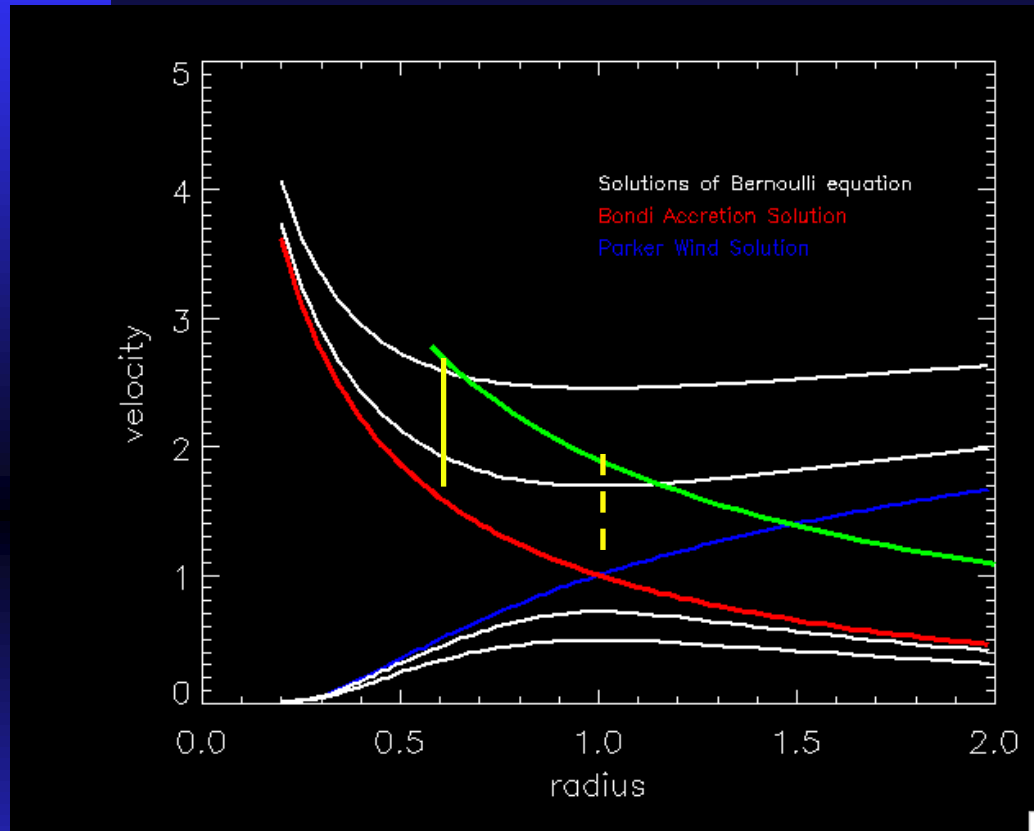


How to form stars $> 30 M_{\text{sun}}$

LIGO/Virgo black hole-black hole mergers



Ionized Bondi accretion flow (with gravity)



