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ASTROPHYSICS

HARVARD & SMITHSONIAN

Using ALMA to Observe a Rare Hydrogen Recombination Line Maser–Emitting Star

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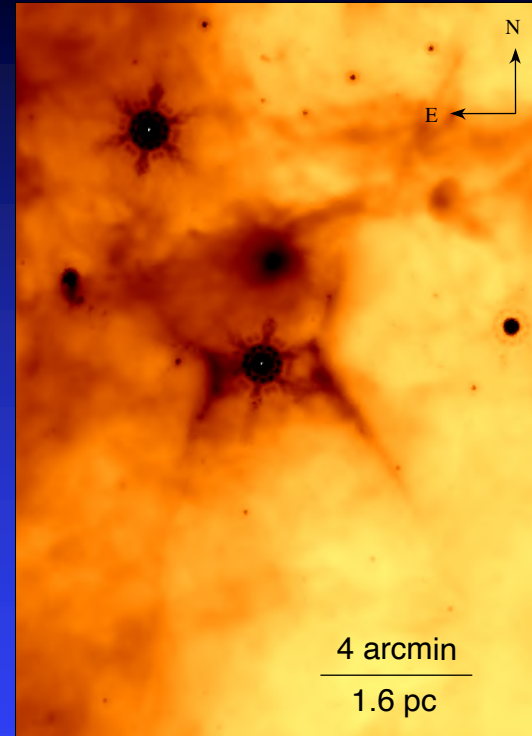
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MWC 349A

- Rare phenomenon – hydrogen recombination line masers
- Maser: natural source of strong radio emission
- Mapping masers allows us to study disk/wind dynamics



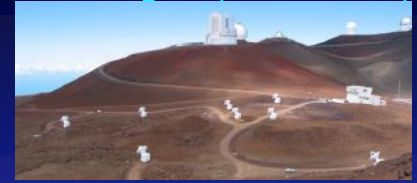
Atacama Large Millimeter/submillimeter Array
(ALMA)



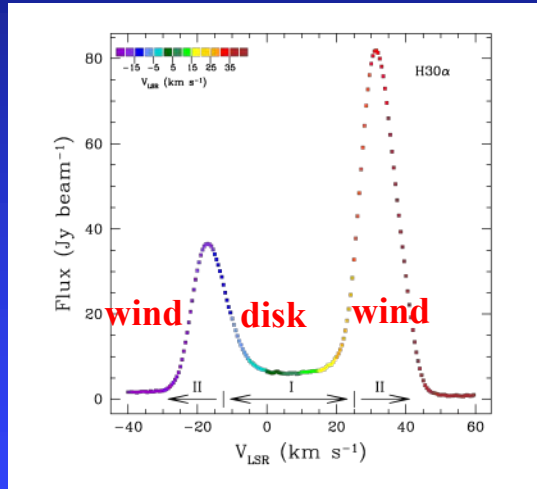
Gvaramadze & Menten 2012

Previous Study with Submillimeter Array (SMA)

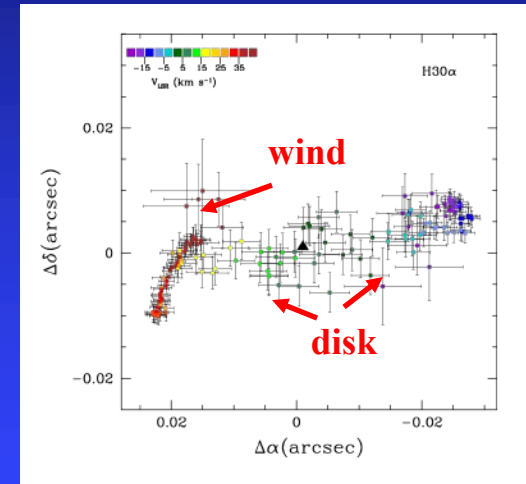
- Identified H30 α /H26 α masers in disk, and in rotating/expanding wind



