

# **Astrophysical Jets and protostellar cores**

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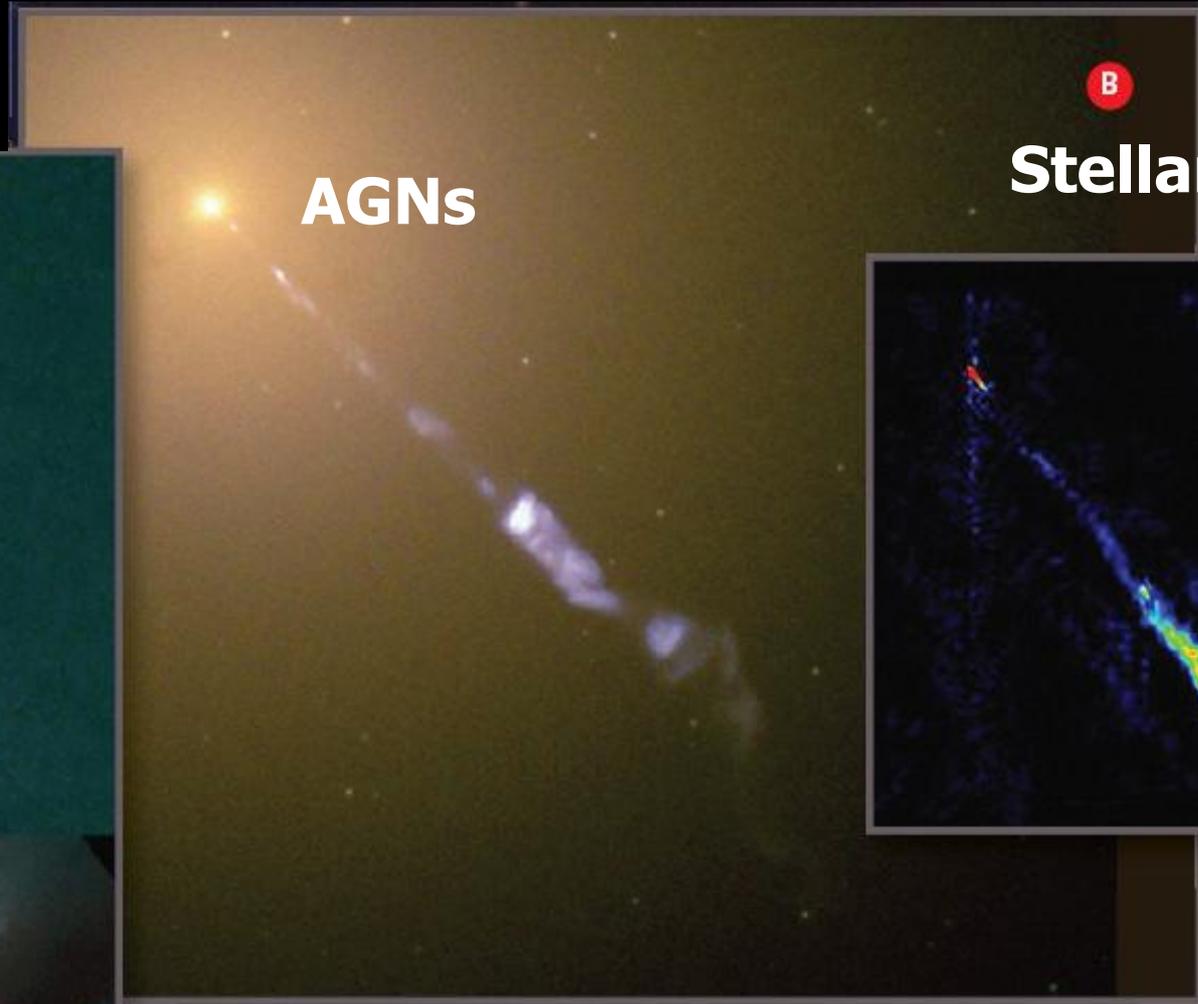
**LLAMA Workshop – FAPESP, August 2011**