$$\frac{1}{2}v^2 + \int \frac{dP}{\rho} - \frac{GM}{r} = \text{const}$$

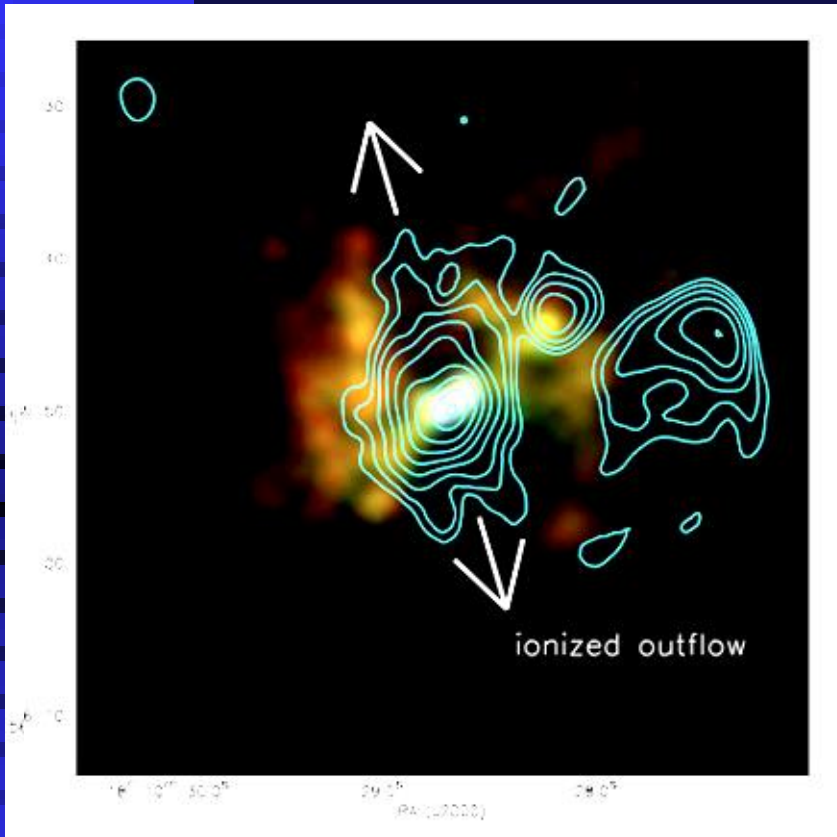
$$R_B = R_g = \frac{GM}{c_s^2}$$

Bondi radius:
sound speed = escape velocity

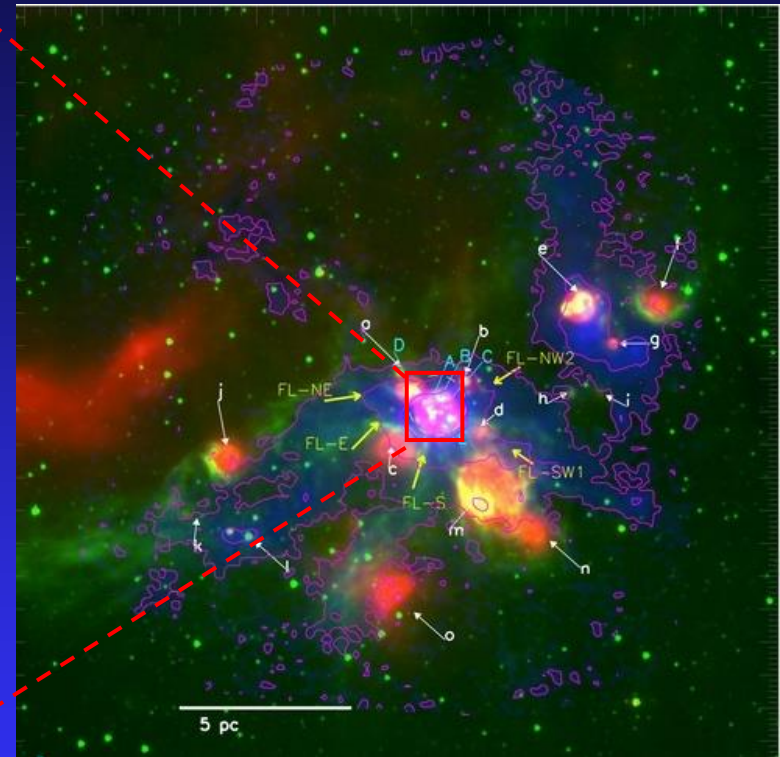
Bondi 1953
Keto 2002

OB Cluster Forming Molecular Cloud G10.6-0.4

