The bow shock at the center of NGC 6334A with deep VLA observations. Is It a colliding wind region or a bow shock of a runaway star?

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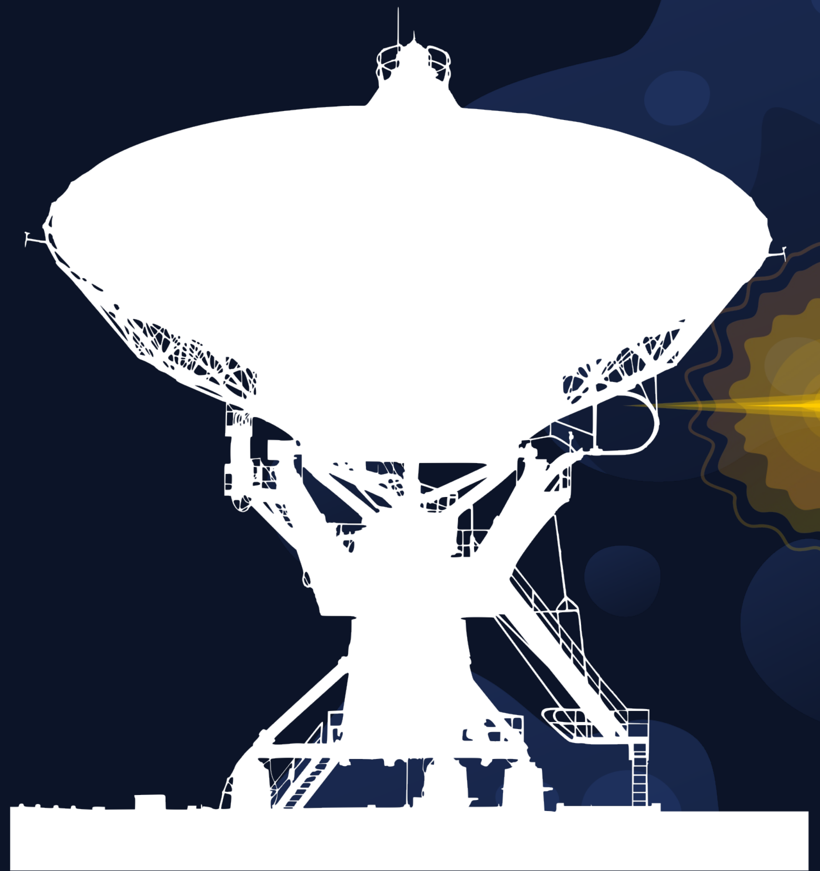
MASSIVE STAR FORMING REGIONS

Clouds of gas and dust gravitationally collapse to form stars in the whole mass spectrum.

MASSIVE STAR FORMING REGIONS

RADIO:

- FREE-FREE EMISSION (Thermal)
- SYNCHROTRON EMISSION (Non-Thermal)



TARGET

Cat’s paw nebula. NGC 6334

NGC 6334A
1.34 Kpc

TARGET

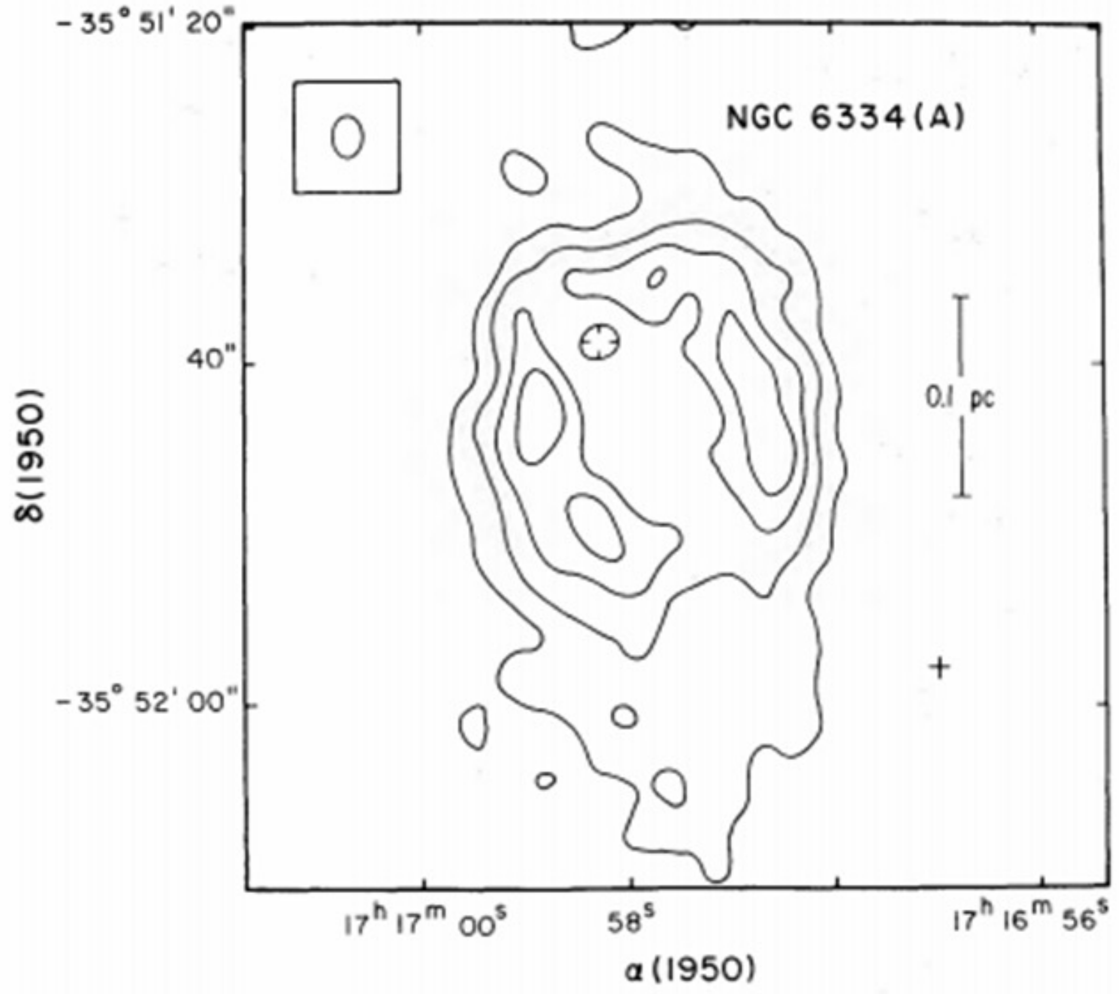


FIG. 3.—VLA map of the compact H II region NGC 6334(A). Contours are 0.05, 0.10, 0.15, and 0.20 Jy (beam area)$^{-1}$. No CLEANing was made in this map. The cross marks the position of the high-velocity H_2O maser found by Rodríguez *et al.* (1978, 1980).

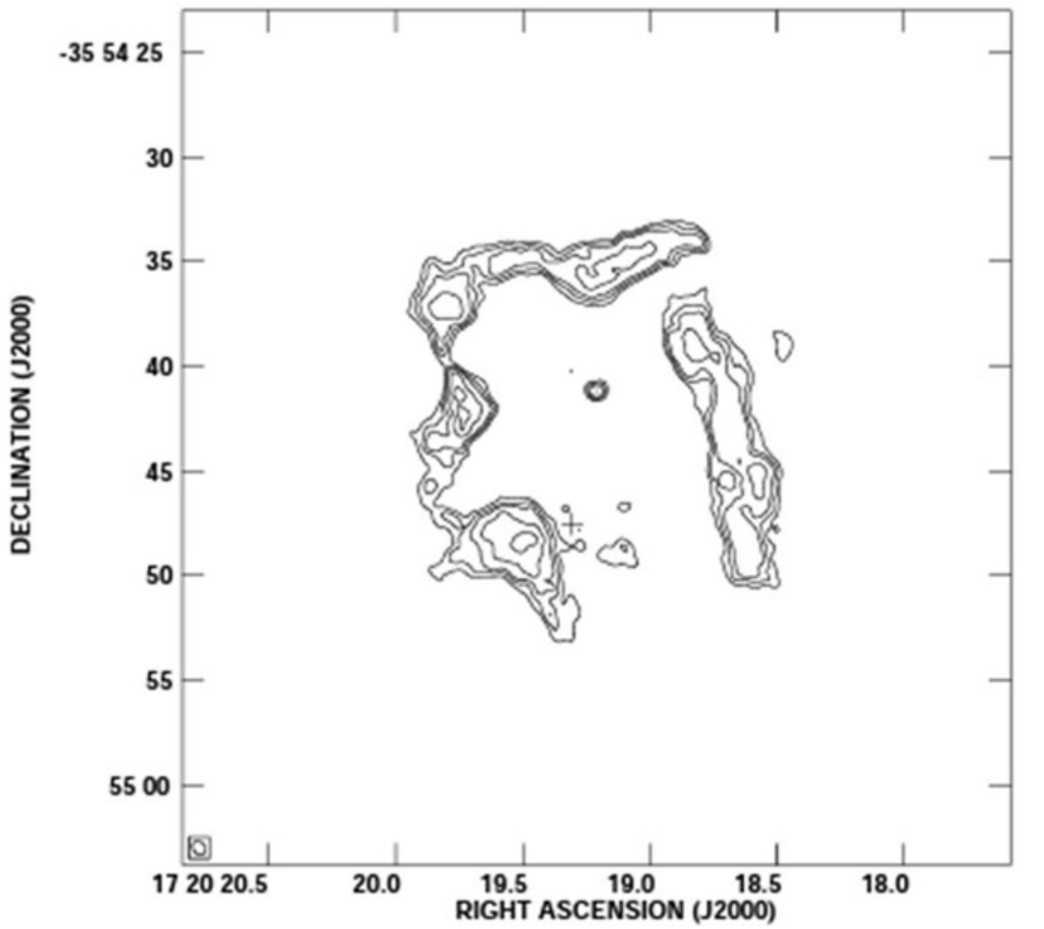
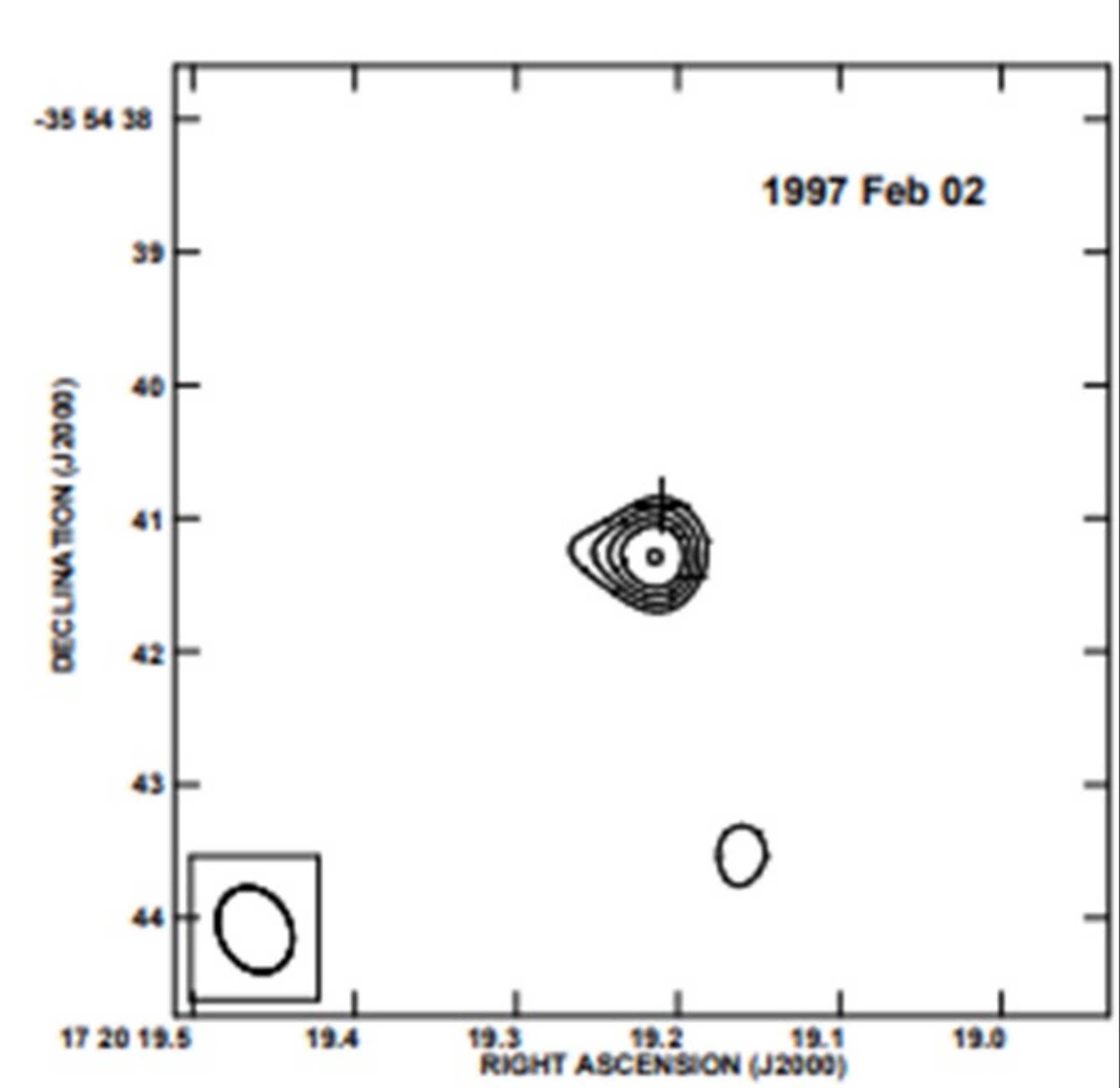


