From Solar System to the Galactic Center through ALMA

Nanda Kumar
IA-Porto

Science Drivers

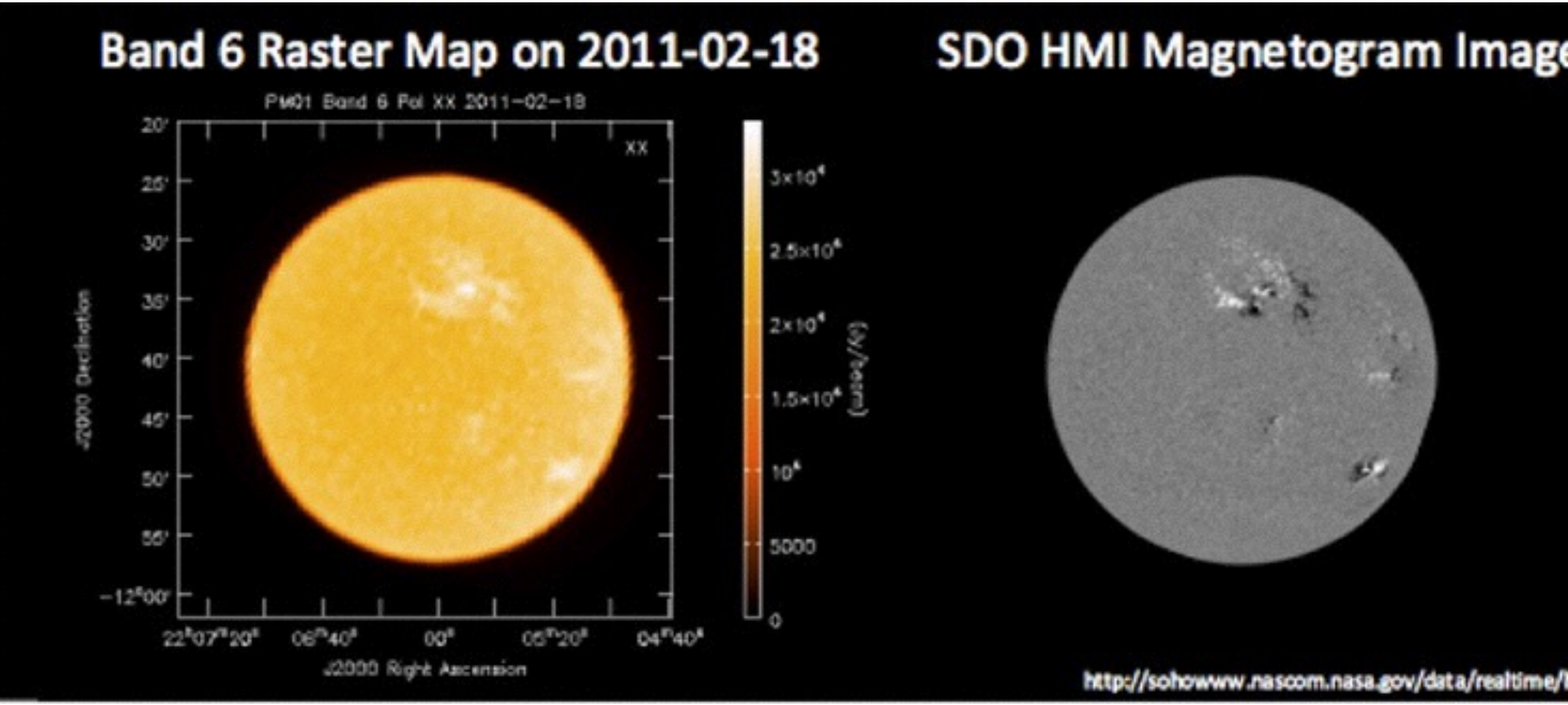
- Cosmology and high redshift universe
- Galaxies and galactic nuclei
- ISM, star formation and astrochemistry
- Circumstellar disks, exoplanets and the solar system
- Stellar evolution and the Sun

The Sun

- Dynamic Chromosphere: Chromosphere is a complex, rapidly evolving plasma structure, the thermal emission from which will be seen through ALMA. It will provide sub-arcsecond snapshots of the dynamic chromosphere to study the ionization structure and temperature of the lower atmosphere of Sun, eliminating the need for complex modeling.

- Radio Recombination Lines : High-n hydrogen RRL, lines from some ions (O VI)

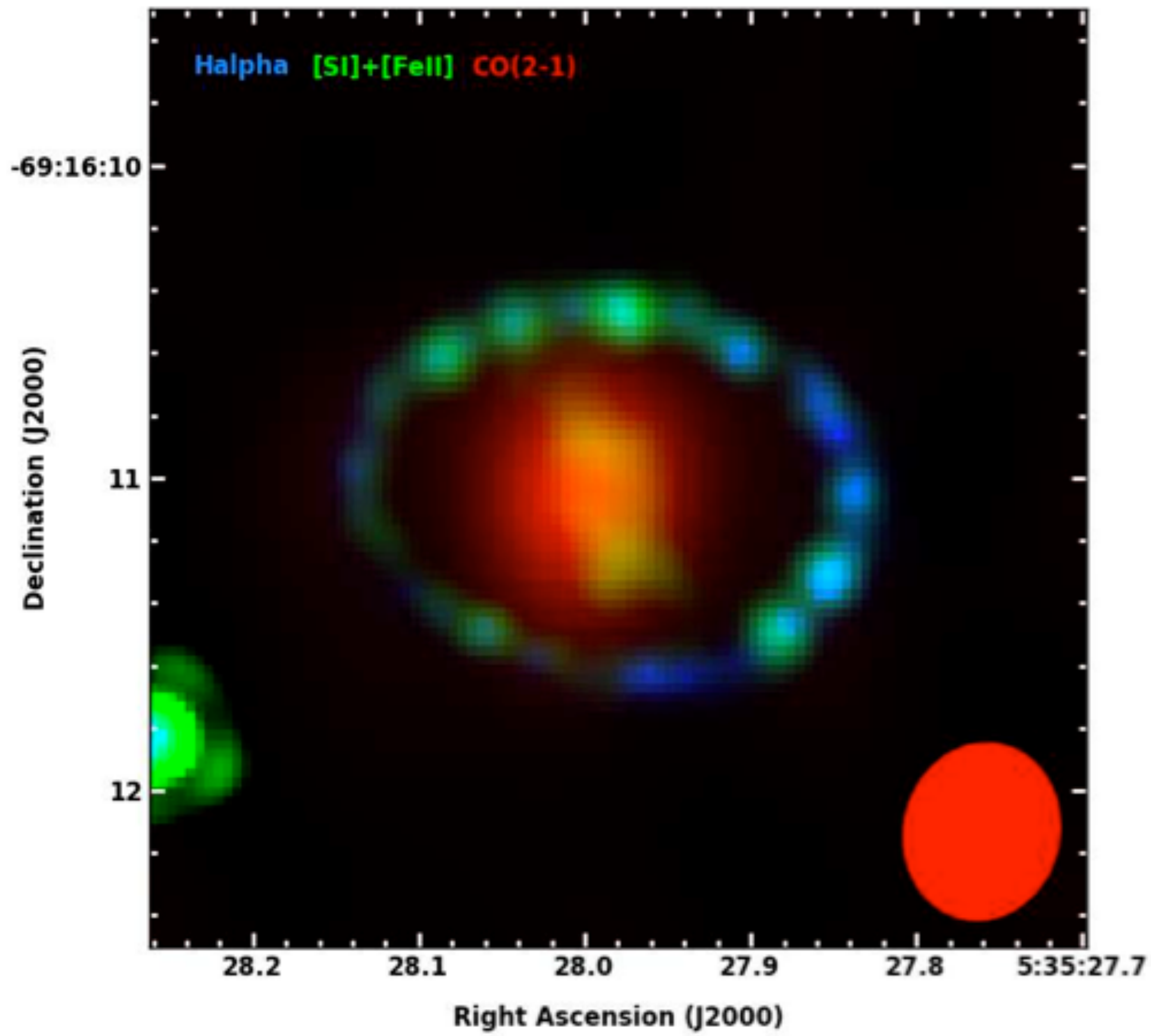
- Flares and Prominences: emission from synchrotron radiation in the sub-THz regime



Solar Chromosphere

Imaged through a high level of atmospheric water vapor substituting the effect of a solar filter.