Contour, 3.6 cm from VLA/EVLA



$L \sim 4 \times 10^6 L_{\text{sun}}$, 180 M_{sun} O-stars



RGB: CH_3OH J=5, tracing E_{up} 35K, 60K, 96K

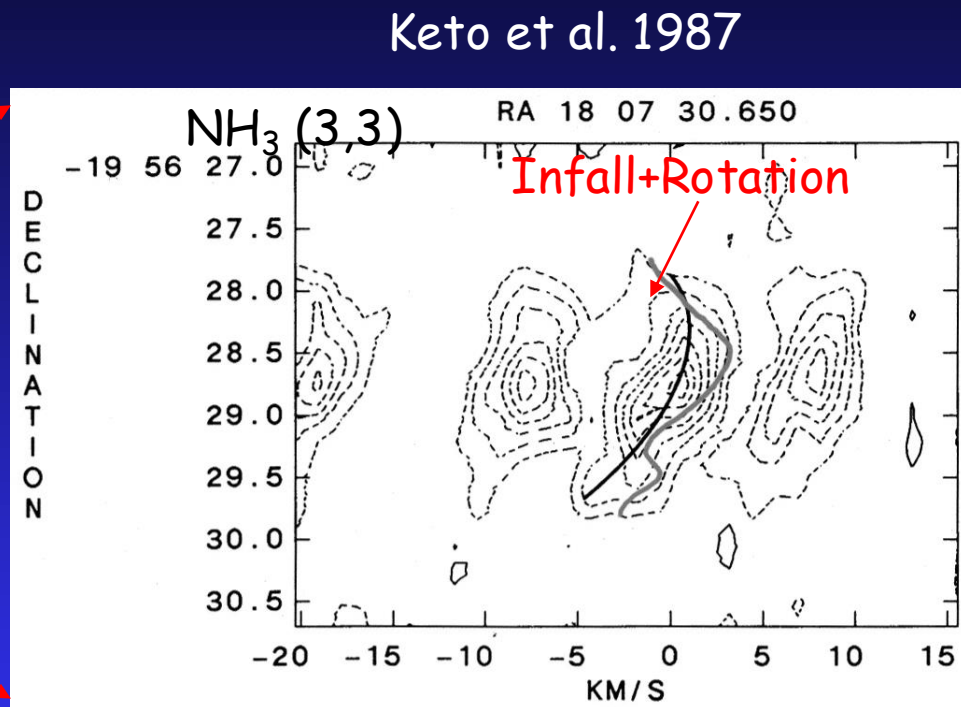
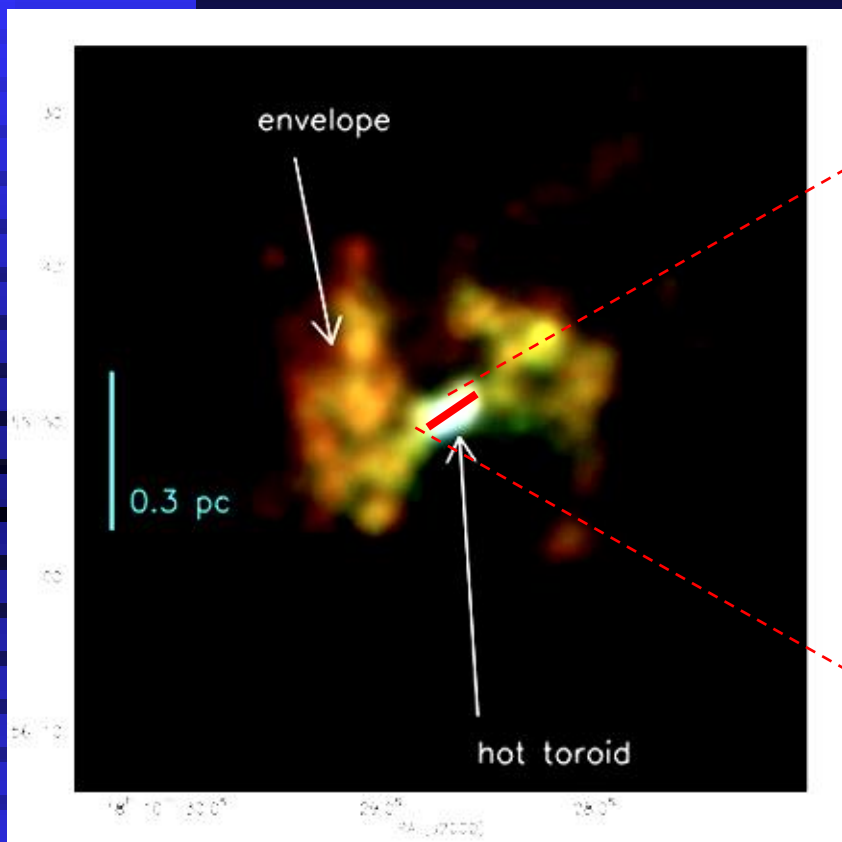
LIU, ZHANG & HO 2011, APJ, 729, 100