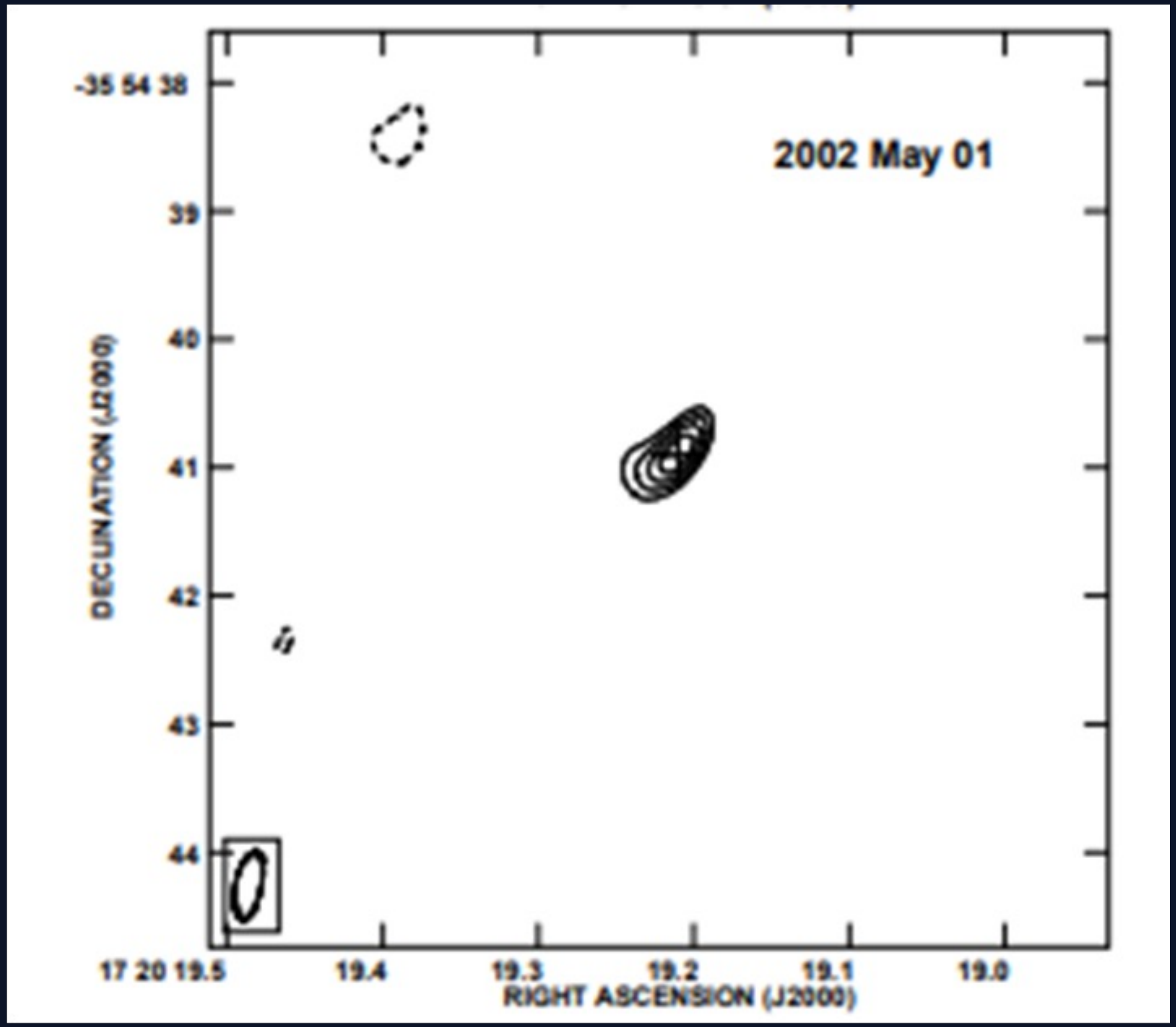
FIG. 4.—The 3.5 cm image of the H II region NGC 6334A. Contours are −4, 4, 5, 6, 8, 10 and 12 × 1.3 mJy beam^{-1}, the rms noise of the image. The compact source near the center of the nebula is proposed to trace the exciting star. There are no known counterparts to this radio source. The small cross marks the position of IRS 19, taken from 2MASS. The half-power contour of the beam (0."72 × 0."56; P.A. = 41°) is shown in the bottom left corner of the image.

- Shell + central compact source

Rodriguez et. al . 1982; Carral et al. (2002)

THE CENTRAL SOURCE: THE MYSTERIOUS SOURCE

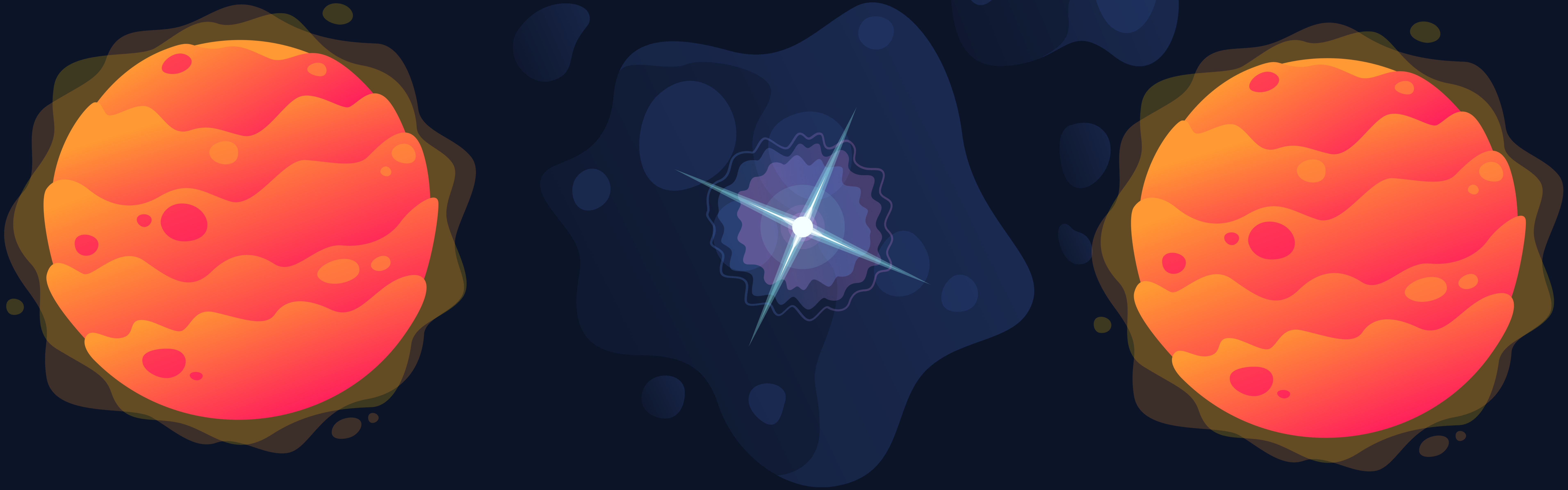




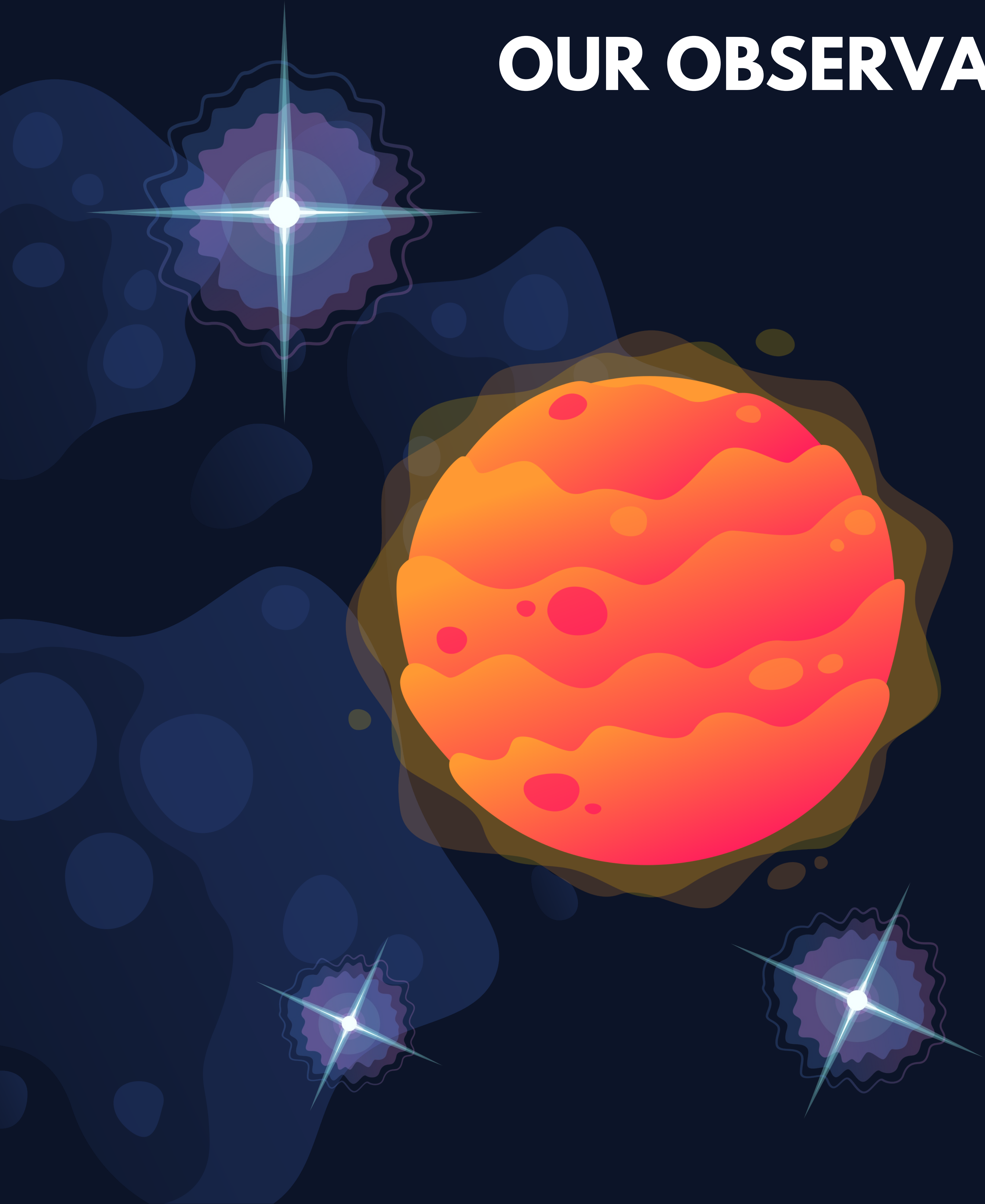
- arc shape
- variability
- negative spectral index
- First suggestion: Colliding wind region.

