

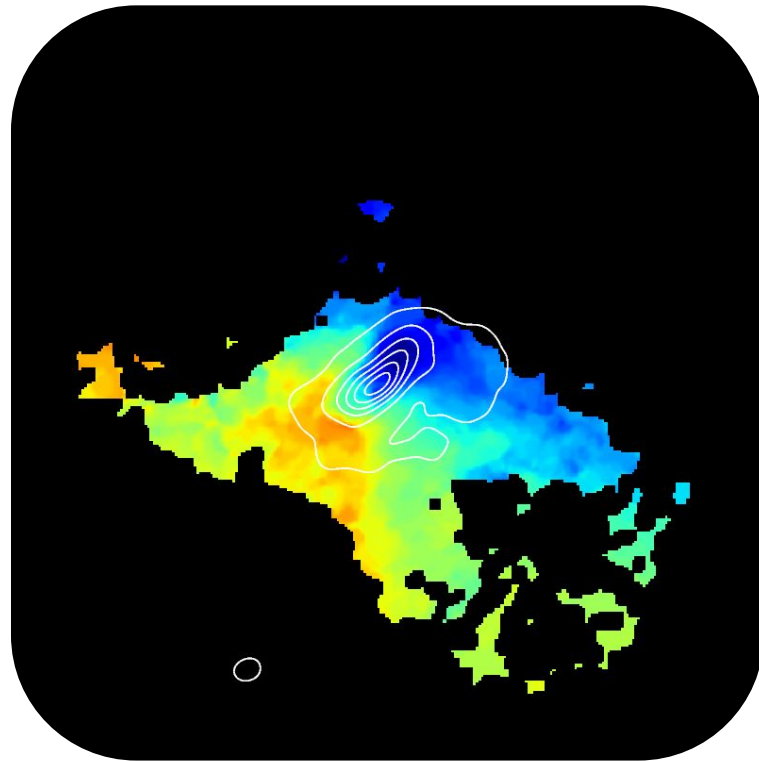


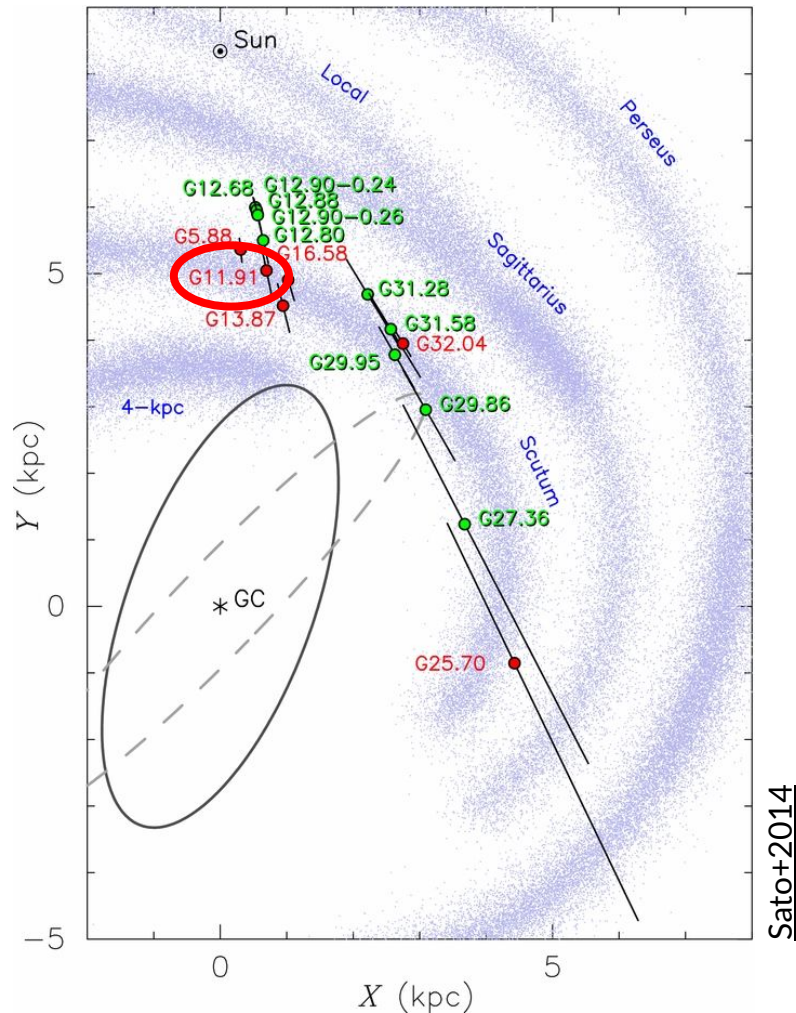
# ALMA study of G11.92-0.61 MM1:

disk-wind or  
YSO multiplicity?

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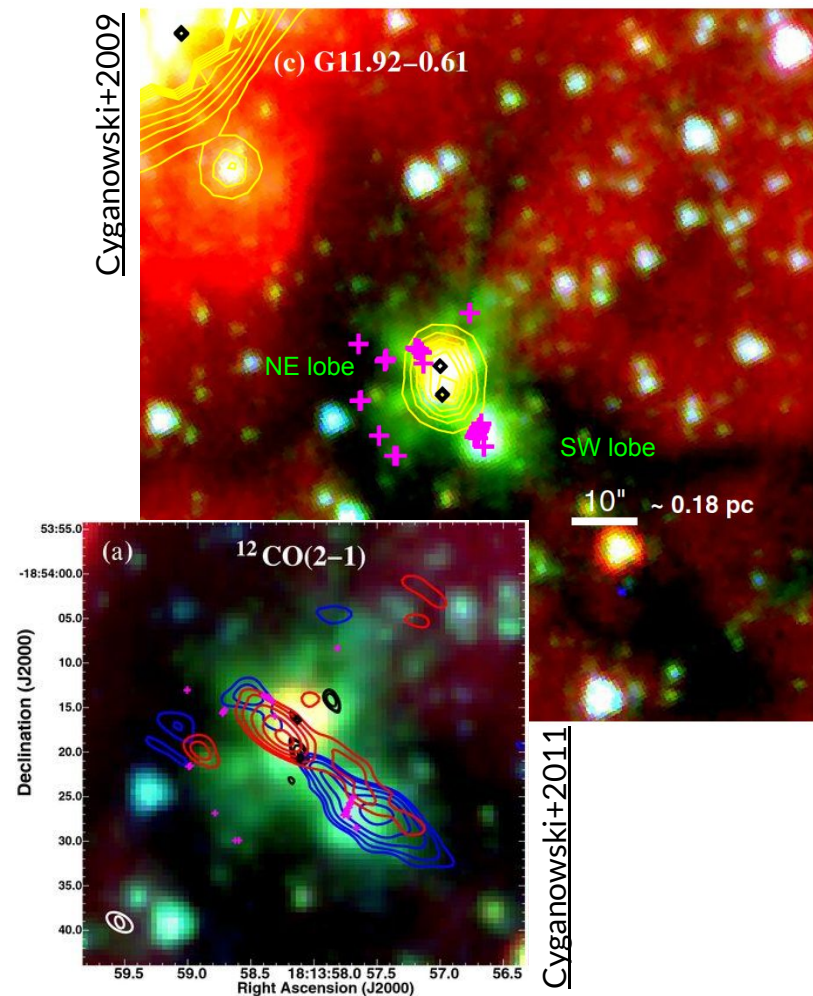