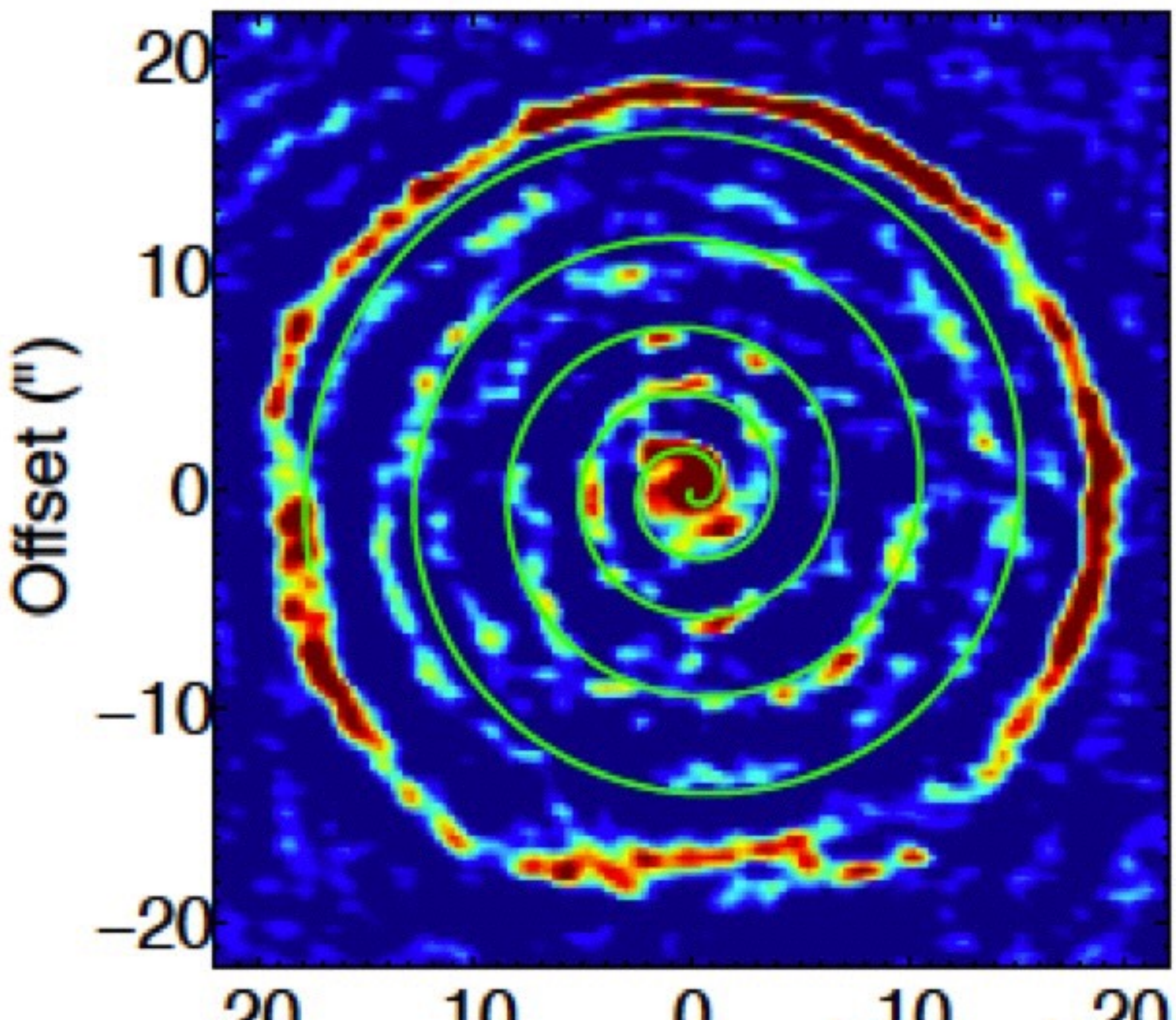
Supernovae



CO and SiO emission detected in the inner ejecta of Supernova 1987A. Scope for studying nucleosynthetic character of the ejecta reflecting the stellar properties.