Rodriguez et. al. (2014)

COLLIDING WIND SCENARIO



OUR OBSERVATIONS



01. VLA Observations taken in 2014

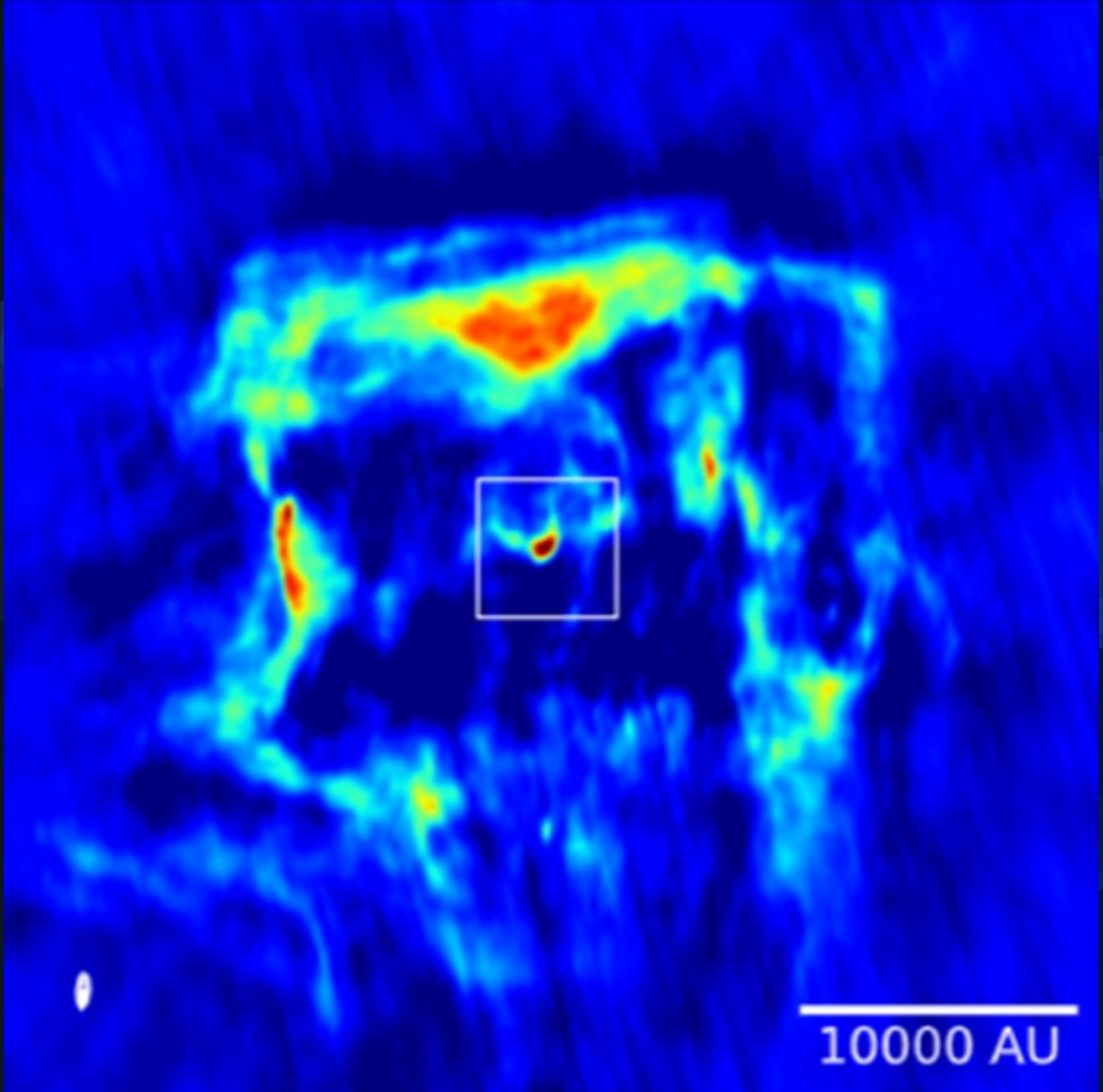
03. A Configuration

04. X(10 GHz), K(22GHz), Ka(33GHz) bands.

05. 3 epochs in X

06. 1 epoch in K and Ka.

Results



Yanza et al. in prep.

Results

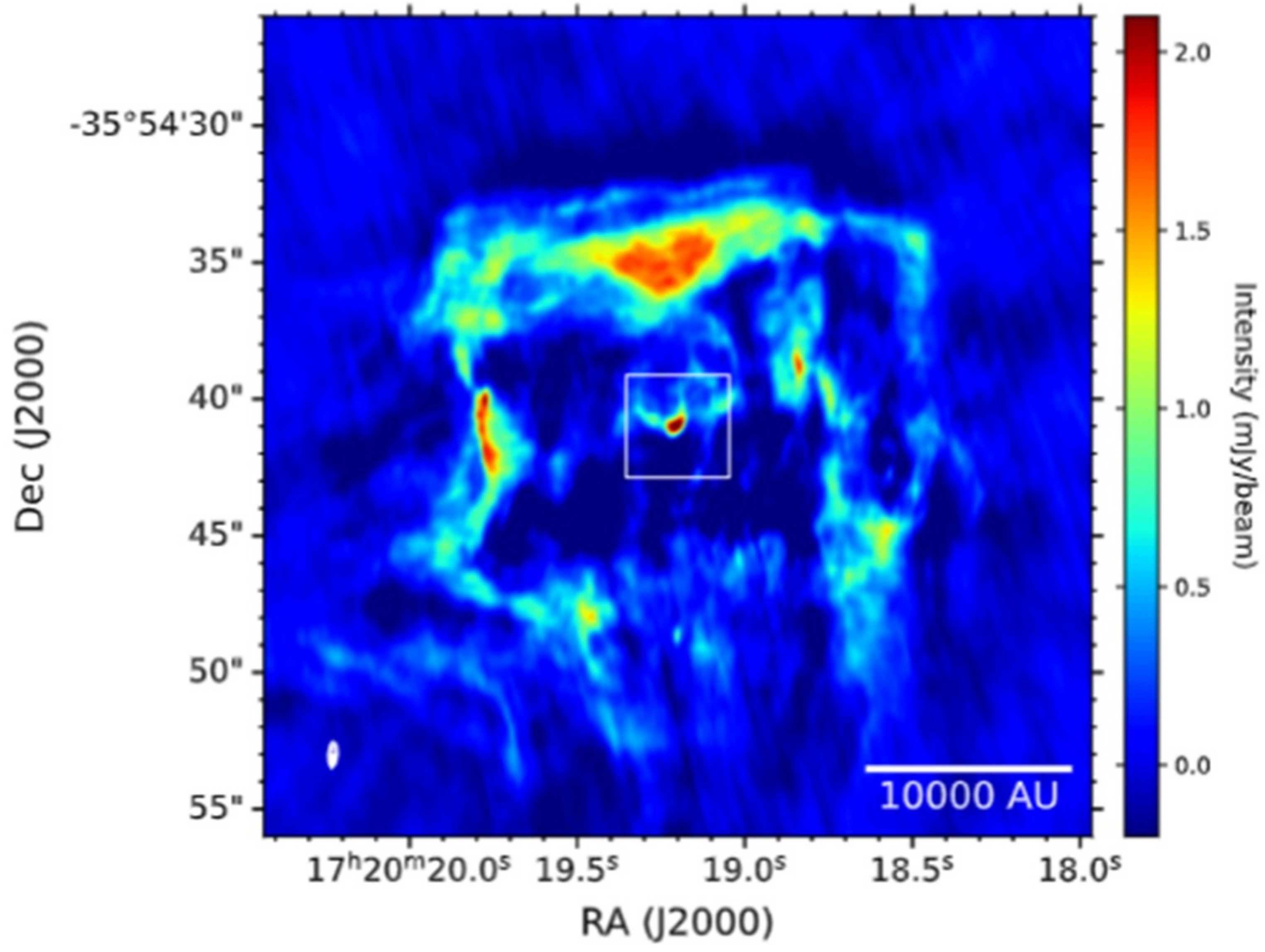
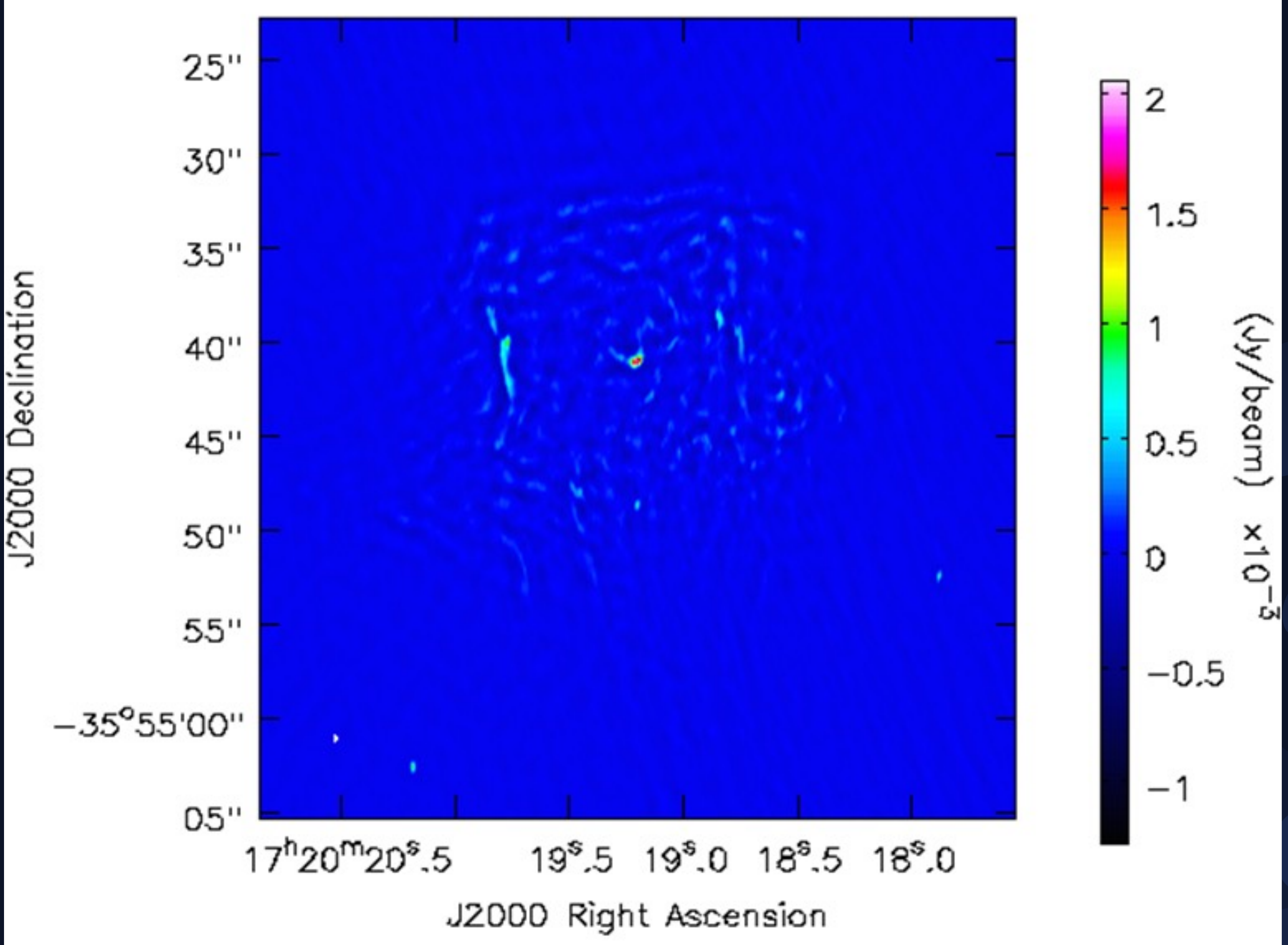


Figure 1. X band (8-12 GHz) image using all visibilities. White square shows the field of view presented in the following images. The synthesized beam is shown in the bottom-left side of the panel