H30 α emission spectrum



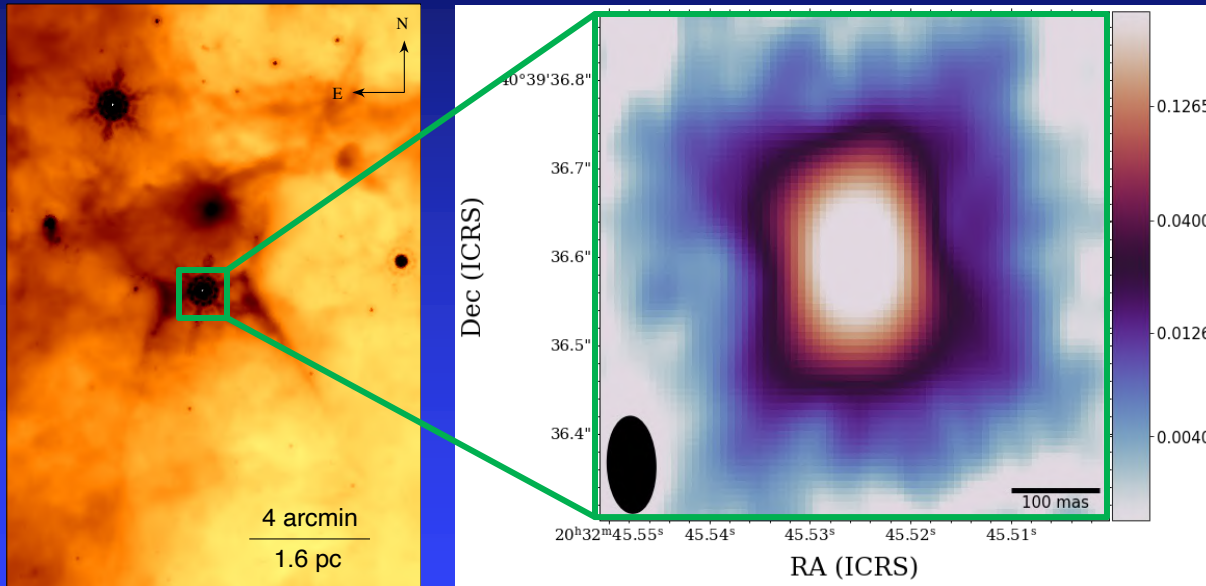
Spatial distribution of H30 α masers



Zhang+ 2017, see also Martin-Pintado+ 2011; Weintraub+ 2008

Continuum Image with ALMA

Band 6 (1.4 mm) continuum

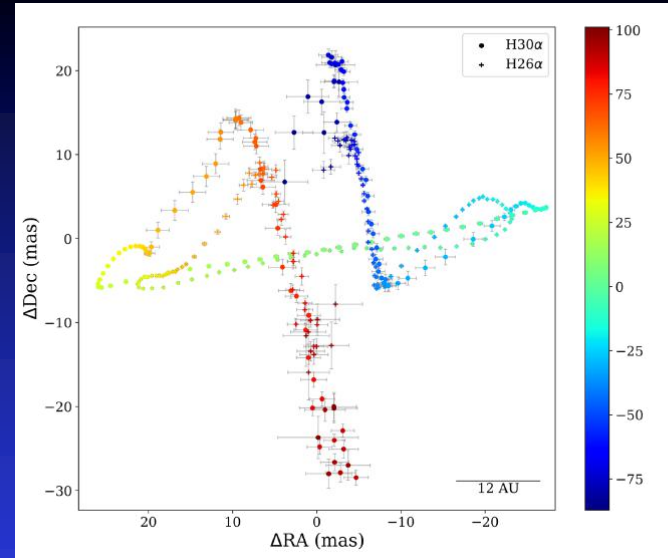
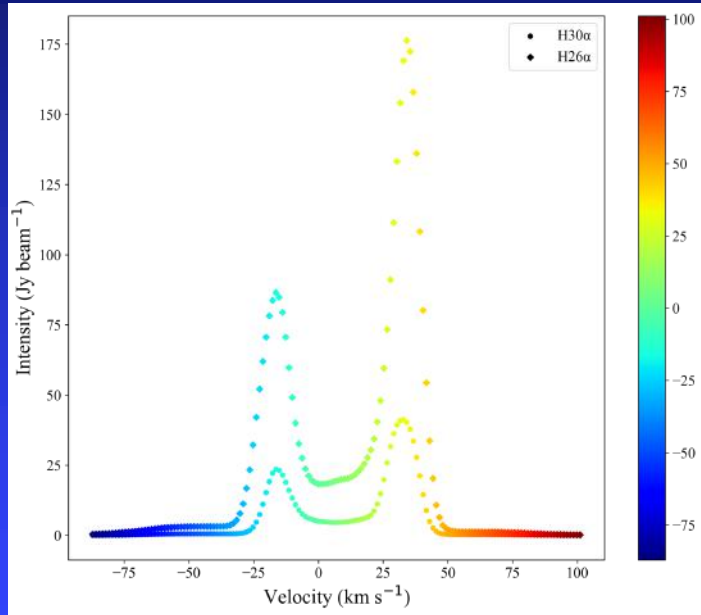


