Hungry Baby Star Eating A Dusty Hamburger and Spitting Spinning Bullets

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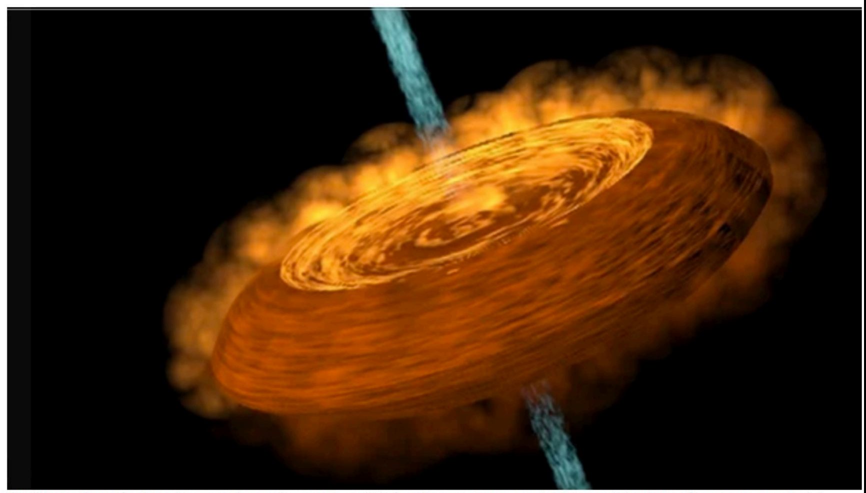
By HANNEKE WEITERING / SPACE.COM / *April 20, 2017, 4:14 PM*

"Space hamburger" spotted in astronomical first



An illustration of a hamburger-shaped accretion disk feeding a young protostar, and the jets of gaseous material ejected from the young star's north and south poles. / YIN-CHIH TSAI/ASIAA

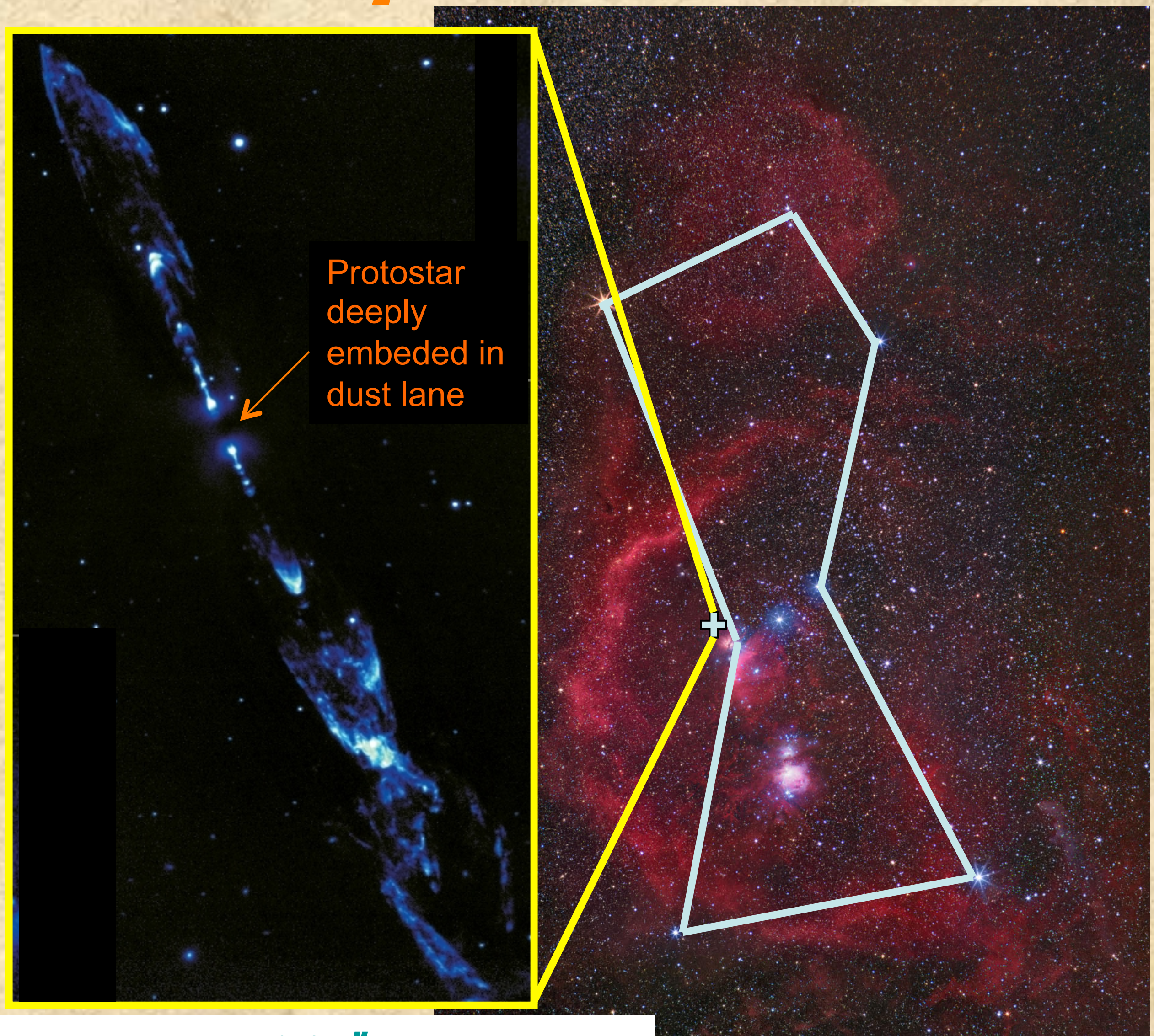
Chin-Fei Lee (ASIAA)

Zhi-Yun Li, Paul Ho, Naomi Hirano, Qizhou Zhang, Sienny Shang

Orion Constellation

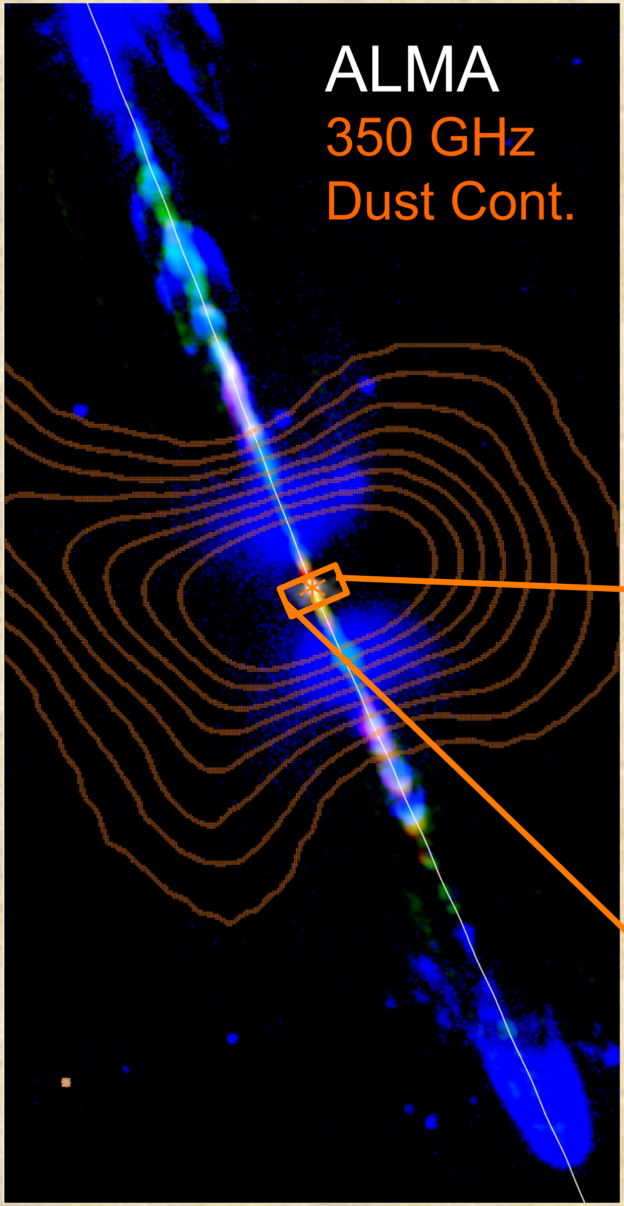
HH 212 Jet in H_2

Molecular jet powered by a Class 0 protostar with ~ 0.2 $M_\odot$ at ~ 40,000 yr old

