High Frequency Radio Emission from Stars within 2pc of Sgr A*

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- **Overview of some recent measurements**
  - **~100 WR/O stars: few million yrs old**
  - **~40-100 proplyd candidates few 10^{5-6} yrs old**
  - **Bipolar Outflows: few 10^{3-4} yrs**
  - **IRS3: a luminous and extended star**
- **Conclusions**

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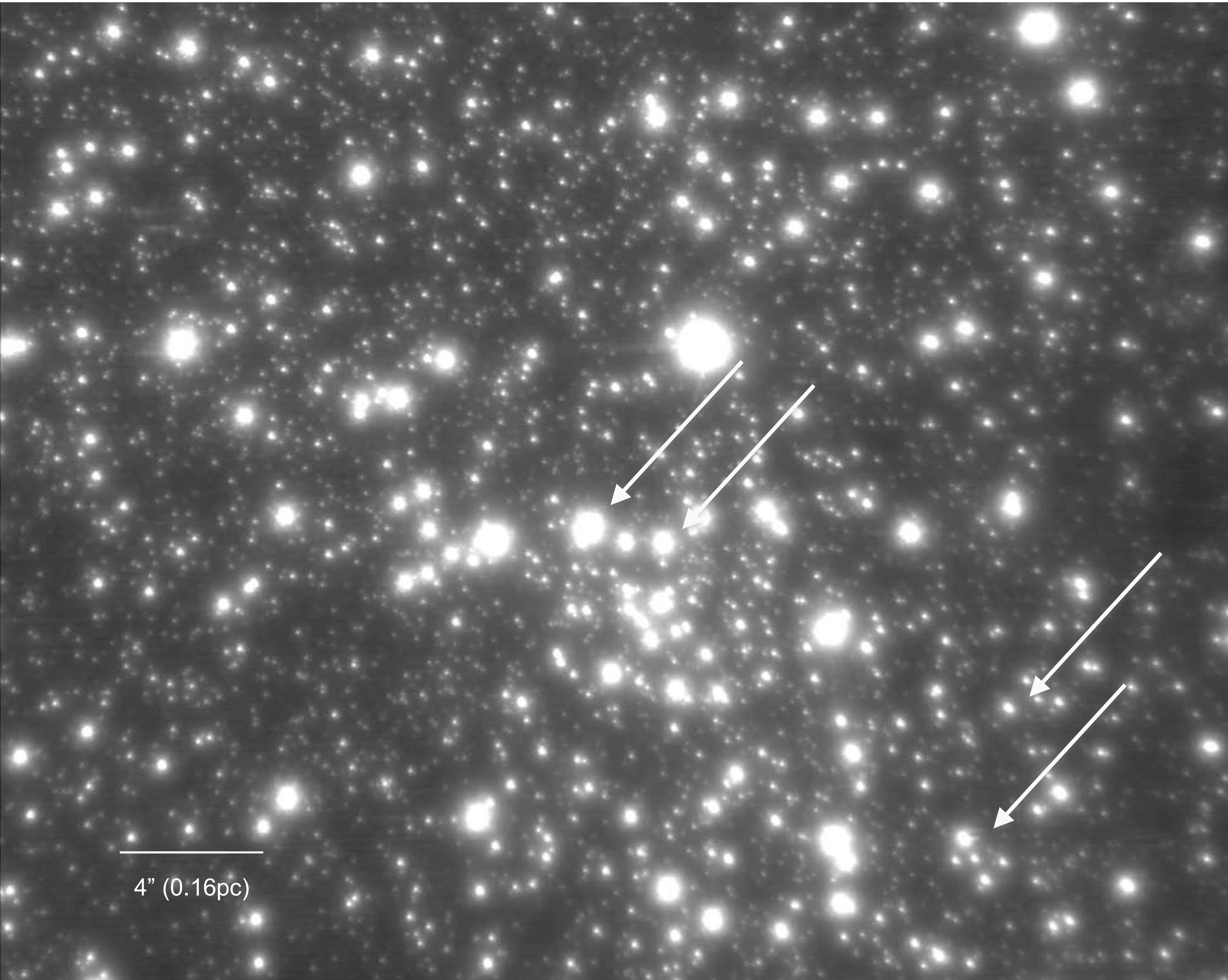
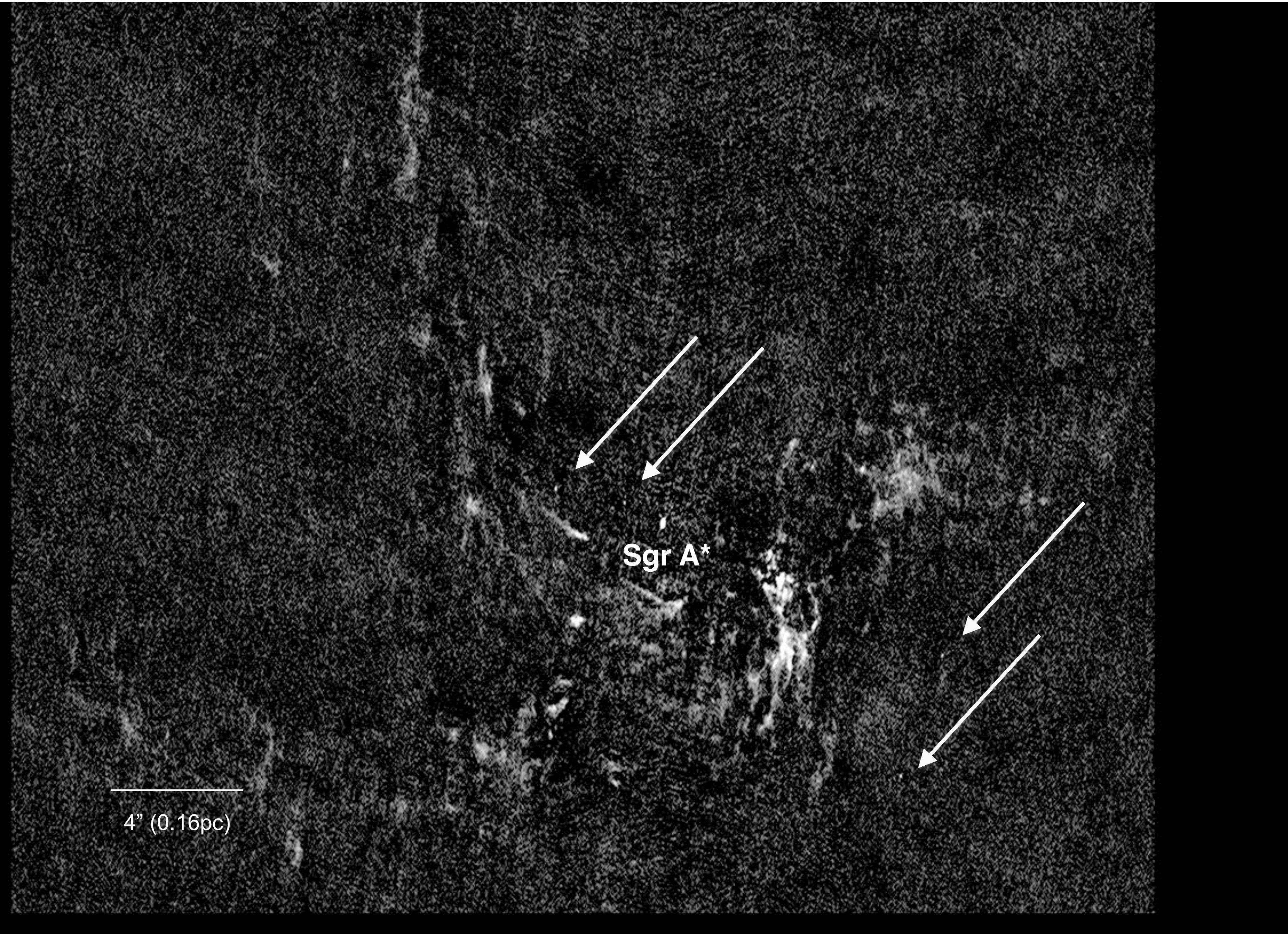
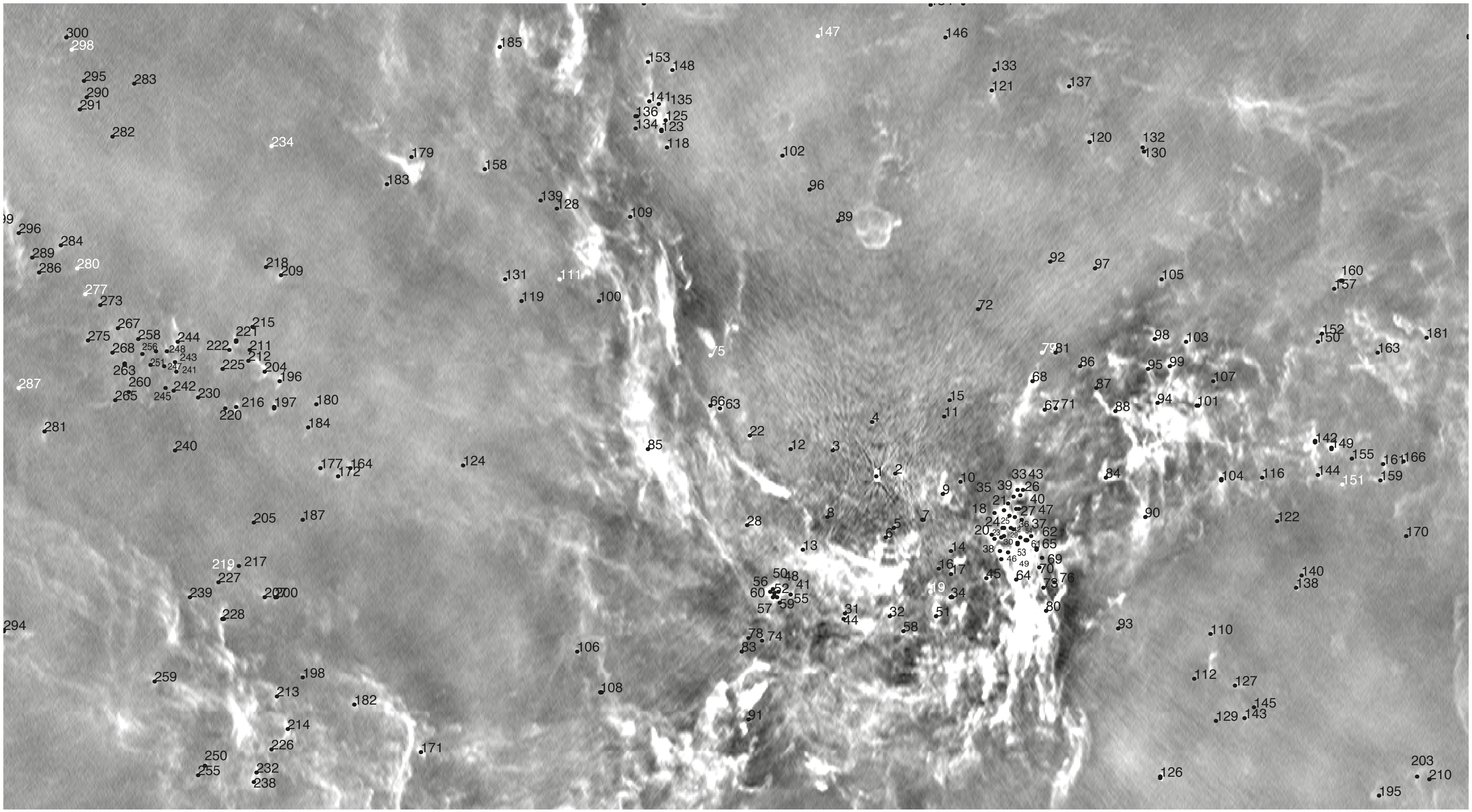
Massive Stars: 2 Microns