Visible structures

- Waist = circumstellar disk
- Hourglass shape = wide-angled ionized wind

Maser Positions

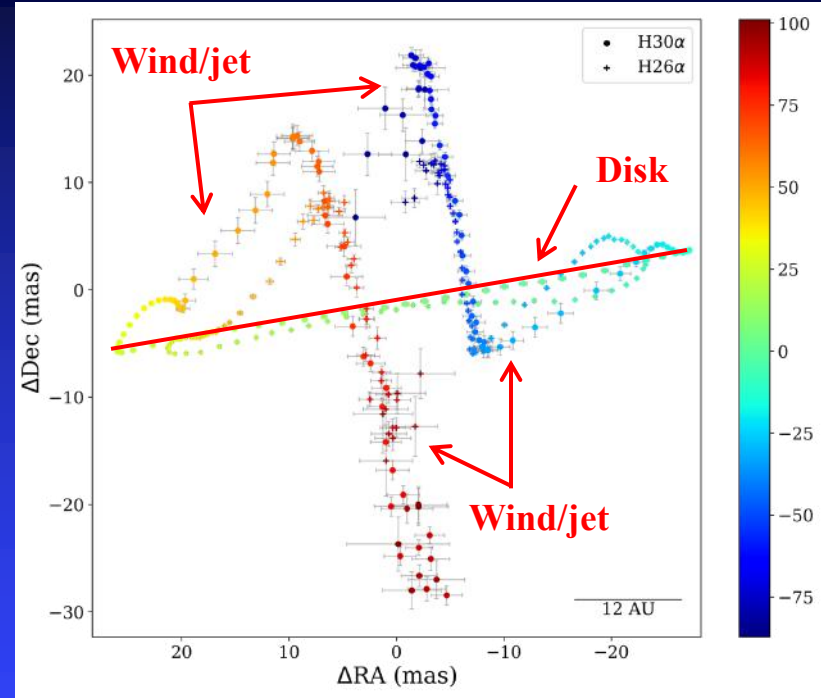
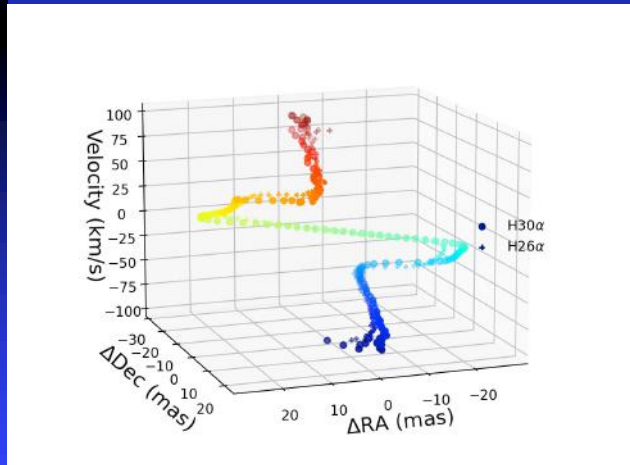
Emission spectra