Blue: 1.2 mm from IRAM 30m

Red: 24 μm , green: 8 μm

Liu+ 2012

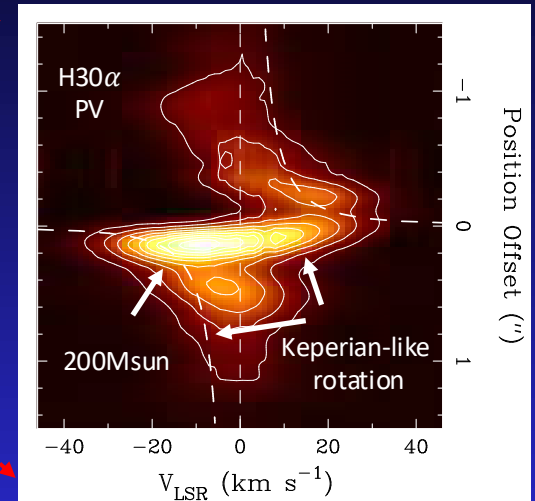
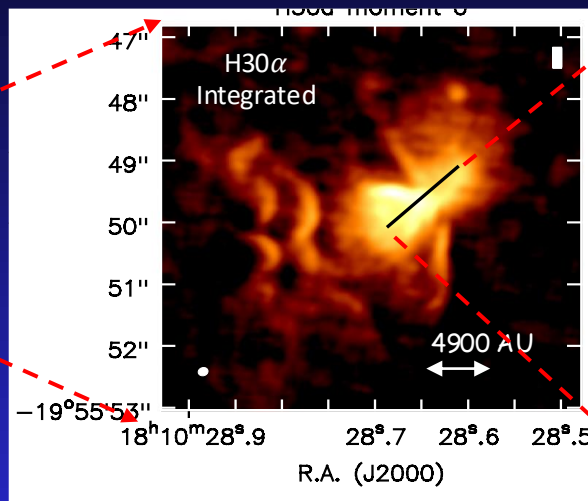
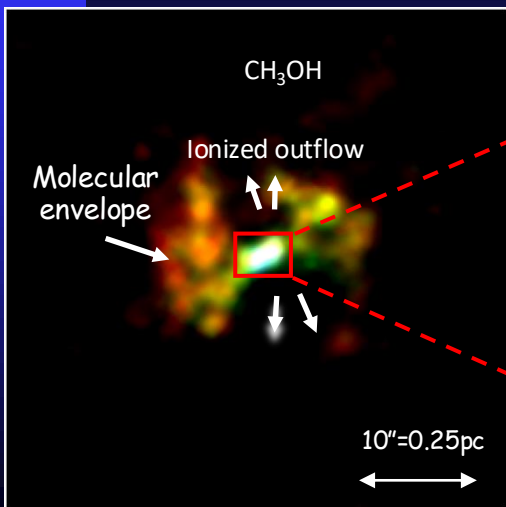
Infall in molecular gas toward the OB Cluster