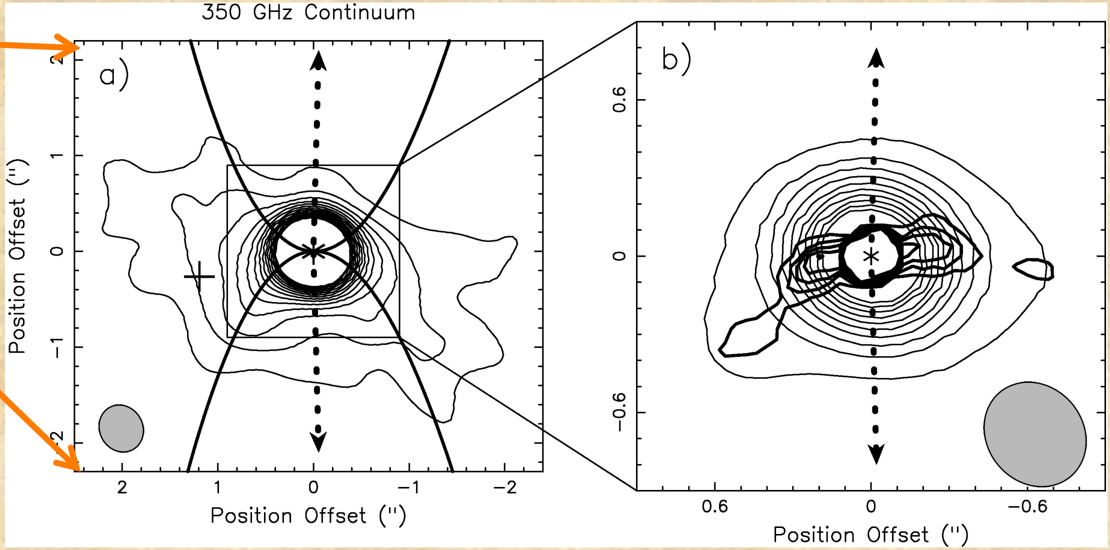


VLT image at 0.34" resolution
McCaughrean et al. 2002

Protostellar Jet, Envelope, Disk in HH 212 system

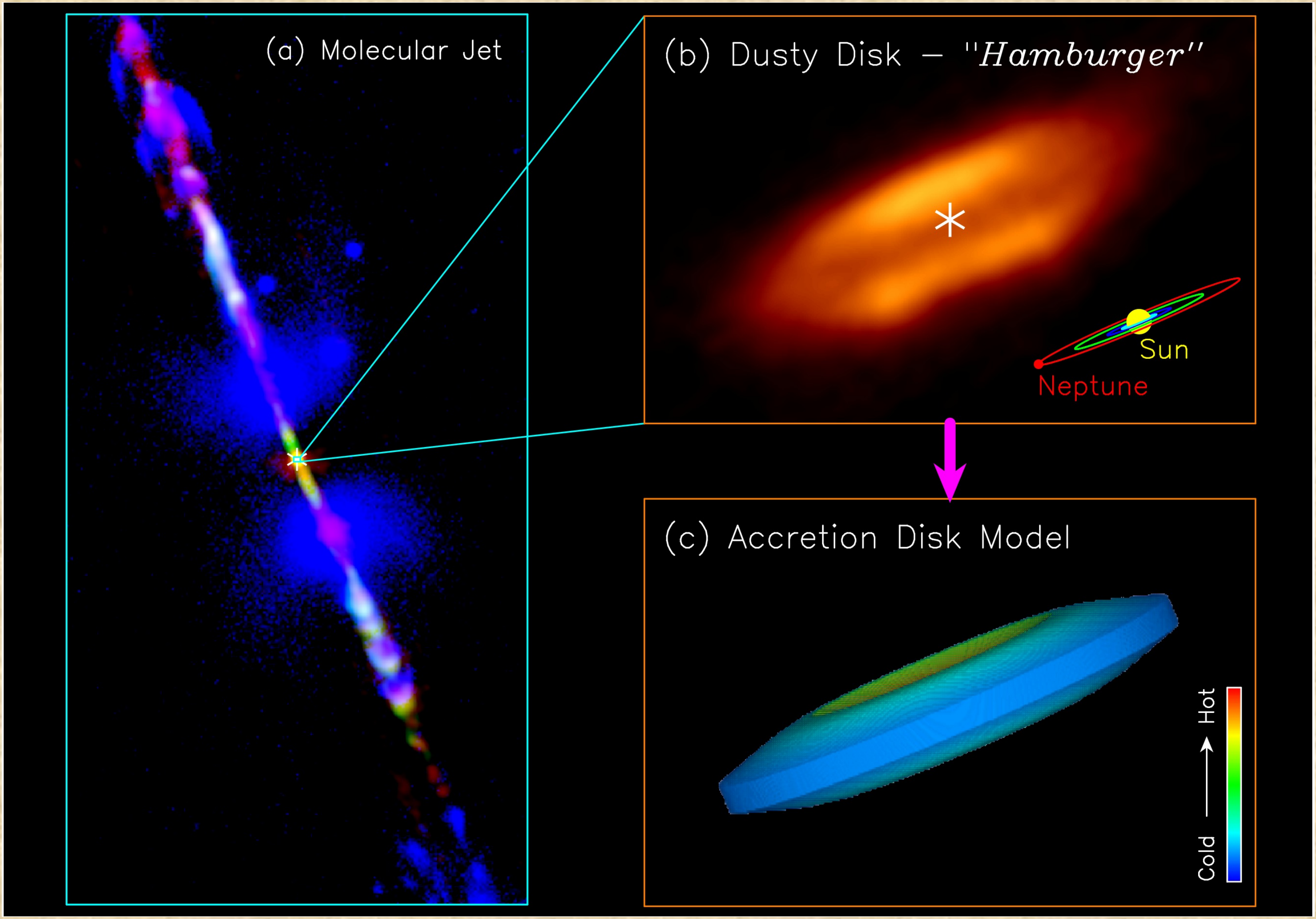


ALMA resolving the Flattened Envelope+Disk at ~ 0.4" res. in 350 GHz continuum. The disk radius < 0.3" (120 AU) (Lee et al. 2014)



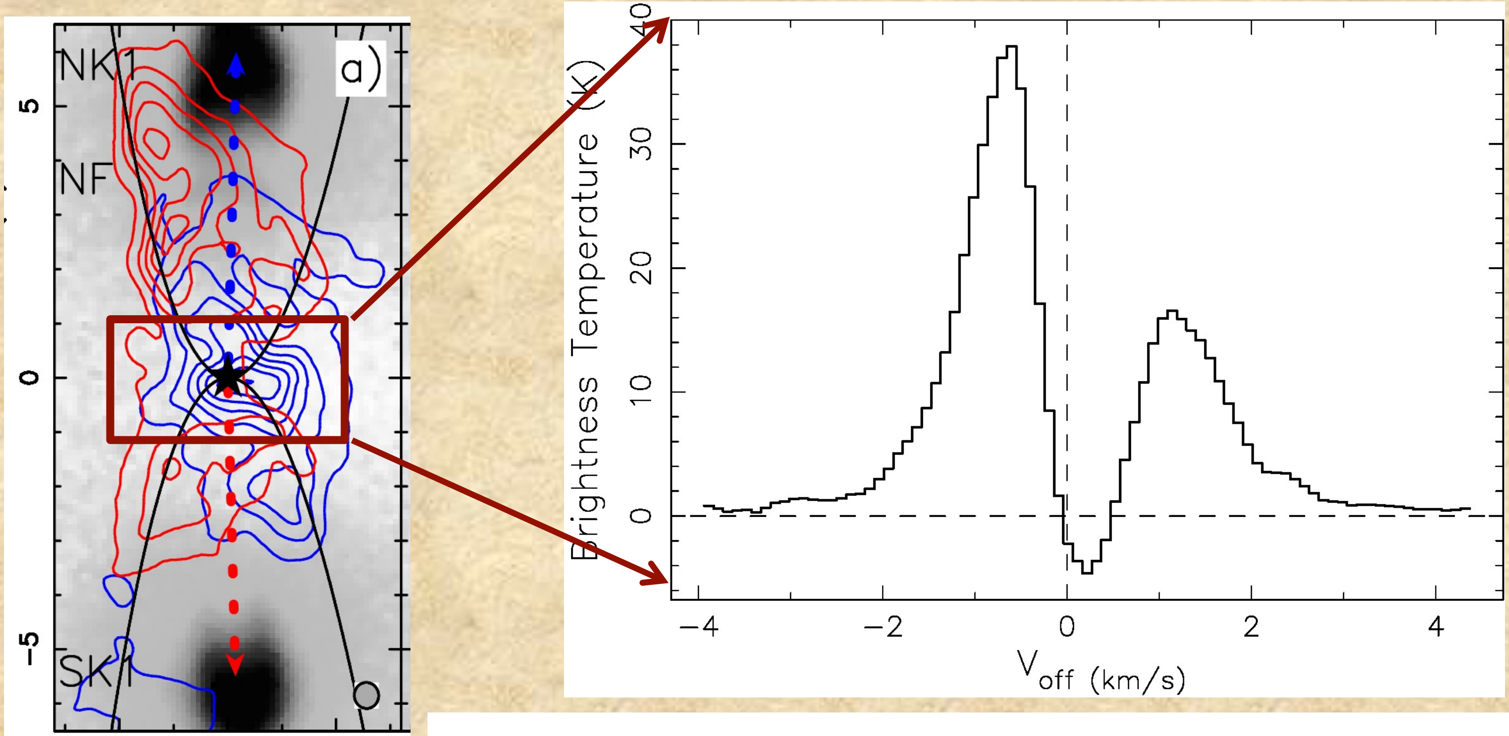
Really a disk? Structure? rotating? The flattened envelope infalling?