Massive Stars: 44 GHz (128 MHz BW)

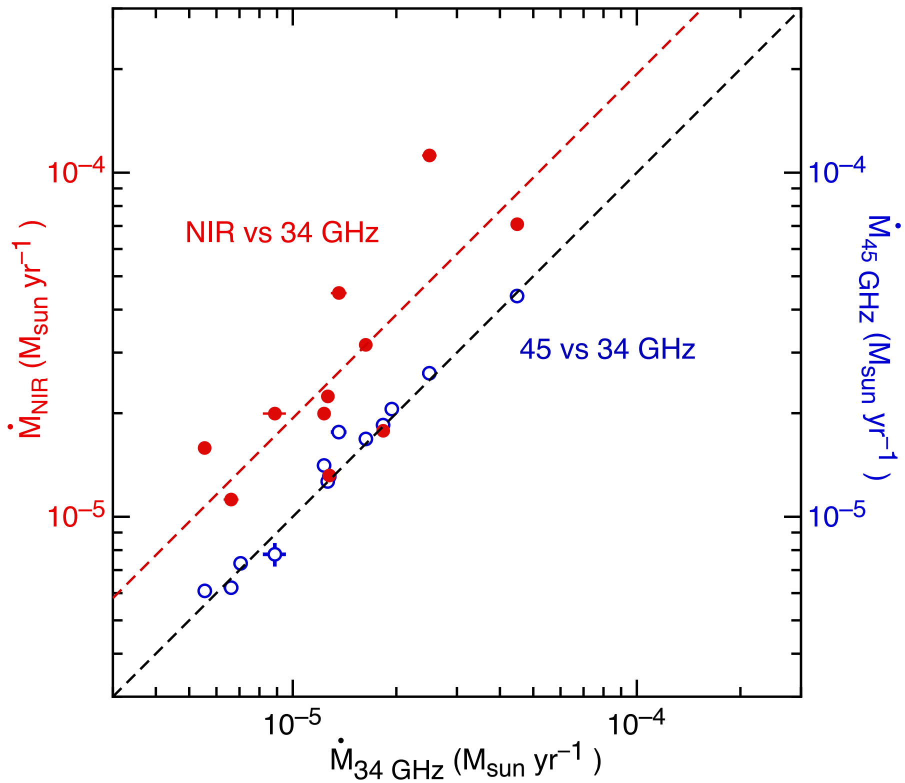


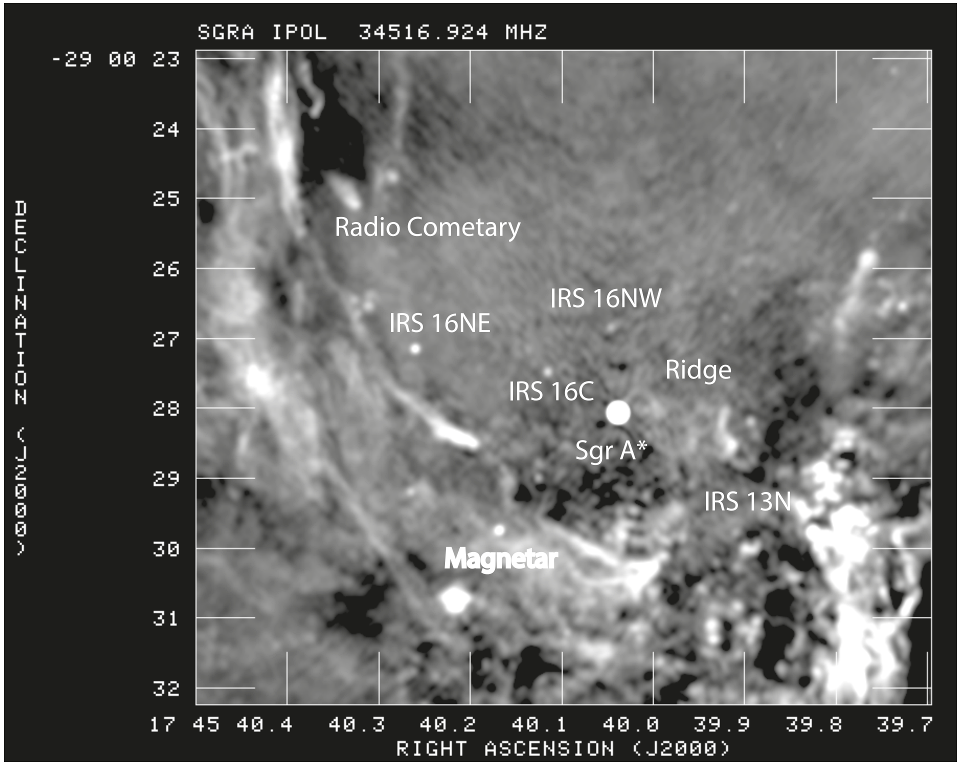
Broad Band Continuum: 35 GHz (8GHz BW)



- Ionized orbiting gas, compact and partially resolved sources
- 320 compact radio sources
- 1/3 of massive stars have radio counterparts
- A number of compact sources with no IR counterparts

Massive Stars: 35 and 44 GHz



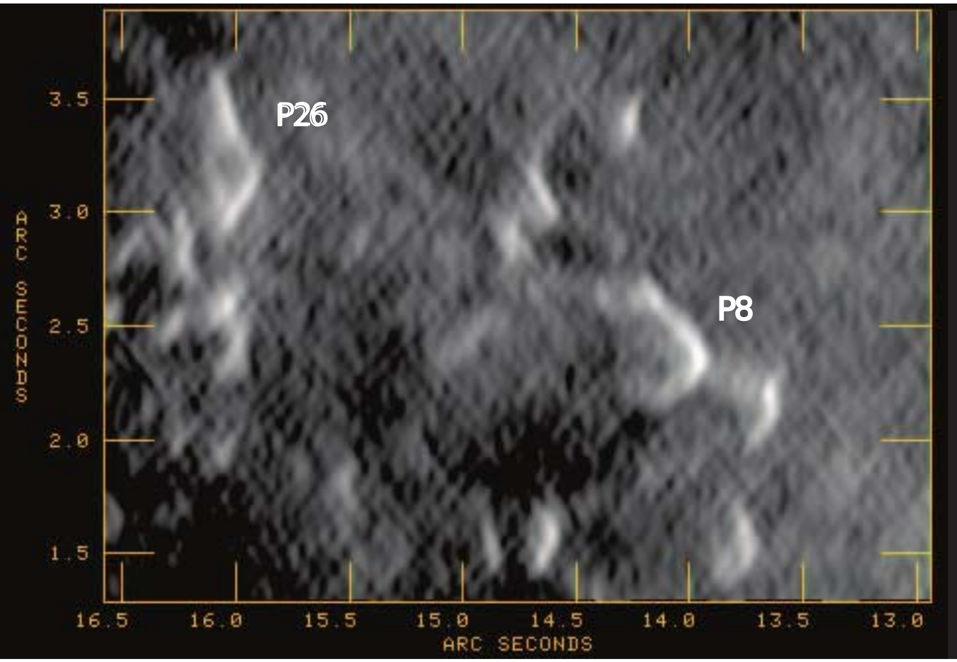


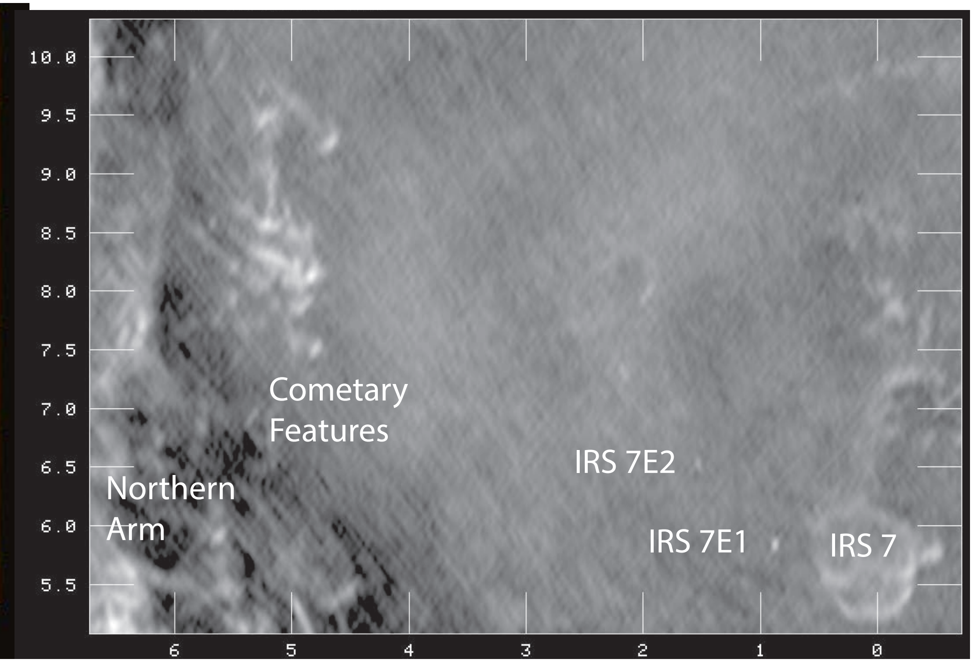
$$\frac{\dot{M}}{10^{-5}\ M_{\odot}\ \mathrm{yr}^{-1}} = 0.152\left(\frac{v_{\infty}}{10^{3}\ \mathrm{km\ s}^{-1}}\right)\left(\frac{S_{7\ \mathrm{mm}}}{1\ \mathrm{mJy}}\right)^{3/4}\left(\frac{d}{1\ \mathrm{kpc}}\right)^{3/2}$$