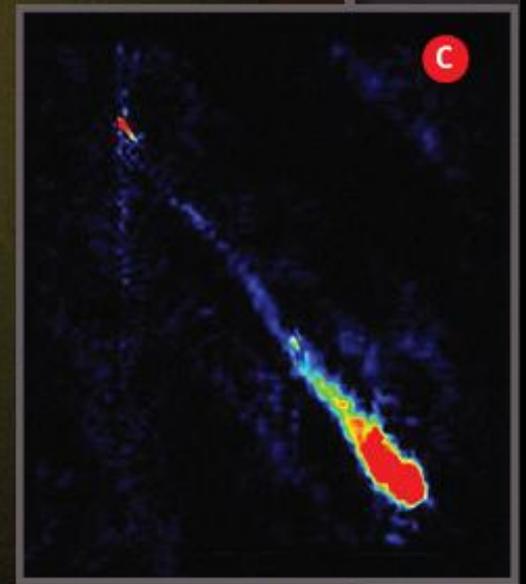
# ASTROPHYSICAL JETS - UBIQUITOUS



**PROTOSTARS**



**AGNs**

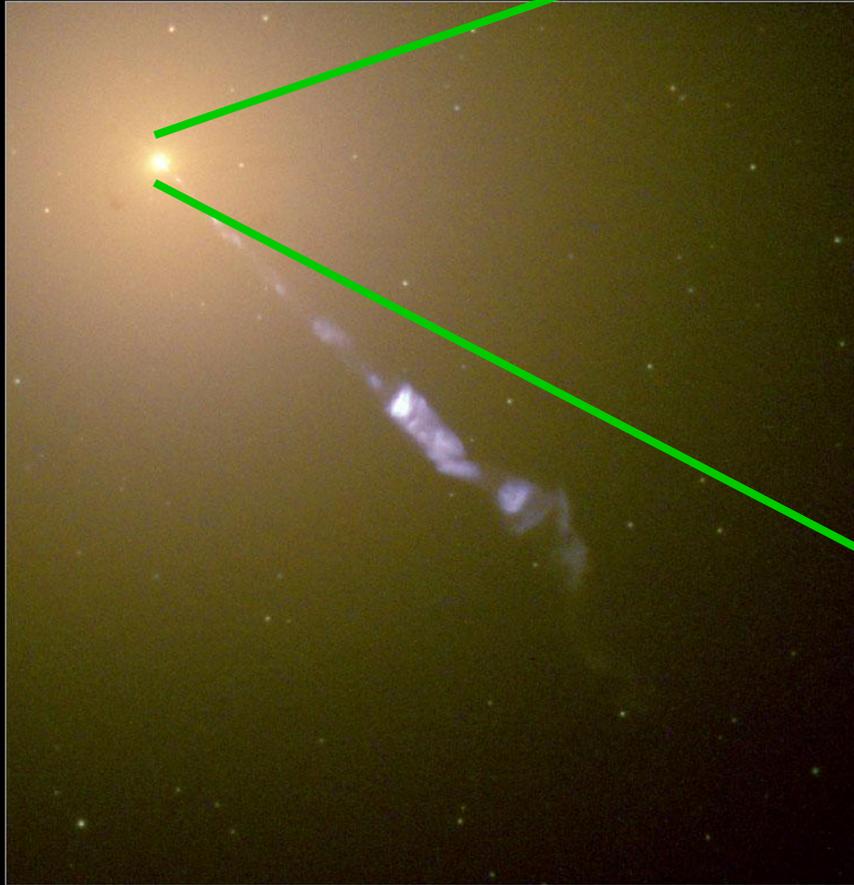


**Stellar-BHs**

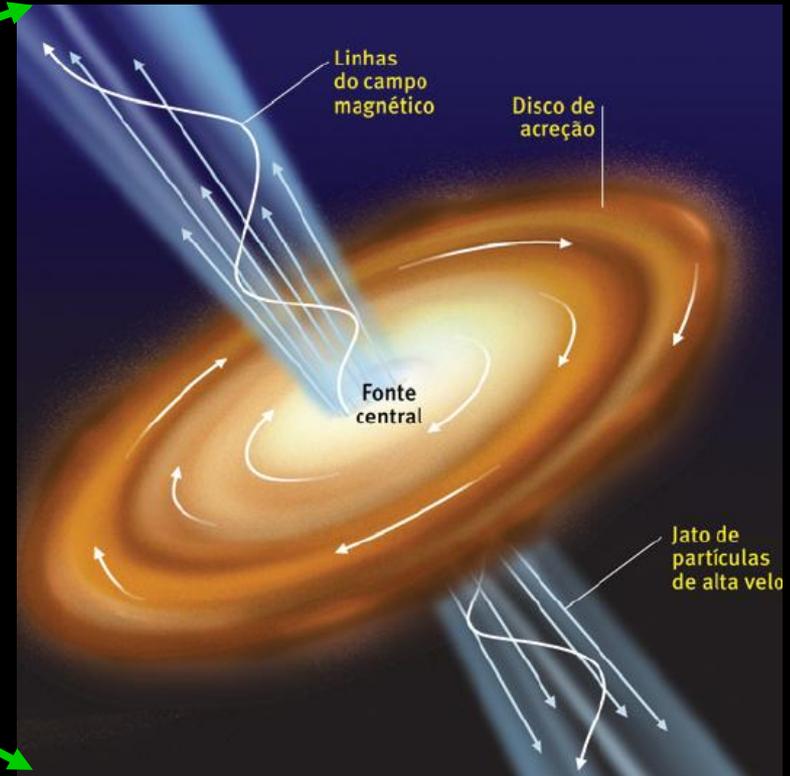
→ Despite difference in scales: similar morphology