Zooming in at 0.02” (8AU) in 345 GHz with ALMA



Lee et al. 2017, Science Advances

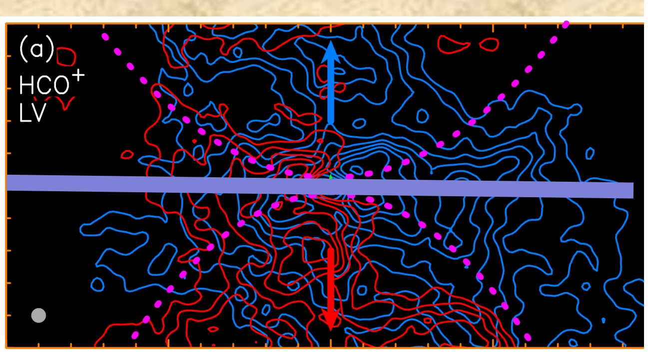
ALMA HCO^+ spectrum toward the central region of the Envelope and disk at ~ 0.45” res

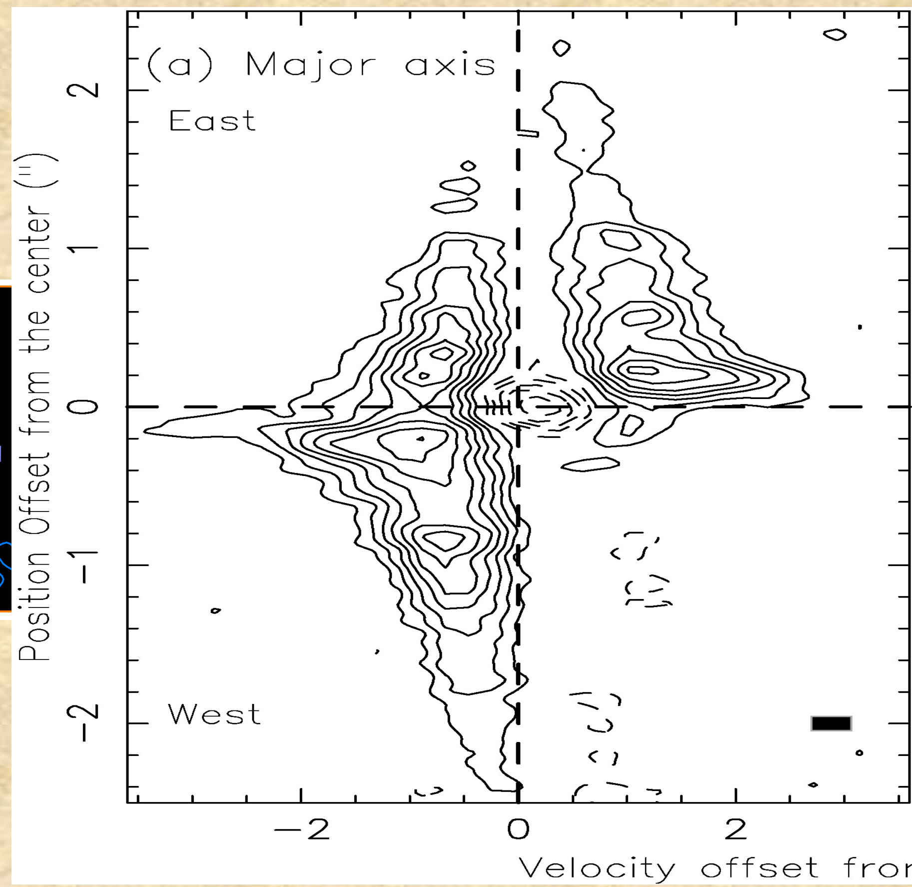


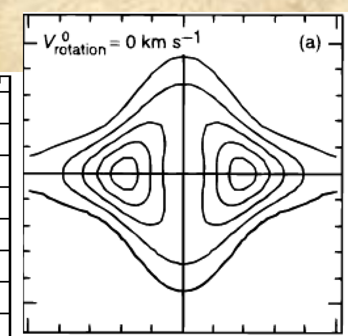
Inverse P Cygni line *profile (Lee et al. 2014)*

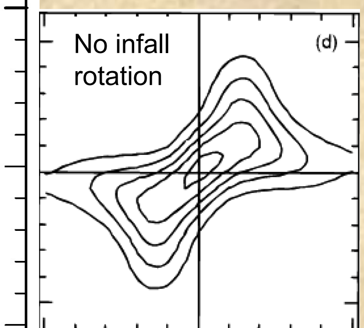
- ➔Infalling envelope (Rotating also?)
- ➔Self absorption
- ➔Further absorption against the disk

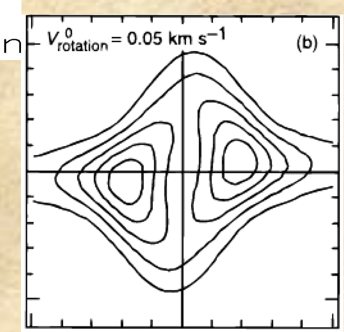
PV Diagram along the envelope axis at 0.04” res