- Radio vs IR mass loss rates
- Mass loss rate is reduced by a factor of ~10
- Reduce the accretion rate onto Sgr A*
- Astrometry, proper motion

Low-mass Proplyds: $10^{5\text{-}6}$ yrs

Radio Continuum image at 34 GHz





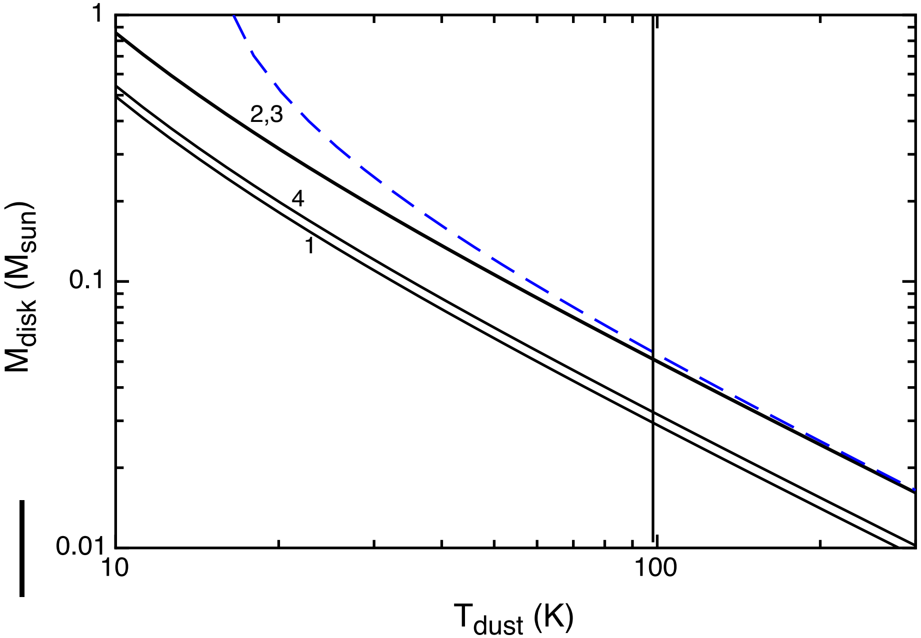
- ~ 44 radio sources with cometary appearance with no near-IR counterparts
- Size scale ~500AU
- [NLy /d^2] $_{(GC)}$ ~ [NLy /d^2] $_{(Orion)}$
- Protostellar disk candidates
- Multiple sources of illumination

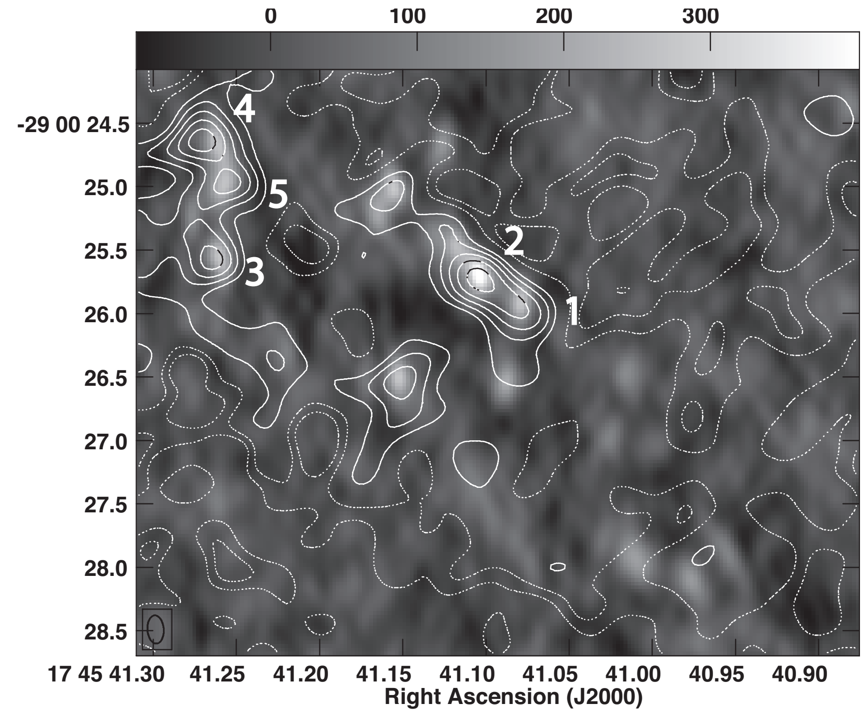
•Cometary morphology
•Size scale ~500AU
•[NLy /d^2] $_{(GC)}$ ~ [NLy /d^2] $_{(Orion)}$
•Protostellar disk candidates
•Multiple sources of illumination

FYZ et al. 2015

- Two arguments in favor of protoplanetary disks
  - 1) Gas needs to be replenished
    - τ (expansion)~ 240 yrs
  - 2) Must be bound by self-gravity to be stable against tidal disruption
    - n(H) ~ 10^6 cm^{-3} << Roche density ~ $2 \times 10^8 (\mathrm{r}/1\mathrm{pc})^{-3}\ \mathrm{cm}^{-3}$