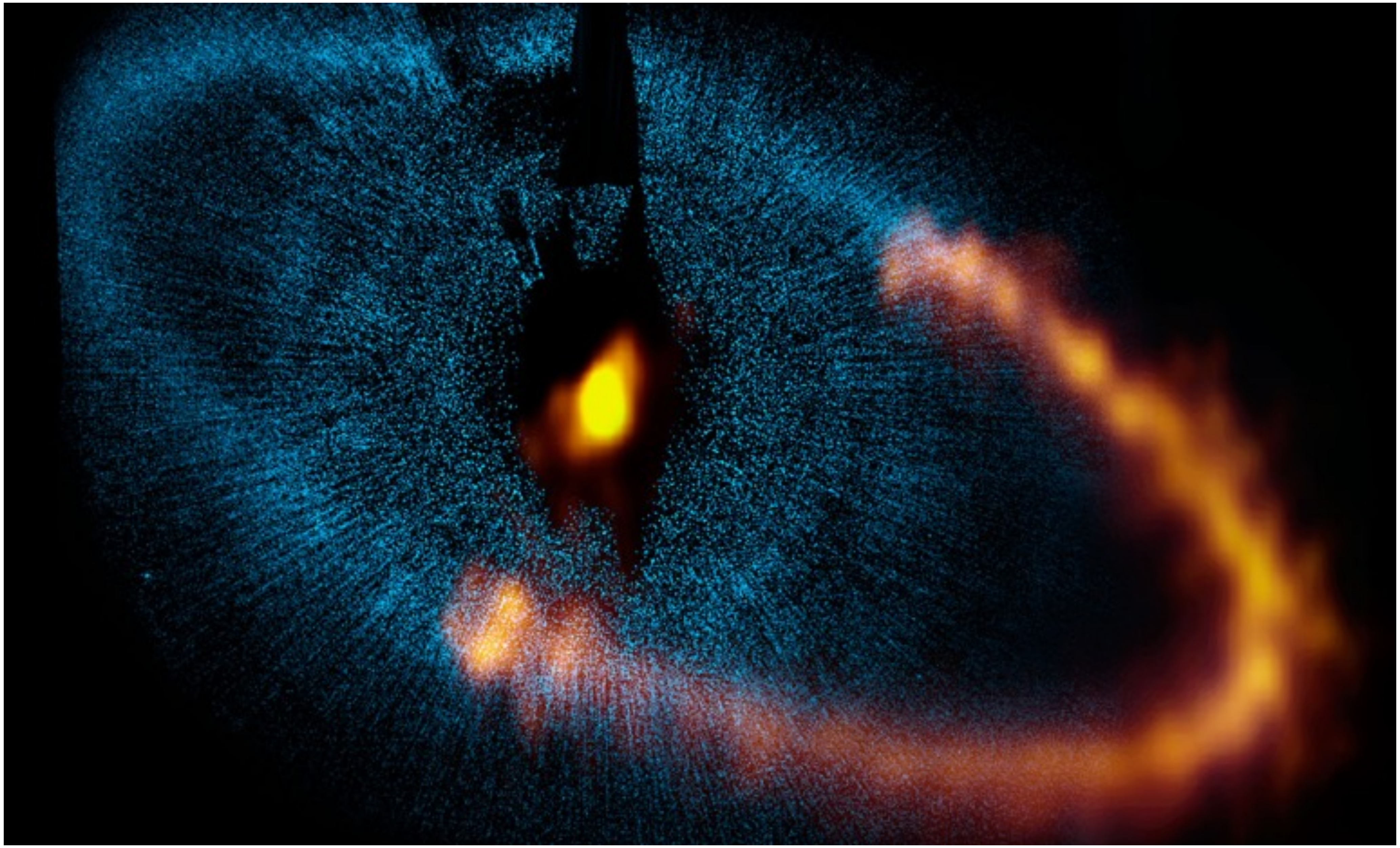
Asymptotic Giant Branch Stars

Molecular shell of R Sculptoris



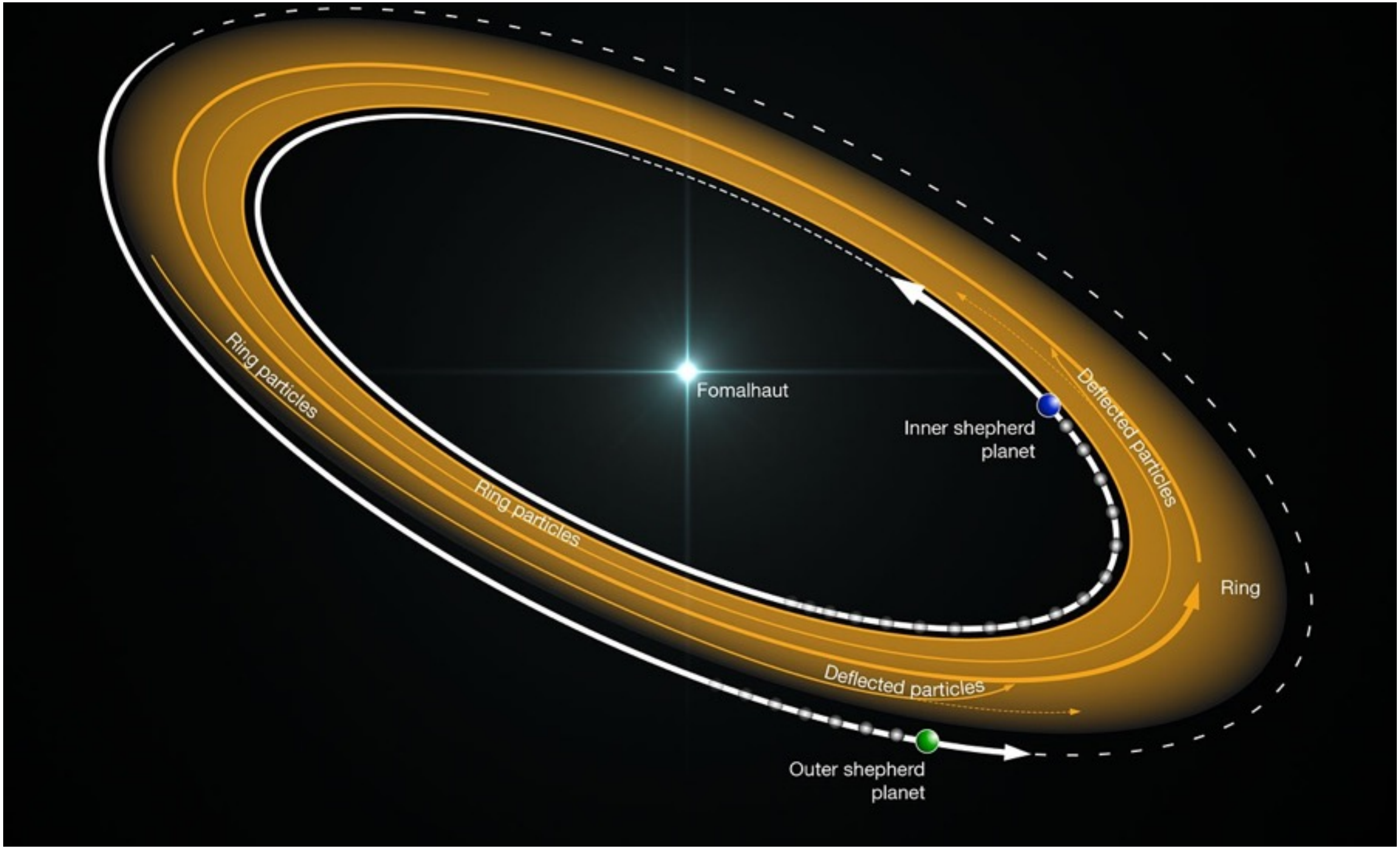
Disks and Planets

- Ring in Fomalhault: planets defining the ring
- Dust traps around young stars: comet factory
- Giant planet formation insight: streams of gas from outer ring to the outer disk



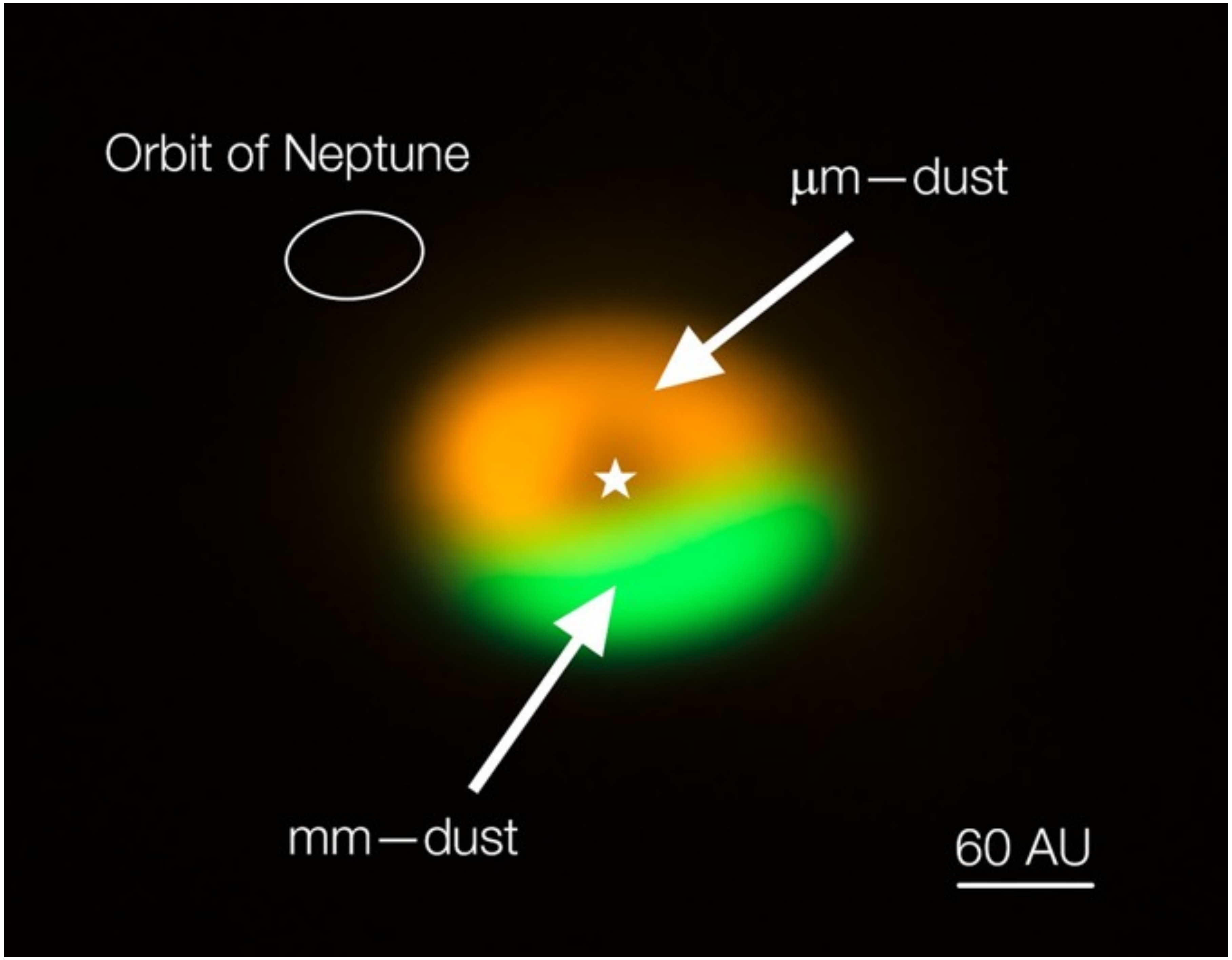
Debris Disks

Fomalhault at 350GHz with ALMA (red) with HST optical image (blue)



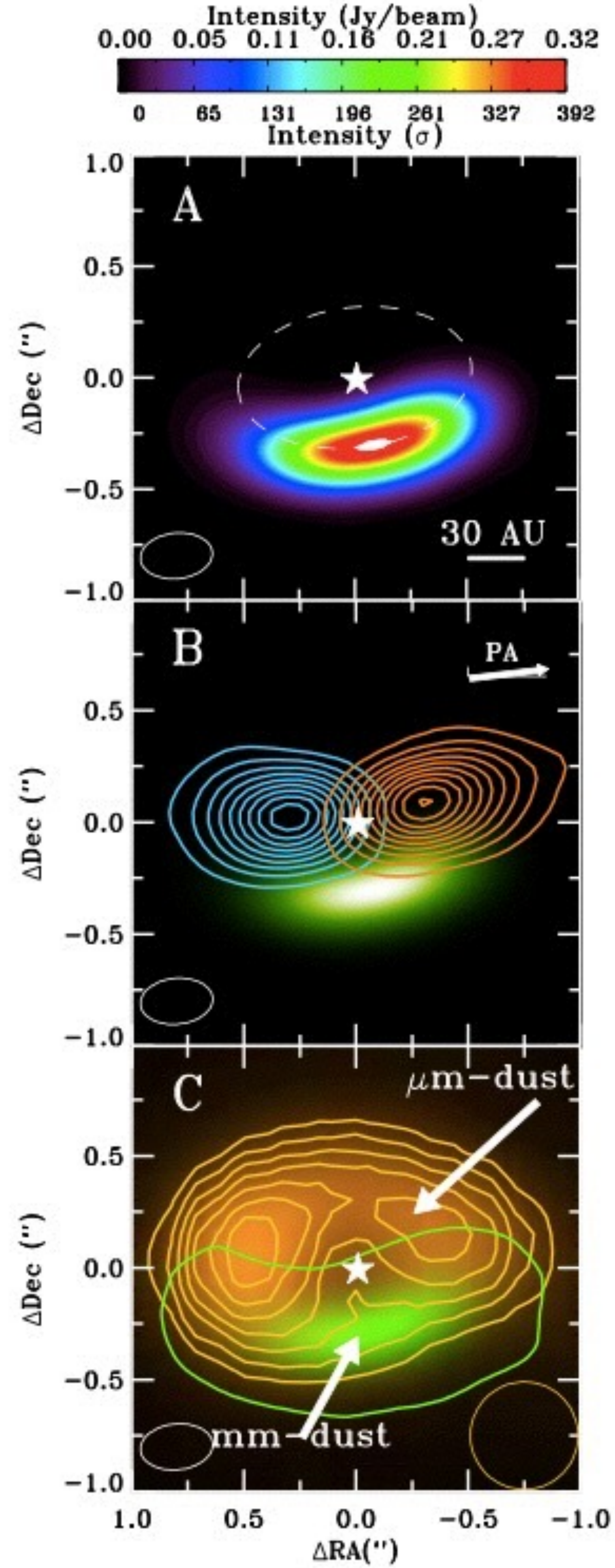
Evidence for shepherd planets defining the sharp ring.
Original idea inspired by voyager studies of Saturn's rings.