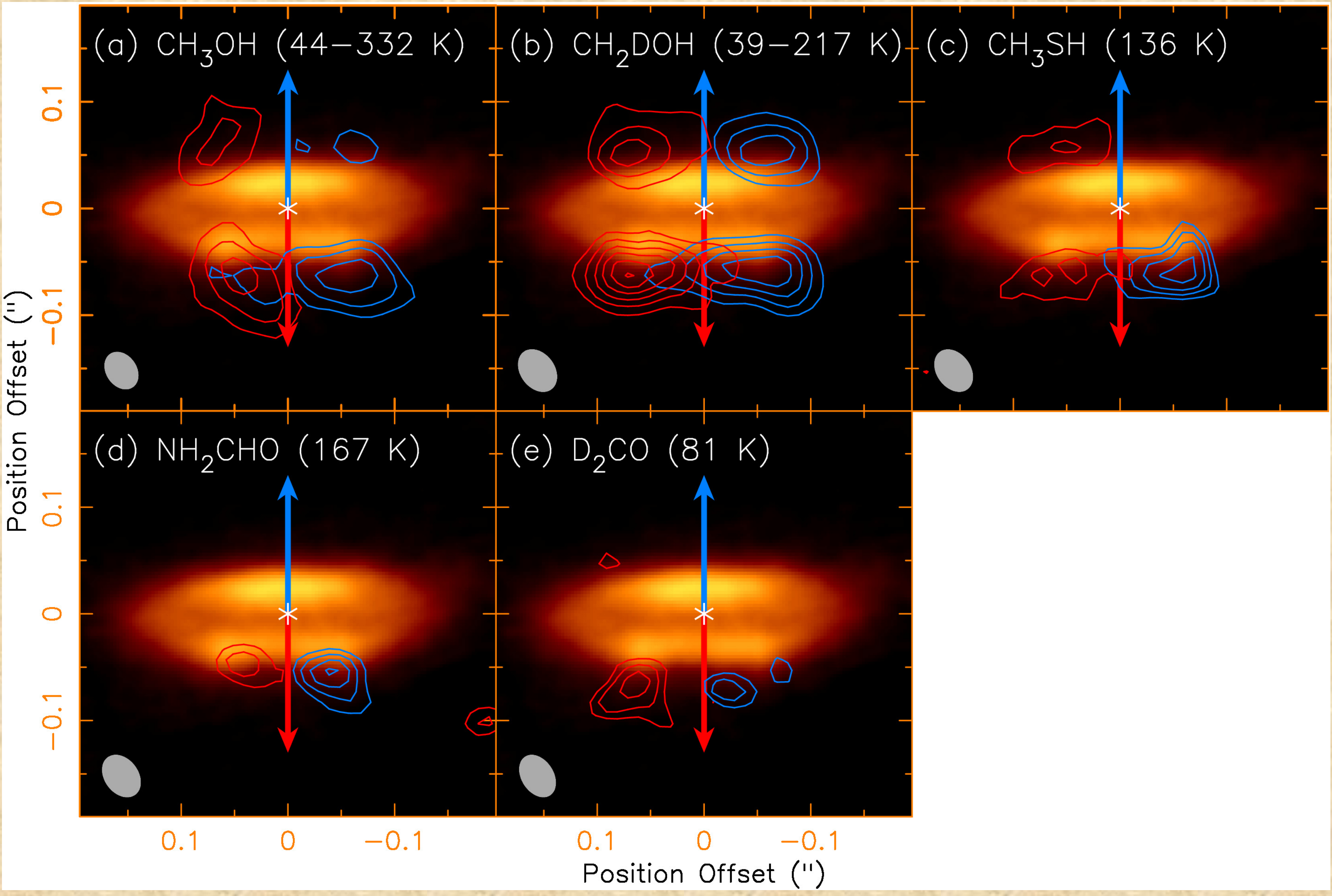


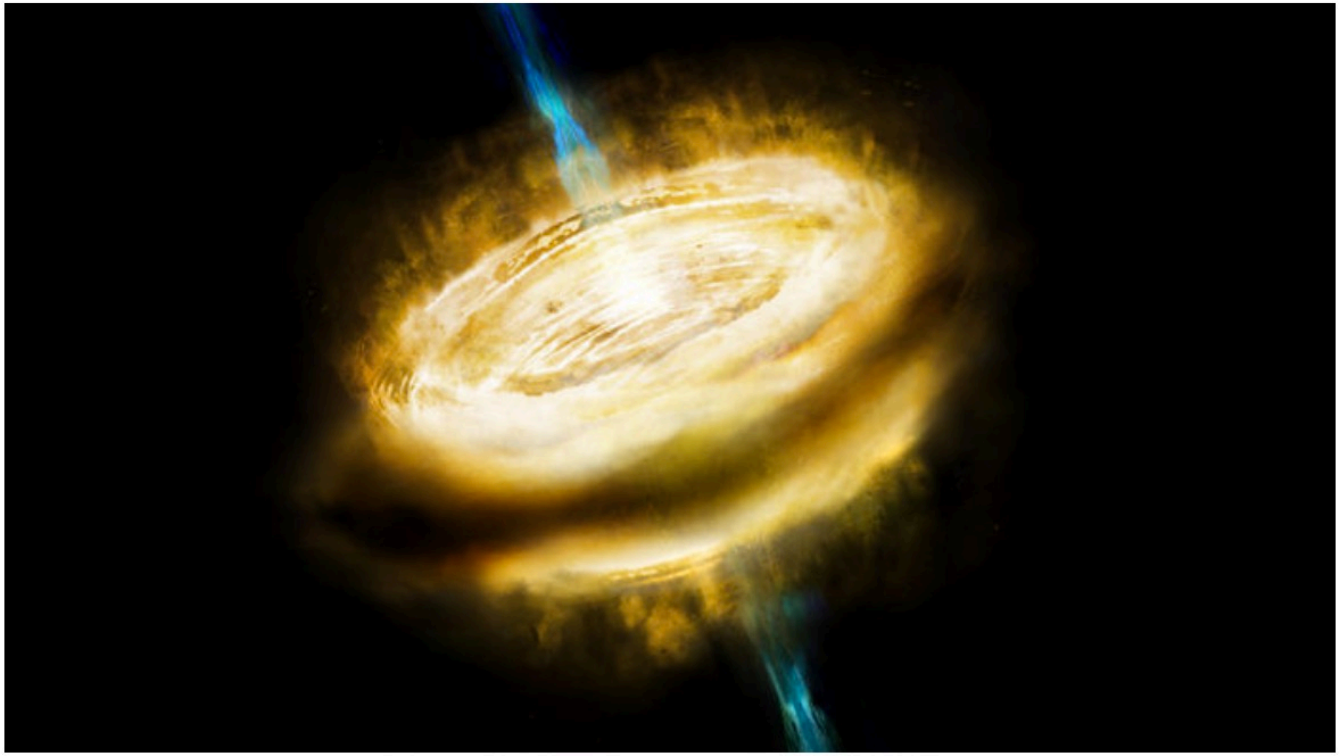




Infalling rotating envelope

Disk Atmosphere in Complex Organic Molecules





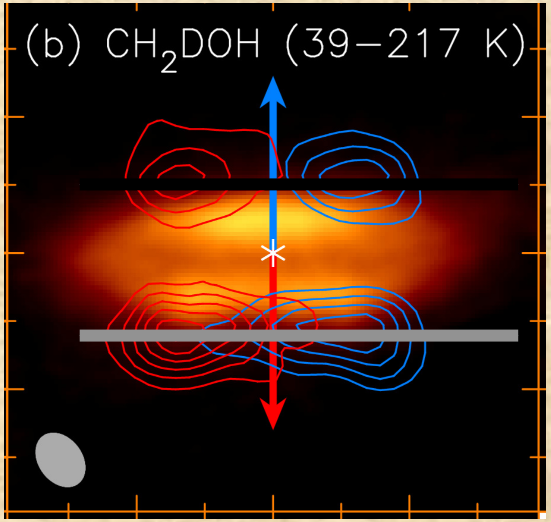
Star-forming disks contain complex molecules early on. Credit: ASIAA/Jung-Shan Chang

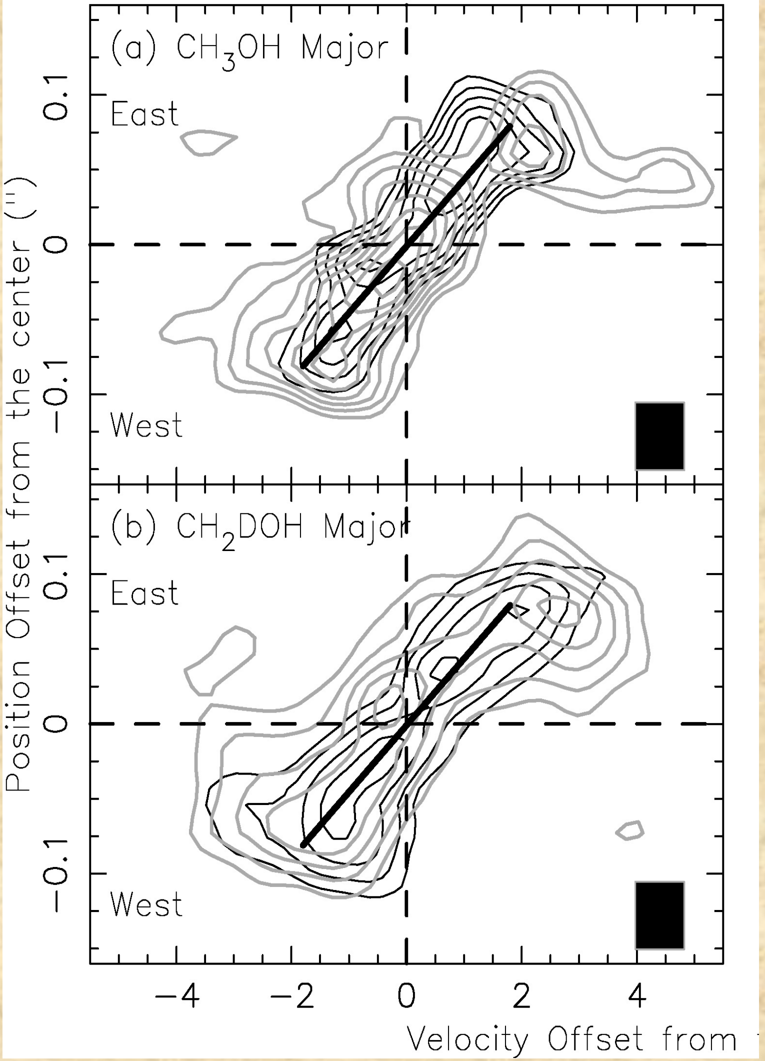
ASTRONOMY AND ASTROPHYSICS · 10 July 2017