Spectral

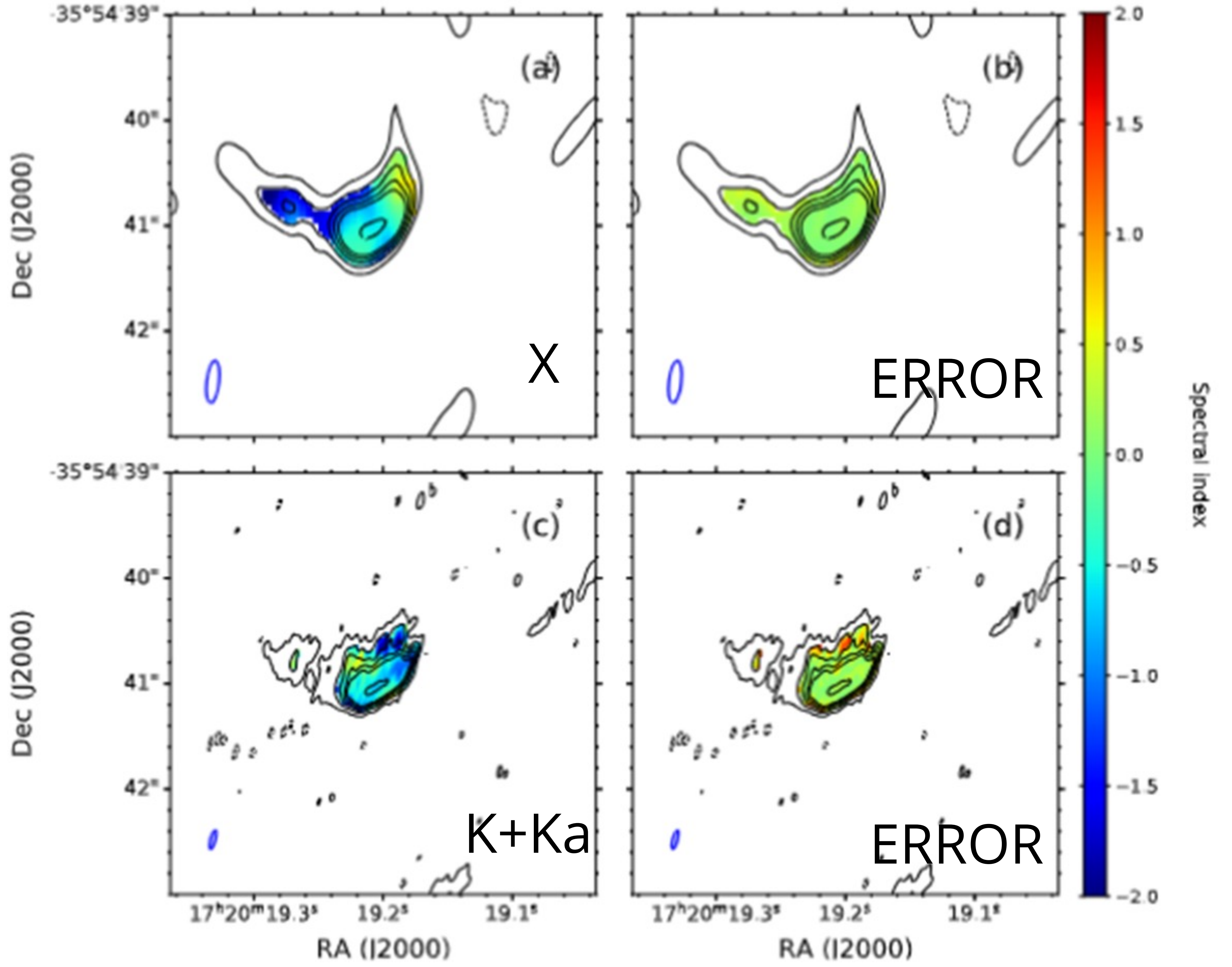
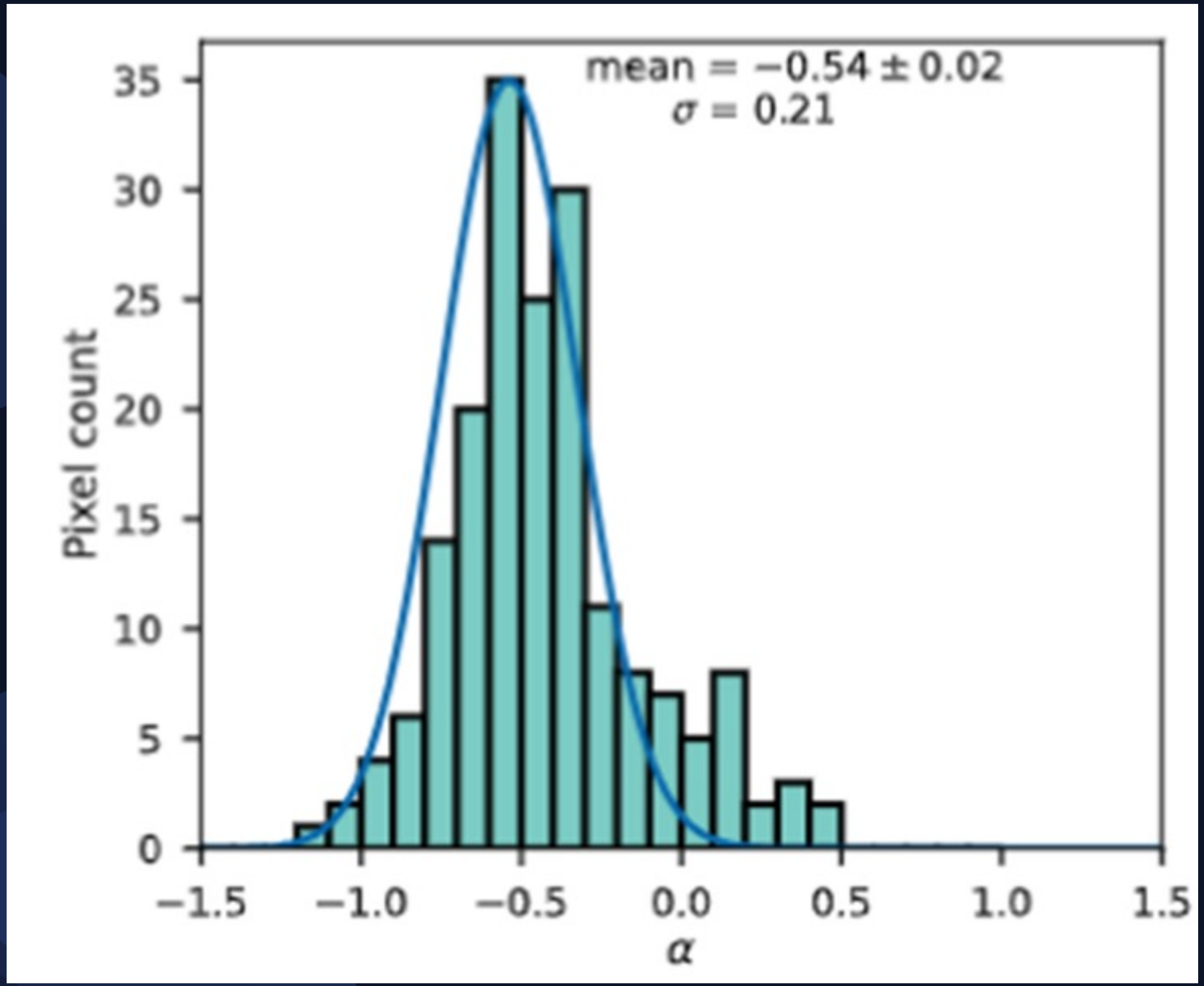
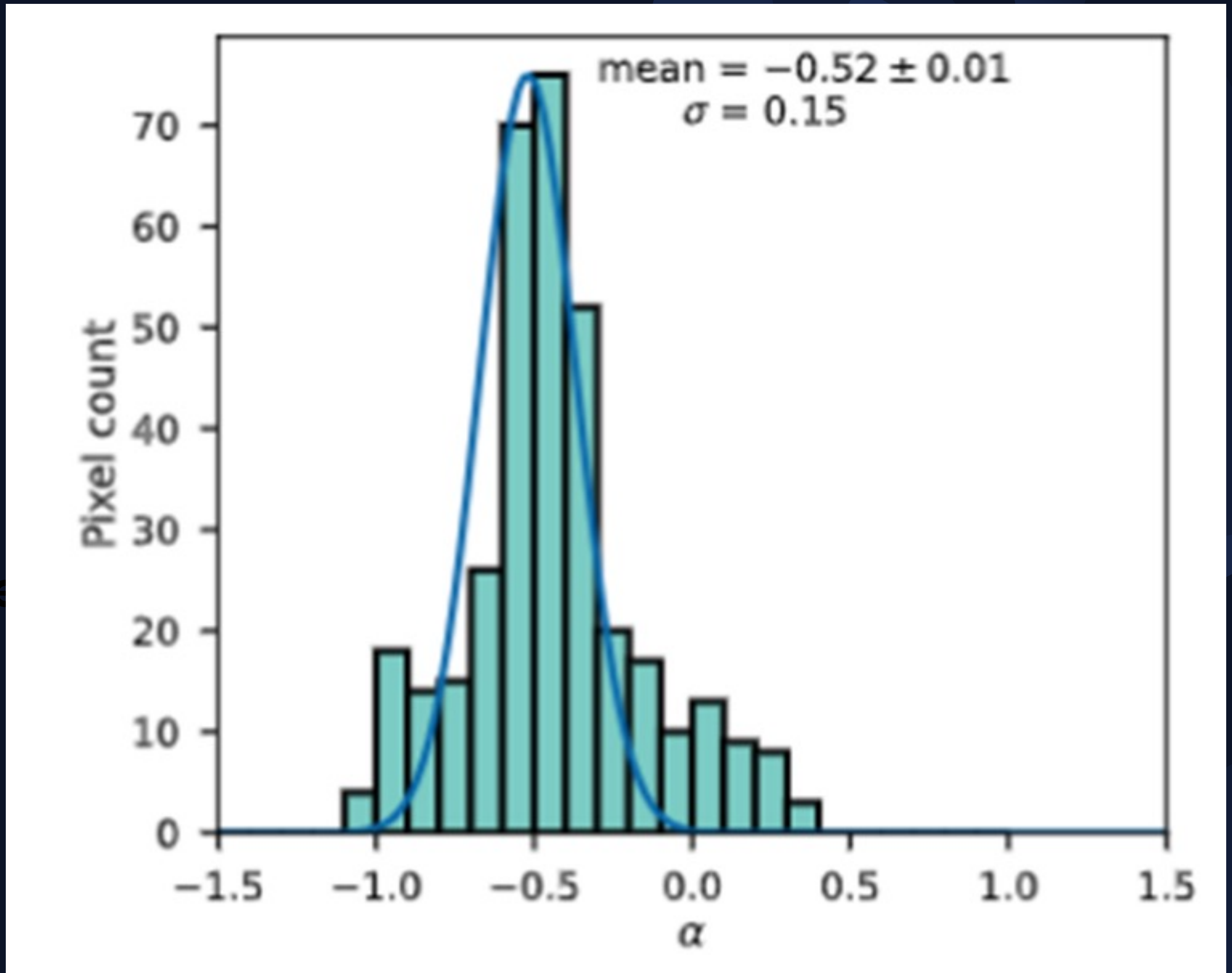


Figure 3. Spectral index maps of VLA J172019.21−355440.9. Panels are: (a) Spectral index map obtained from all observations in full X-band, (b) spectral index error in the X band, (c) spectral index from the combination of the K- and Ka-bands, and (d) spectral index error in the K+Ka band. Spectral index results are given in the regions where the radio continuum is > $6\sigma_{noise}$. Regions below this value are masked. Contour levels synthesized beam sizes are the same as in Fig. 2 for their corresponding band.

Spectral index



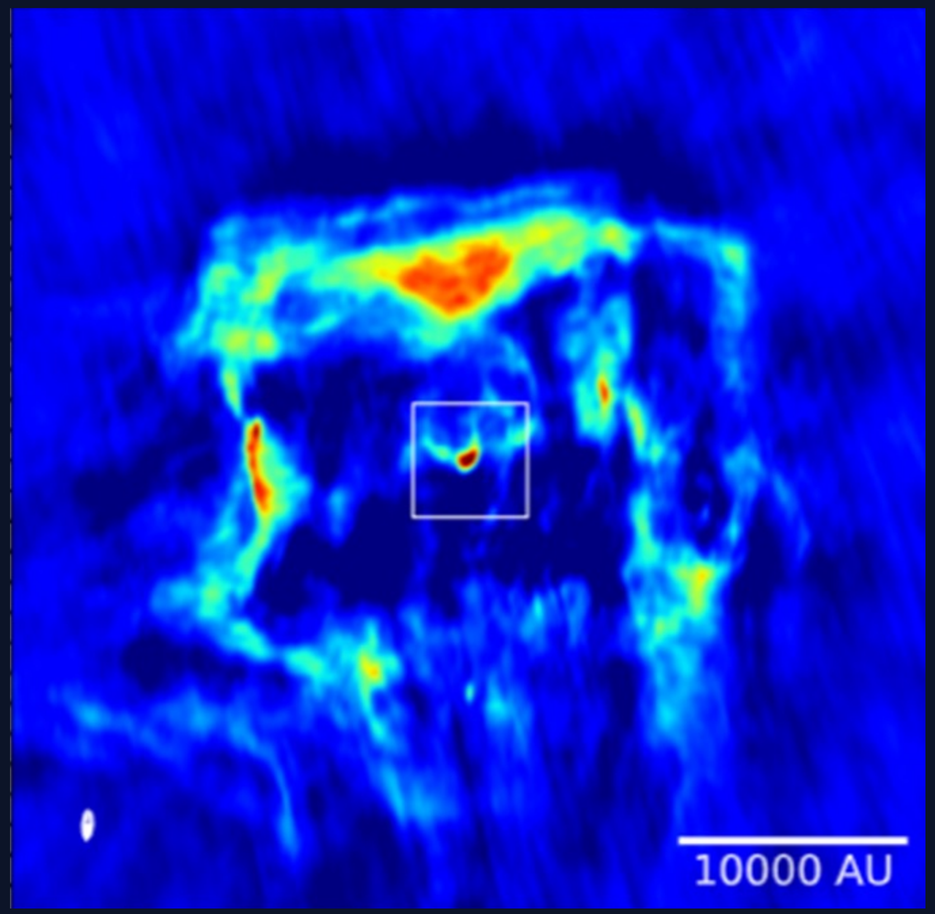


-0.5 → CWR

In this scenario...