- H26 α and H30 α
- Positions obtained via a centroid fitting method
- Color indicates radio velocity (km/s)

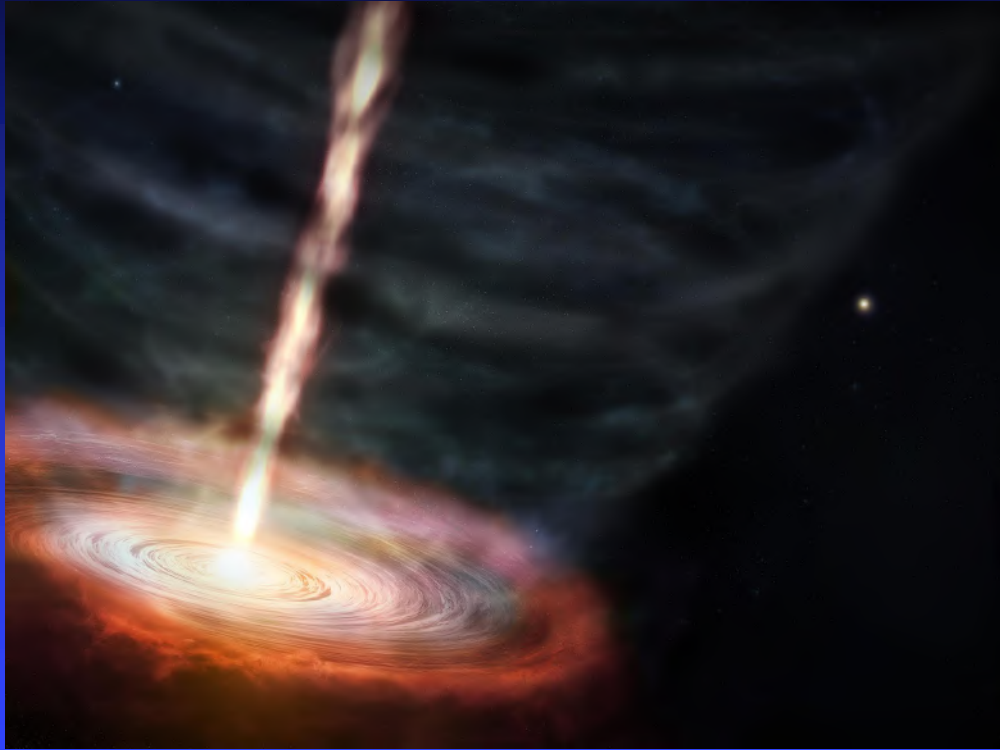
Structures Visible in the Maser Plot

- Disk masers confirm inclination angle of 9° and extent of maser emissions
- Space velocities of masers along the polar axis can reach > 500 km/s (too high for photoevaporating wind)



Suggests a jet component!

What does this look like?



Summary

- Spatially resolved an hourglass structure in 1.4 mm continuum.
- Masers are distributed in a Keplerian disk and in an ionized wind above and below the disk.
- **First evidence of a collimated jet!** - new group of high-velocity masers along the polar axis.

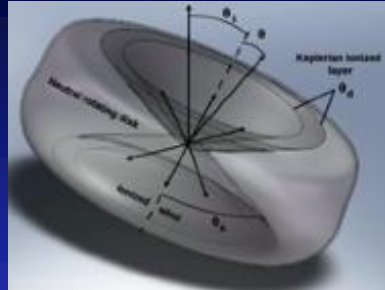
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Additional Slides