Organic molecules spotted in star-forming disk

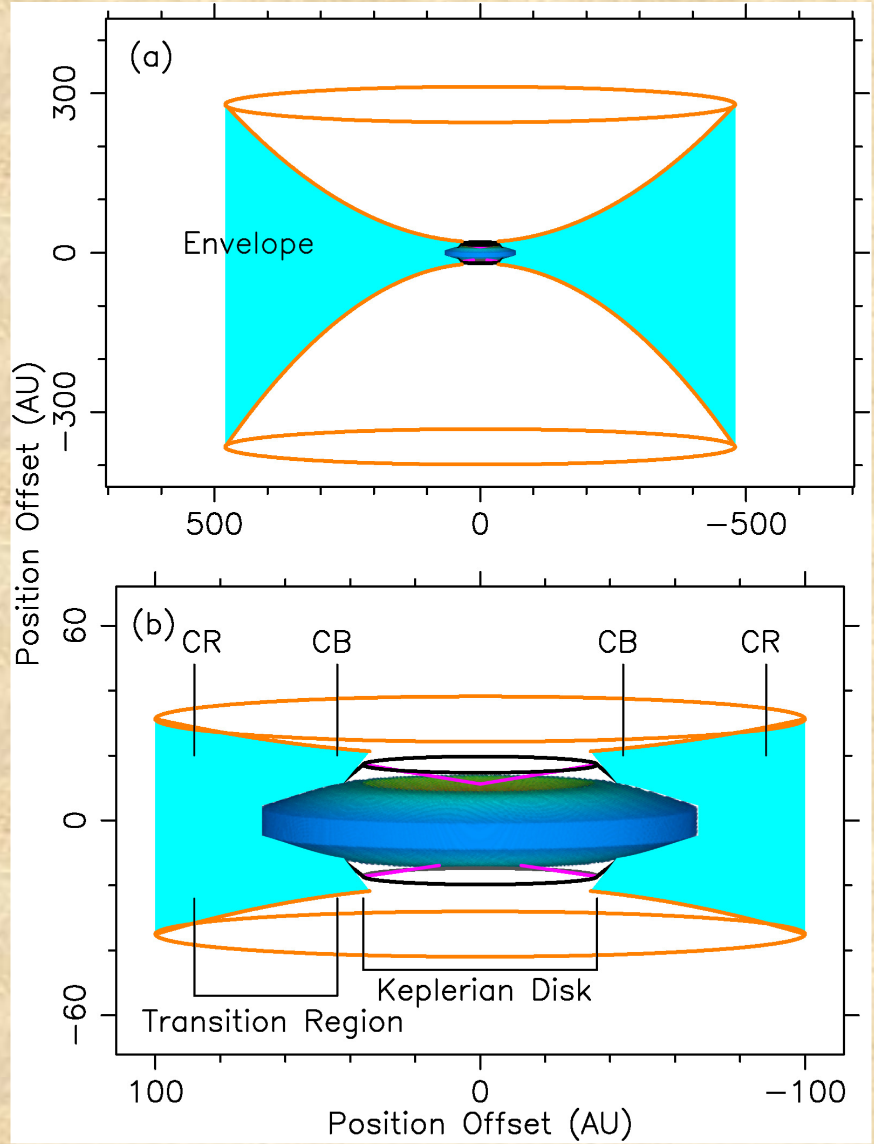
Life's building blocks seen around young would-be star.

Kinematic of the Disk Atmosphere





Cartoon for the flattened envelope and disk



Flattened Envelope [0.1” (40 AU) – 2.5” (1000 AU)]

Disk [0.0025” (1 AU) – 0.1” (40 AU)]

CB: Centrifugal Barrier
CR: Centrifugal radius

Kinematic model for the envelope & disk

In the envelope, we assume conservation of *l* & energy:

$$v_\phi = \frac{l}{r} \qquad v_r = -\sqrt{\frac{2GM}{r} - \frac{l^2}{r^2}}$$

Then, Centrifugal radius (CR): $$r_c = \frac{l^2}{GM}$$

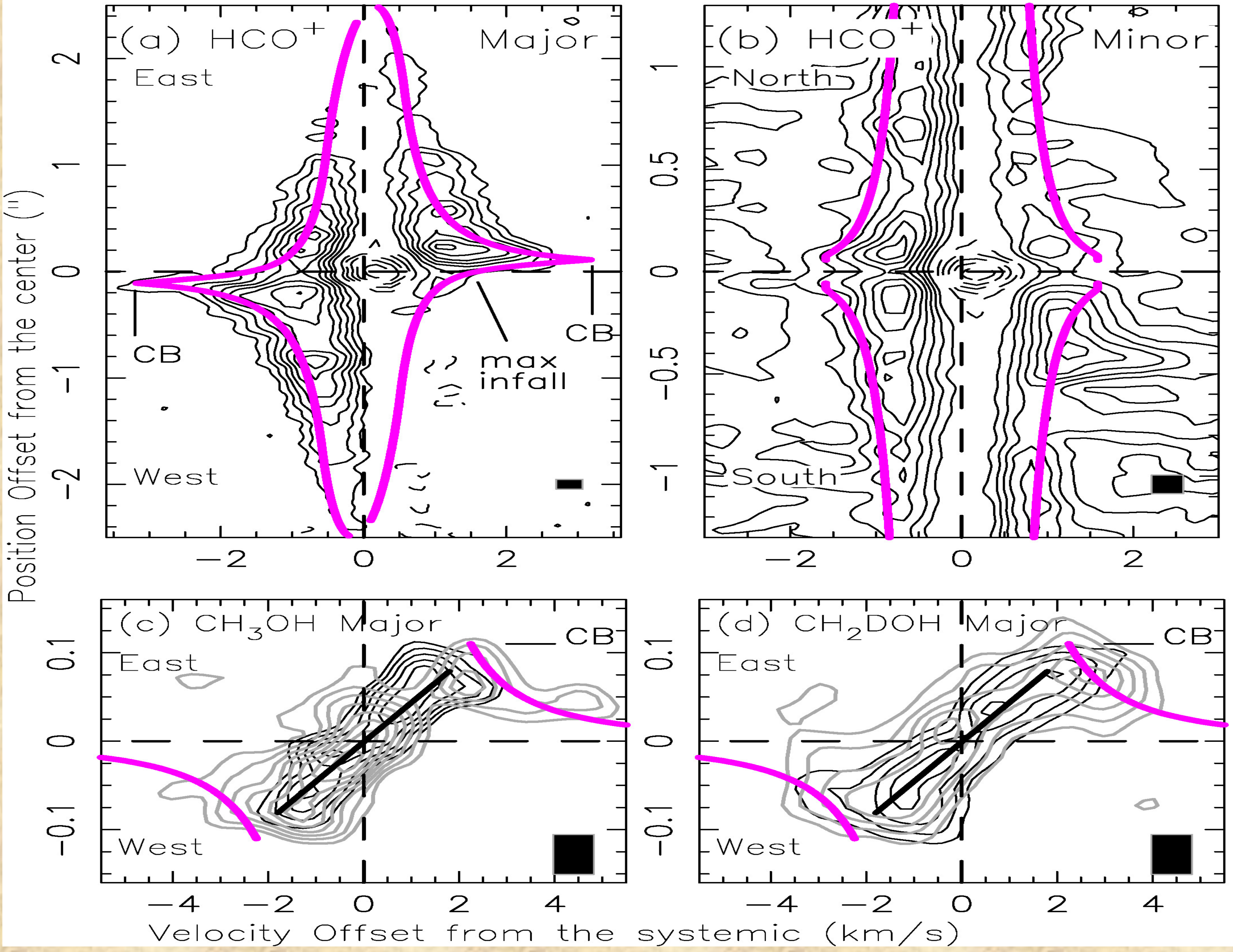
Centrifugal Barrier (CB): $$r_0 = \frac{l^2}{2GM}$$