Boley et al. 2012, ApJ, 750, 21



Dust traps in Protoplanetary disks.

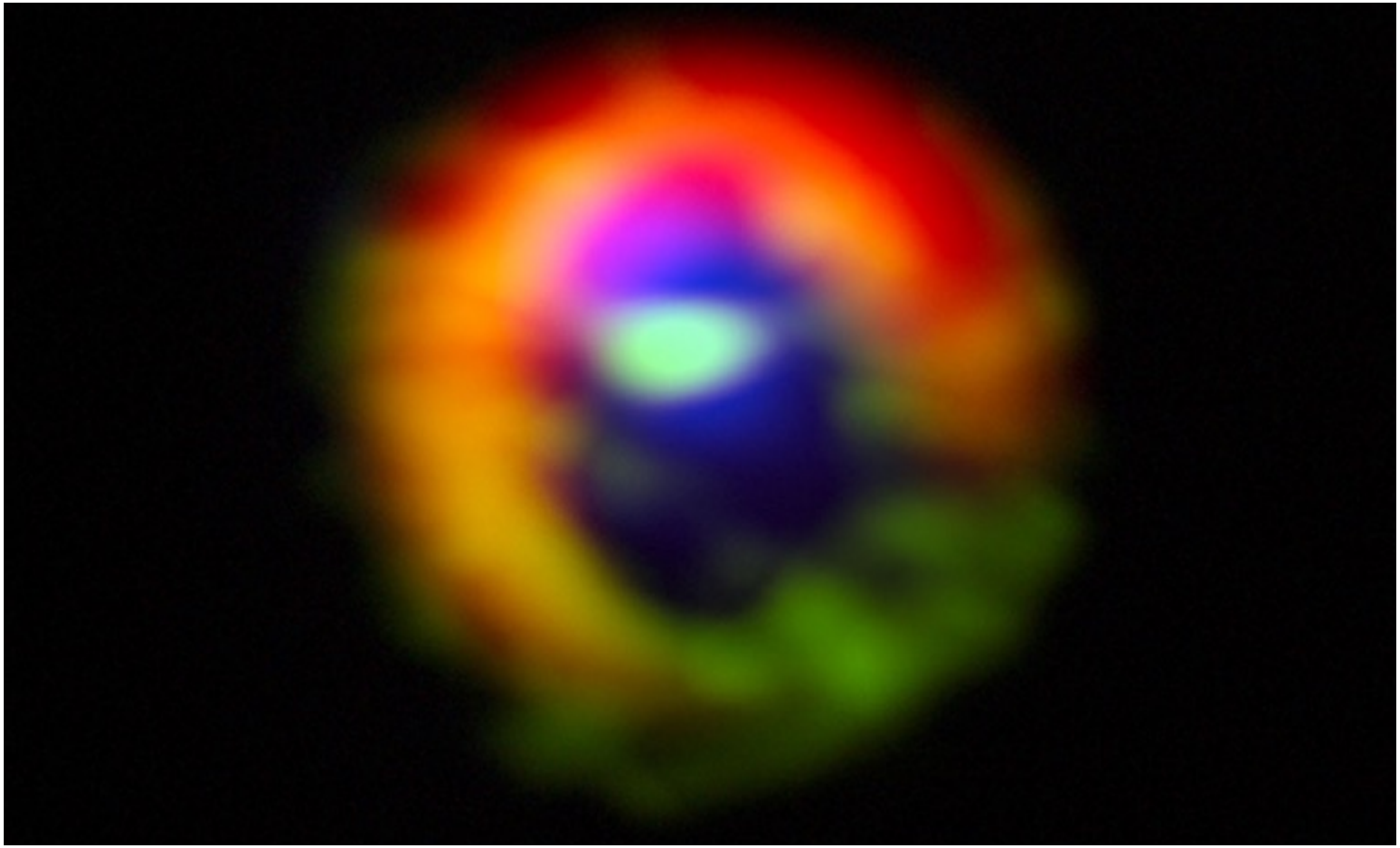
Oph-IRS48, Orange is micron sized dust from VLT/VISIR observations, green is mm sized dust from ALMA



Intensity (Jy/beam)
0.00 0.05 0.11 0.16 0.21 0.27 0.32
0 65 131 196 261 327 392
Intensity (σ)
A
30 AU
B
PA
C
μm-dust
mm-dust
ΔDec ('')
ΔRA('')
1.0 0.5 0.0 −0.5 −1.0

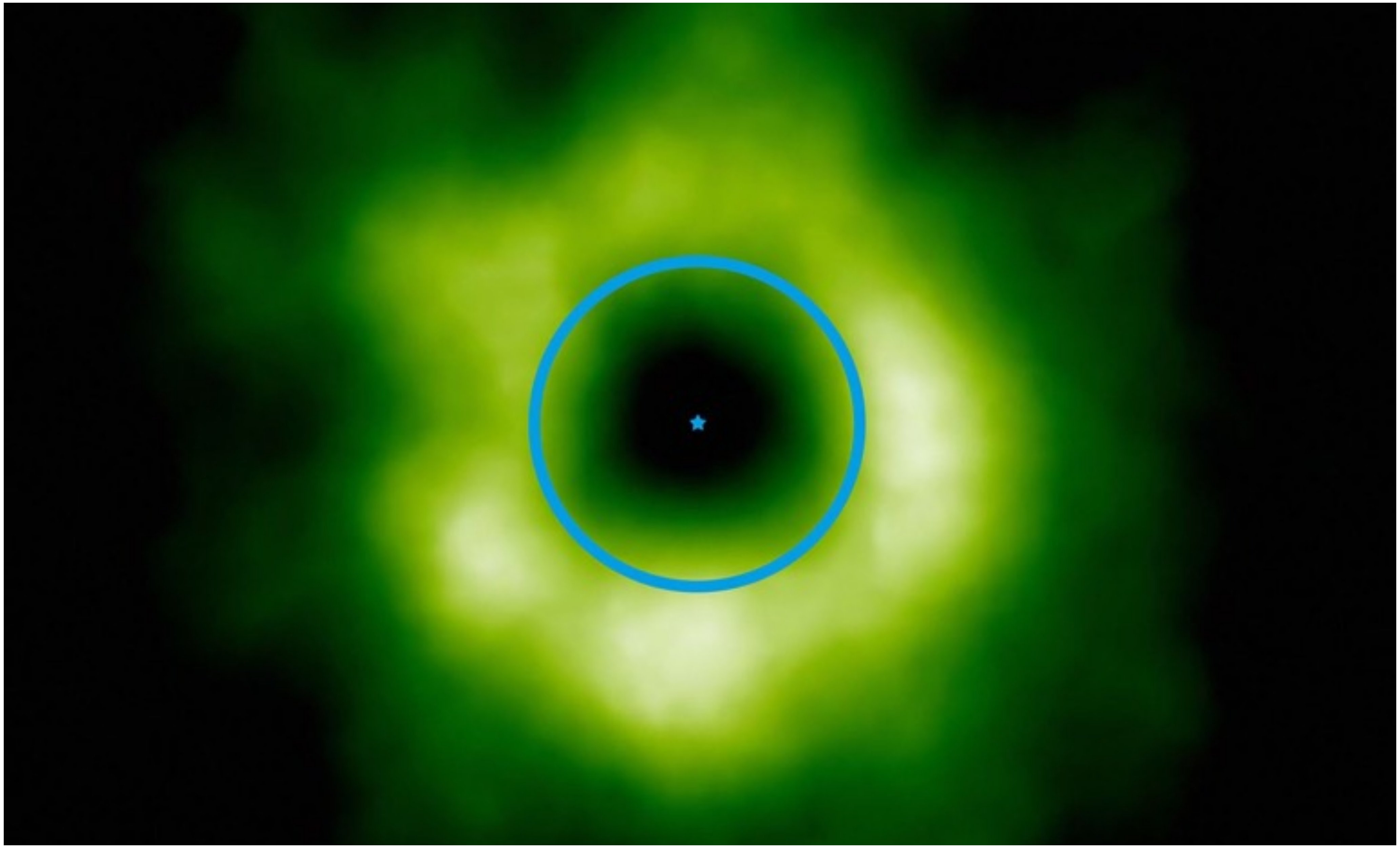
Simulation showing how a planet can create a dust trap

Large grains can not survive inside as they would be broken to small grains through collisions are get pulled to the star