Model

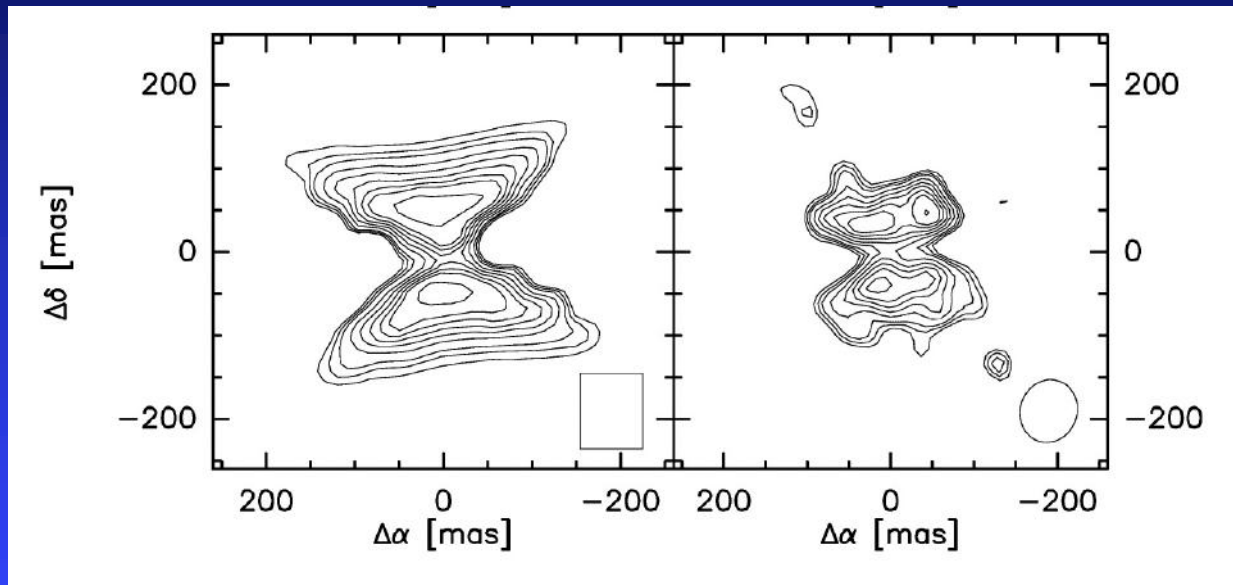


Báez-Rubio+ 2013

- Central star of 35 M_{sun}
- Ionized disk in Keplerian rotation
- Expanding, rotating wind with terminal velocity of 60 km/s

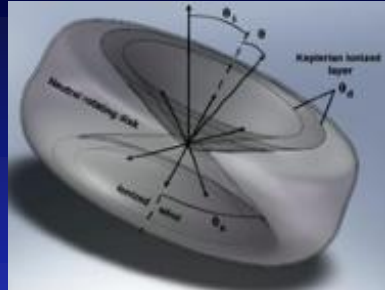
Model – Data Comparison

Model continuum emission Observed 7mm continuum emission



Báez-Rubio+ 2013

Revised Model



$$v_r = v_{rot} + [v_{wind} + v_{jet} \times f(\psi - \psi_0)] \frac{r^{b_v}}{r} z$$

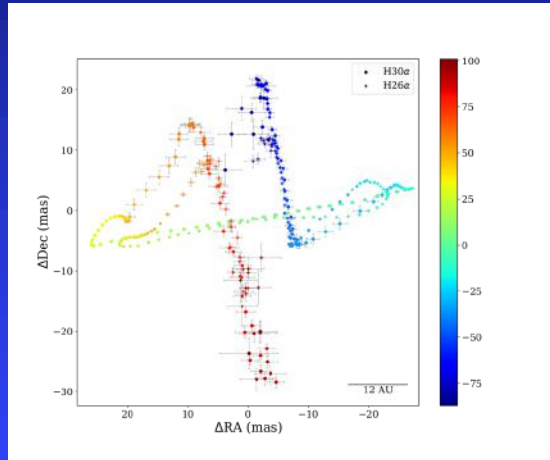
Martínez + in preparation

- Central star of 35 Msun
- Ionized disk in Keplerian rotation
- Expanding, rotating wind with terminal velocity of 60 km/s
- Narrow opening-angle jet along disk rotation axis (**new component add to Bález-Rubio+ 2013**)