Star Formation near Sgr A*: ALMA DATA



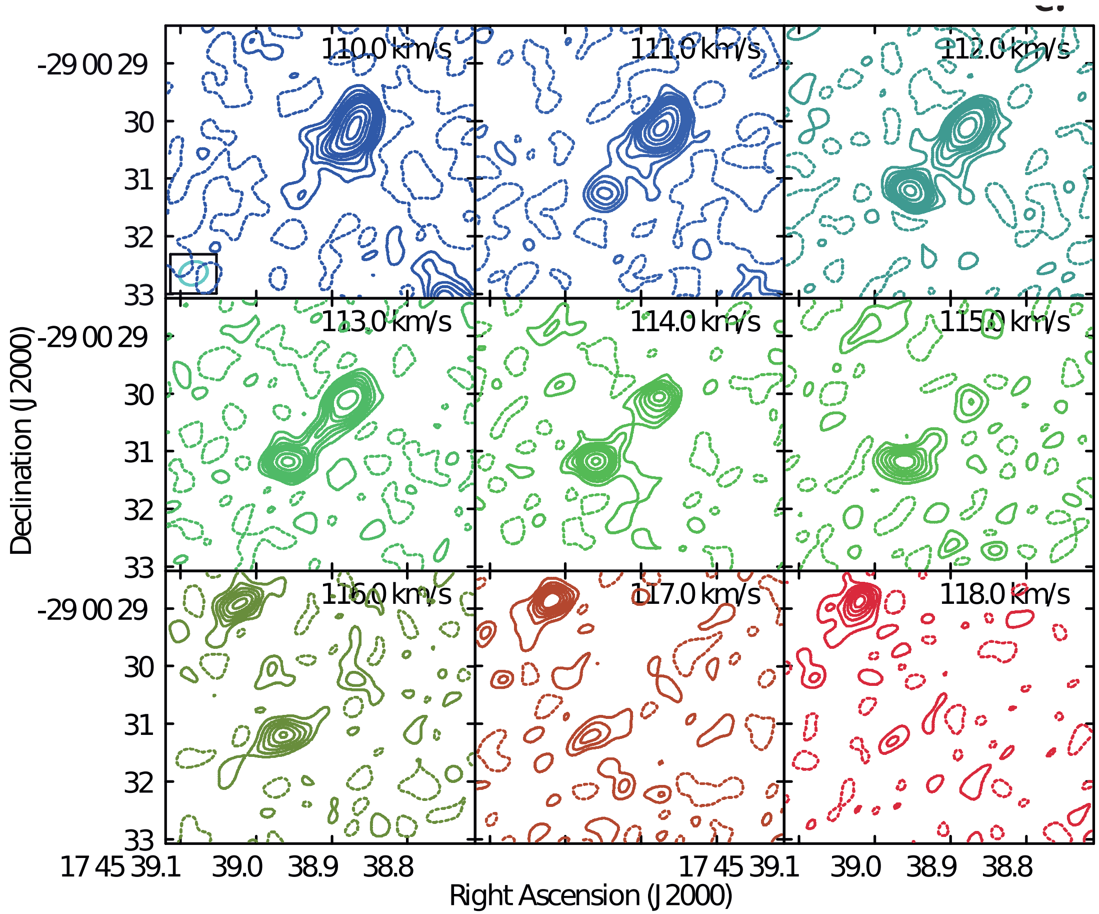


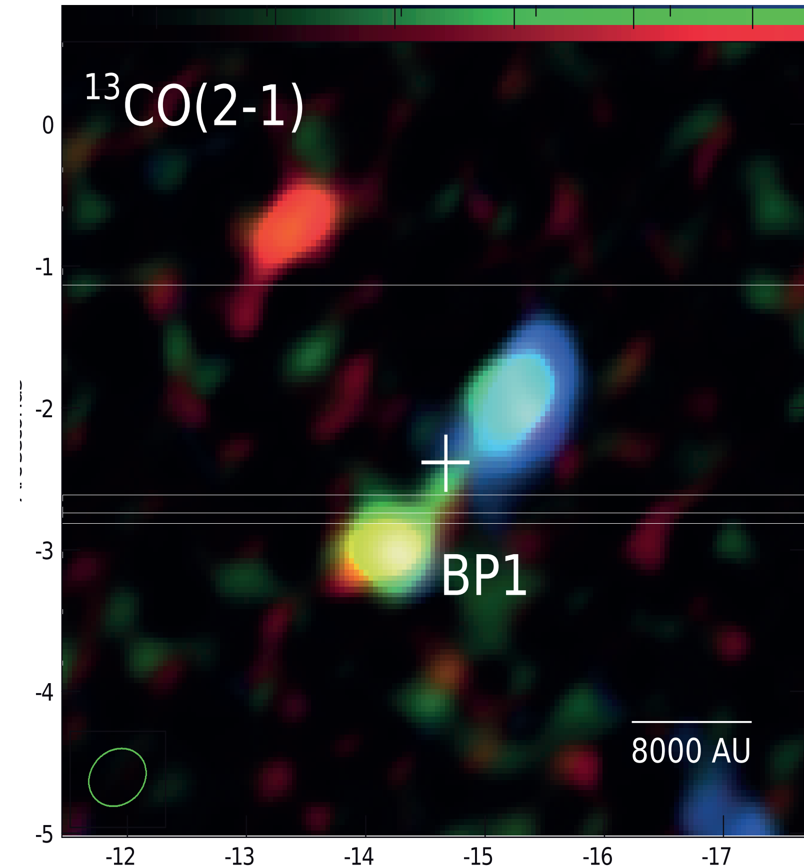
- Disk mass 0.03-0.06 M_{sun}
- Size scale ~500AU
- Minimum Mass Solar Nebula ~ 0.01M_{sun}