# 01.

# Background

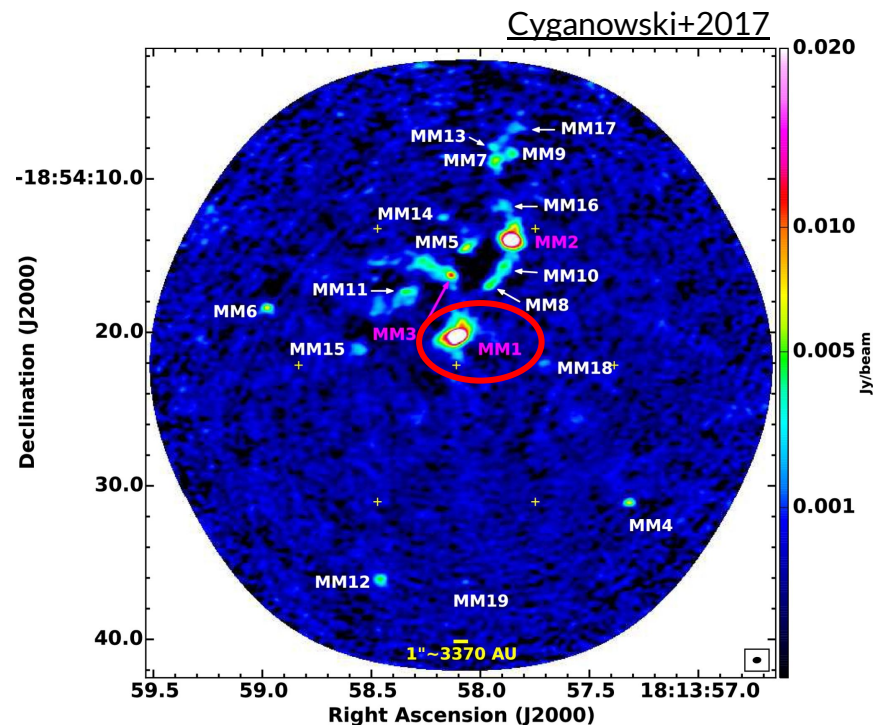
# G11.92-0.61 Region

- Extended Green Object (EGO) - **MYSO** with **active outflows** traced by the  $4.5\ \mu\text{m}$  emission of shock-excited molecular lines
- Protostellar cores and 6.7 GHz methanol & 22 GHz water masers are associated with the NE core
- Only one of [Cyganowski+2009]'s EGO showing multiple 6.7 GHz methanol maser loci - more than one MYSO



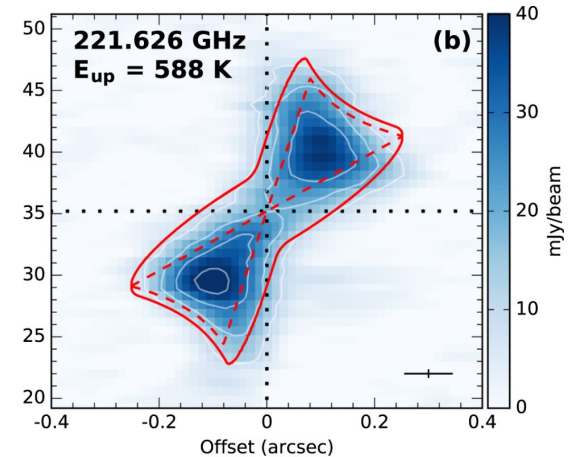
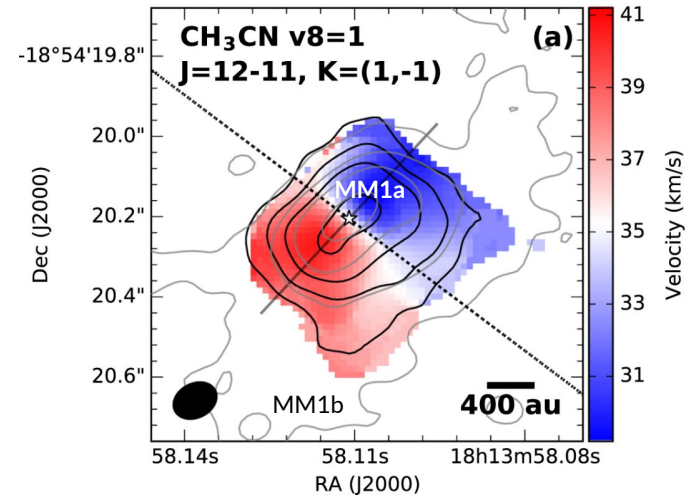
# G11.92-0.61 MM1

- ALMA observation revealed presence of 19 cores (3 high-mass and 16 low-mass)
- MM1 - the **brightest and most massive mm-core**, an example of a forming proto-O star with an active outflow and ongoing accretion
- **MM 1a drives the dominant large-scale outflow** - NE-SW orientation of the outflow coincides with the EGO's orientation