1

2



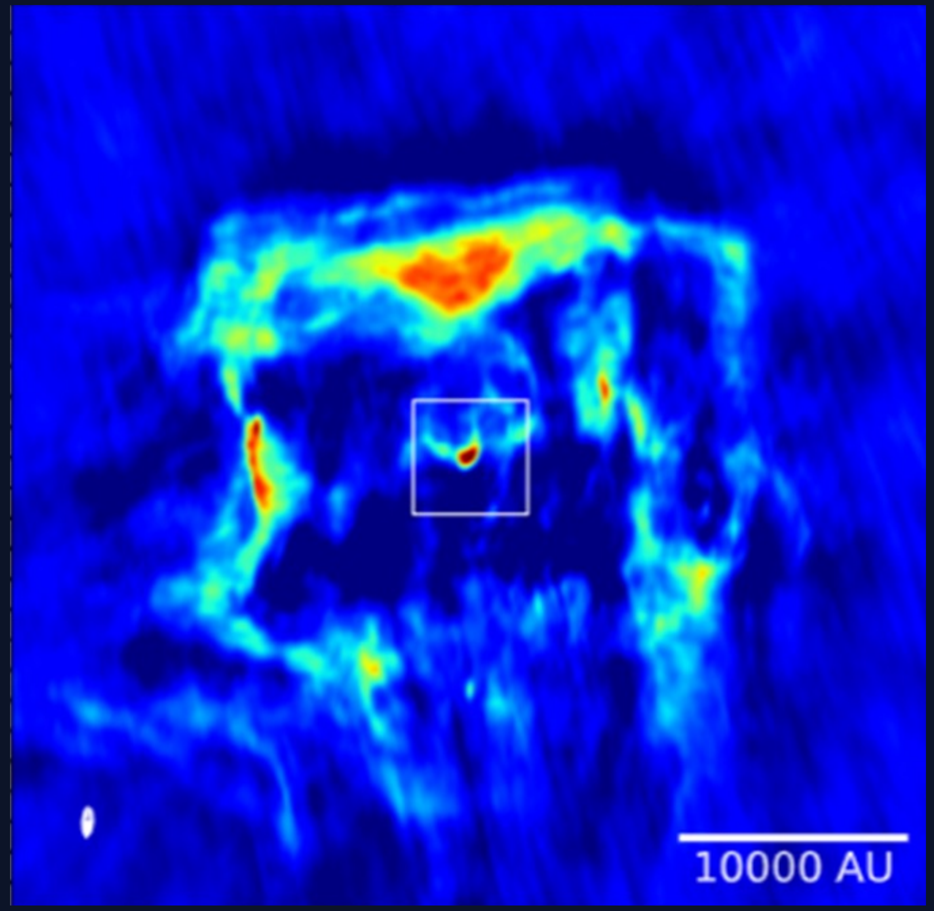
From Rodriguez et al. (1982), Carral et al. (2002), the spectral type of ionizing star is O7. 5 (10^5 Lsun).

e.g. Dzib et al. (2013)

In this scenario...

1

2



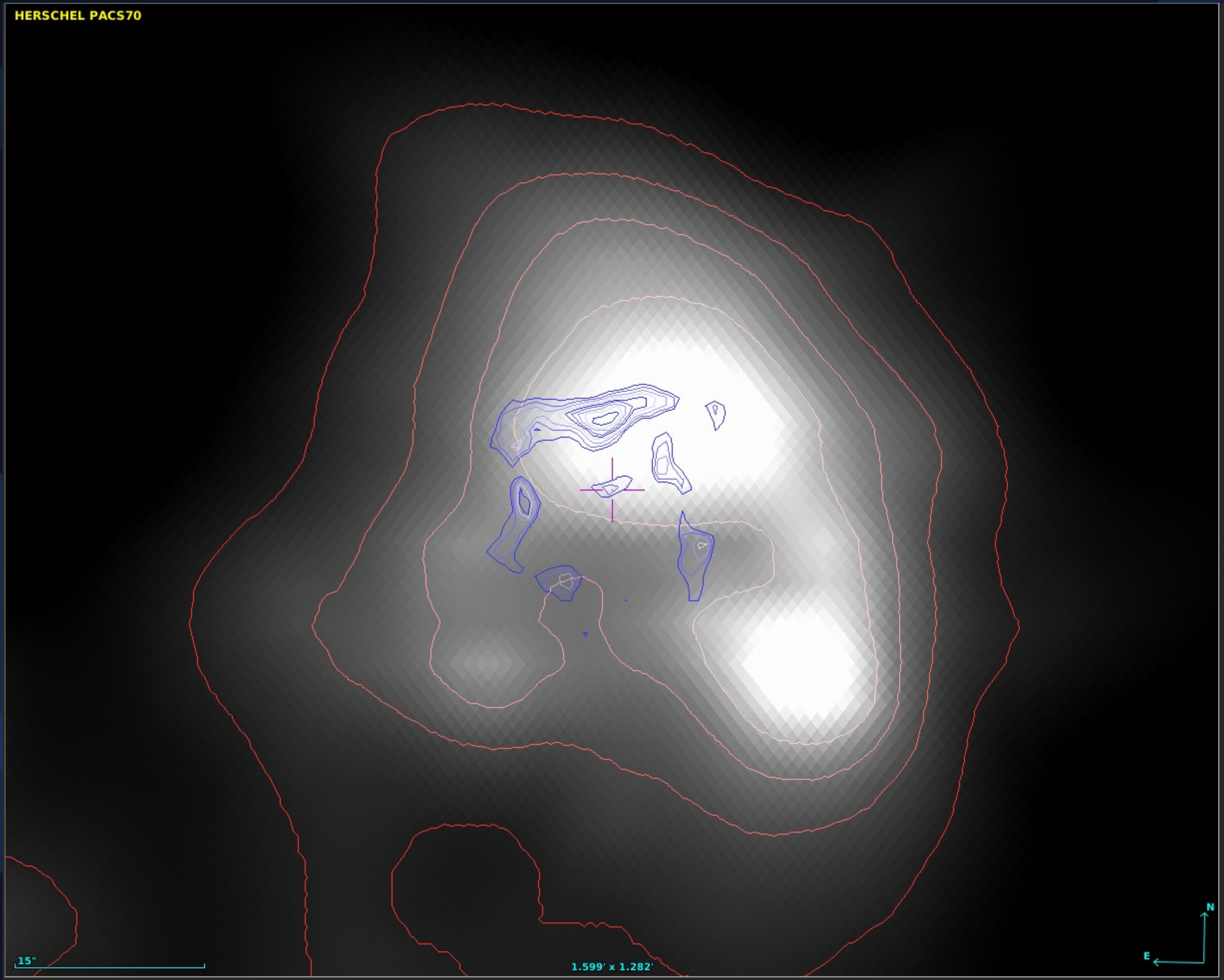
Where are the stars?

From Rodriguez et al. (1982), Carral et al. (2002), the spectral type of ionizing star is O7. 5 (10^5 Lsun).

e.g. Dzib et al. (2013)

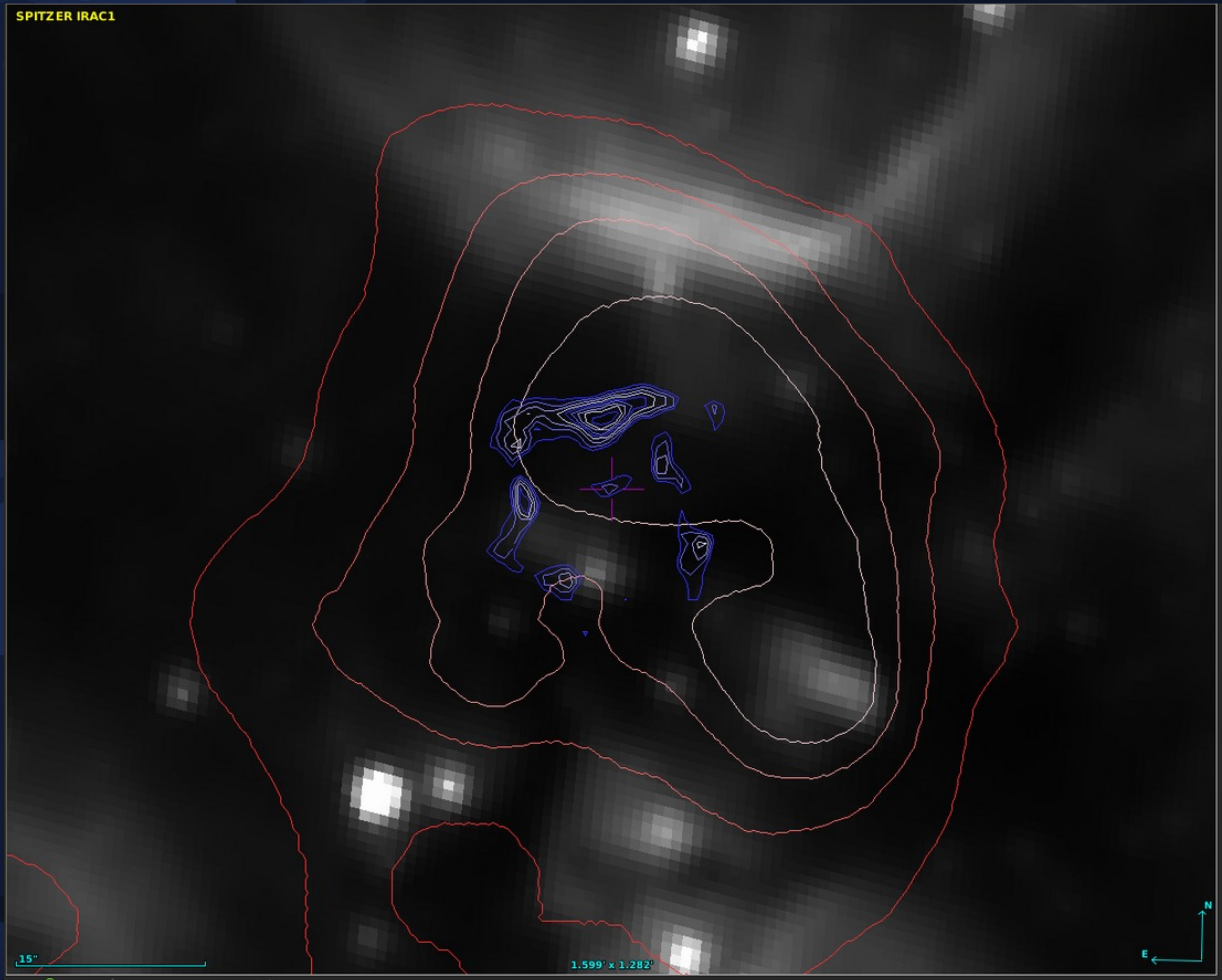
Let’s look for them!

Herschel 70um

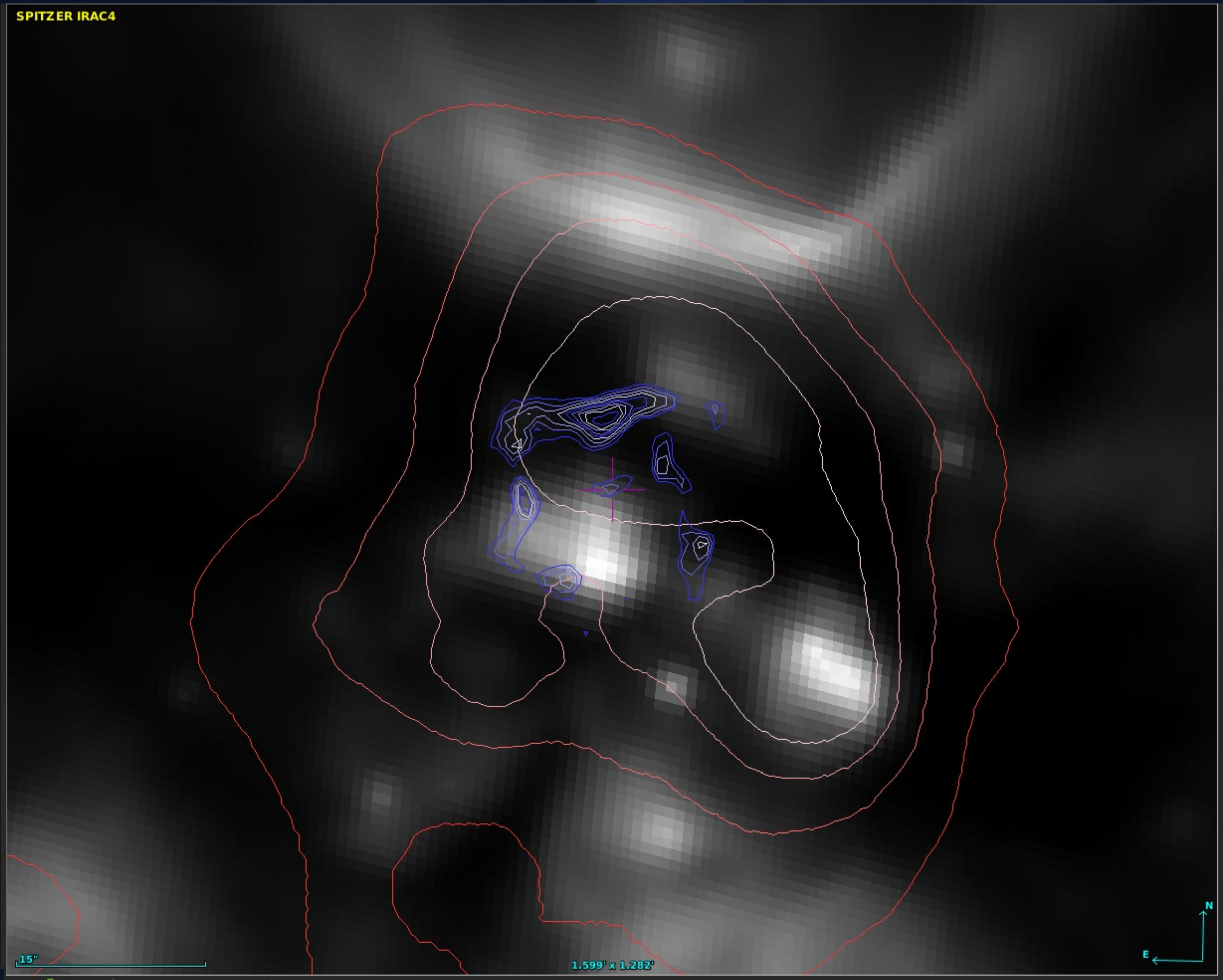


Spitzer

IRAC1



IRAC4



Exploring the spectral type of the ionizing star

Spectral type of the ionizing star

Calculating the spectral type of the ionizing star using the luminosity of the shell in compact configuration data.
Flux of ionizing photons:

$$\left[\frac{\dot{N}_\mathrm{i}}{\mathrm{s}^{-1}}\right] = 8.852 \times 10^{40} \left[\frac{S_\nu}{\mathrm{Jy}}\right] \left[\frac{\nu}{\mathrm{GHz}}\right]^{0.1} \left[\frac{T_\mathrm{e}}{10^4\ \mathrm{K}}\right]^{0.35} \left[\frac{D}{\mathrm{pc}}\right]^{2}. \qquad \text{(B.18)}$$