RGB: CH_3OH $J=5$, tracing E_{up} 35K, 60K, 96K

LIU, ZHANG & HO 2011, APJ, 729, 100
<http://www.cfa.harvard.edu/~hlu/>

ALMA observations of H30 α

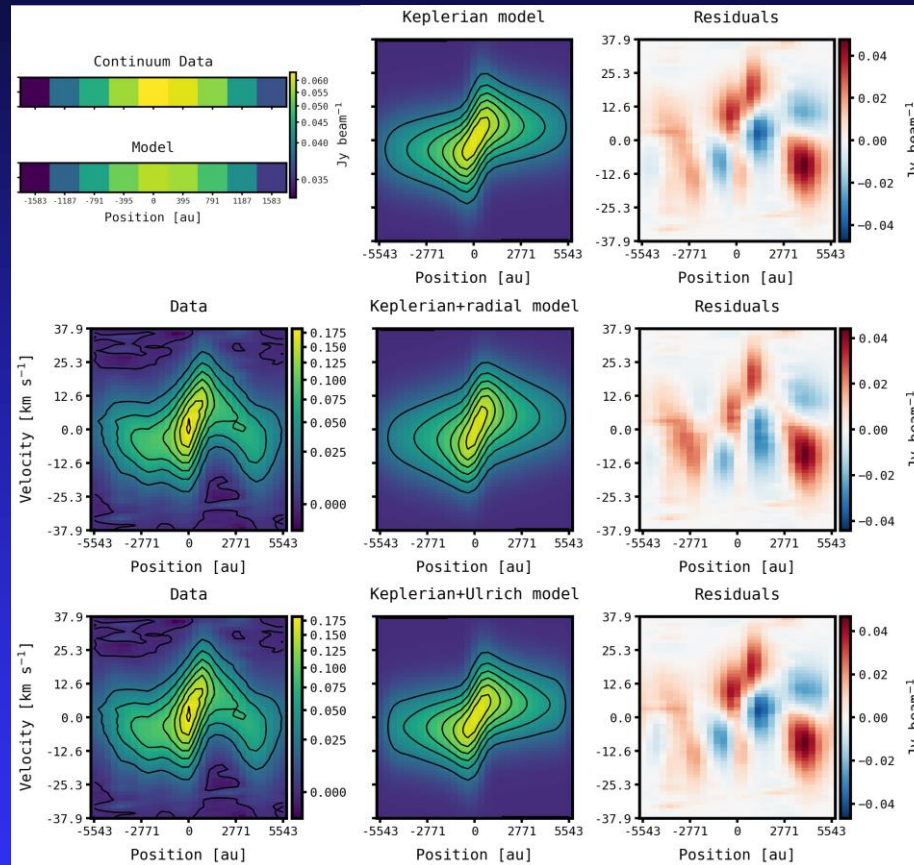


Position-velocity diagram indicates an accelerated rotation,
suggestive of gravitationally driven accretion