# G11.92-0.61 MM1

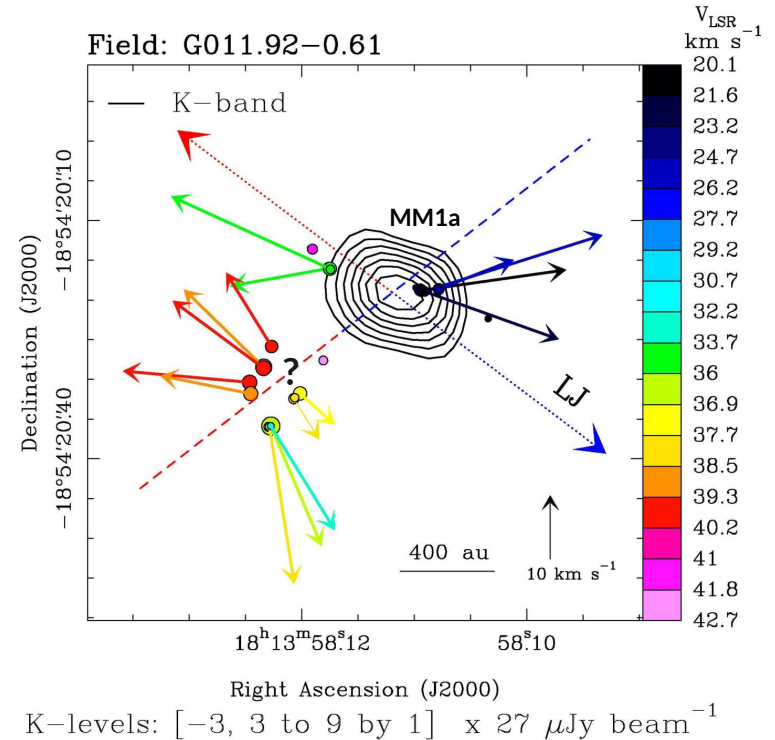
- Massive Keplerian accretion disk around MM1
- The enclosed mass of the central object was estimated to be of  $\sim 40 M_{\odot}$
- A weak 1.3 mm continuum source MM1b - a sign of disk fragmentation? [Ilee+2018]  
! separated from MM1 by  $\sim 2000$  au and seems in fact be located outside of the disk !



Ilee+2018

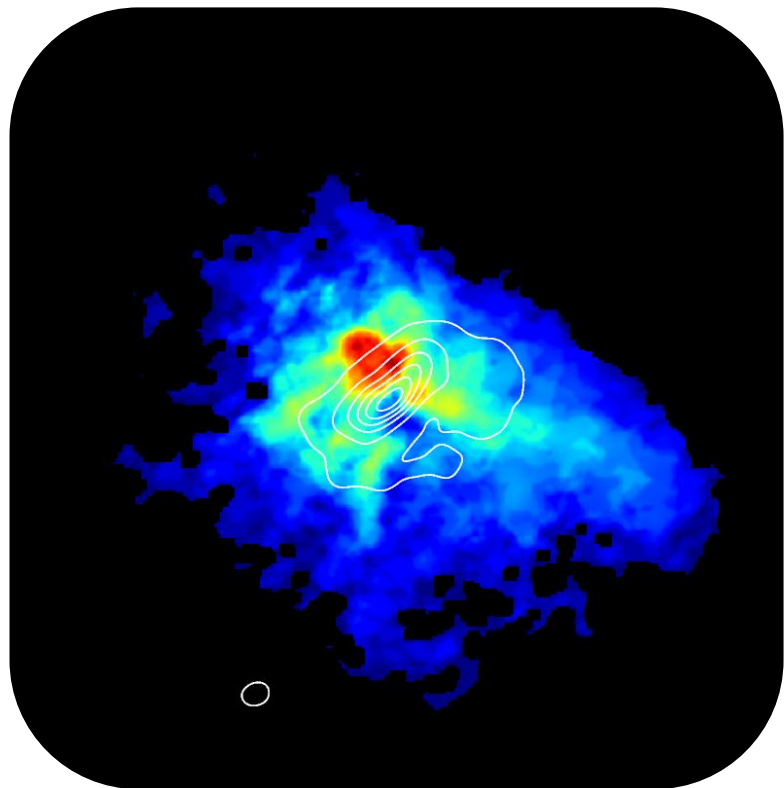
# G11.92-0.61 MM1

- A strong 22 GHz water maser in MM1a shows a bipolar structure and velocity pattern similar to the large-scale outflow
- However, the trigger of the water emission is not clear
- [Moscadelli+2019] suggested that the 22 GHz water maser may be explained by either a **disk-wind** or **YSO multiplicity**



Moscadelli+2019





**02.**

**ALMA  
observation**

# G11.92-0.61 MM1

Date:

September 29th, 2021

[project 2019.1.01639.S]

Configuration:

C43-9/10 with 45 antennas

Synthesised beam size:

$0.028'' \times 0.025''$ , PA=-66°

Spectral windows:

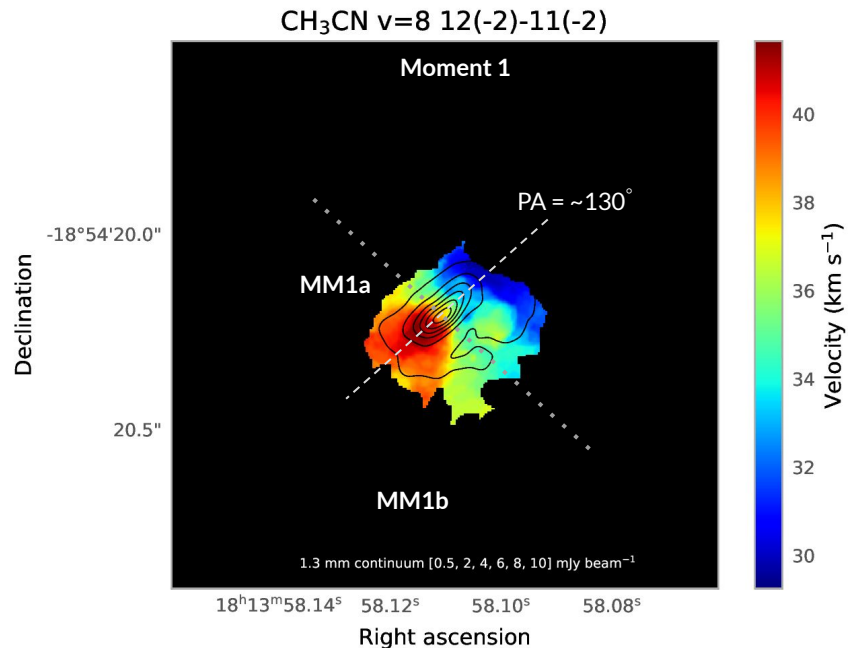
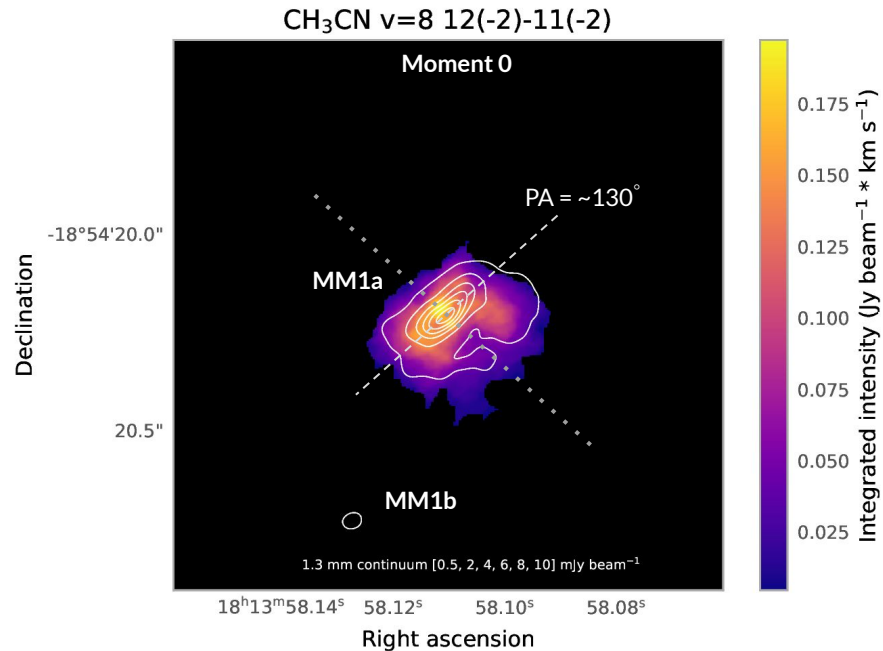
Band 6 [220.63, 222.15, 221.44, 219.91, and 219.44 GHz]