# UNIVERSAL MODEL FOR JET ORIGIN?

The M87 Jet



Hubble  
Heritage



**Magneto-centrifugal**  
acceleration out off  
accretion disk around the  
source (**Blandford & Payne**  
**1982**)

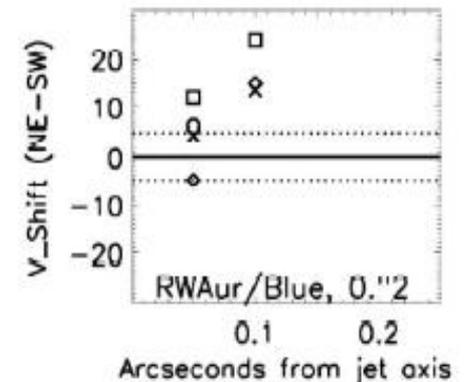
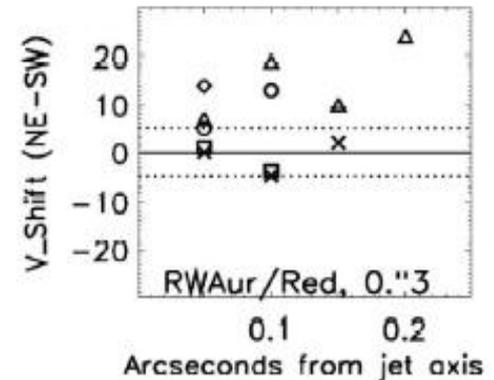
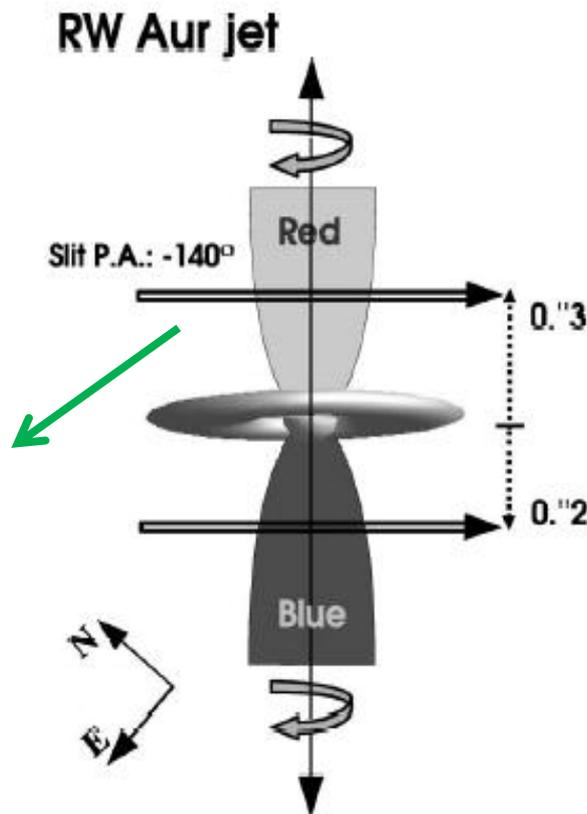
# PROTOSTELLAR JETS: probe jet launching & rotation

## Is jet rotating? (probe magneto-centrifugal mechanism)

- Optical line measurements (HST) at the jet basis:

Doppler shift **velocity asymmetries of 10-25 km/s** at  $\sim 10$  AU  
(Bacciotti et al. 2002)

**Interpreted as evidence of rotation**



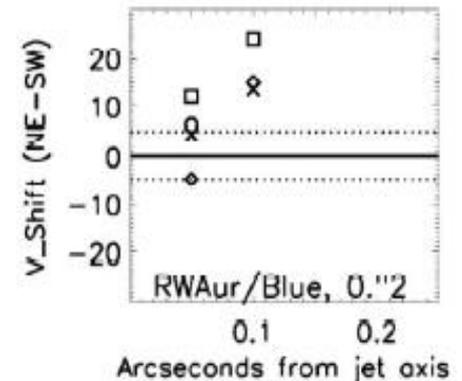
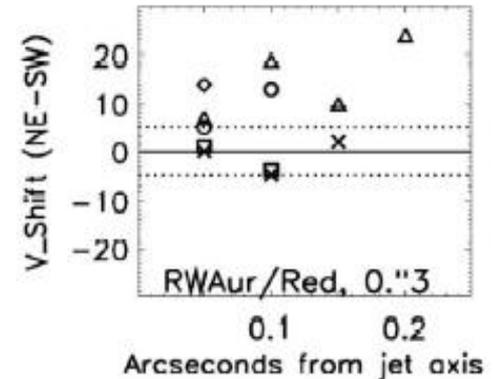
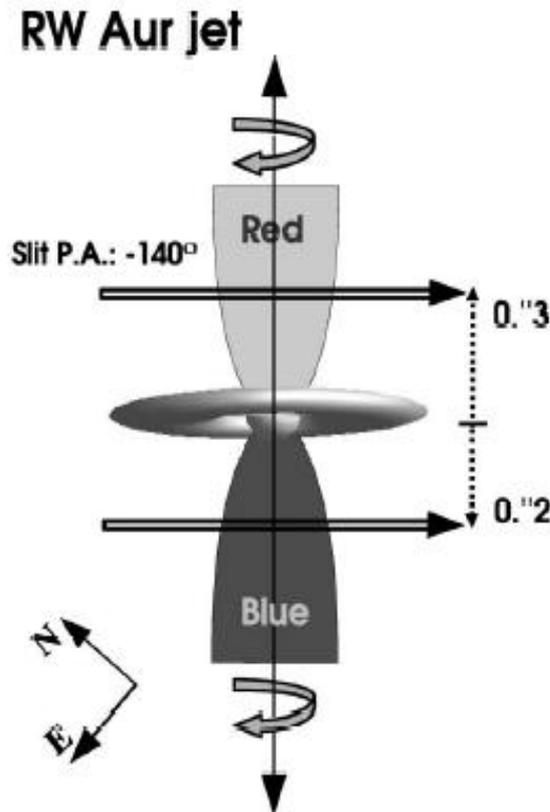
# PROTOSTELLAR JETS: probe jet launching & rotation

**However ambiguity:**

- **Numerical MHD simulations** (Cerqueira & de Gouveia Dal Pino 2004; Cerqueira et al. 2007) :