(Sanchez-Monge, Beltran et al. 2013, A&A, 550, A21)
Using Sv =6 Jy, v=23.2GHz, Te=1e4K and D=1340pc.
Ni = 1.3x10^48 → **O9 star**

SEDFITTER

Software that consider a set of sources to be studied. For each source, the SED fitter can fit models, such as model stellar photospheres, YSO model SEDs, as well as galaxy and AGB templates, to the multi-wavelength photometry measurements of this particular source using linear regression. Models: Robitaille et al. (2017)

Luminosity, distance and extinction are free parameters.

Model set	Icon	Star	Disk	Envelope	Cavity	Ambient	Inner radius	Variables	Models
s-s-i		yes	...	...	...	...	...	2	10 000
sp-s-i		yes	passive	...	...	...	R_{sub}	7	10 000
sp-h-i		yes	passive	...	...	...	variable	8	10 000
s-smi		yes	...	...	...	yes	R_{sub}	2	10 000
sp-smi		yes	passive	...	...	yes	R_{sub}	7	10 000
sp-hmi		yes	passive	...	...	yes	variable	8	10 000
s-p-smi		yes	...	power-law	...	yes	R_{sub}	4	10 000
s-p-hmi		yes	...	power-law	...	yes	variable	5	10 000
s-pbsmi		yes	...	power-law	yes	yes	R_{sub}	7	10 000
s-pbhmi		yes	...	power-law	yes	yes	variable	8	10 000
s-u-smi		yes	...	Ulrich	...	yes	R_{sub}	4	10 000
s-u-hmi		yes	...	Ulrich	...	yes	variable	5	10 000
s-ubsmi		yes	...	Ulrich	yes	yes	R_{sub}	7	10 000
s-ubhmi		yes	...	Ulrich	yes	yes	variable	8	10 000
spu-smi		yes	passive	Ulrich	...	yes	R_{sub}	8	10 000
spu-hmi		yes	passive	Ulrich	...	yes	variable	9	10 000
spubsmi		yes	passive	Ulrich	yes	yes	R_{sub}	11	40 000
spubhmi		yes	passive	Ulrich	yes	yes	variable	12	80 000

SEDFITTER

We fitted different YSO models to our source. The data was taken from different telescopes reported by Tigé et al. (2017)

- Spitzer. IRAC
- Herschel
- MSX
- APEX
- SIMBA

SEDFITTER

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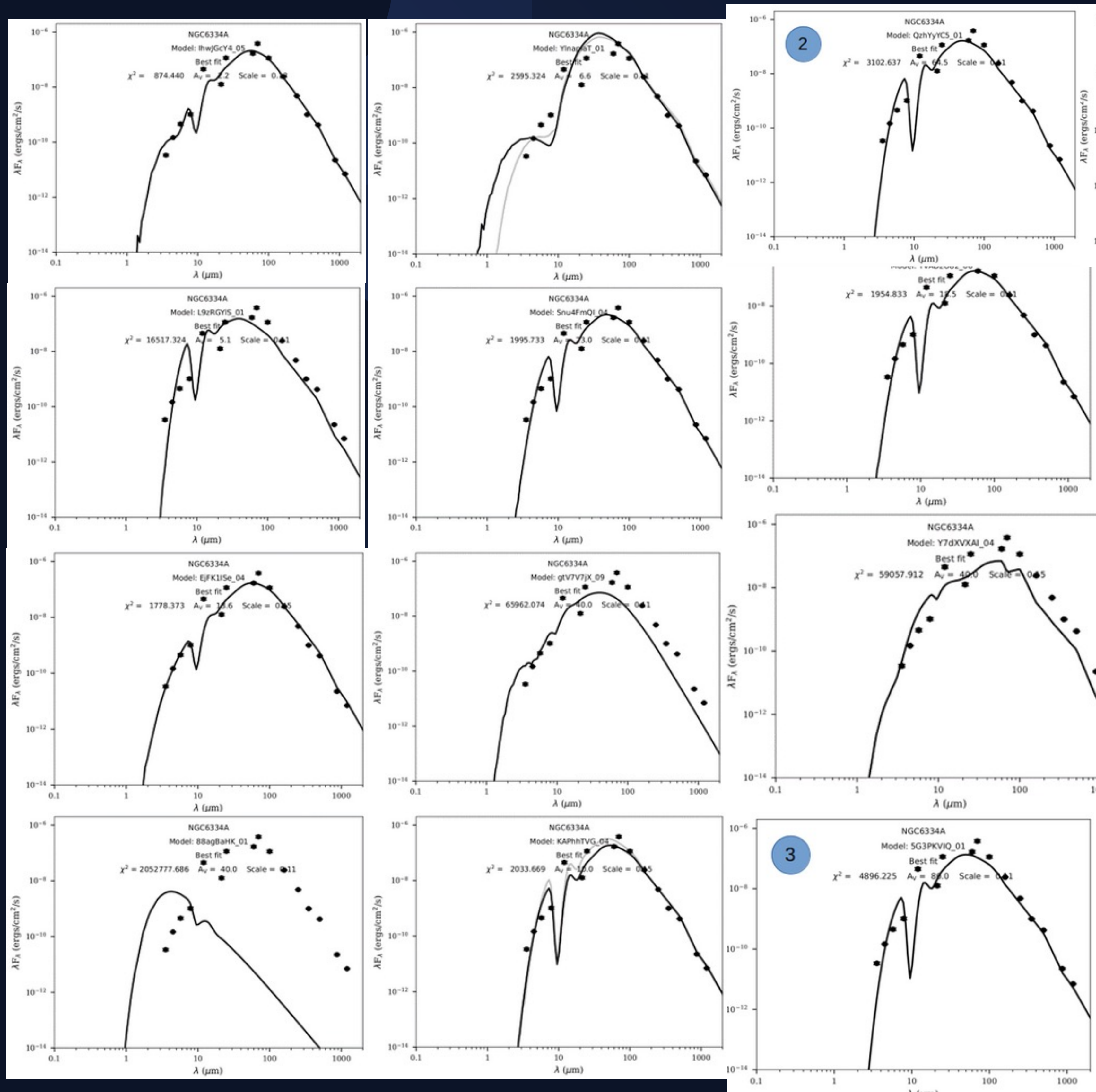
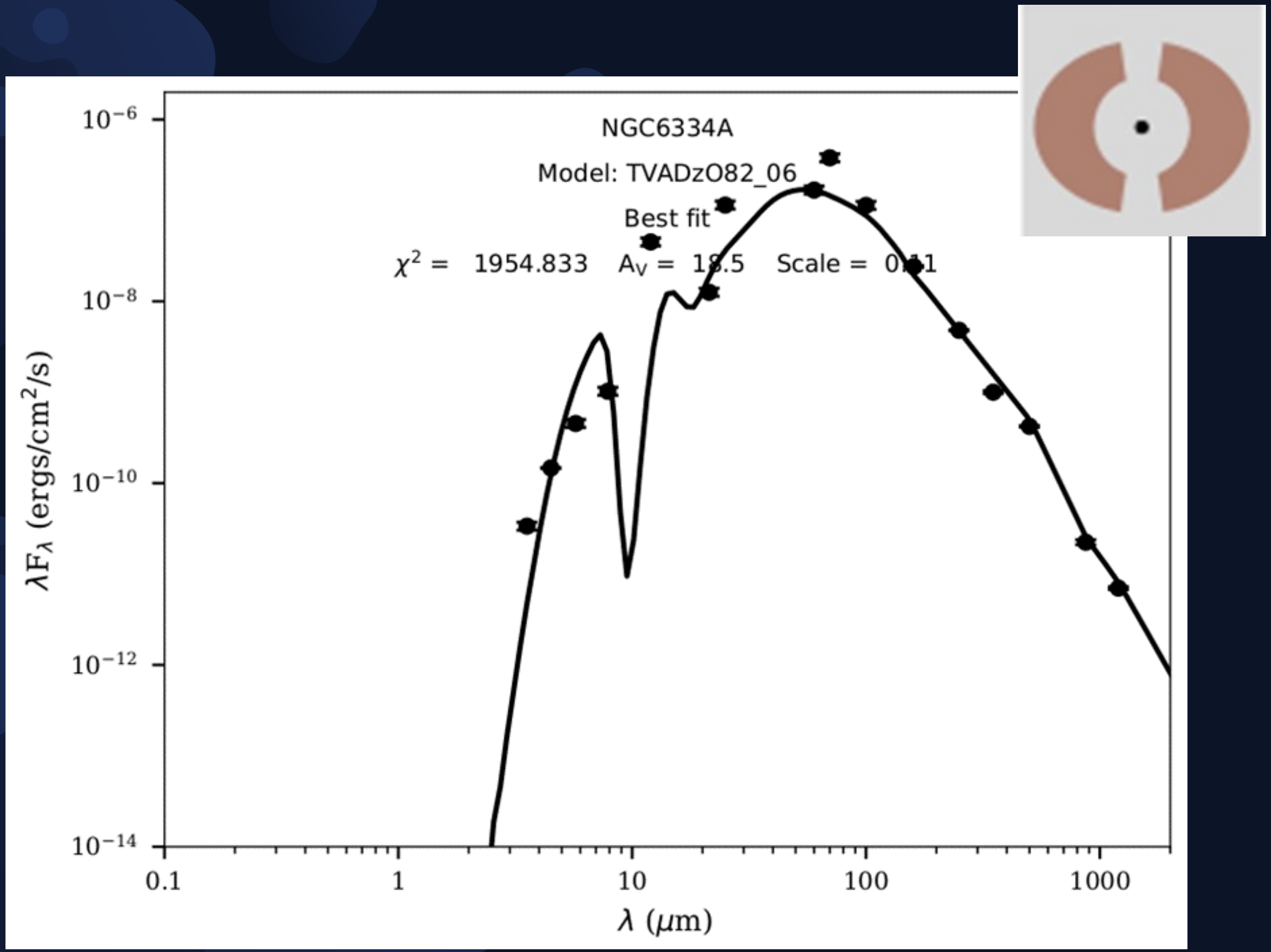
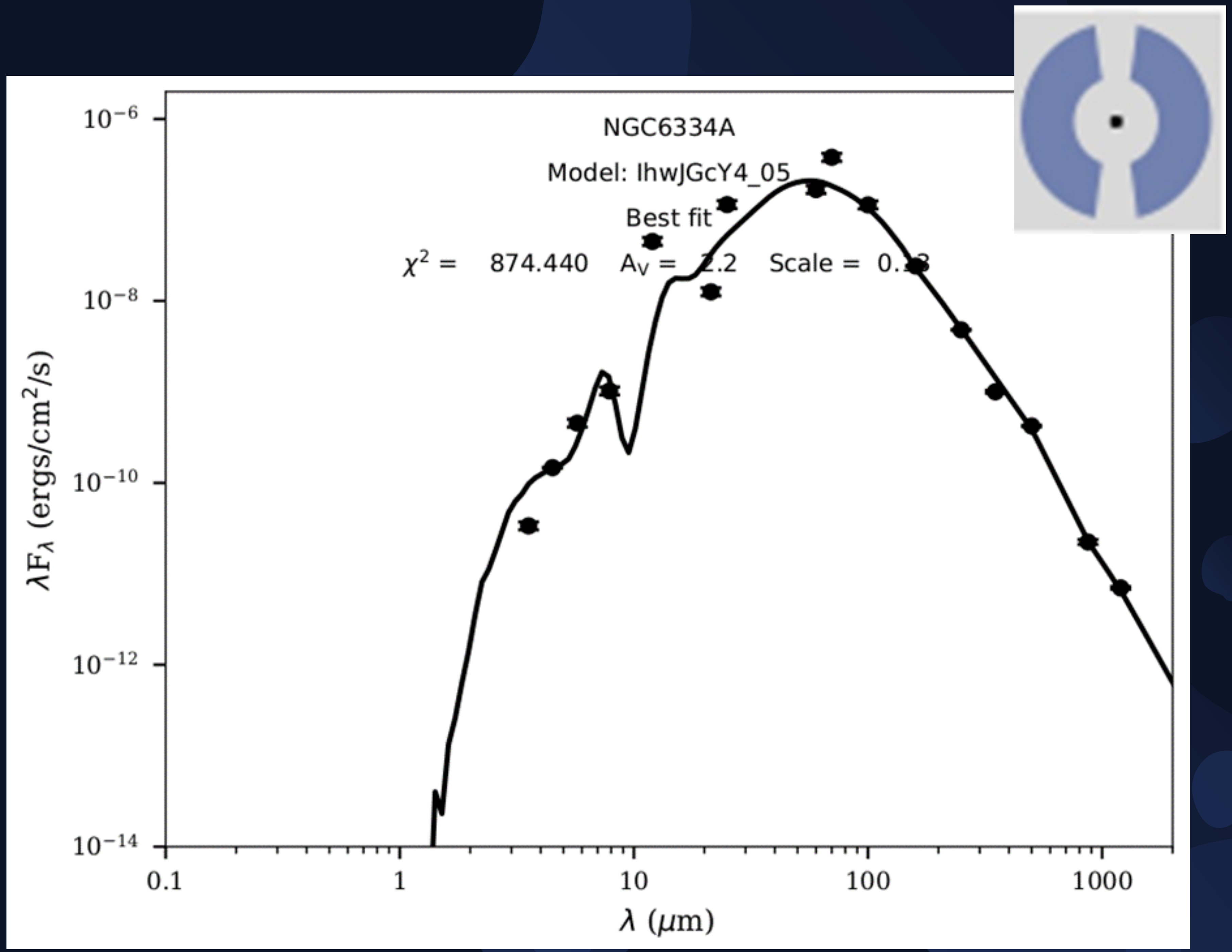