In the disk with $r <= r_0$, we assume a Keplerian rotation

$$v_\phi = \sqrt{\frac{GM}{r}}$$

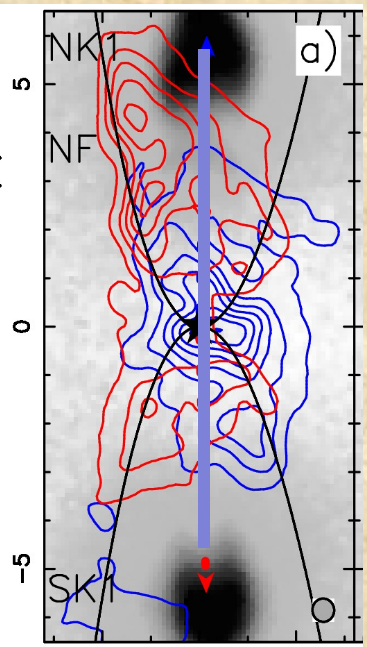
➔ Only 2 parameters, *l* and *M*

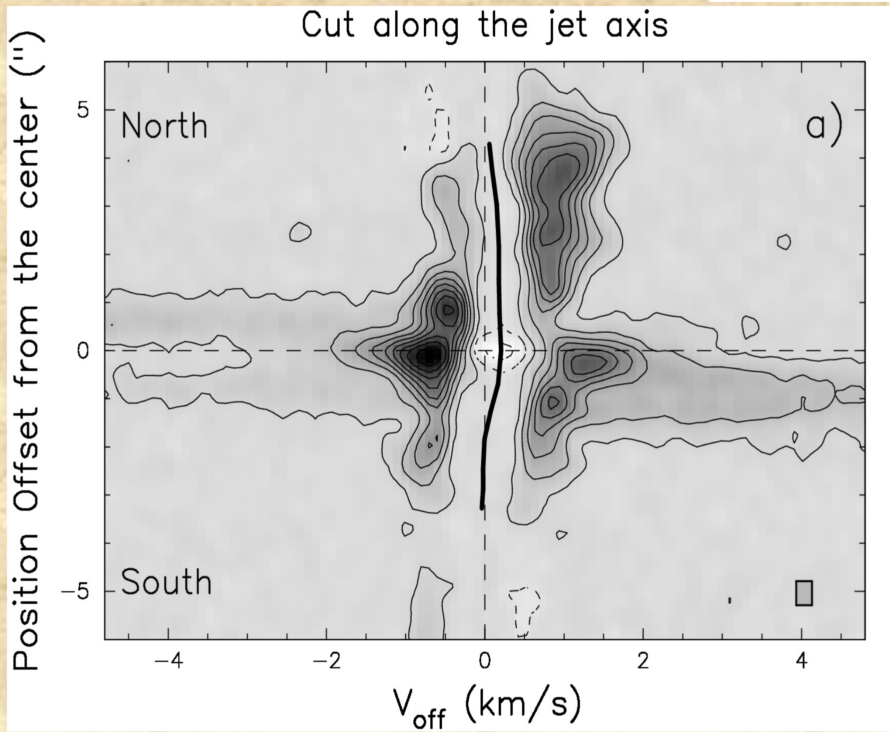
Model Results vs Observations

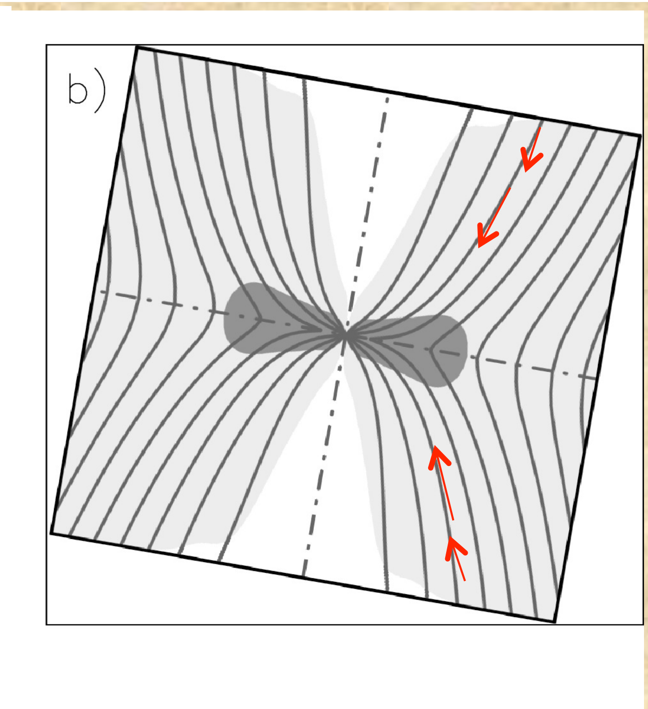


Position-Velocity Diagram along the jet axis in HCO^+

Extended Infalling envelope +
Hour-glass B-field morphology





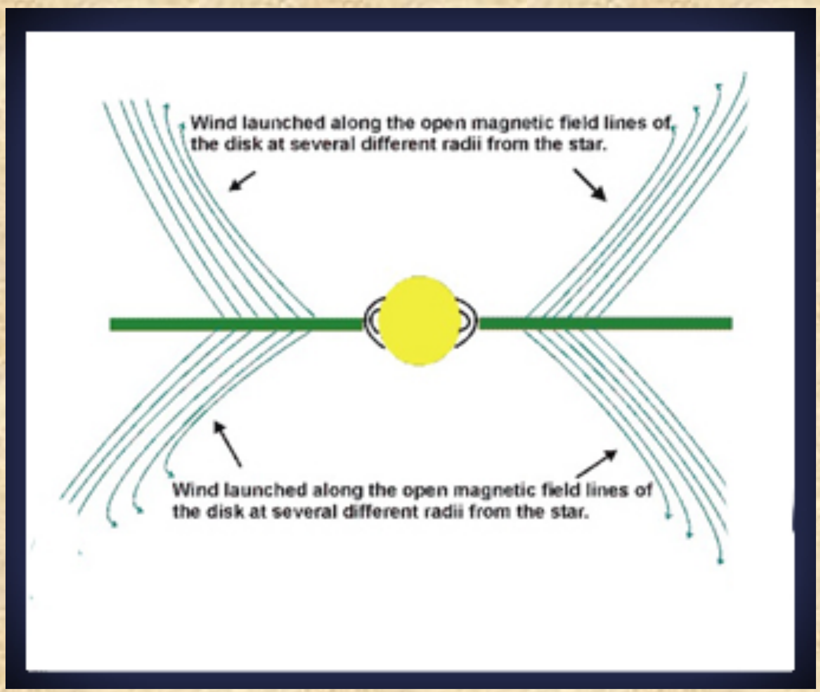


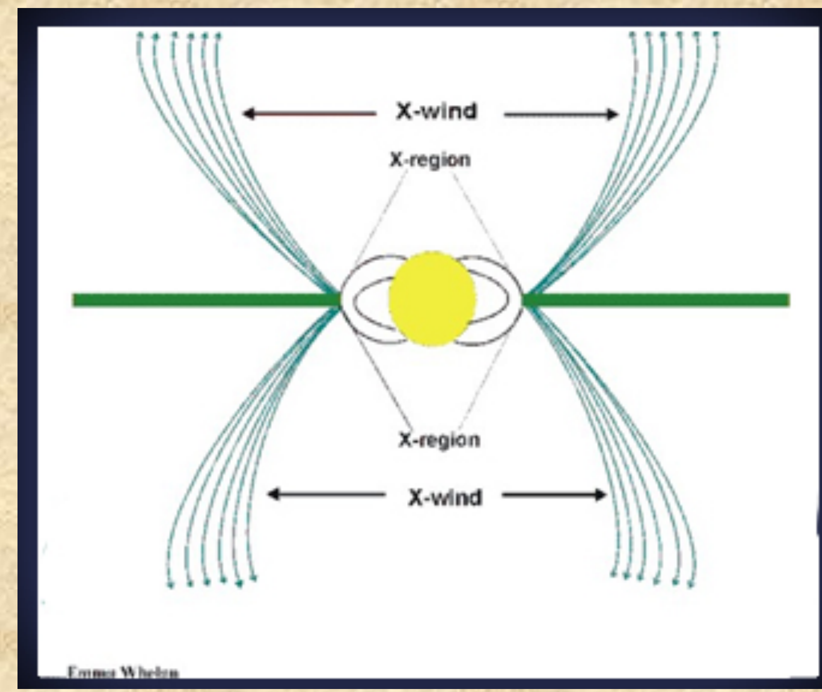
➔ Magnetic field regulated infall motion in extended envelope?

Two most popular jet models

Disk wind model: a range of disk radii down to corotation radius!

X-wind model: at corotation radius (X-point)!