Millimeter contours over 7mm

Radio proplyds have mm counterparts

^{13}CO (2-1) 22 GHz: ALMA

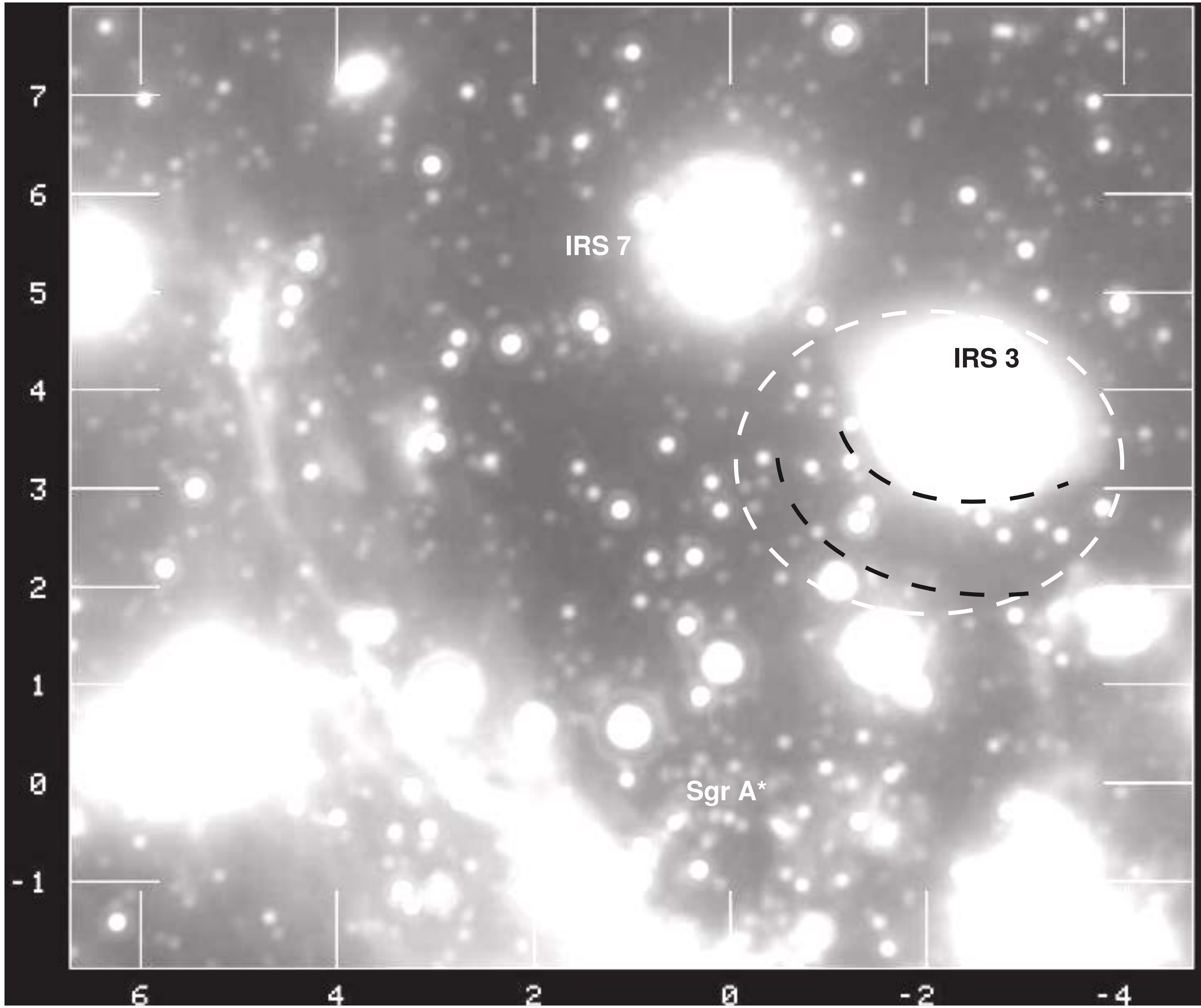




- The lobe mass 0.32 M_{solar}
- Momentum rate L/c ~5.7x10$_2$ L_{solar}
- A population of low-mass bipolar outflow sources
- Mean dynamical age is 6500 yrs

IRS 3: Evolved AGB Star vs a Dusty Young Star

- IRS 3: brightest most extended @8.3μm with R=1" (8000AU)
- Asymmetric envelope
- No OH masers
- 4.5" (0.18pc) from Sgr A*