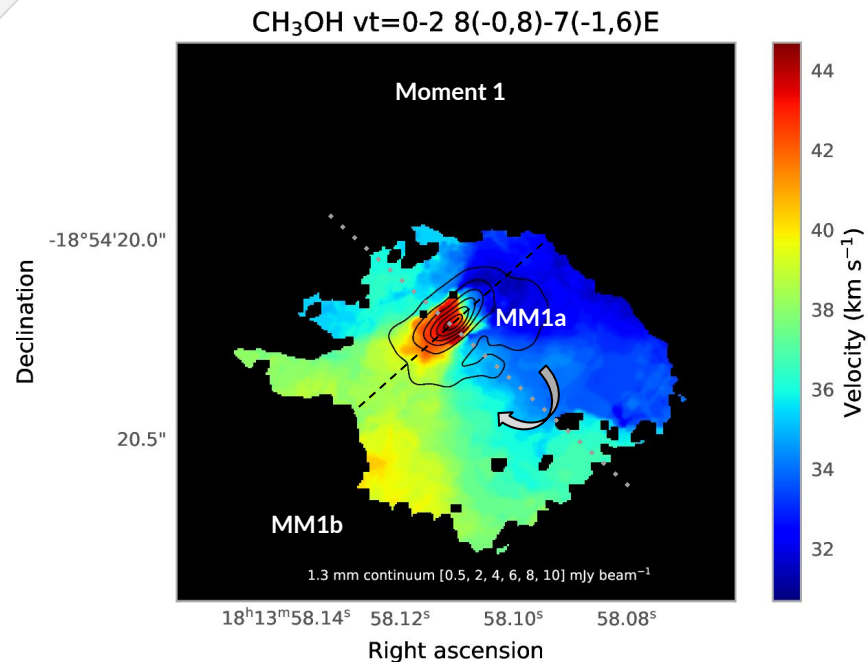
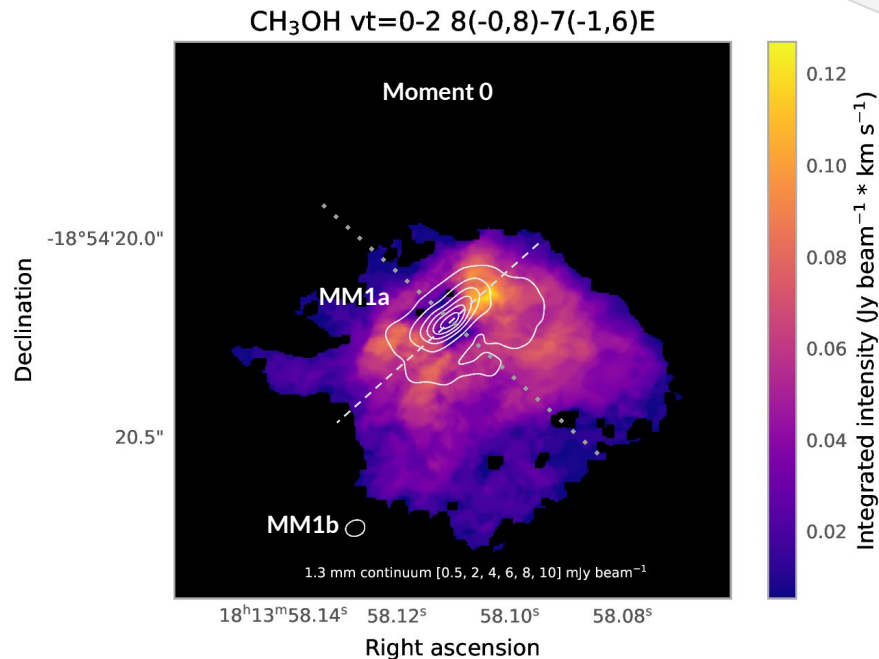
# Compact

Disk interpretation - agrees with the results of [Jlee+2016](#), [Jlee+2018](#)