Gas streams in the Young star HD142527
to aid formation of Giant Planets

CO 3-2, HCO+ 4-3, Continuum
Band 7, ~ 850micron

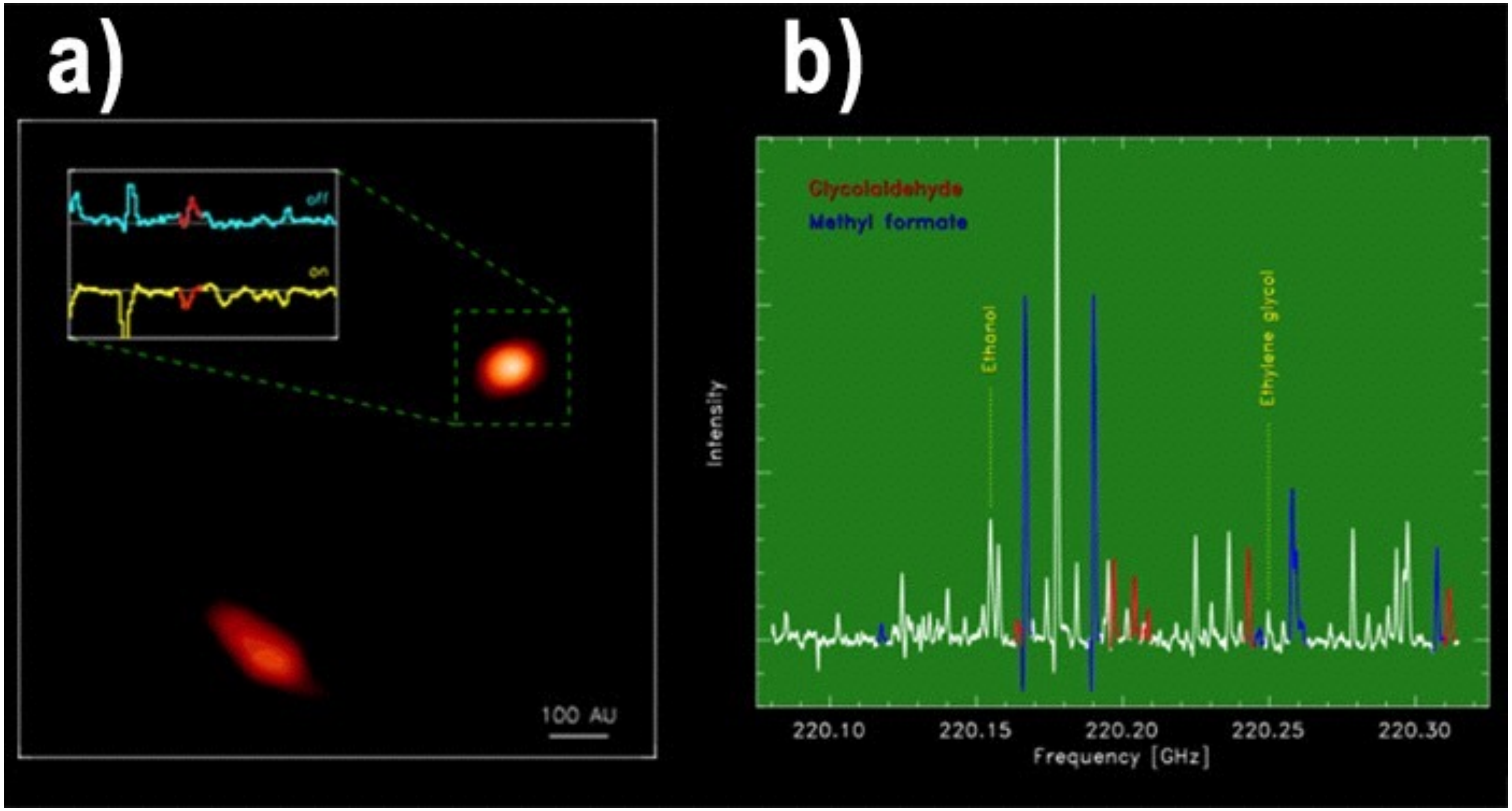


Snow Line in TW Hydra

N2H+ image of TW Hydrae disk. Radius ~30AU.
Chunhua et al. 2013, Science, 341, 630

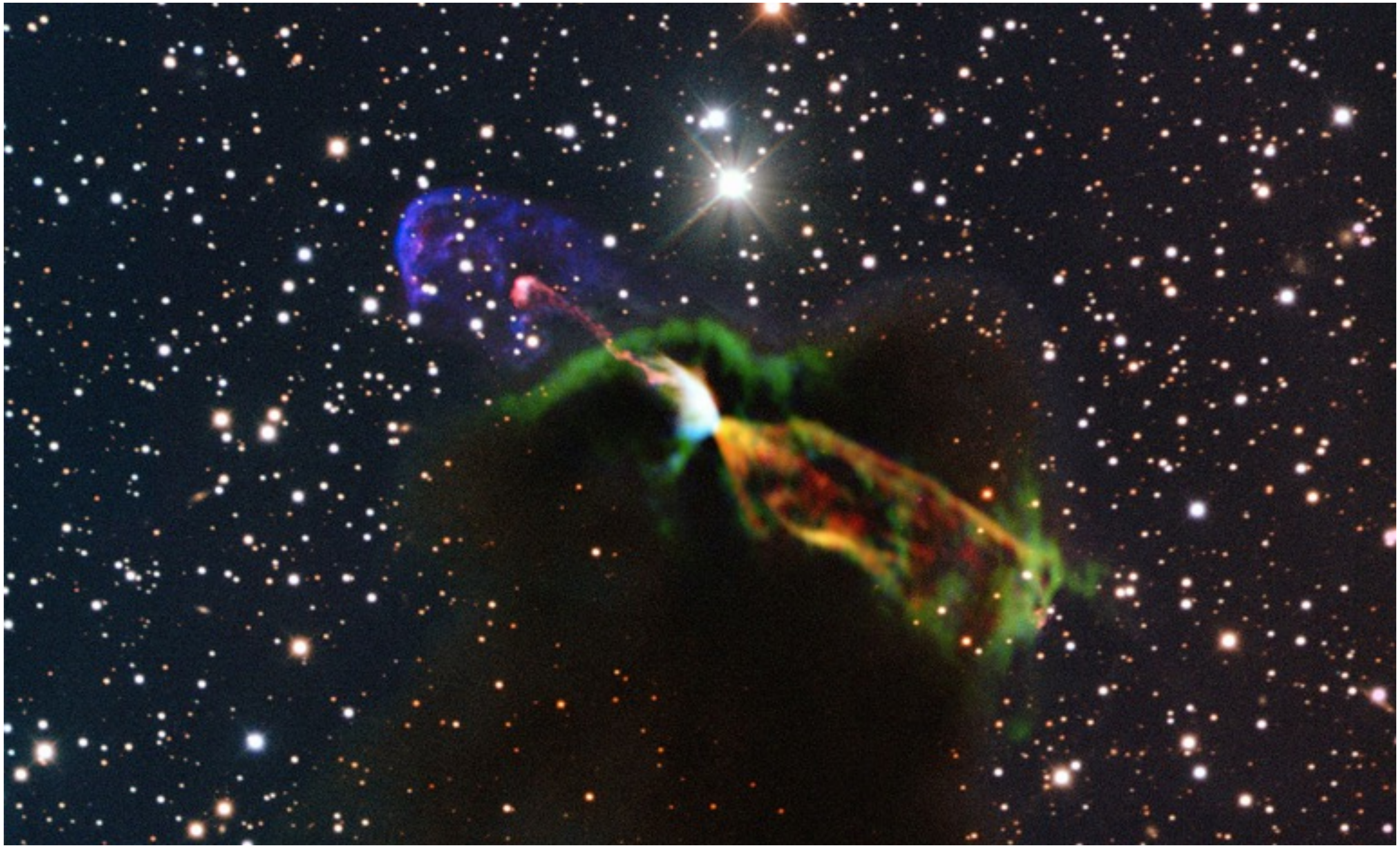
Star Formation: Low Mass

- Simple sugar molecules in young stellar disks
- Brown dwarfs disks are capable of forming planets
- Detailed view of outflows. very high velocity components



How complex can molecules become before being incorporated into the planets?

IRAS16293: band 9 continuum image of the solar type protostar with the spectrum showing Glycolaldehyde lines. The gas is observed in a region of ~30AU and slowly moving towards the planet forming zones.