IRS 3: Evolved AGB Star vs a Dusty Young Star

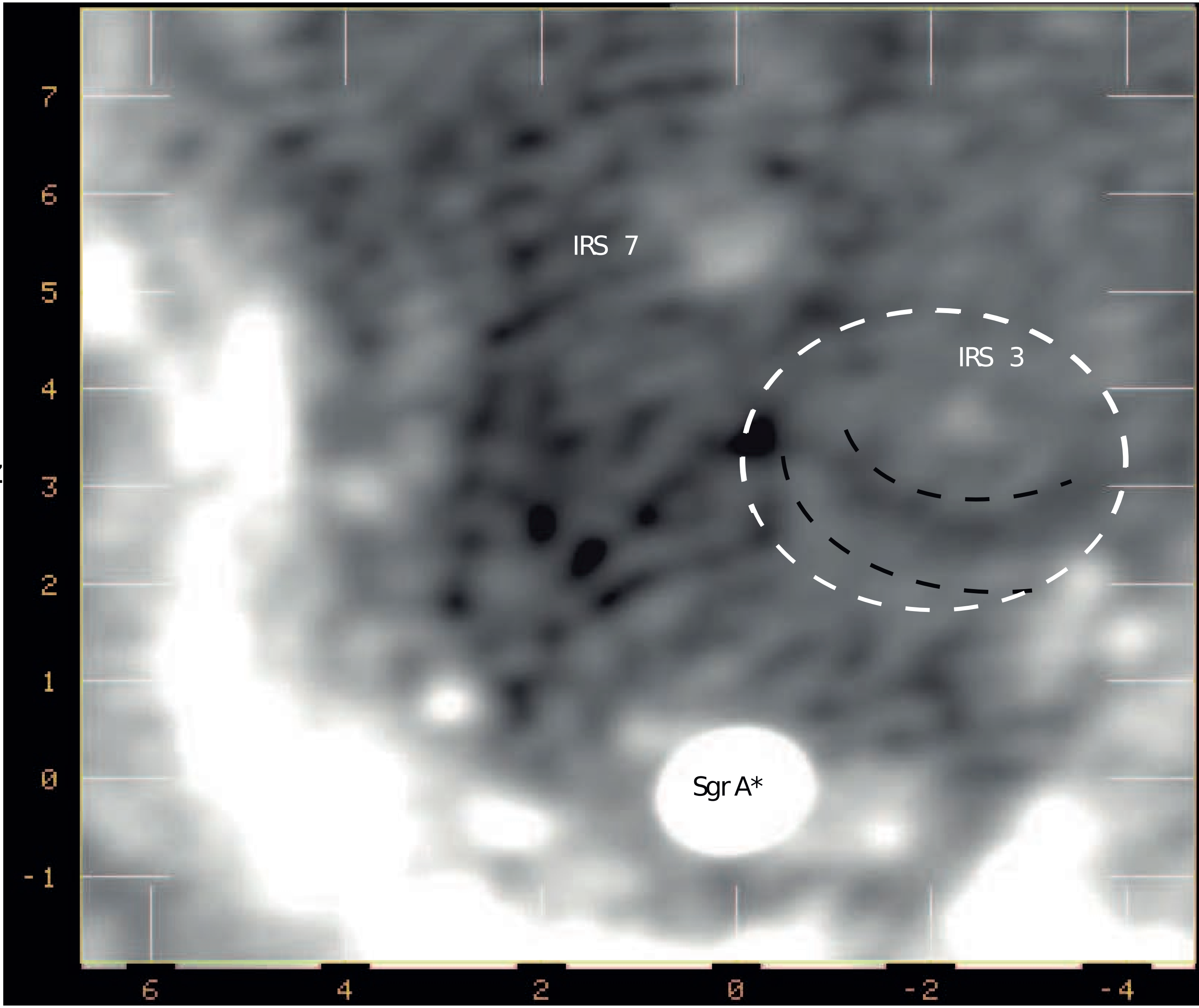
•α=1.85+/-1.13
between 44, 226 GHz

• α=1.32+/-0.32
between 34, 44 GHz

•α=1.17+/-.33
between 226, 350 GHz

•Consistent with an
•AGB star

•Asymmetric shell
•in the direction of
•proper motion



Tidal Disruption of IRS 3: ALMA DATA

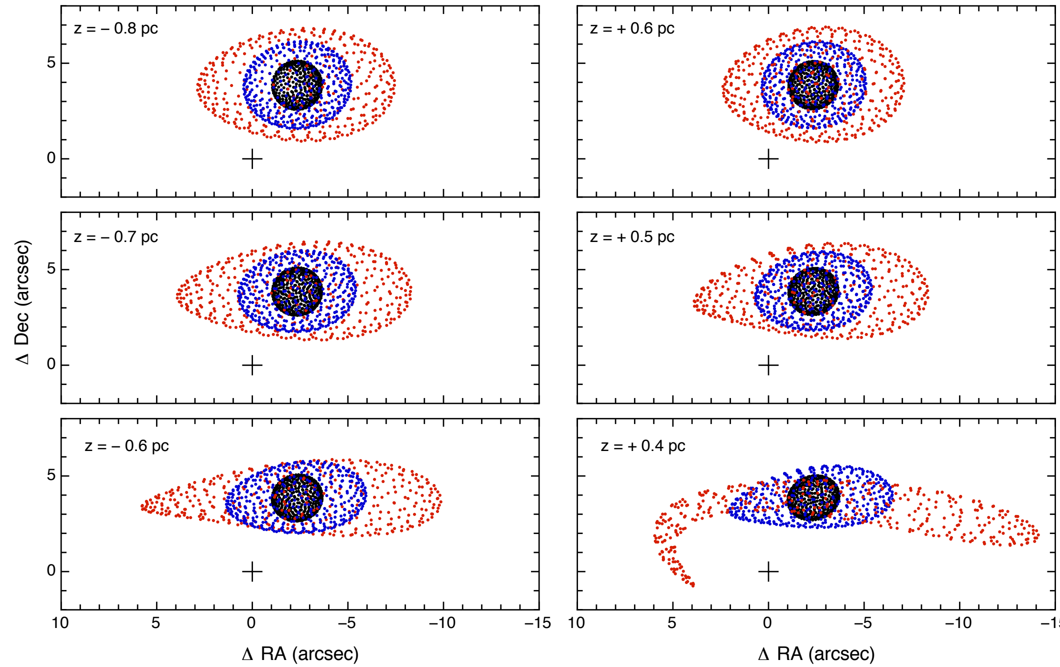
•Envelope mass ~ 0.3 Ms0lar

•If $\tau_{expansion} \sim \tau_{orbital}$ then tidal distorted

•Fluid elements expanding as they orbit Sgr A*

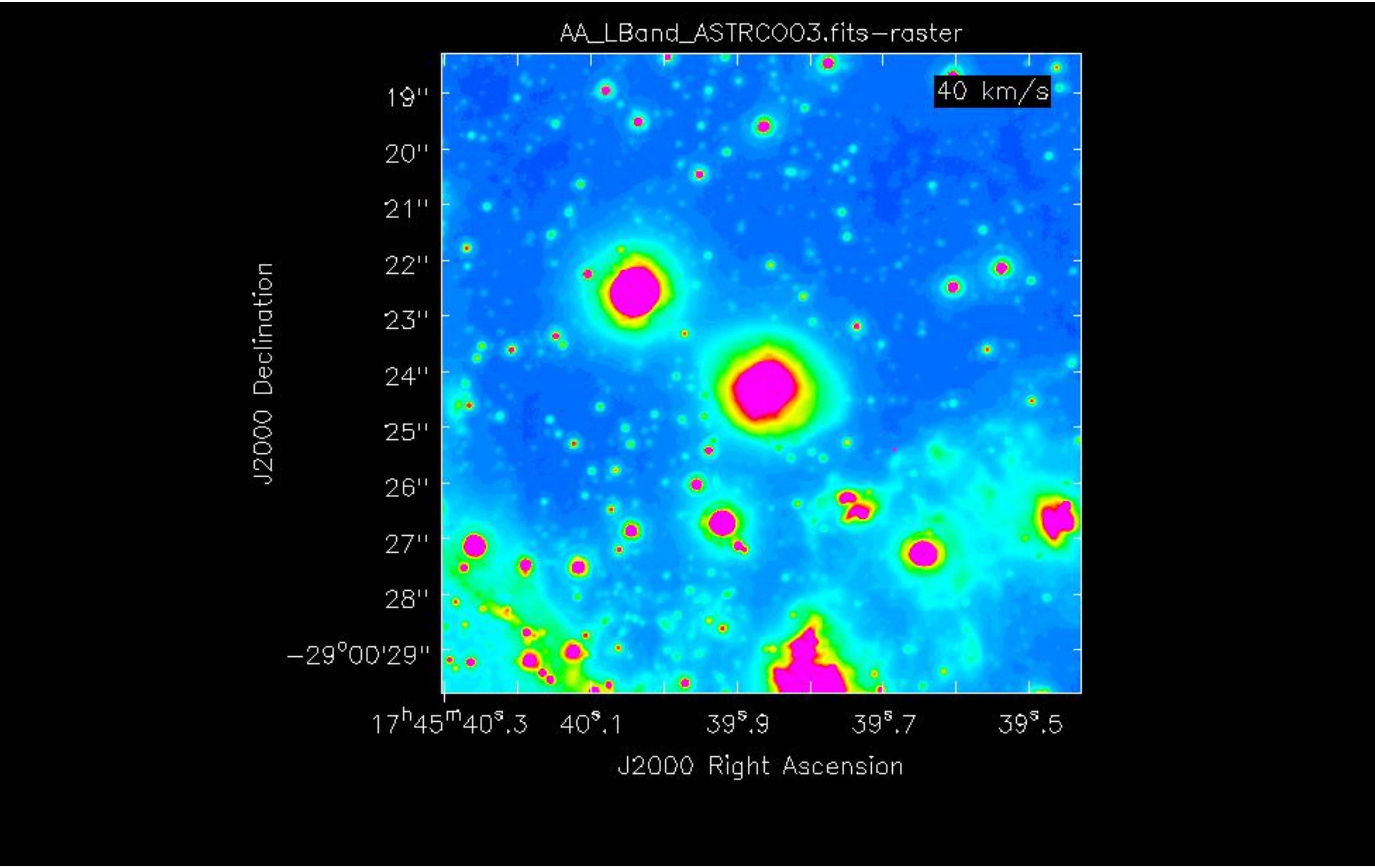
•The strength of distortion:
IRS 3 is 0.7 pc in front or 0.5 pc behind