SEDFITTER



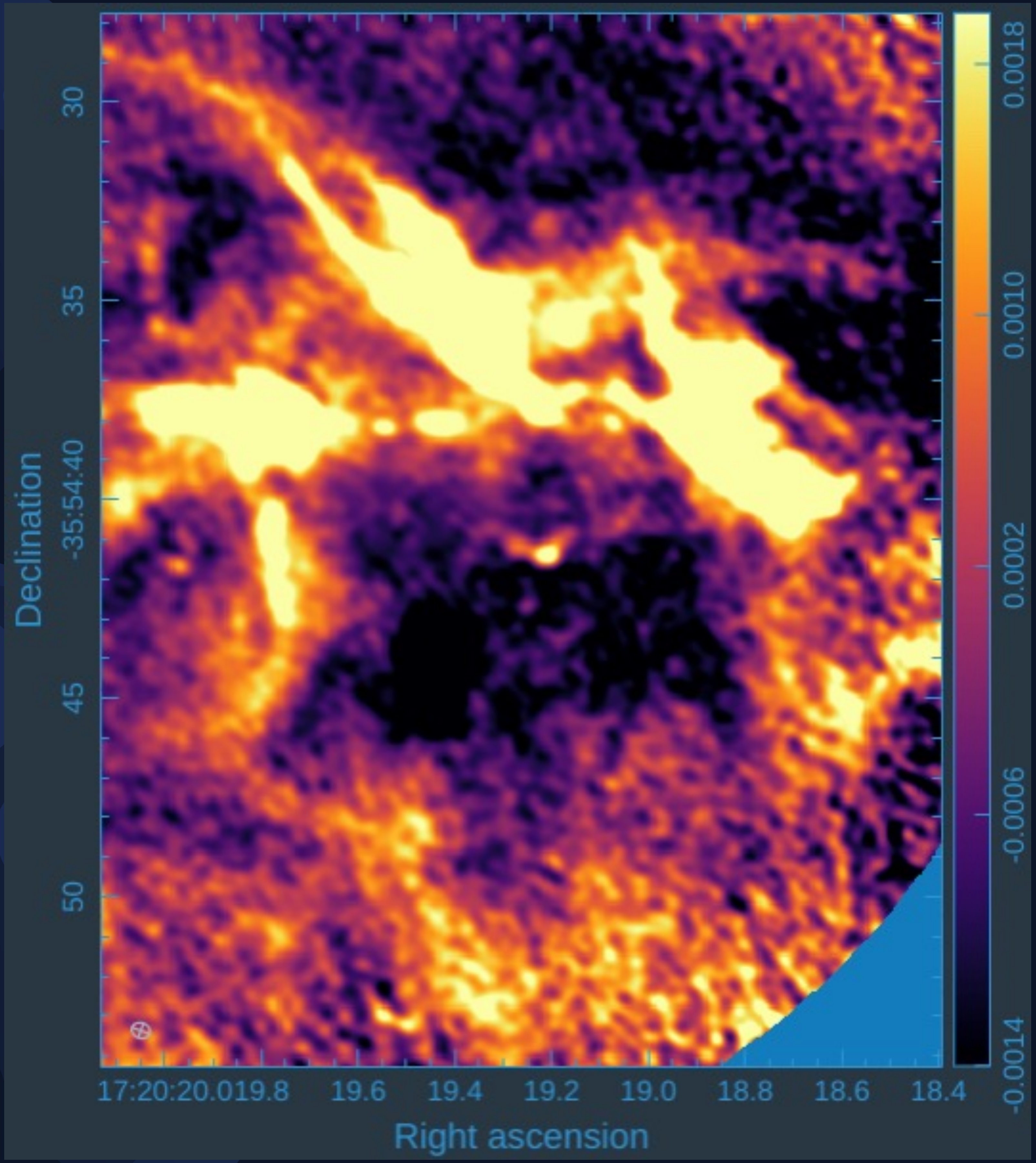


Teff=21000 K → B2

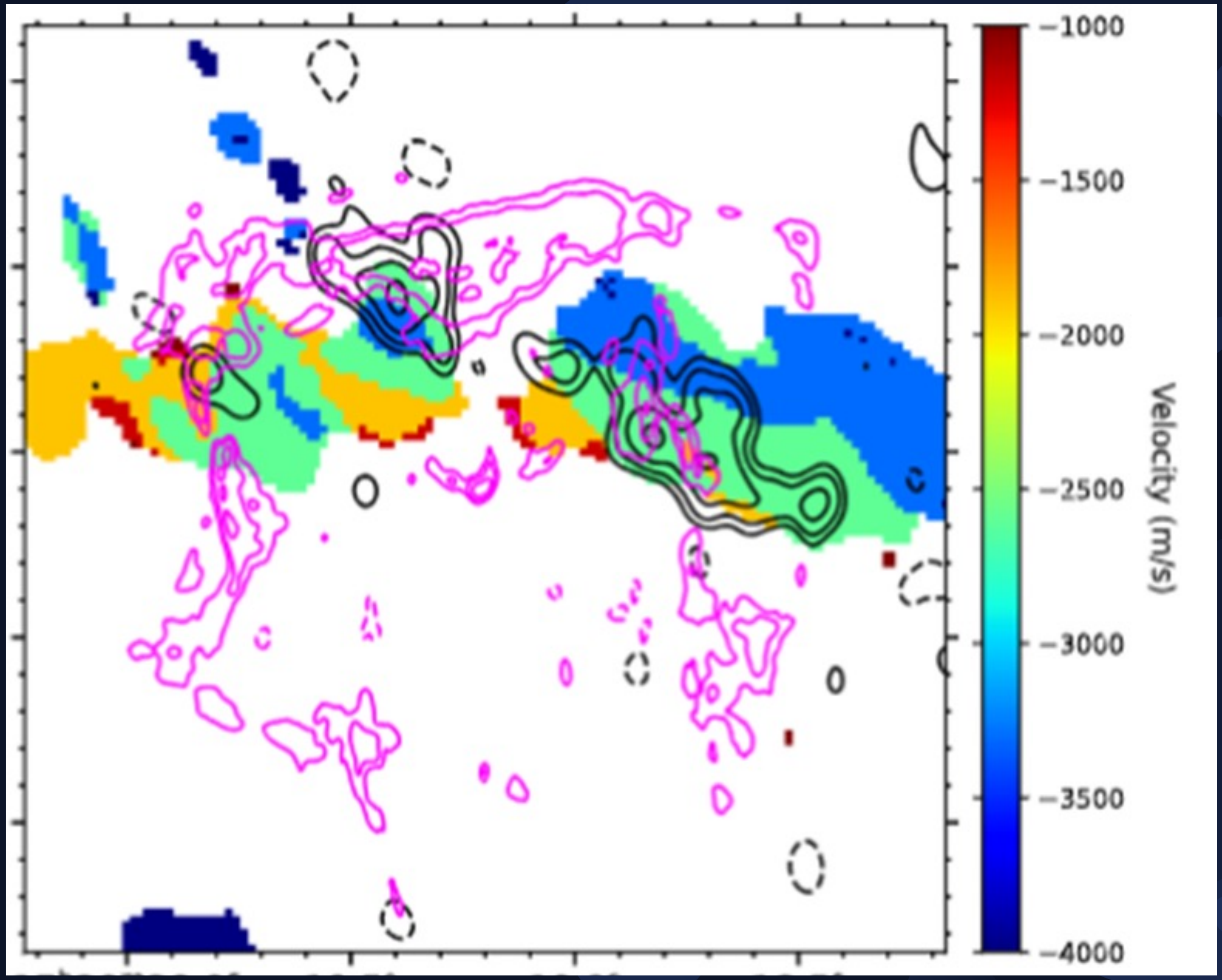
Teff=16000K → Intermediate star

There is a cavity

ALMA

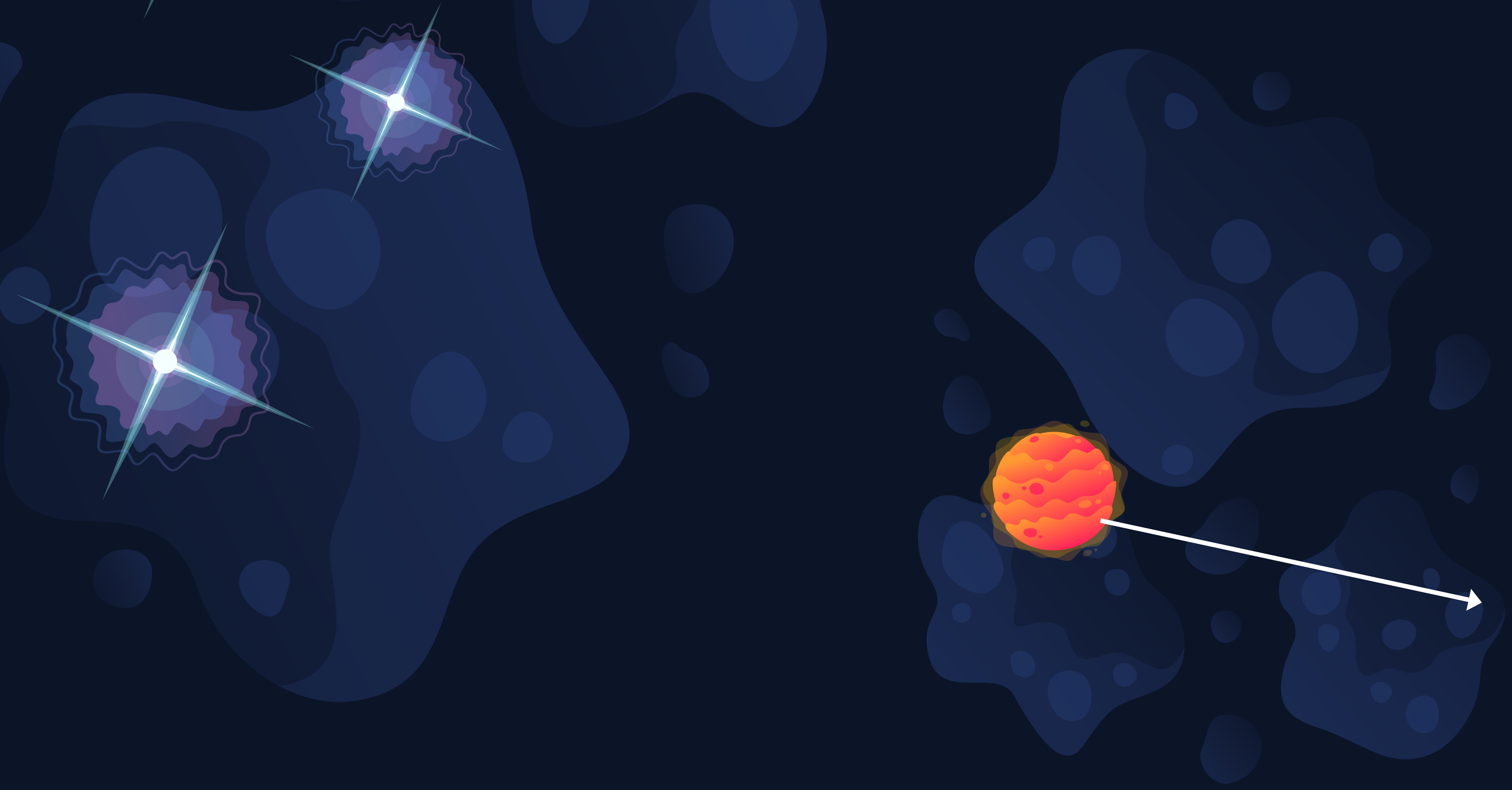


SMA



Palau et al. (2021)