**Same velocity asymmetries:**  
produced by *non-rotating* precessing jet



# REMOVE AMBIGUITY ON JET ORIGIN

**Jet conference in Crete Island (2008):**

*"...to remove ambiguity and probe inner accretion disks and protostellar jet launching we have to wait for ALMA."*

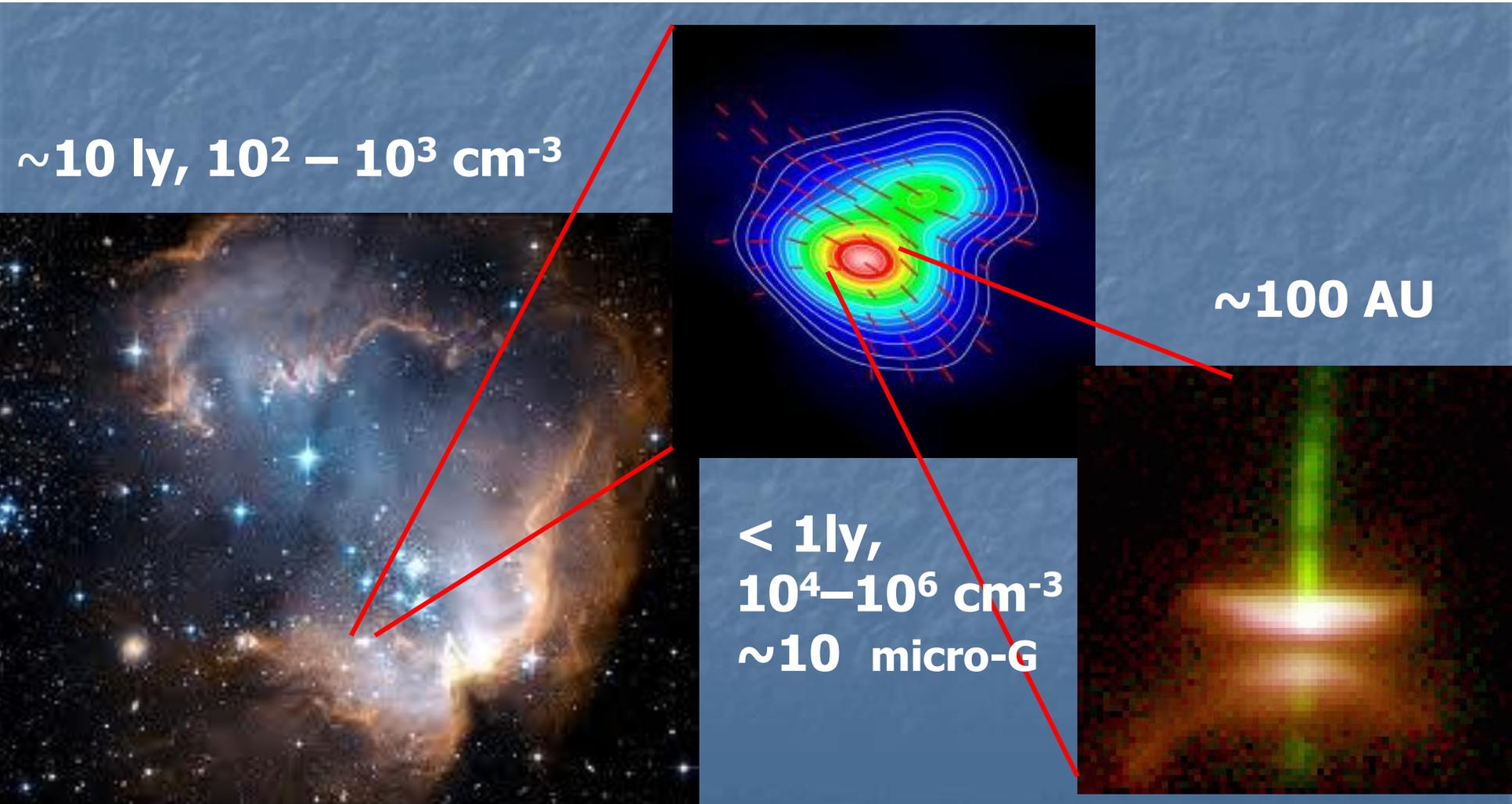
**...and with LLAMA: probe scales  $\sim$  AU**

# REMOVE AMBIGUITY ON JET ORIGIN

**Sub-mm ALMA-LLAMA interpherometry of dust and molecular emission** (e.g. SiO(5-4) at  $\sim 217$  GHz; Hirano et al. 2006):

- ✓ **Probe protostellar accretion disks and jet basis**
- ✓ **Probe rotation and -> universal jet launching mechanism**
- ✓ **Probe star formation stages** 