Herbig Haro Flow HH46/47

NTT optical image + ALMA composite
pink and purple are optical, orange and green are CO data

Resolved protoplanetary disk around HD100546

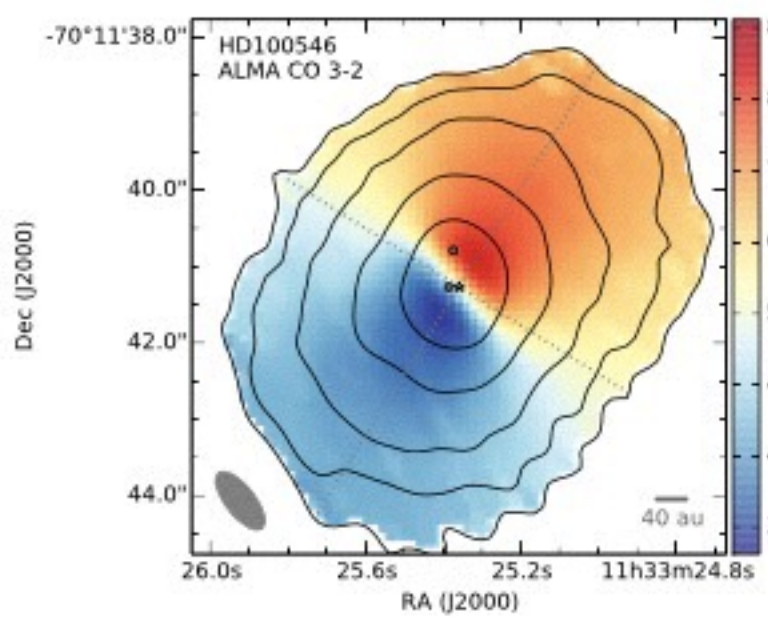


FIG. 3.— The CO (3–2) moment maps for the HD 100546 disk. The zeroth moment (velocity integrated intensity) map is overlaid in contours shown at [3,6,12,24,48,96]×rms, where rms is 0.125 Jy beam^{-1} km s^{-1}. The first moment (intensity weighted velocity) map is shown in color. Dotted lines show the major and minor axes obtained from fitting the dust continuum visibilities. Filled circles show the positions of the two planet candidates for HD 100546 (Brittain et al. 2013; Quanz et al. 2013). The synthetized beam is shown at the bottom left corner.

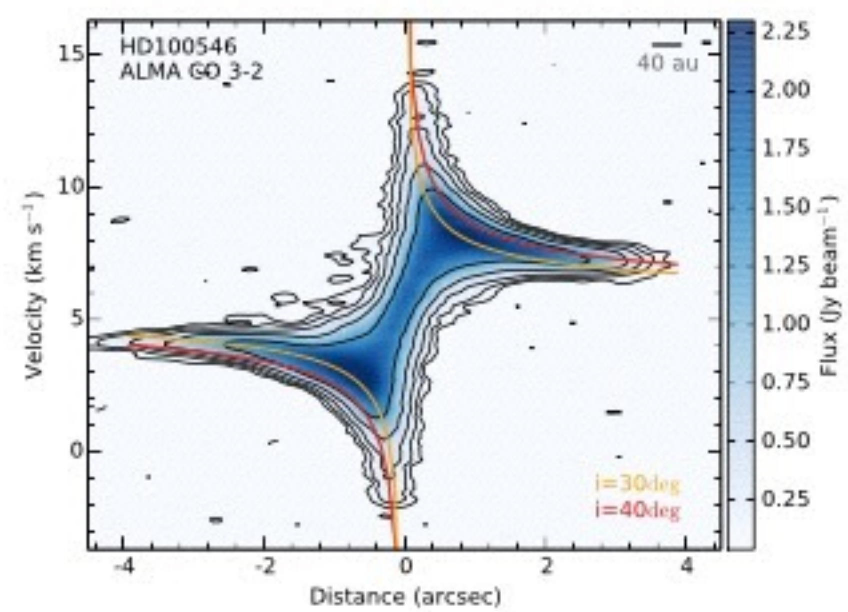


FIG. 4.— PV diagram of CO (3–2) along the major axis shown in Fig. 3. Contours are shown at [3,6,12,24,48,96]×rms, where rms is 27 mJy beam^{-1} per channel. Negative contours are shown by dashed lines. Orange and red curves show the expected keplerian velocity for a central star of 2.4 $M_\odot$ and inclination angle of 30° and 40°, respectively. See Section 4.4 for discussion.

Pineda et al. 2014, ApJ, 788, 34

Star Formation: High Mass

- The revised holy grail: Disks around high mass stars

- Radiation pressure problem, fragmentation induced starvation, ionized gas pressure, all inhibiting the upper limit on the accretion mass.

Star Formation: High Mass

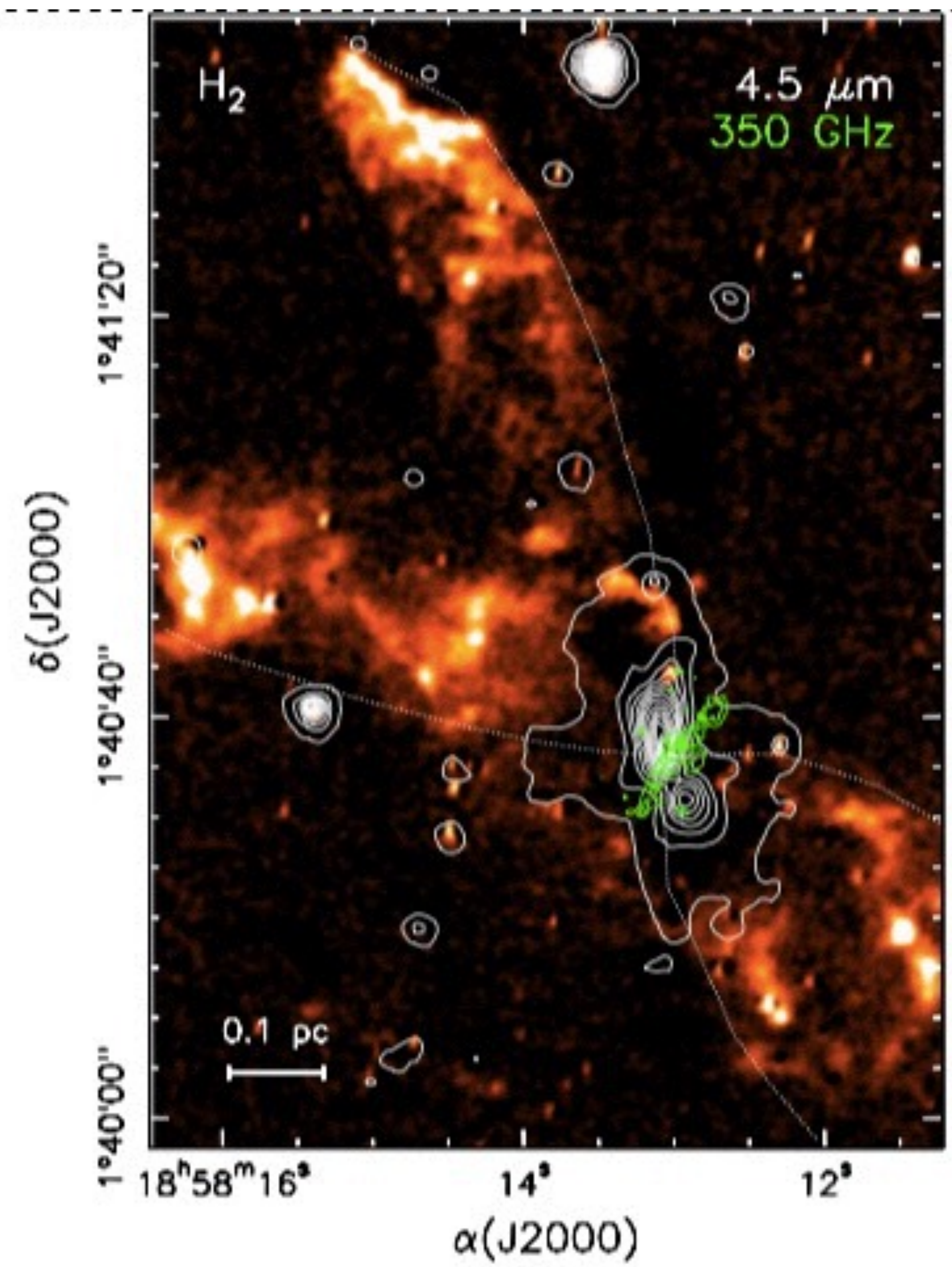


Fig. 15. Image of the H_2 2.12 μm line emission towards G35.20. The white and green contours are, respectively, maps of the 4.5 μm emission from the *Spitzer*/GLIMPSE survey (Benjamin et al. 2003) and 350 GHz continuum emission from our observations. The dotted curves outline the bipolar pattern.