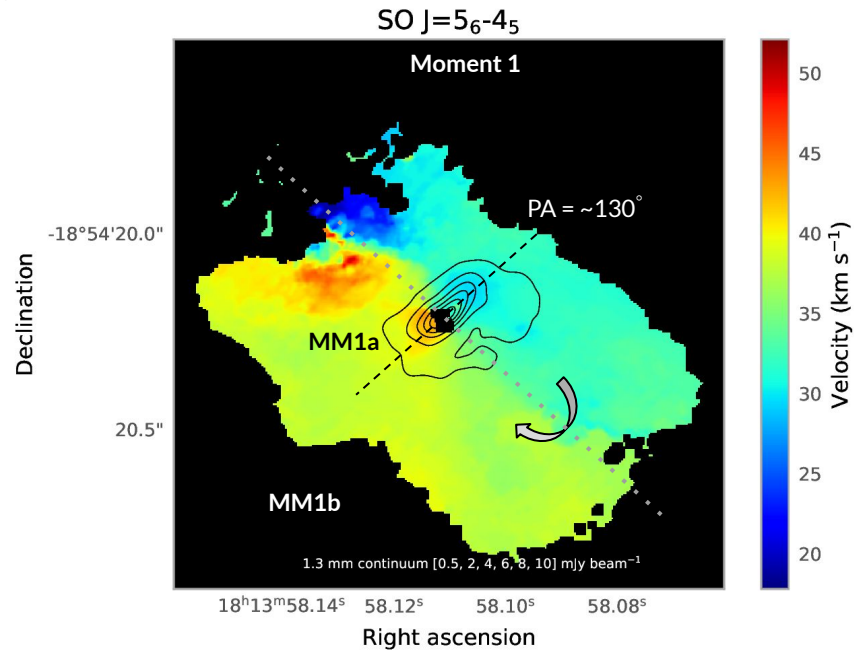
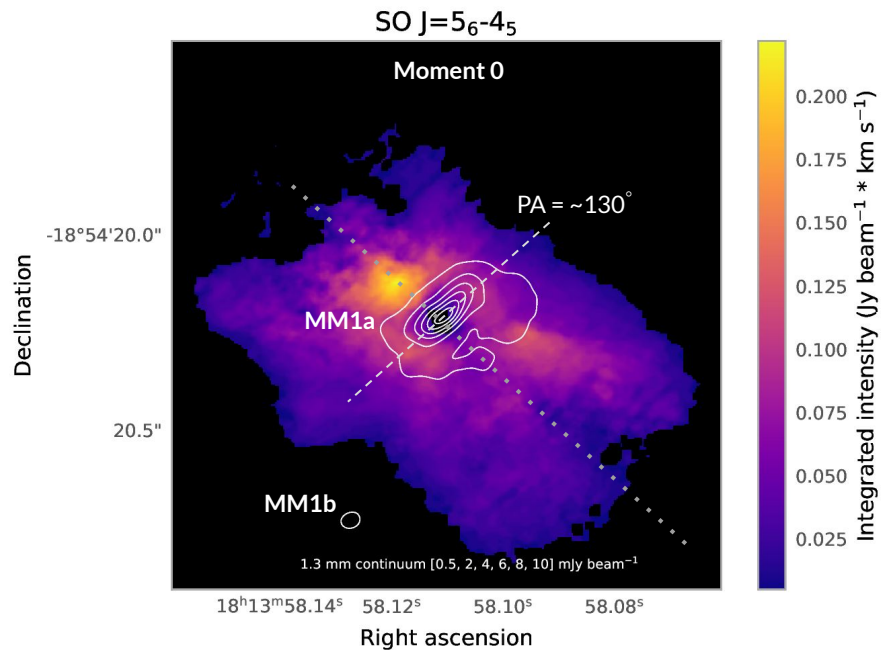
# Intermediate

Rotation at large radii?

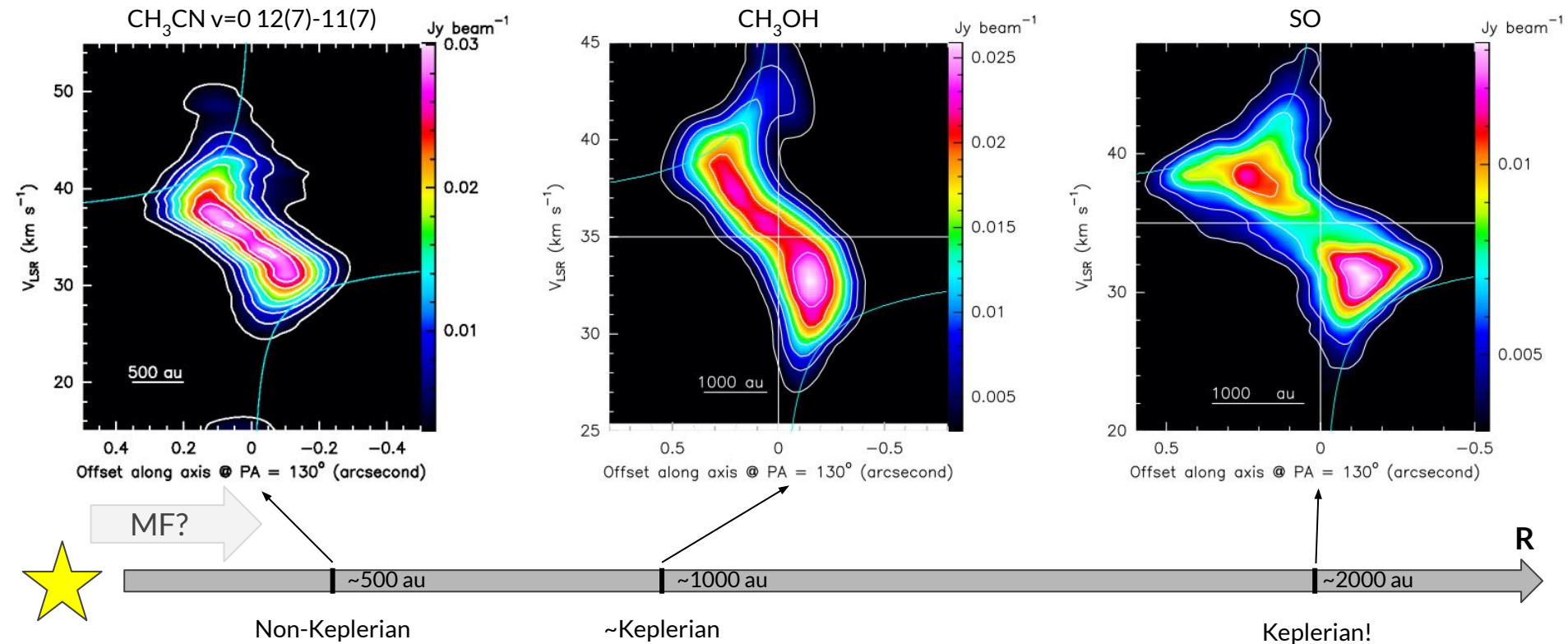


# Extended

Rotation at large radii?