# Star Formation: not well understood

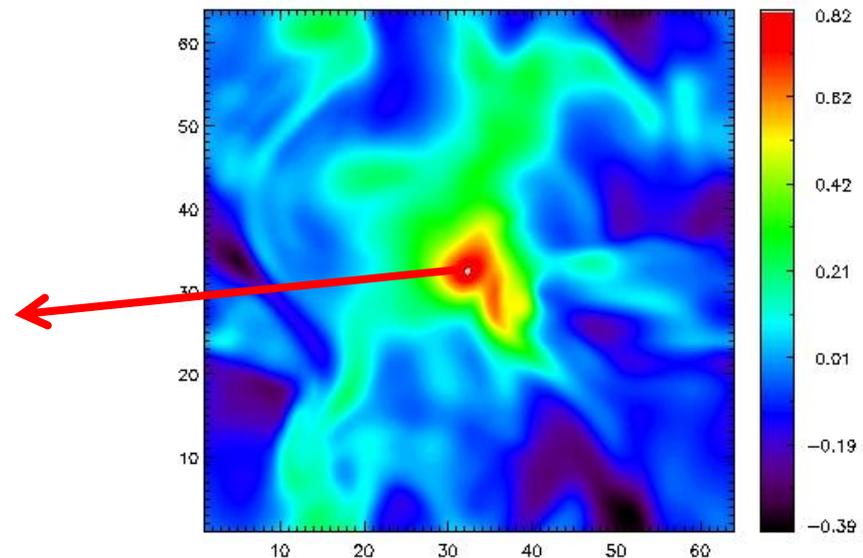


# Collapsing cores formation

Self-gravitating gas + central spherical potential ( $\sim 1/r^2$ )

**Protostellar core forms (few ly):**

because magnetic field removed by turbulence

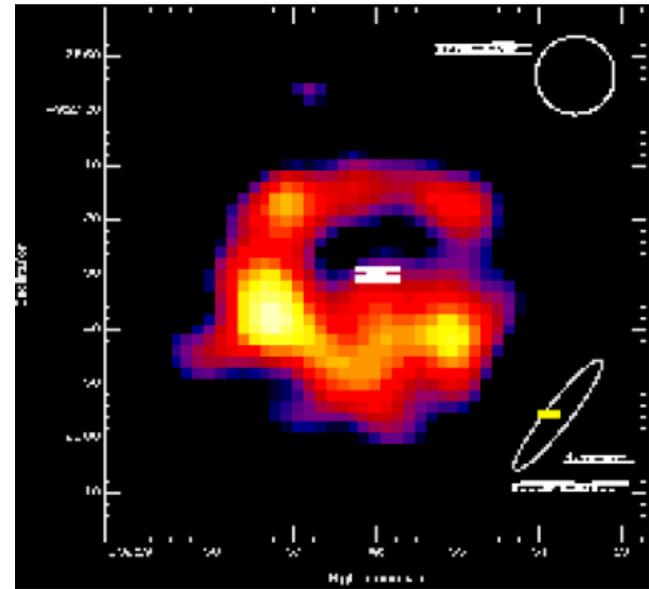
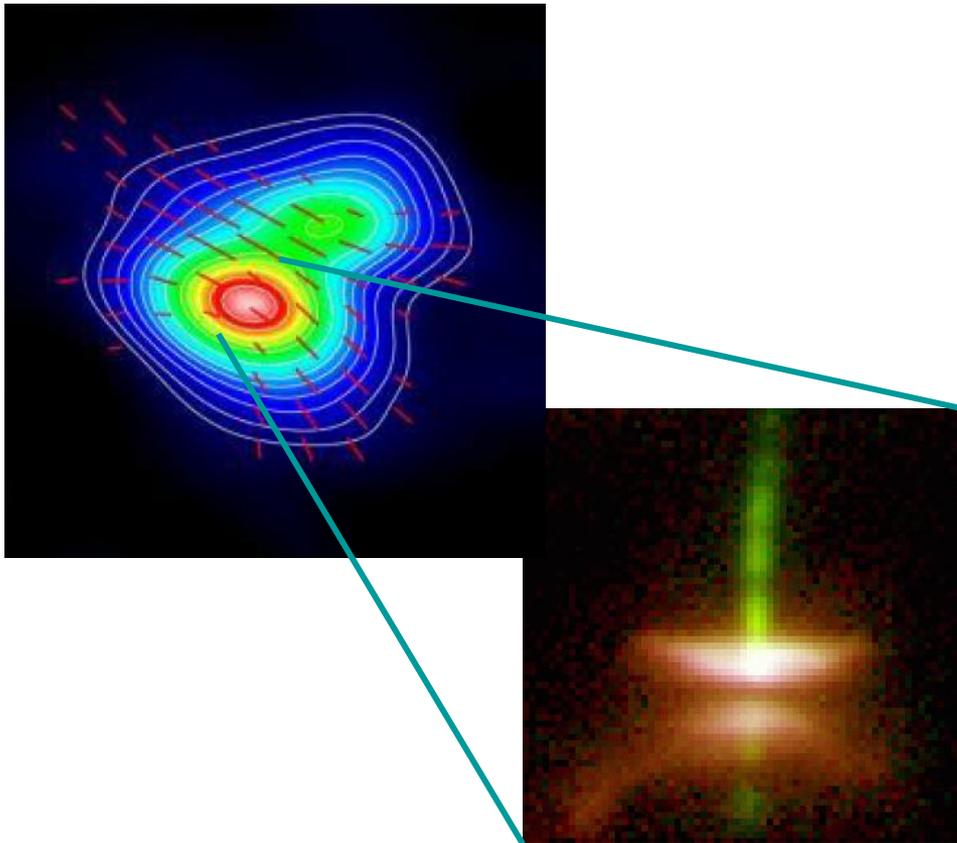