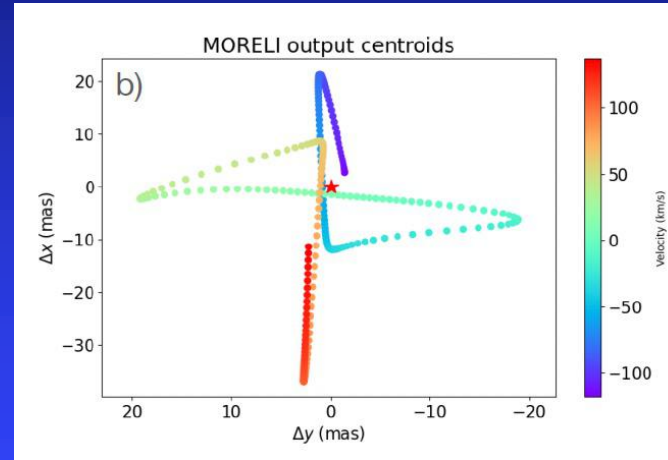
Model and Data Comparison

- Model with a disk, rotating/expanding wind and a jet fits the data

Observed maser distribution



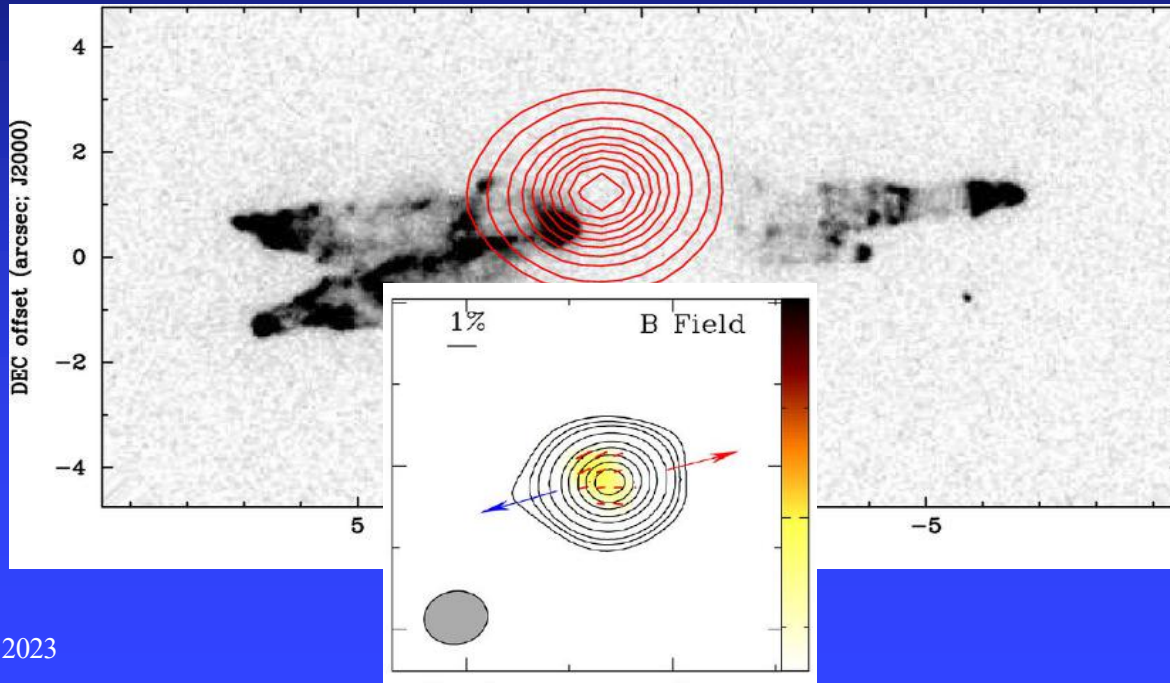
Model



Protoplanetary Nebula: CRL 618

- Magnetic fields detected aligned with the outflow axis

H α image and 0.8mm continuum
Sabin, Zhang+ 2014



Model and maser locations on disk