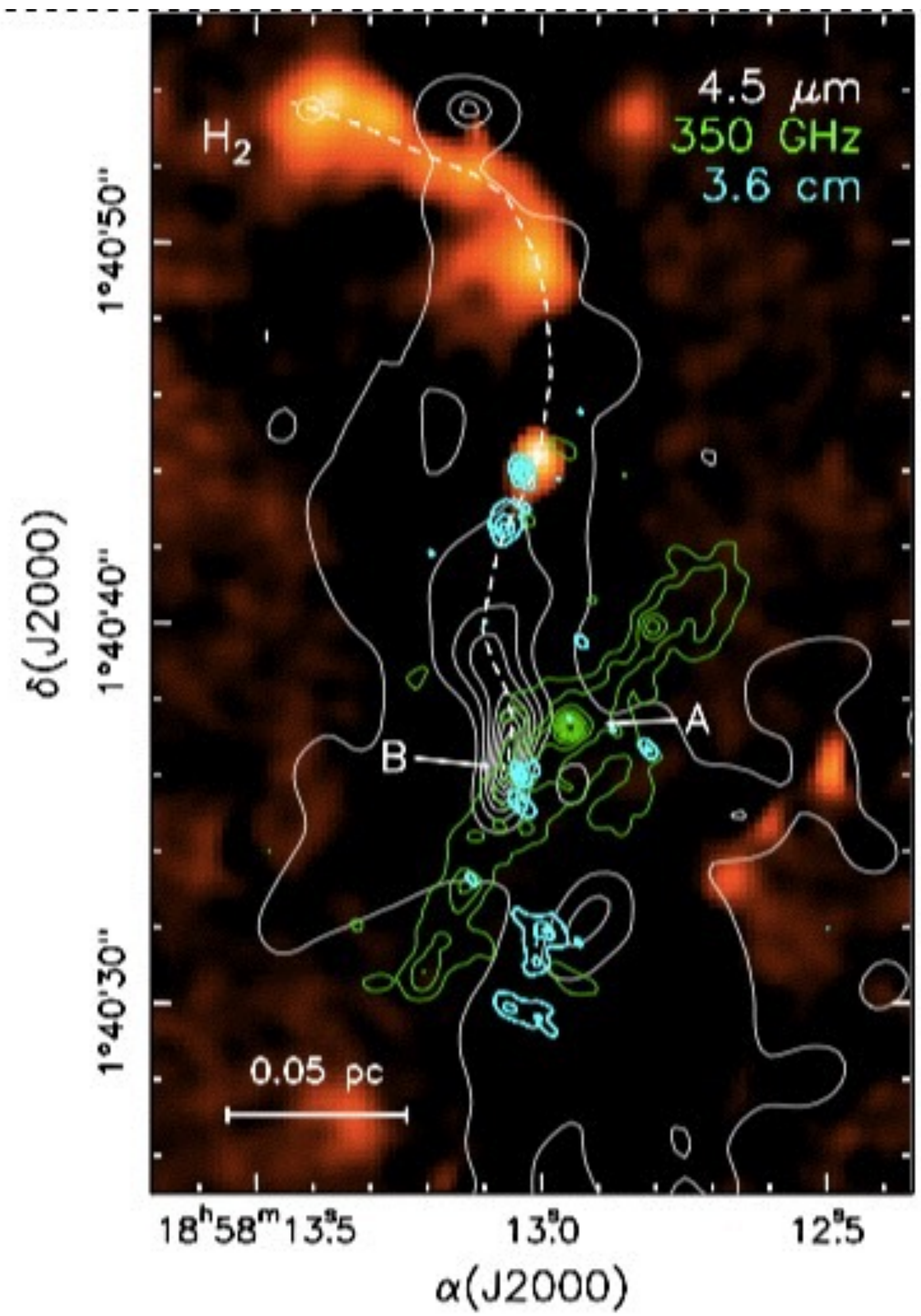
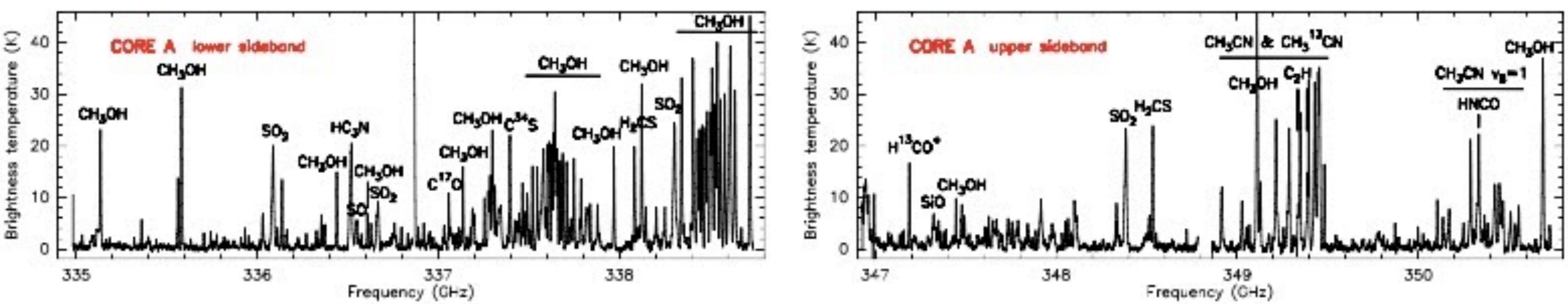
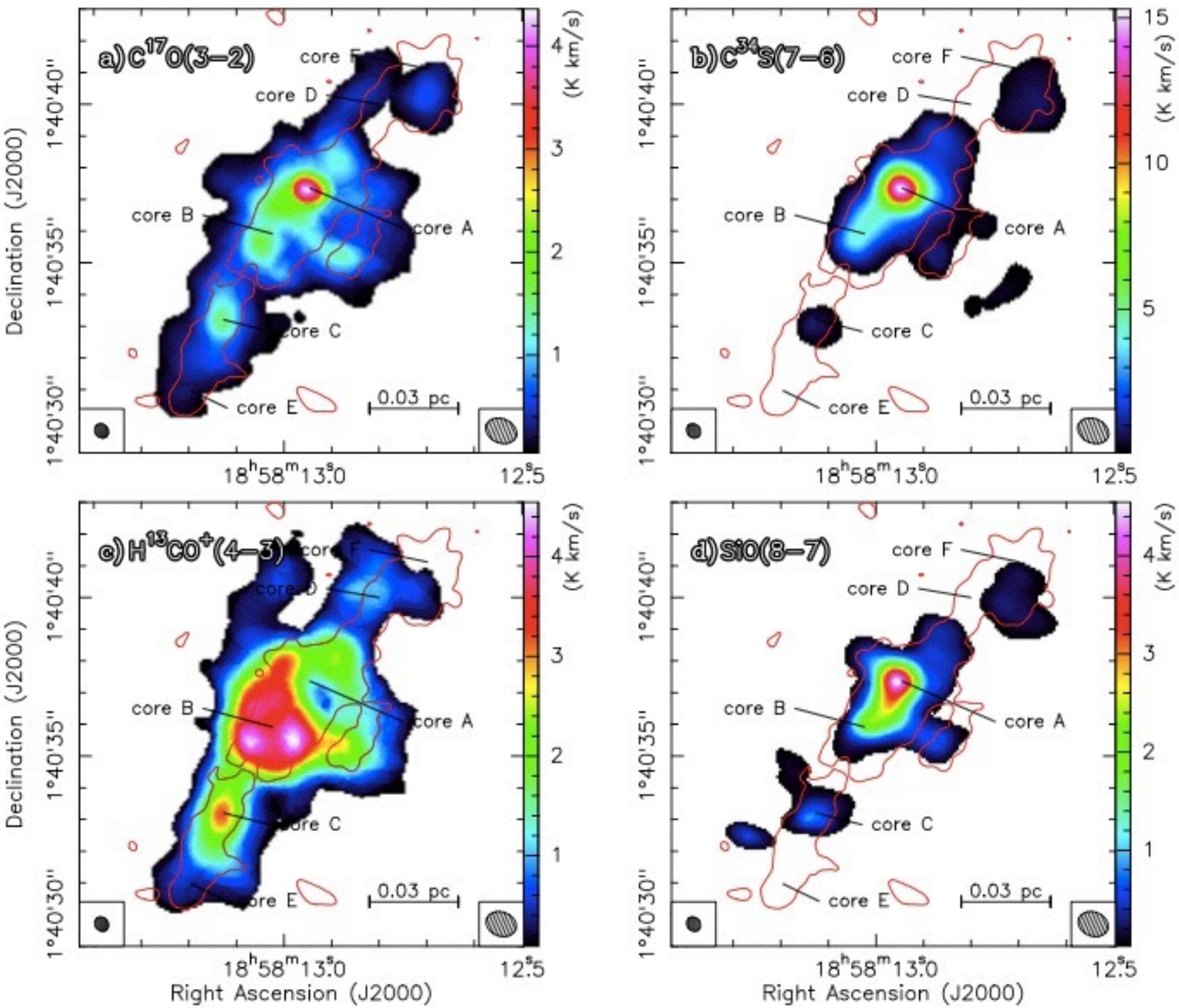