$t=95 \text{ Myr}$   $\beta=3$ ,  $n=100 \text{ cm}^{-3}$

**(Leão, Santos-Lima, deGDP, Lazarian 2011)**

# $\sim 100$ AU scales: formation of rotationally supported disks

## Observations:



**disk around protostar**  
SCUBA (200 $\mu$ m - 1mm)

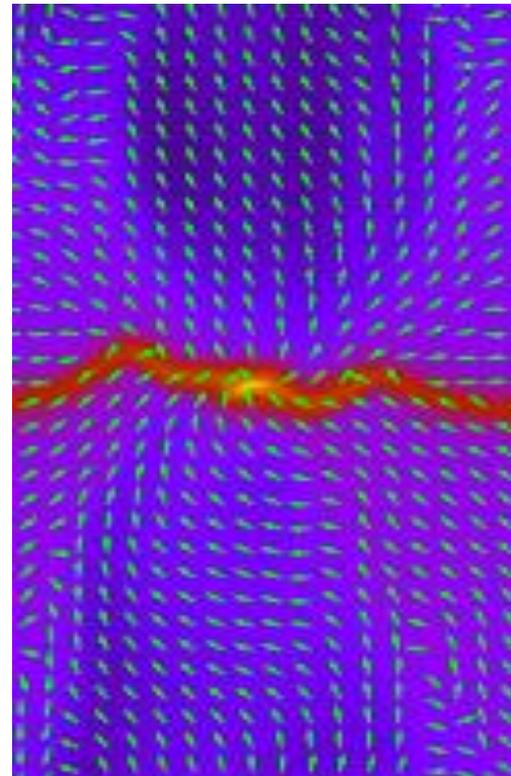
# $\sim 100$ AU scales: formation of rotationally supported disks?

**BUT theory:**

**Magnetic fields of cloud cores** suppress formation of **rotationally supported** disks:

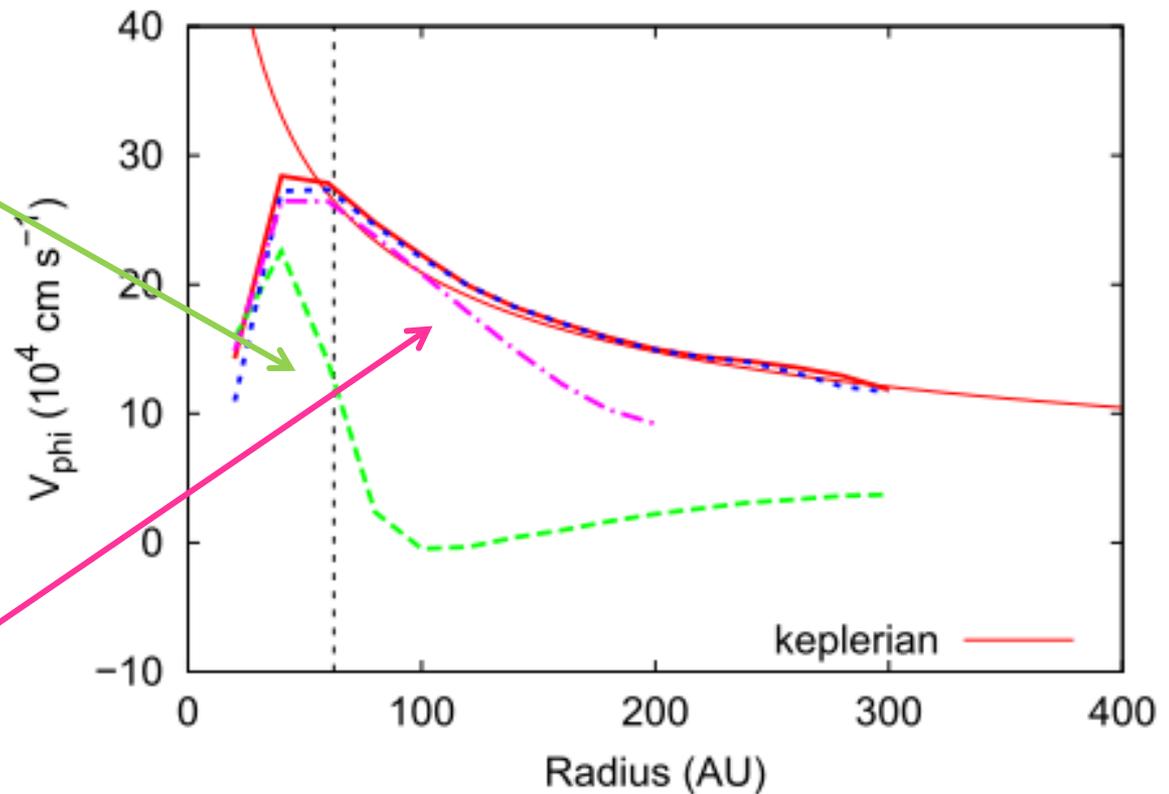
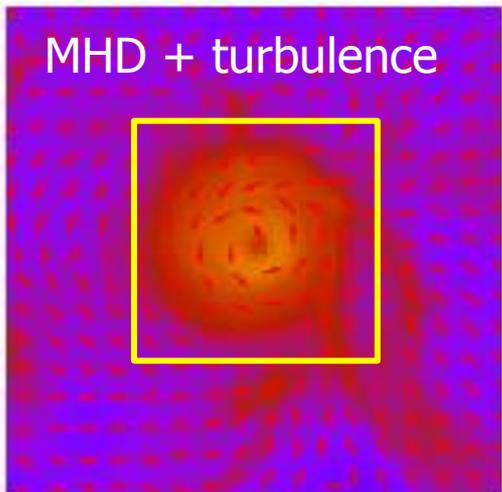