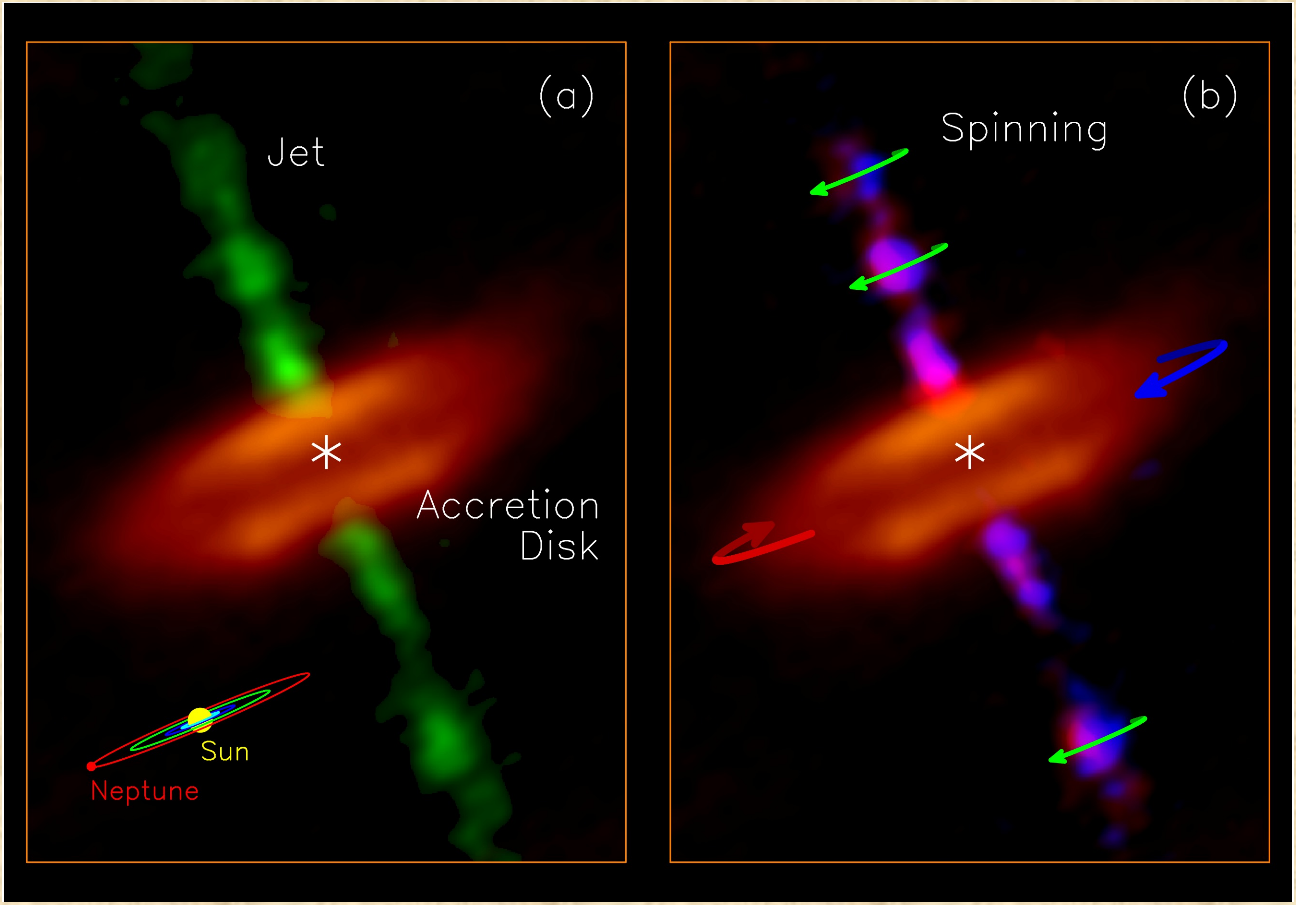


From JetSet webpage!

**** Jets are likely to be the dense central parts of the winds

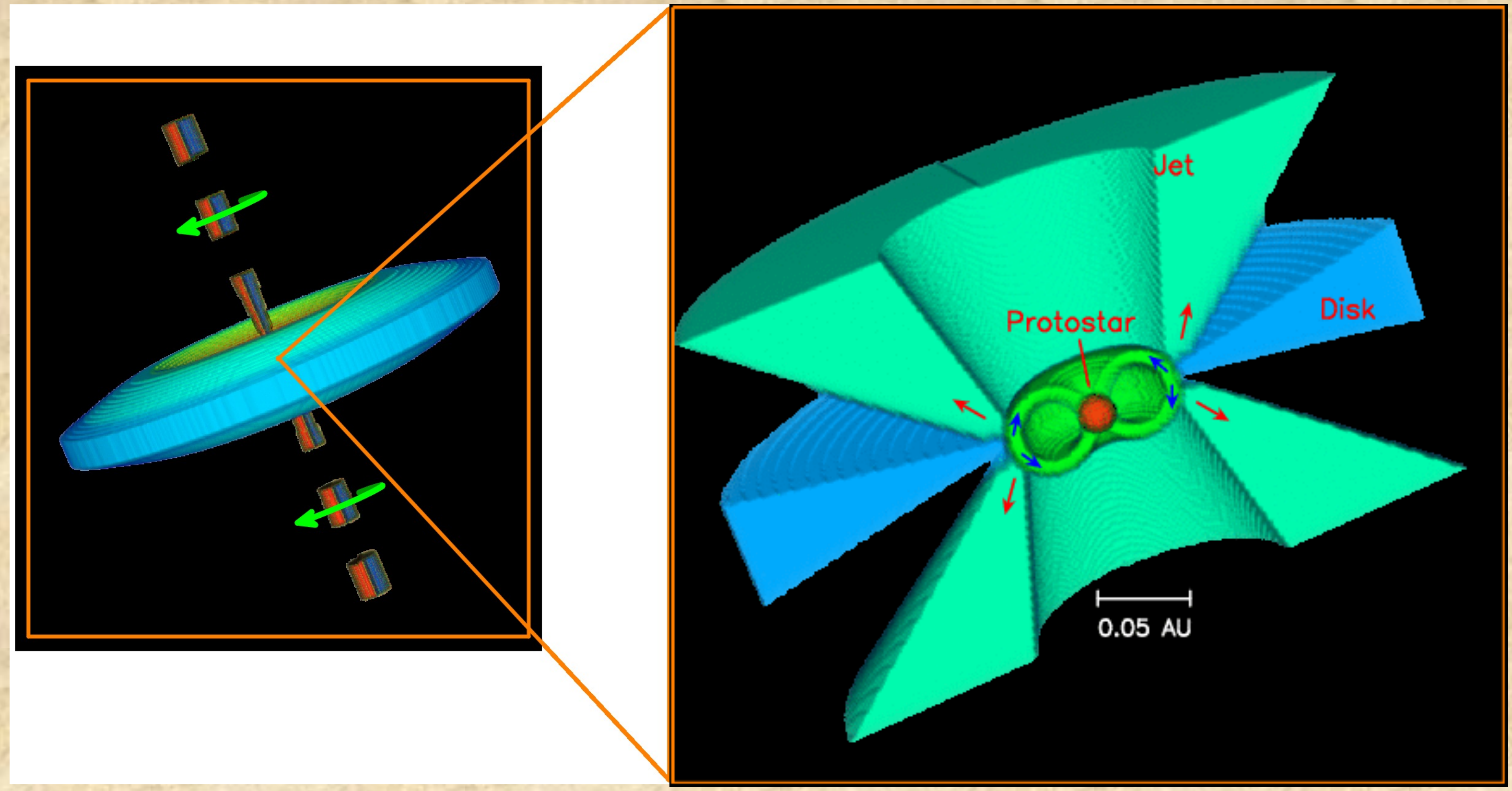
Different launching radii are adopted in the two models and thus different angular momenta can be carried by the jets.

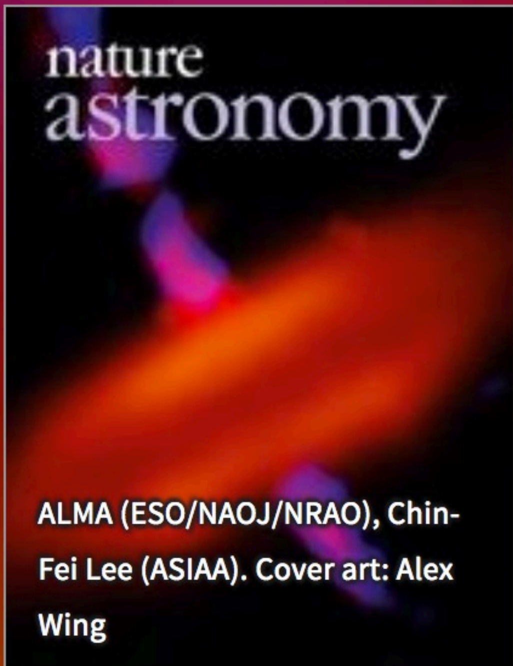
SiO Innermost Jet at 0.02" res: jet rotation



Sense of velocity gradient is the same as that of disk
==> jet rotation with *l* ≤ 10 AU km/s!
➔ Launching radius ~ 0.05 AU (Lee et al. 2017)