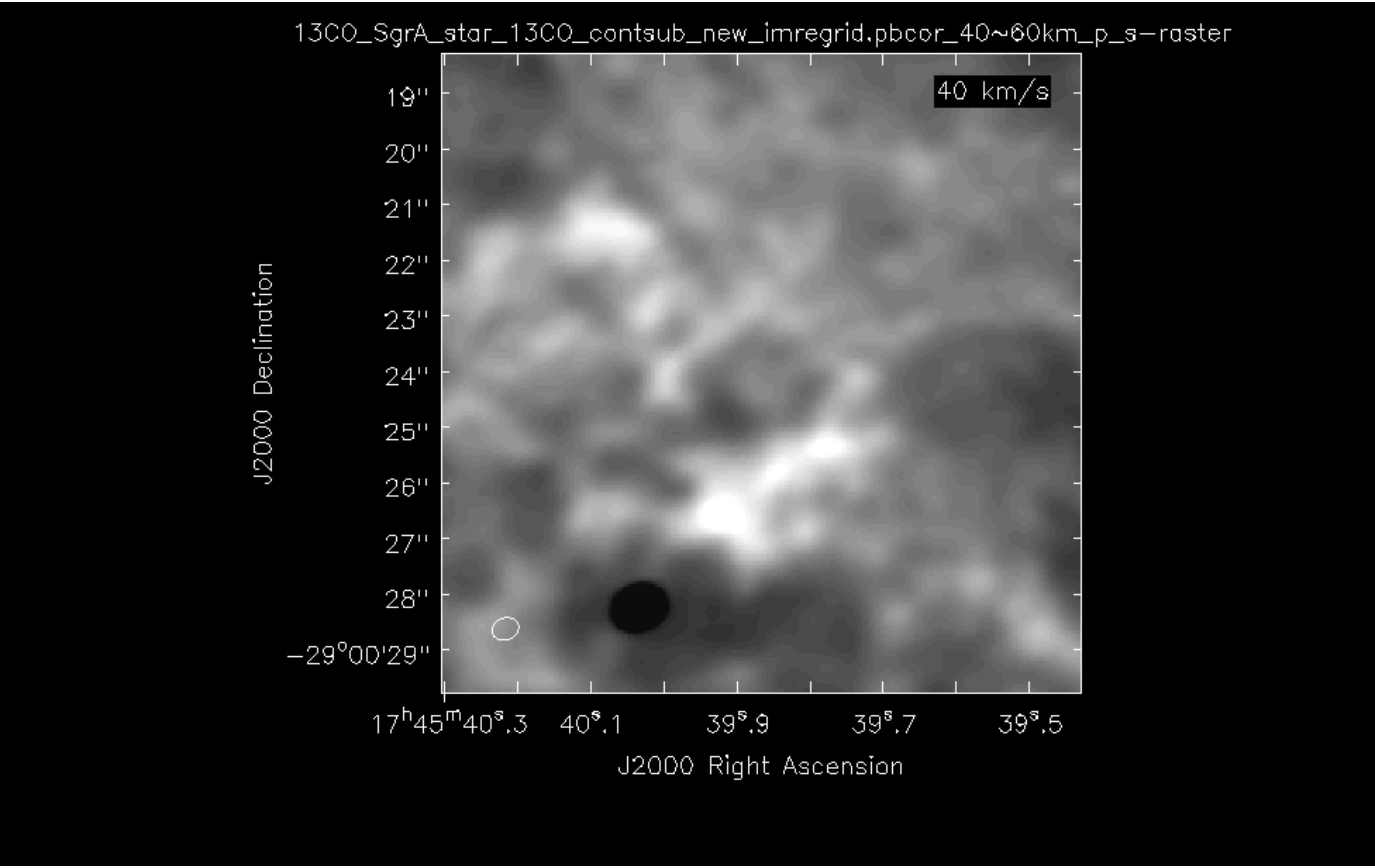
•Radial and tangential velocities are known



Tidal distortion of IRS 3 envelope

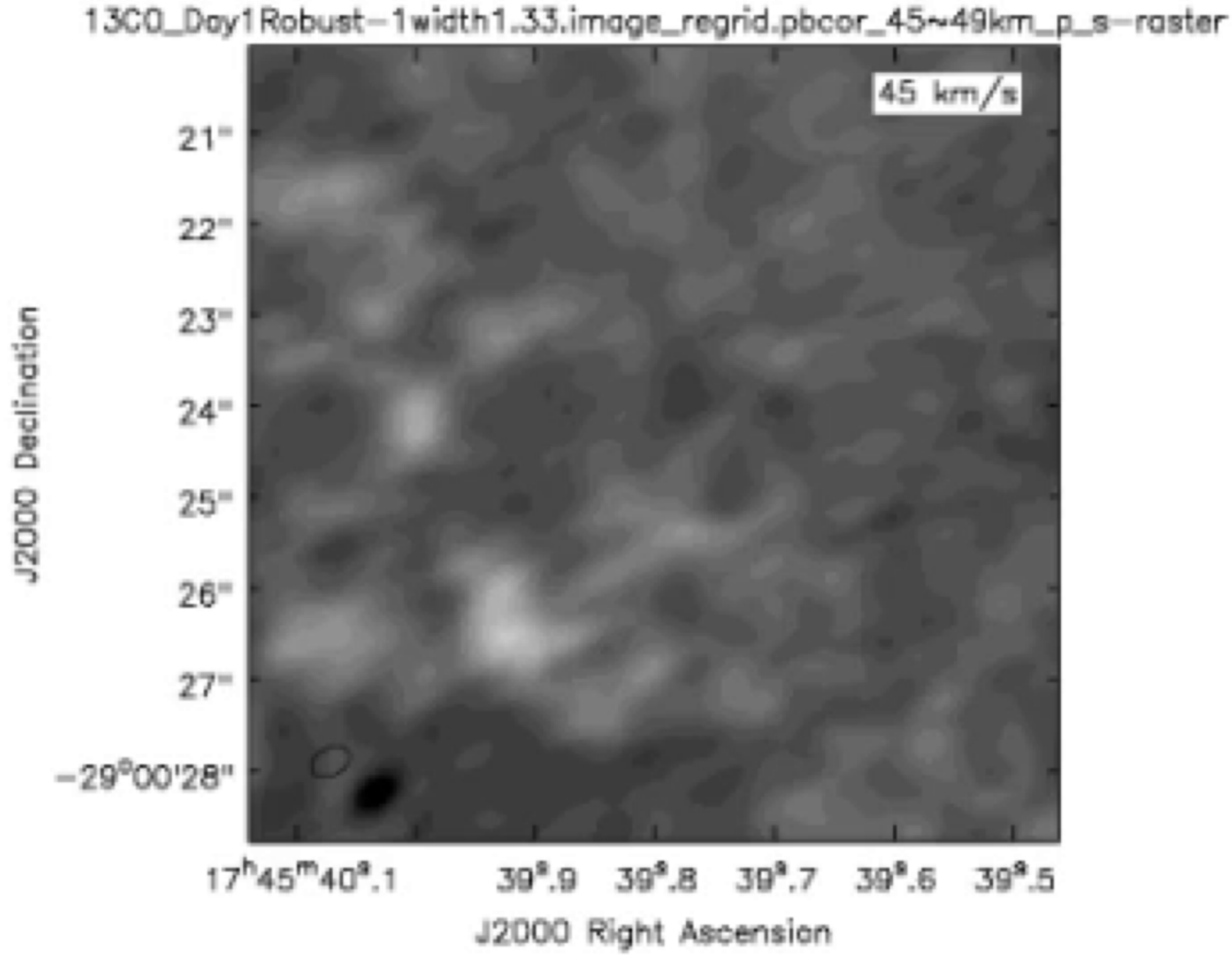
7500, 5000 and 2500 years red, blue and black


AA_LBand_ASTRC003.fits-raster
40 km/s
19"
20"
21"
22"
23"
24"
25"
26"
27"
28"
−29°00'29"
J2000 Declination
17h45m40s.3
40s.1
39s.9
39s.7
39s.5
J2000 Right Ascension



13CO_SgrA_star_13CO_contsub_new_imregrid.pbcor_40~60km_p_s-raster
40 km/s
19"
20"
21"
22"
23"
24"
25"
26"
27"
28"
-29°00'29"
J2000 Declination
17h45m40s.3
40s.1
39s.9
39s.7
39s.5
J2000 Right Ascension

IRS 3: ^{13}CO velocity Cube



•D
•S
•M

- **Conclusions**

  - ❑ Sensitive radio and mm observations
  - ❑ Large number of protostellar candidates and bipolar CO outflows
  - ❑ Implying ongoing low-mass star formation near Sgr A*