**magnetic braking**



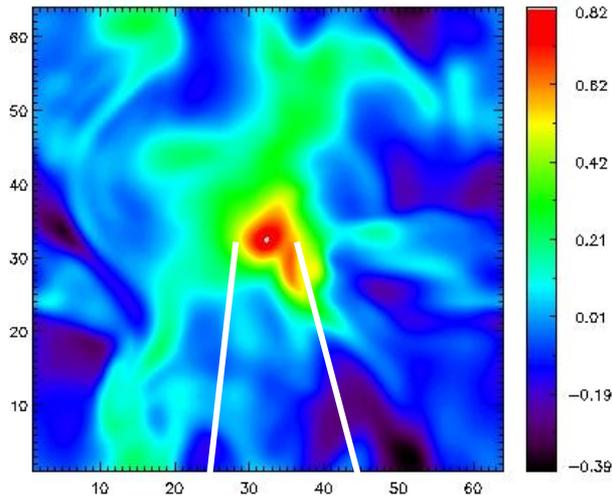
**Ideal MHD simulation:**  
**fails to form Keplerian**  
**disk around protostar**

# Formation of quasi-Keplerian disk by turbulent removal of MF



**Santos-Lima, de Gouveia Dal Pino,  
Lazarian 2010; 2011**

# Probing star formation with ALMA-LLAMA

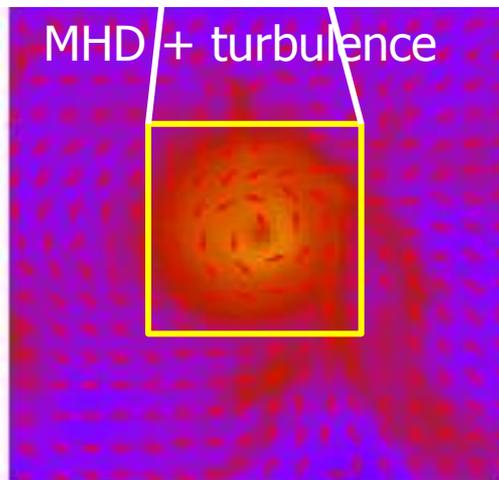


**ALMA & LLAMA** (sensitivity, angular and velocity resolution, and high freq. performance):

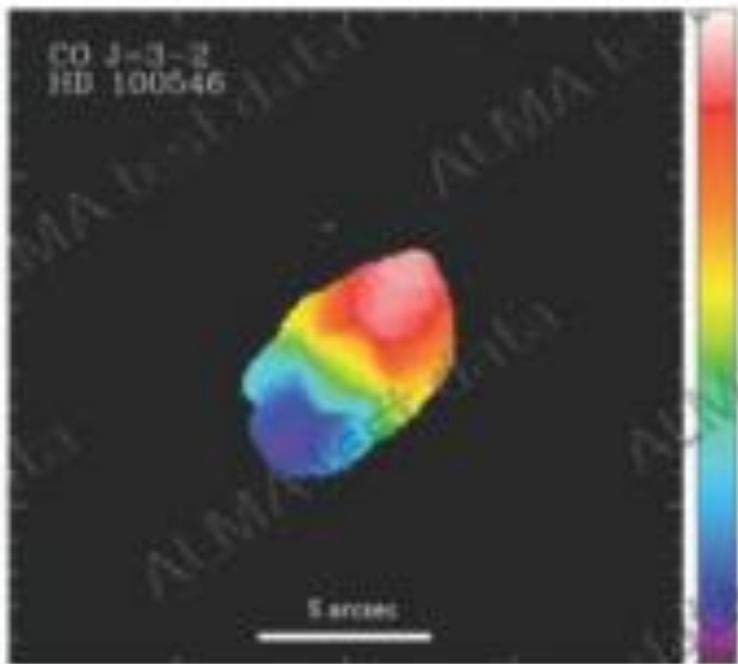
✓ **Measure MFs** from dust polarization; Zeeman effect in molecular transitions at low freqs. (e.g. CN @  $\sim 114$  GHz; Crutcher et al. 1999); and Chandrasekhar-Fermi effect (Heiles & Crutcher05; Falceta-Goncalves et al. 10); or Goldreich-Kylafis (1981) effect.

✓ **Probe core collapse** with MF removal

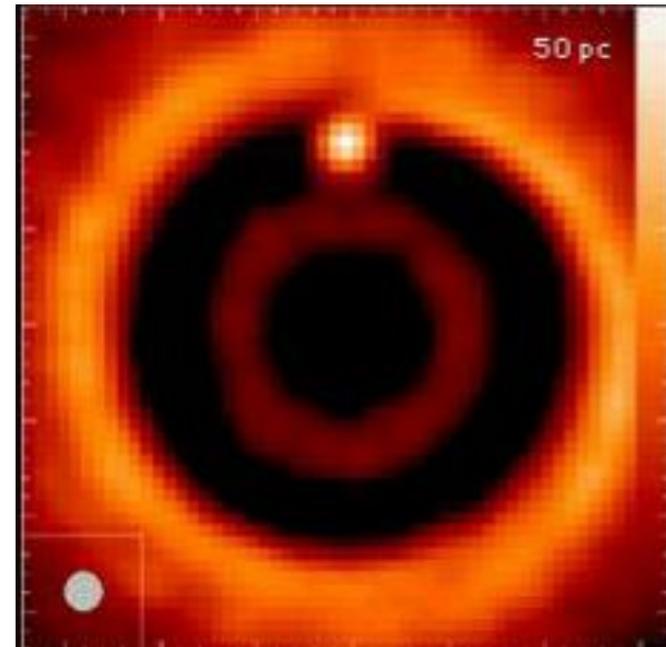
✓ **Probe protostellar disk formation** with magnetic braking stopped by turbulent transport of MF?