Accretion And Jet launching





ALMA (ESO/NAOJ/NRAO), Chin-Fei Lee (ASIAA). Cover art: Alex Wing

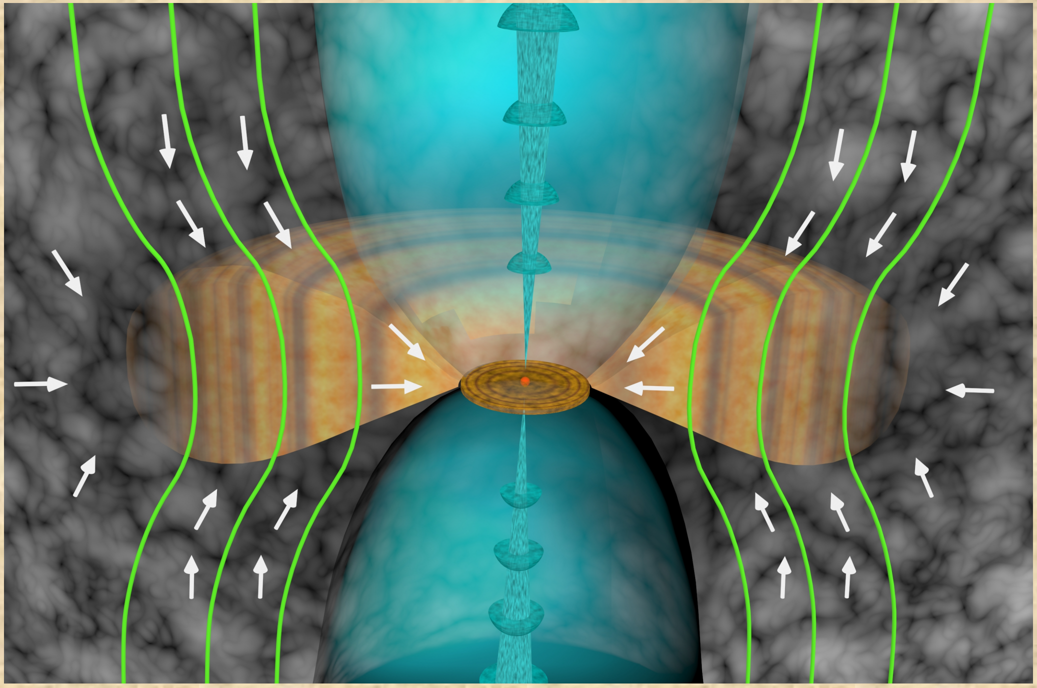
Volume 1 Issue 7

Spinning bullets from a young gun

Observations of a narrow, high-velocity jet launched from the innermost regions of a protostar/disk system reveal the presence of spinning clumps of material within the jet. This putative rotation implies that the jet removes angular momentum from the disk, thus allowing disk material to accrete onto the central protostar.

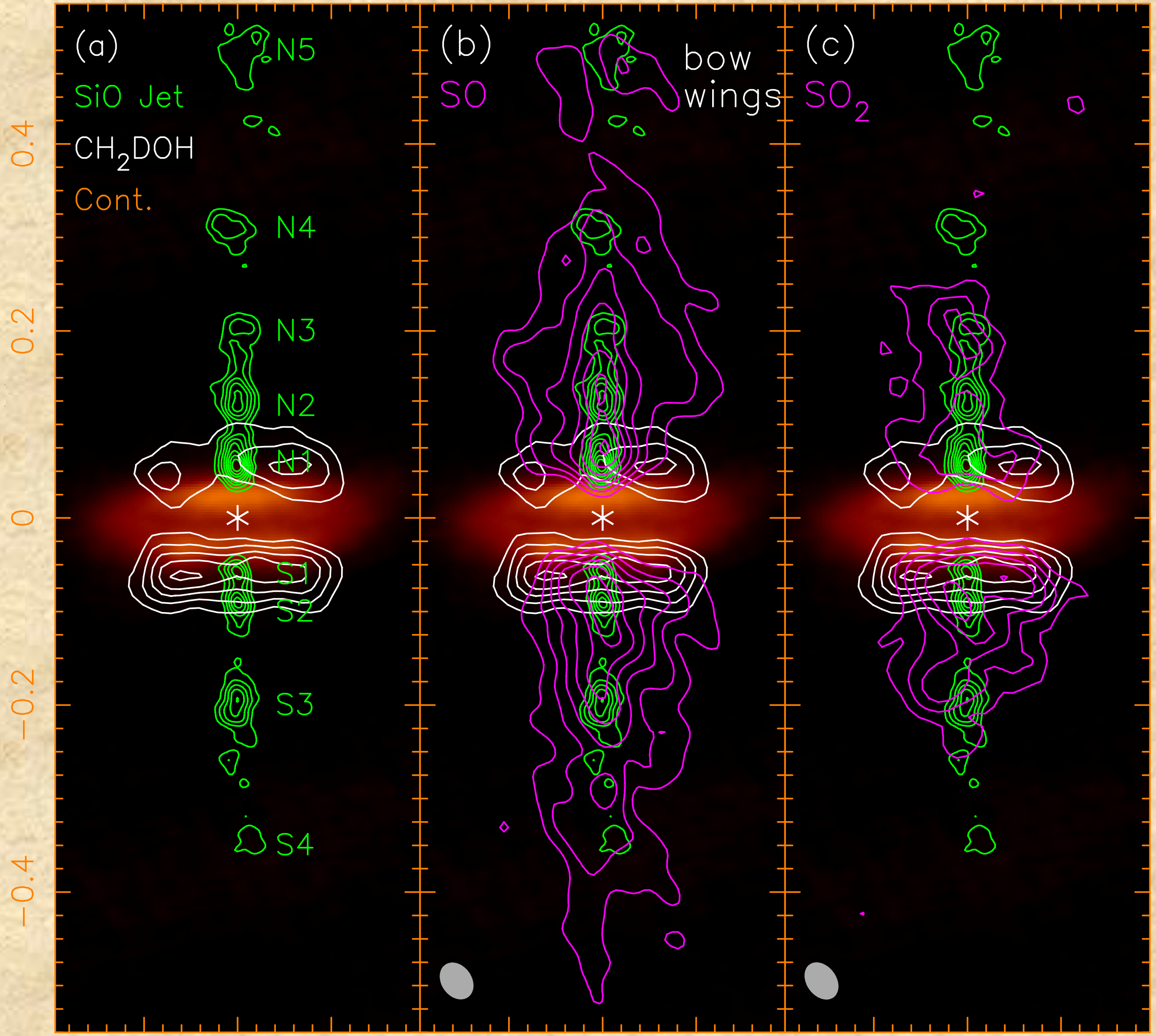
See Lee *et al.* **1**, 0152 (2017).

Formation Process of a Solar System like our own



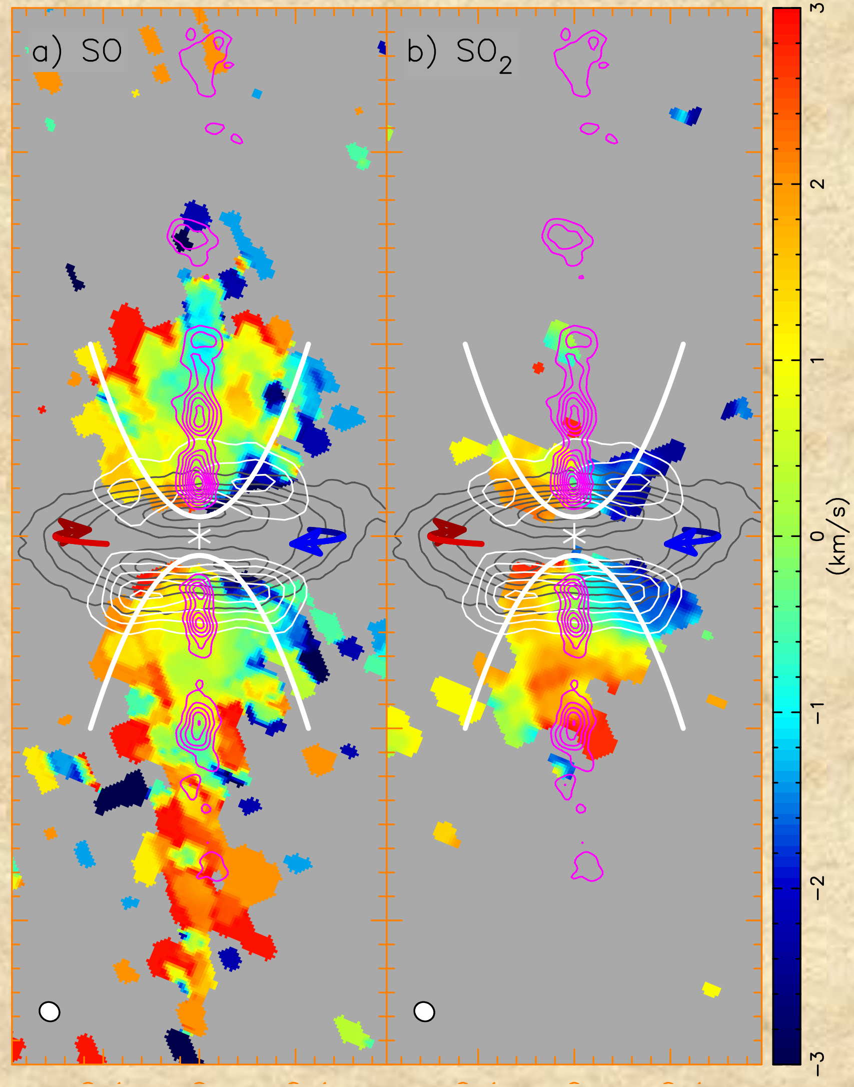
Jet is likely to be launched from only the innermost part of the disk and is likely magnetized. Keplerian disk will become protoplanetary disk in the later phase.

Slow Molecular Outflow



Lee et al. under revision

Slow Molecular Outflow: Rotating



Disk Wind?