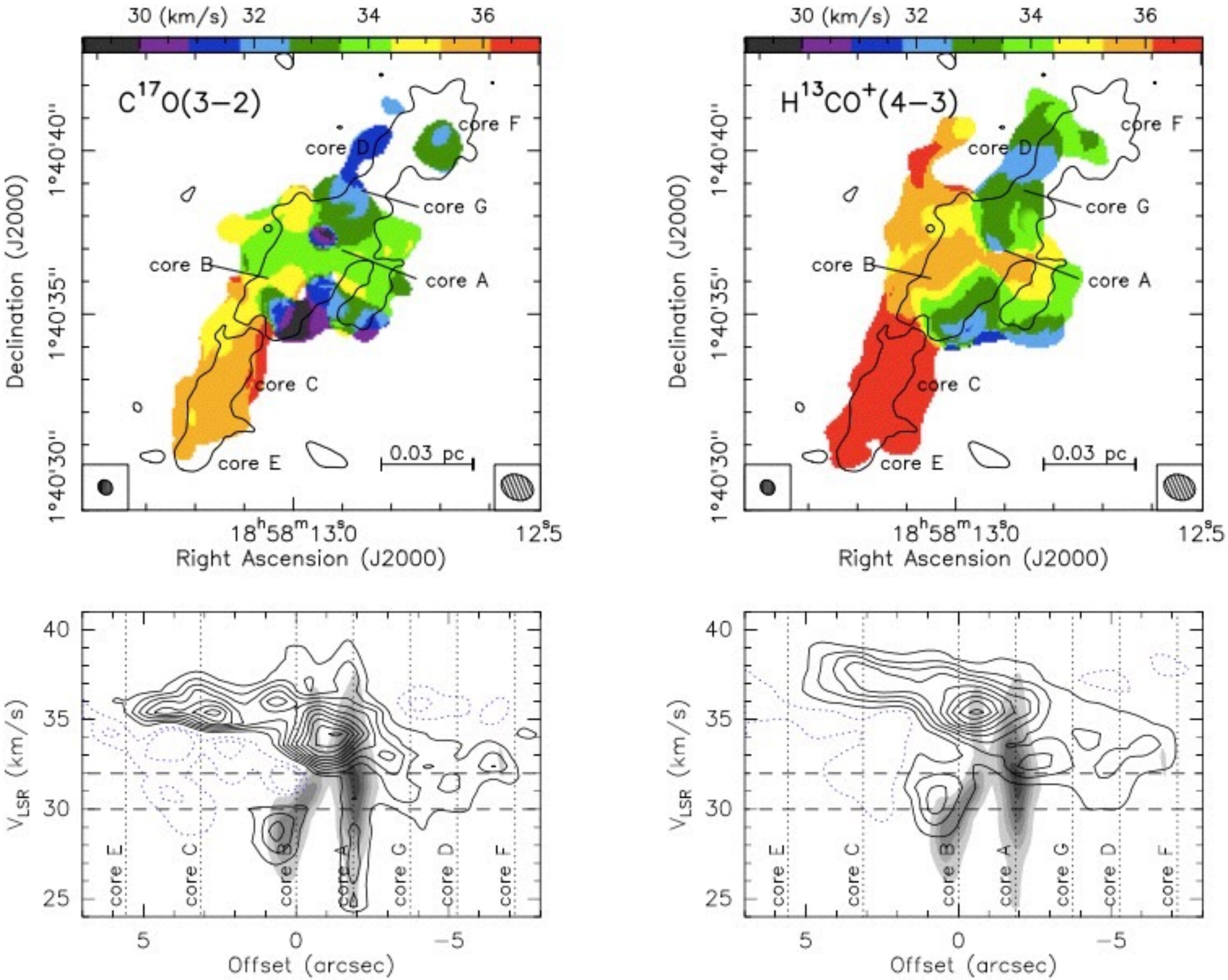
Fig. 16. Same as Fig. 15, with overlaid also the 3.6 cm continuum map of Gibb et al. (2003) (cyan contours). The resolution of the IRAC image (white contours) has been enhanced by HiRes deconvolution (Velusamy et al. 2008). The dashed curve outlines the shape of the jet, which is bending by almost ~90° at an offset of ~11″ to the north of core B.

Spectrum of G35.20

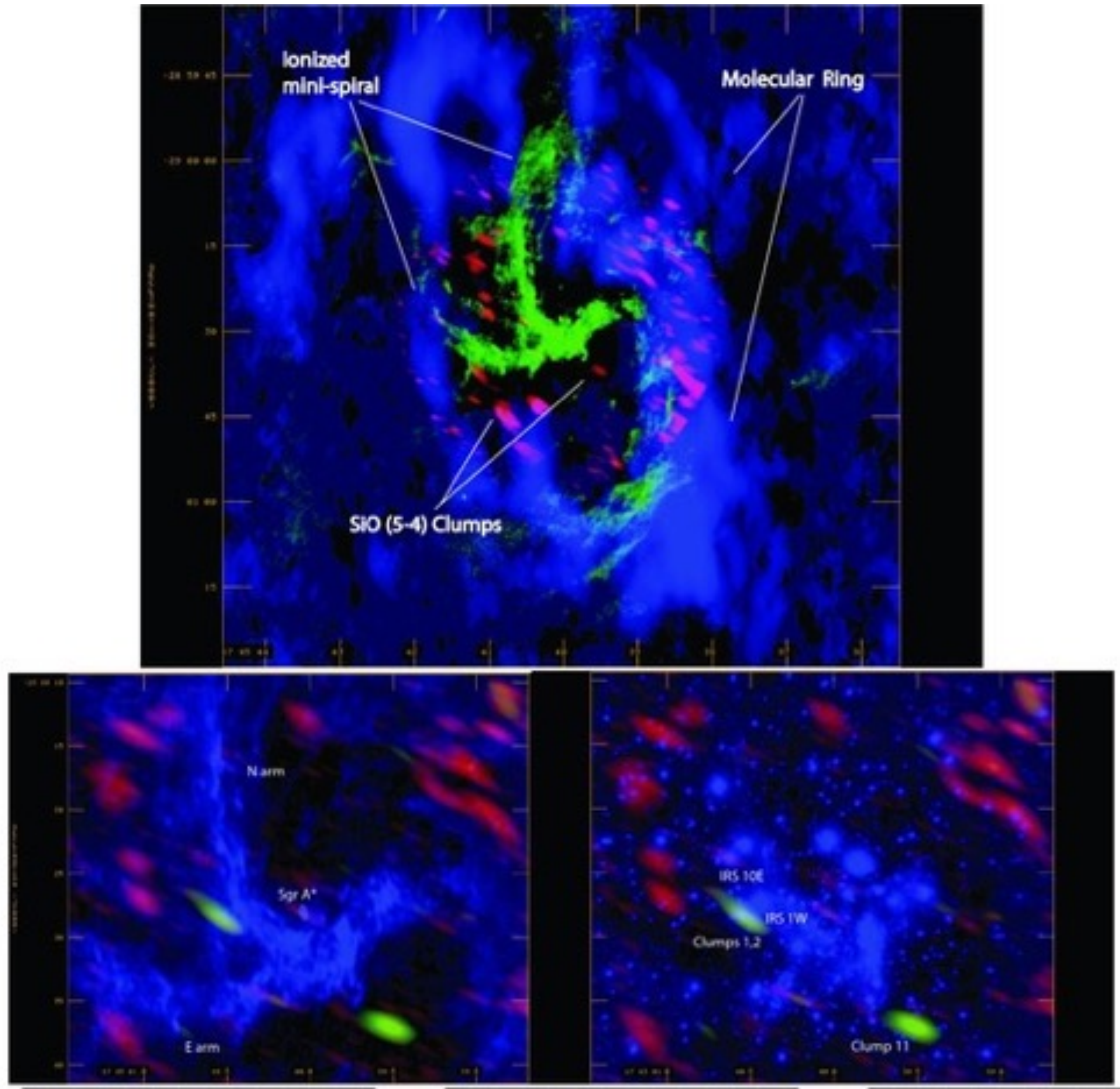




a) C17O(3–2)
b) C34S(7–6)
c) H13CO+(4–3)
d) SiO(8–7)
core A
core B
core C
core D
core E
core F
0.03 pc
(K km/s)
Declination (J2000)
Right Ascension (J2000)
1°40'40"
1°40'35"
1°40'30"
18h58m13.0s
12.5s


30 (km/s) 32 34 36
C17O(3–2)
H13CO+(4–3)
core A
core B
core C
core D
core E
core F
core G
0.03 pc
Declination (J2000)
1°40'40"
1°40'35"
1°40'30"
18h58m13.0s
12.5s
Right Ascension (J2000)
VLSR (km/s)
Offset (arcsec)

- Sanchez-Monge et al. 2013, A&A, 552, 10
- Beltran et al. 2014, A&A, 571, 52
- Sanchez-Monge et al. 2014, A&A, 569, 11



Galactic Centre

SiO clumps in a zone forbidden for star formation!

Yusef-Zadeh et al. 2013, ApJ, 767, L32

Galactic Center

- 11 SiO(5-4) clumps within 0.6pc of SgrA* , interior to the 2pc circumnuclear molecular ring
- Three clumps closest to SgrA* display the largest central velocities and dispersions at ~150km/s
- Remaining clumps trace the mini spiral and have small line widths (18-56 km/s)
- SiO clumps are interpreted as high mass protostellar clumps associated with outflows

Thanks and Good Luck with the increased power of ALMA