Galvan-Madrid, Zhang et al. 2023



MCMC modeling



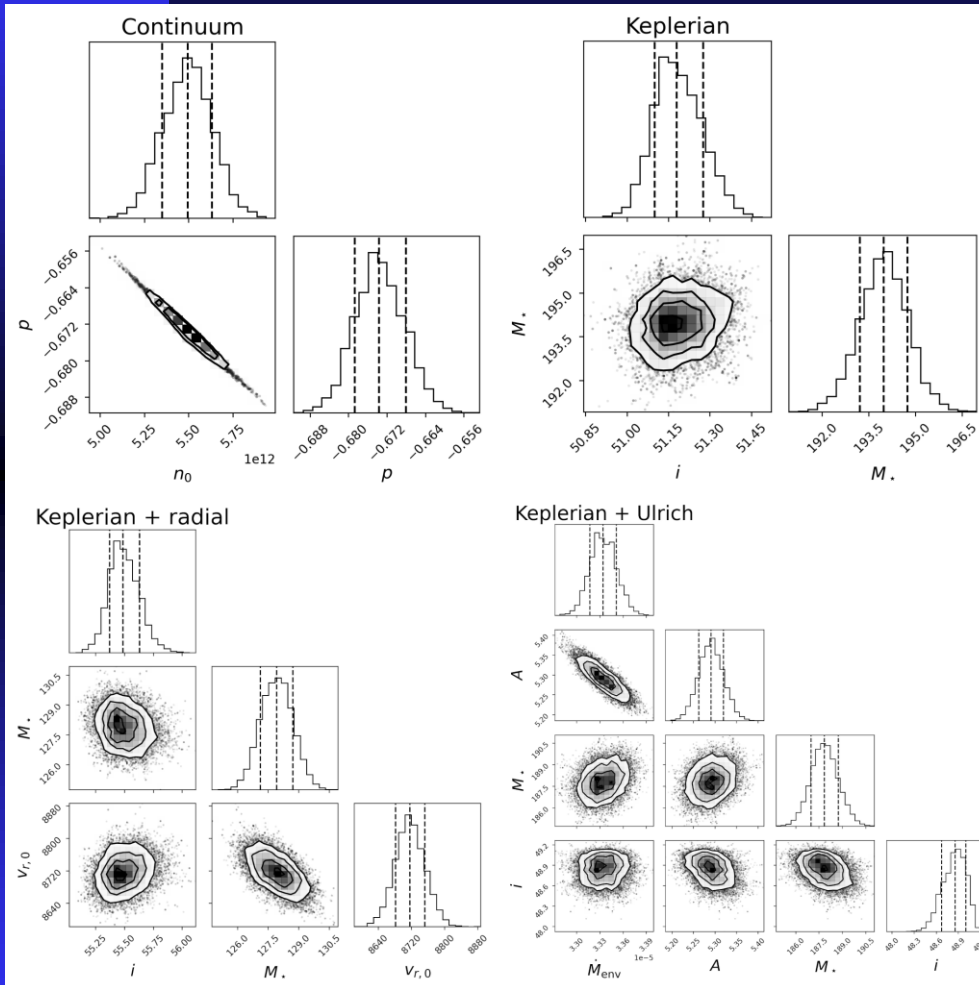
Galvan-Madrid, Zhang et al. 2022

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Arcetri

30

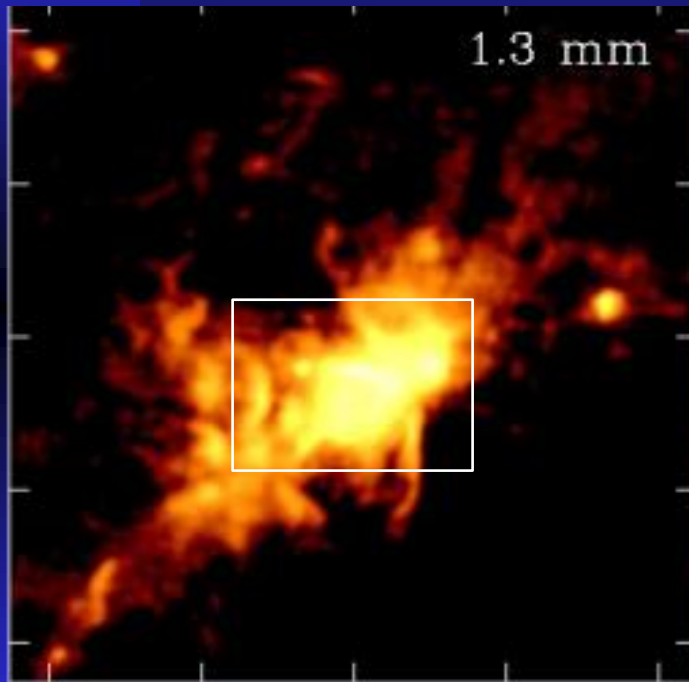
MCMC modeling



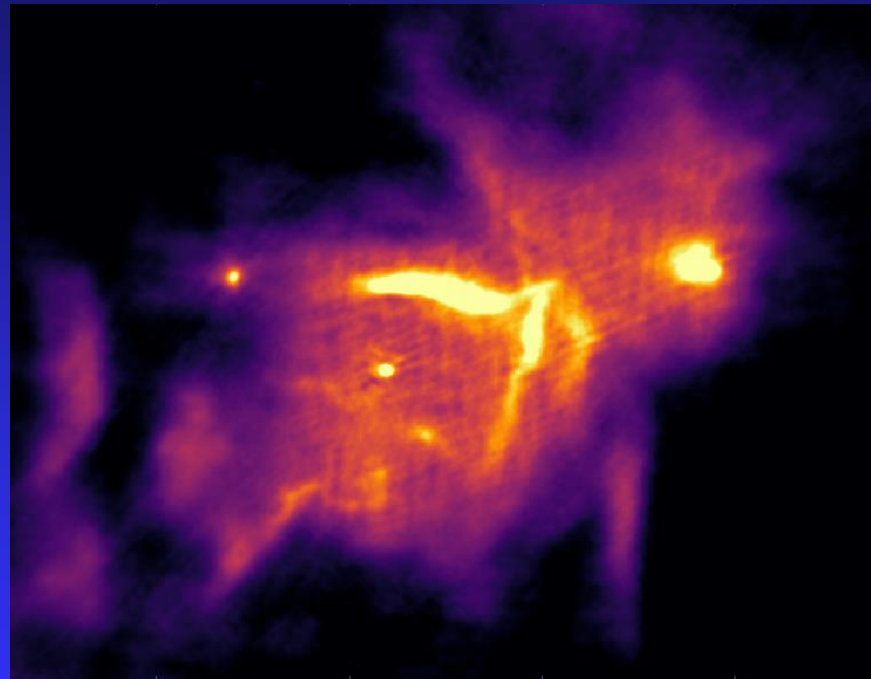
- Fit three different model:
 - ◆ Keplerian
 - ◆ Keplerian + infall
 - ◆ Keplerian + Ulrich flow
- $M_* = 130 - 195 M_{sun}$

Galvan-Madrid, Zhang et al. 2023

ALMA 1.3mm continuum



Galvan-Madrid, Zhang et al. 2023



Zhang+ in prep

Thank you for many years of collaborations and
friendship.

Happy retirement! I look forward to reading your
future papers on IRAS 20126+4104!

Astronomy & Astrophysics manuscript no. 59724
April 15, 2026

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Evidence for a bloated massive protostar in IRAS 20126+4104

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