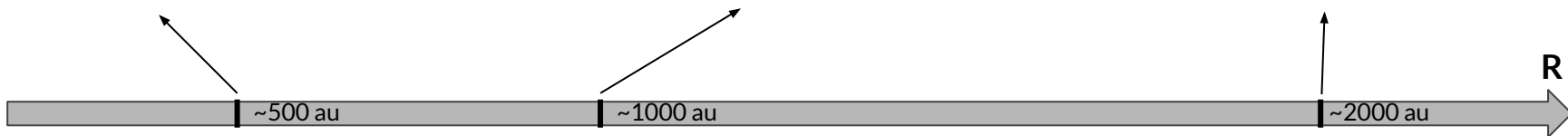
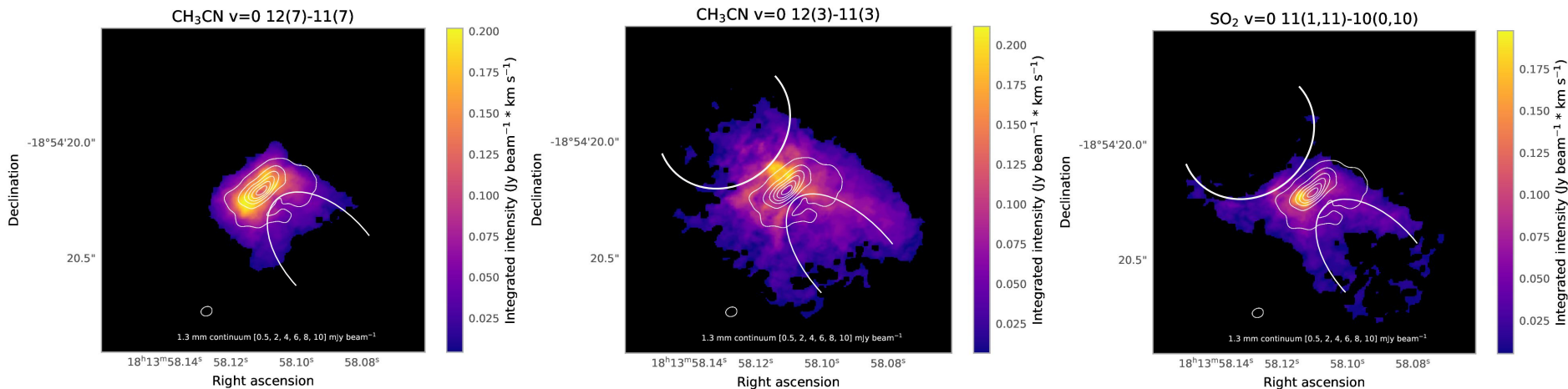


# PV diagrams



# PV diagrams

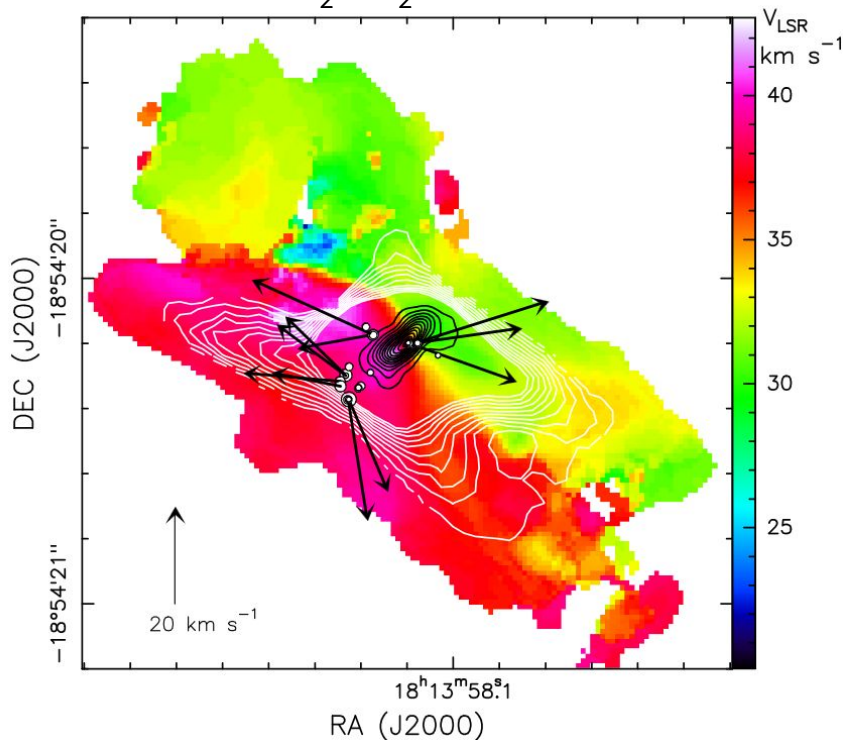
Outflow cavities traced  
at different scales



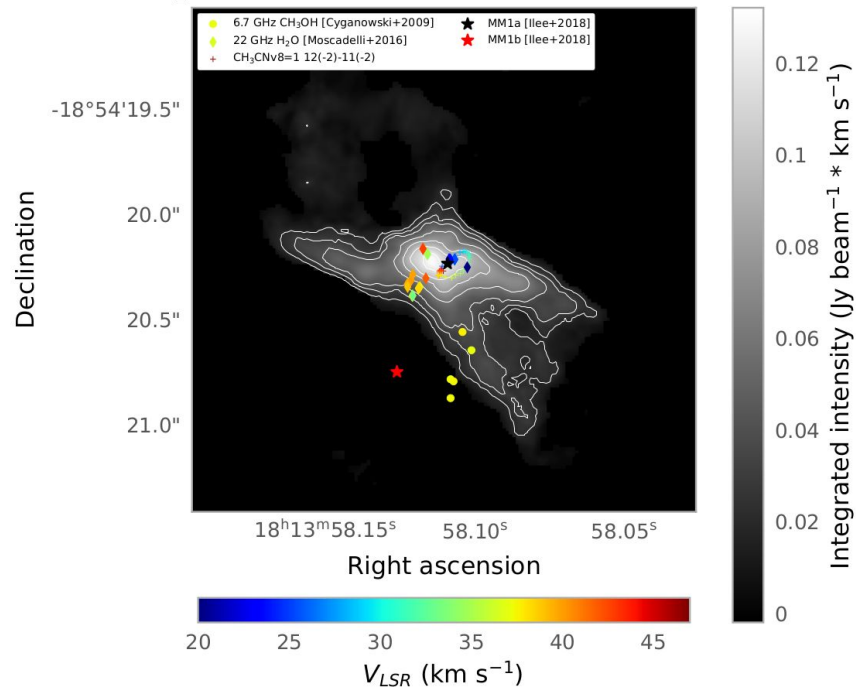
# Masers

H<sub>2</sub>O masers trace a wide outflow-launching region

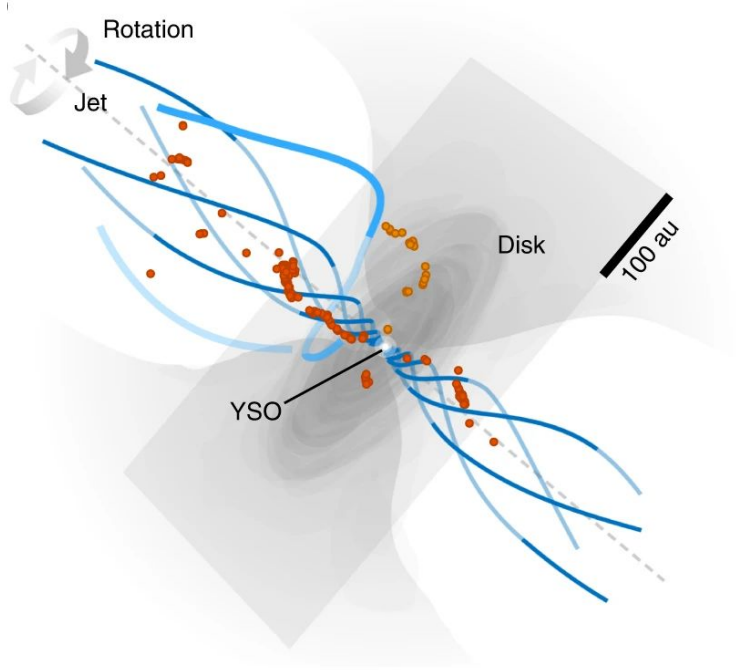
SO<sub>2</sub> + H<sub>2</sub>O masers



SO<sub>2</sub>  $v=0$  11(1,11)-10(0,10) (219.355 GHz)