# ALMA 1<sup>st</sup> results on star formation regions - promising



**CO (3-2) observation of disk around young star embedded (345 GHz): colors probe rotation**

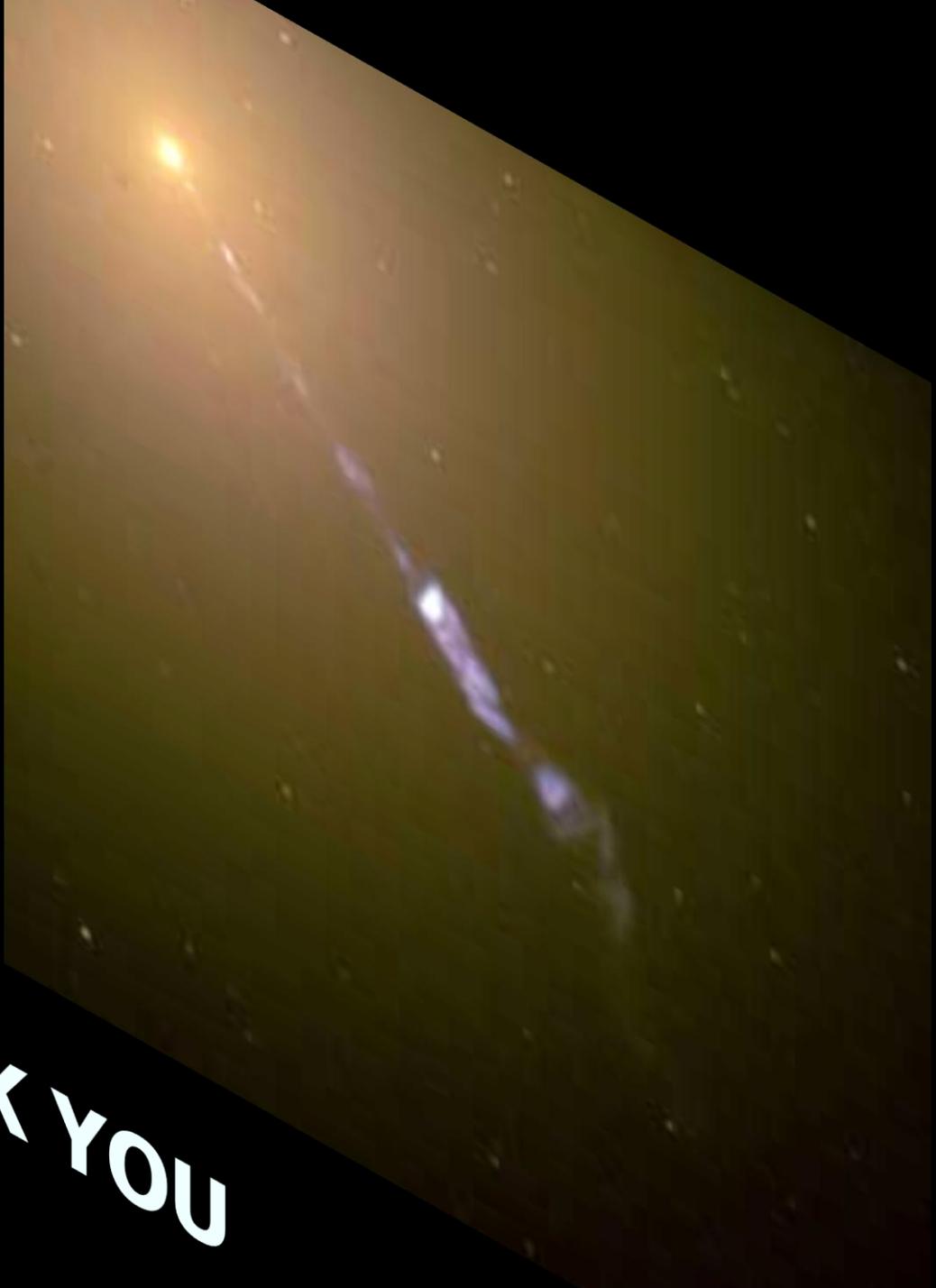


**Simulation of ALMA observations at 950 GHz of a disc with protoplanet (orbital radius 5AU) (Wolf & D'Angelo 2005)**

# Summary

## ALMA-LLAMA:

- ✓ **Probe protostellar accretion disks & jet basis**
- ✓ **Probe rotation and -> universal jet launching mechanism?**
- ✓ **Probe cloud core collapse and star formation** with MF removal (down to 100 AU)
- ✓ **Probe protostellar disk formation** with magnetic braking stopped by turbulent transport of MF @ <100 AU
- ✓ **Polarization measures** required to estimate MFs (Magalhaes' talk)



**THANK YOU**