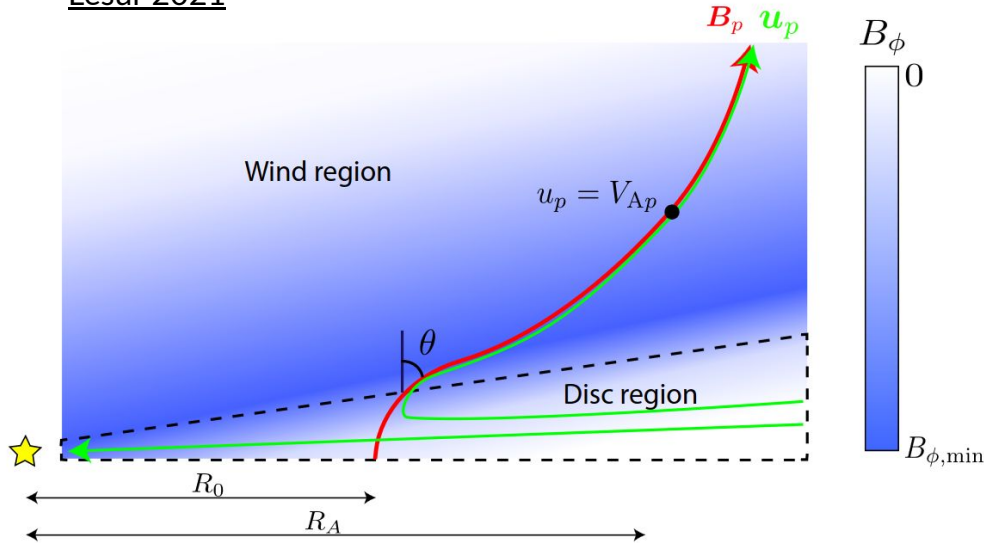
Moscadelli+2022

# 03.

## Disk-wind

# Models

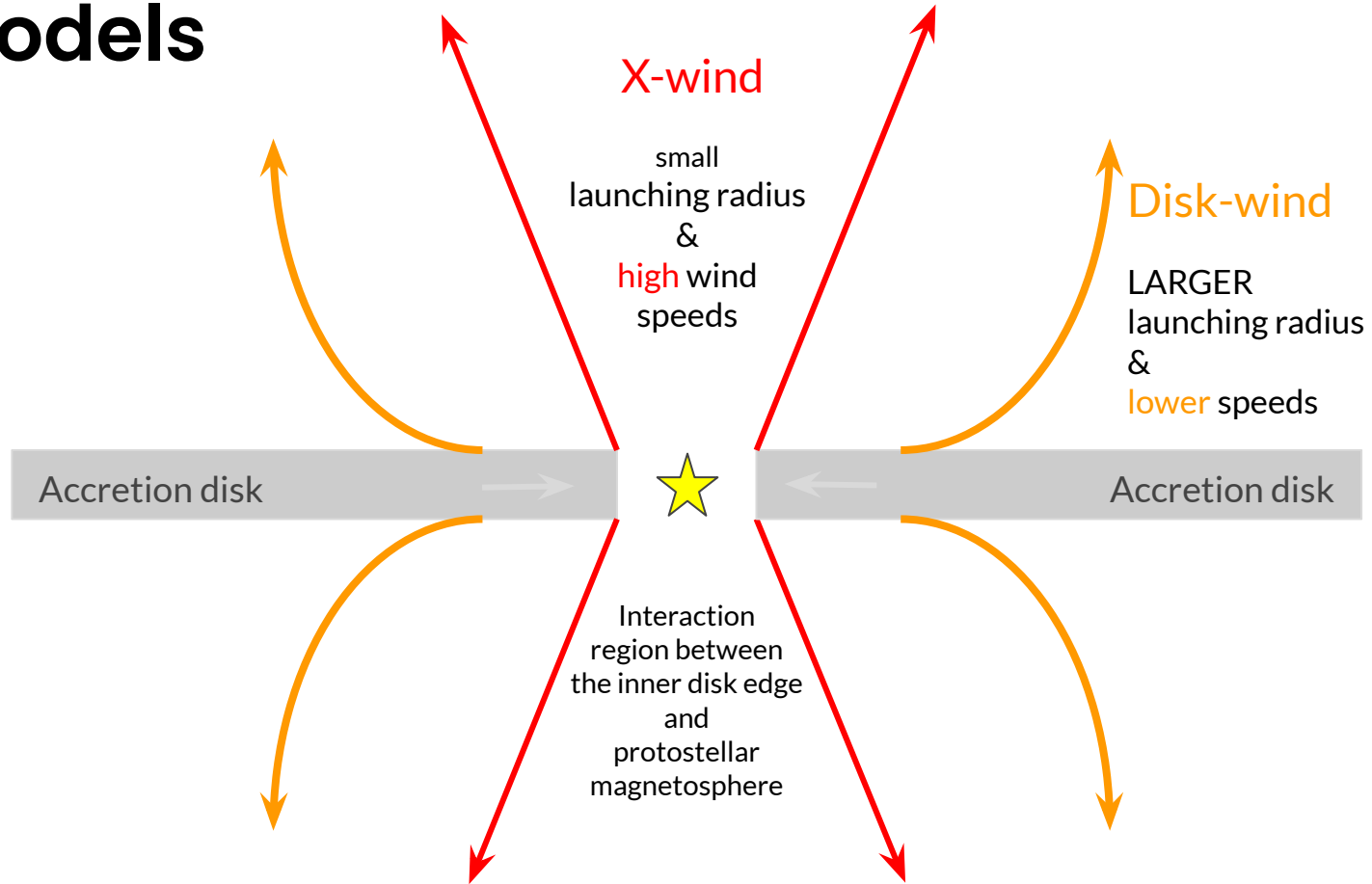
Lesur 2021



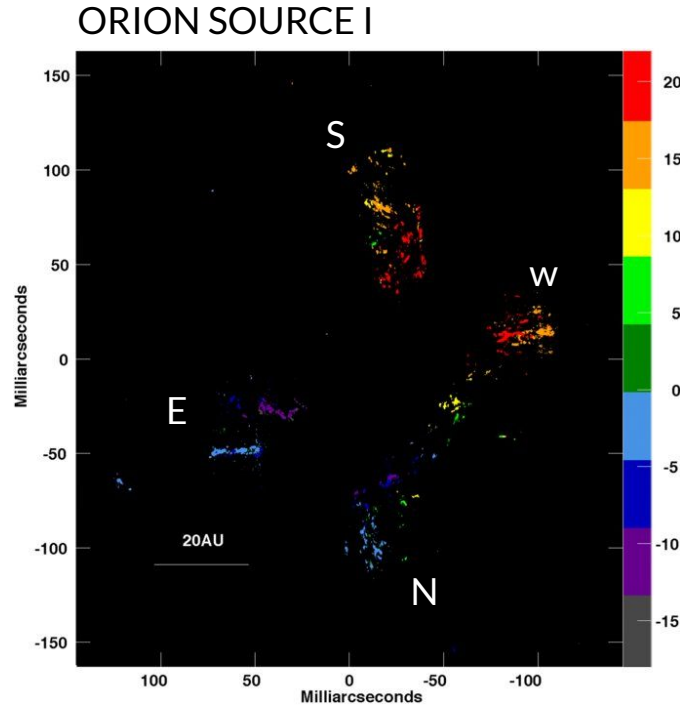
- The **launching region** is extended and the **streamlines** are  **$\sim$ parabolic**
- Misalignment between MF and streamlines of accretion -> **corkscrew-like pattern** in the magnetic field
- From  $R_0$  to  $R_{Alfven}$ , the outflow is in  **$\sim$ solid rotation**

Angular momentum [Accretion]  $\rightarrow B_{toroidal}$   $\rightarrow$  Angular momentum [Outflow]

# Models



# Known cases in MYSO

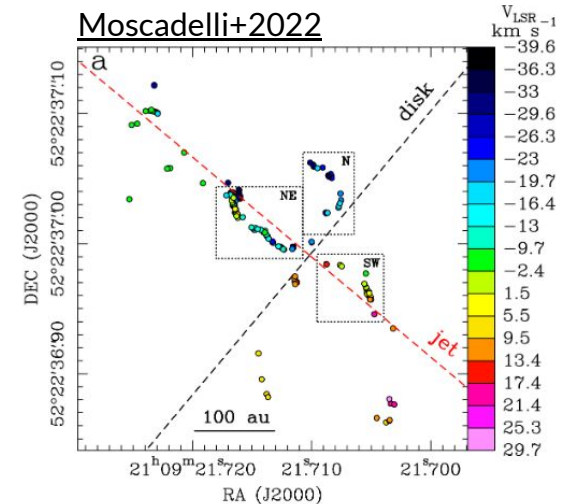
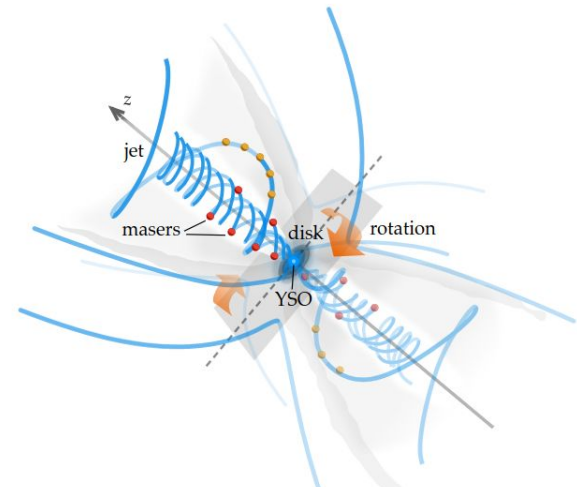


Matthews+2010

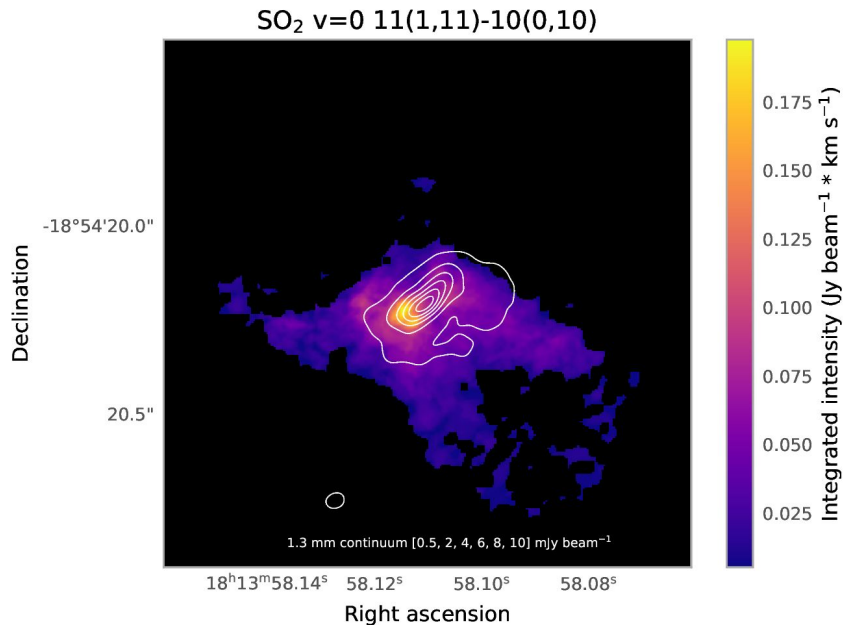
- VLBI imaging of **SiO maser** in MYSO **Orion Source I**
- Molecular material within **~20–100 AU** of the MYSO
- **X-shaped locus** - the emission in the S and E arms is blueshifted, and emission in the N and W is redshifted

# Known cases in MYSO

- **Global VLBI observations of the 22 GHz water masers in IRAS 21078+5211**
- **The first direct observation of a disk-wind**
- Water masers trace streams of gas from the YSO's disk:
  - close to the disk rotation axis the masers trace **sinusoidal patterns** (signatures of a **spiraling motion** along the jet axis)
  - at larger separation the maser **velocity changes linearly** with the radial distance (maser stream **co-rotates** with its launch point from the disk)



# Conclusions



- G011.92-0.61 is one of **the clearest** cases of a **disk wind** detected in MYSO
- The strong collimated outflow is probed at the scales from ~5000 au up to ~10 000 au, the detected molecular emission traces **parabolic outflows** centered on MM1a
- The Keplerian rotation profile obtained for the molecular outflow tracers suggests **the magneto-centrifugal launch of the wind**



# Thanks!

Do you have any questions?

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