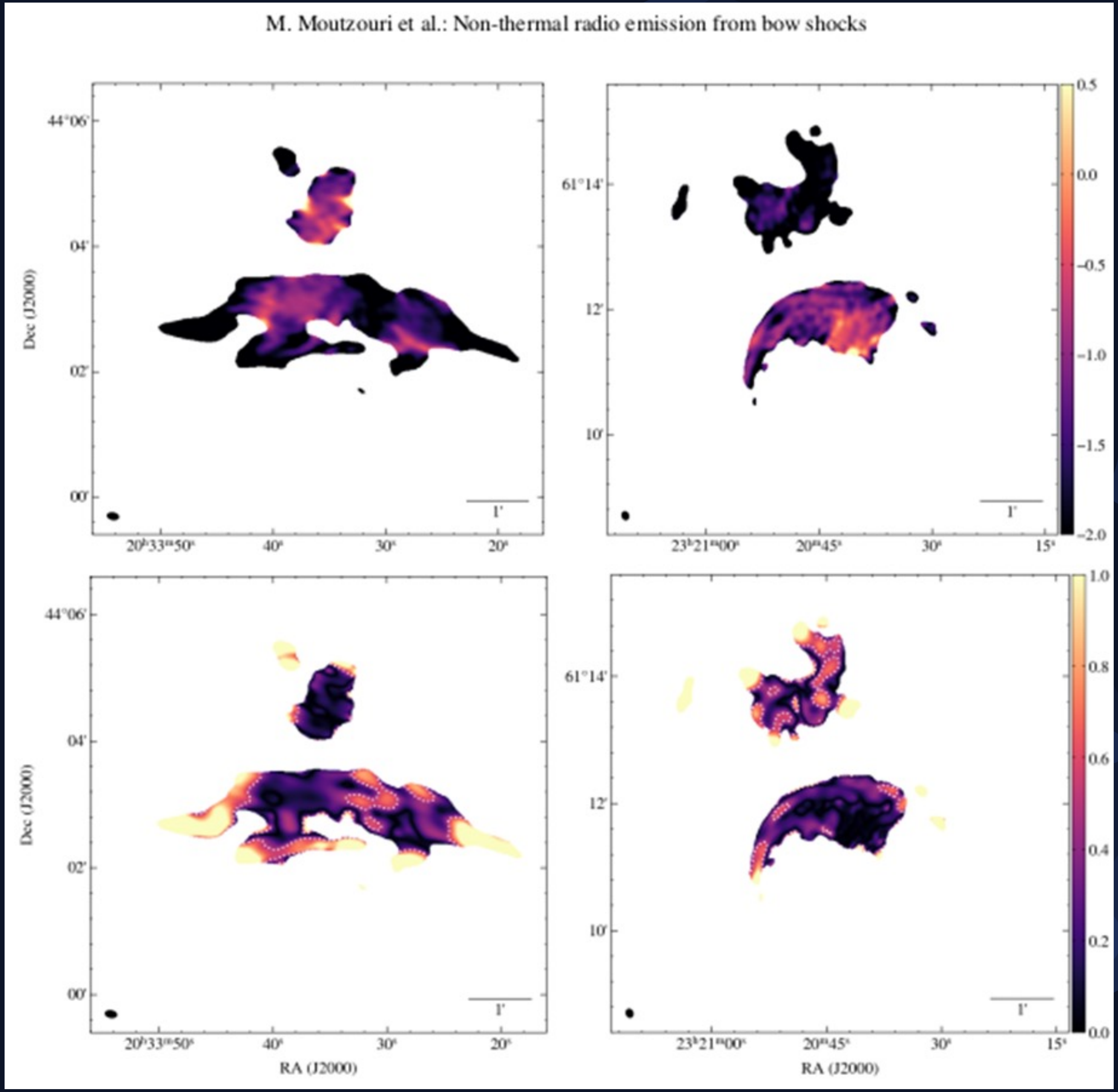
RUNAWAY STAR SCENARIO



Non-thermal emission in runaway stars

Massive star

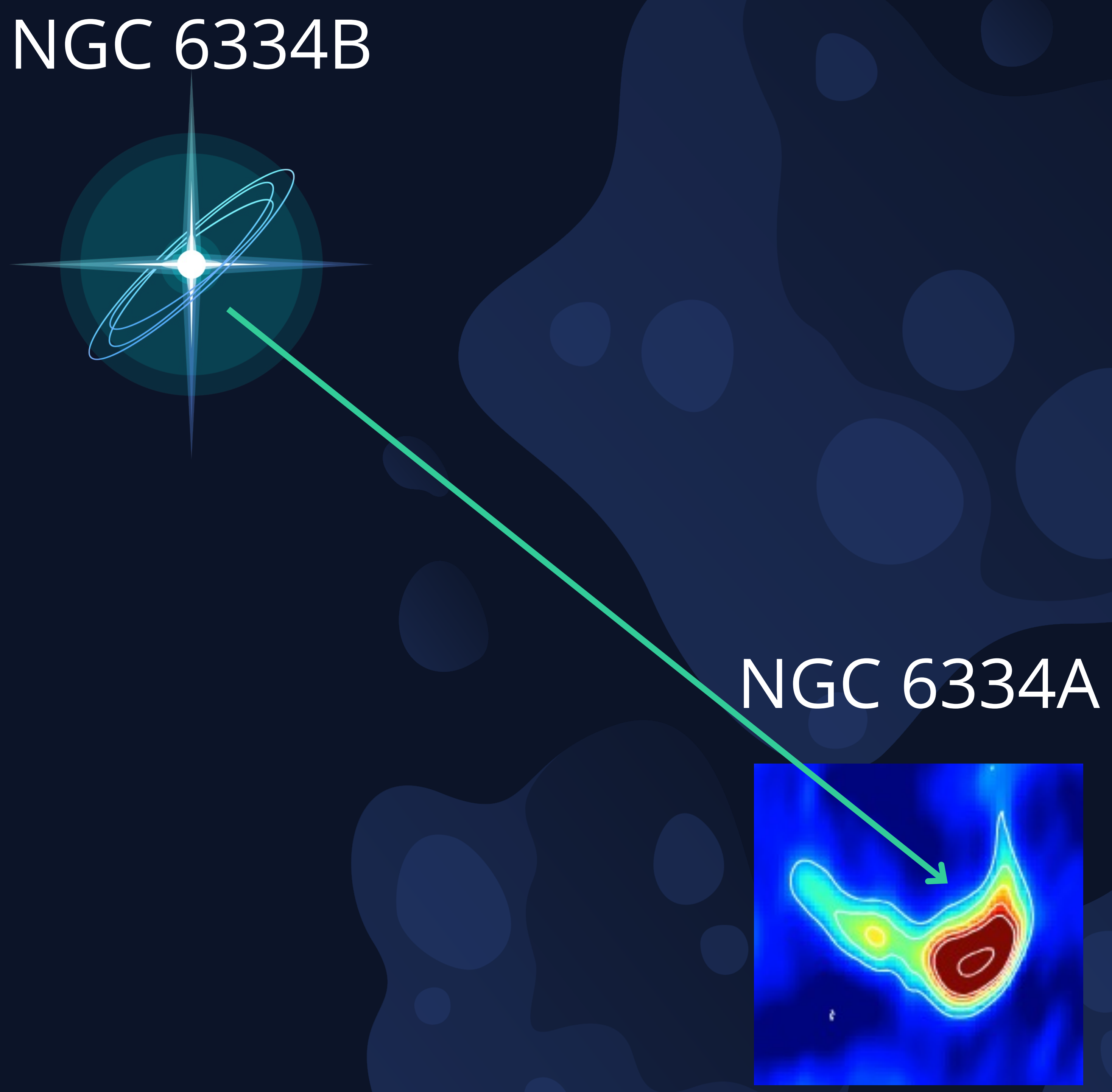
Pereira et al. (2016) reported B2 runaway star with non-thermal emission.



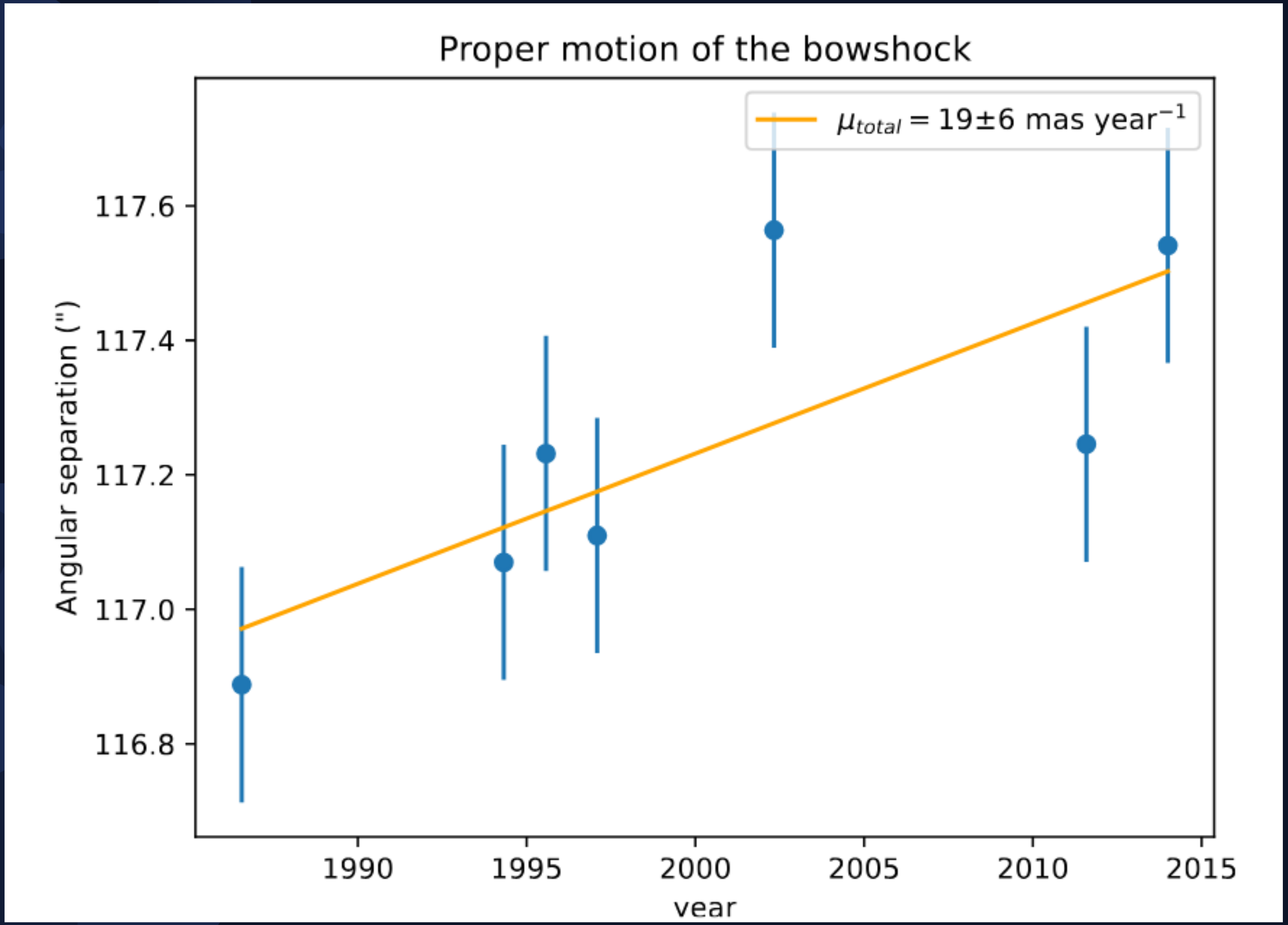
Velocity of the source

VLA DATA:

- 1986
- 1994
- 1997
- 1998
- 2002
- 2011
- 2014

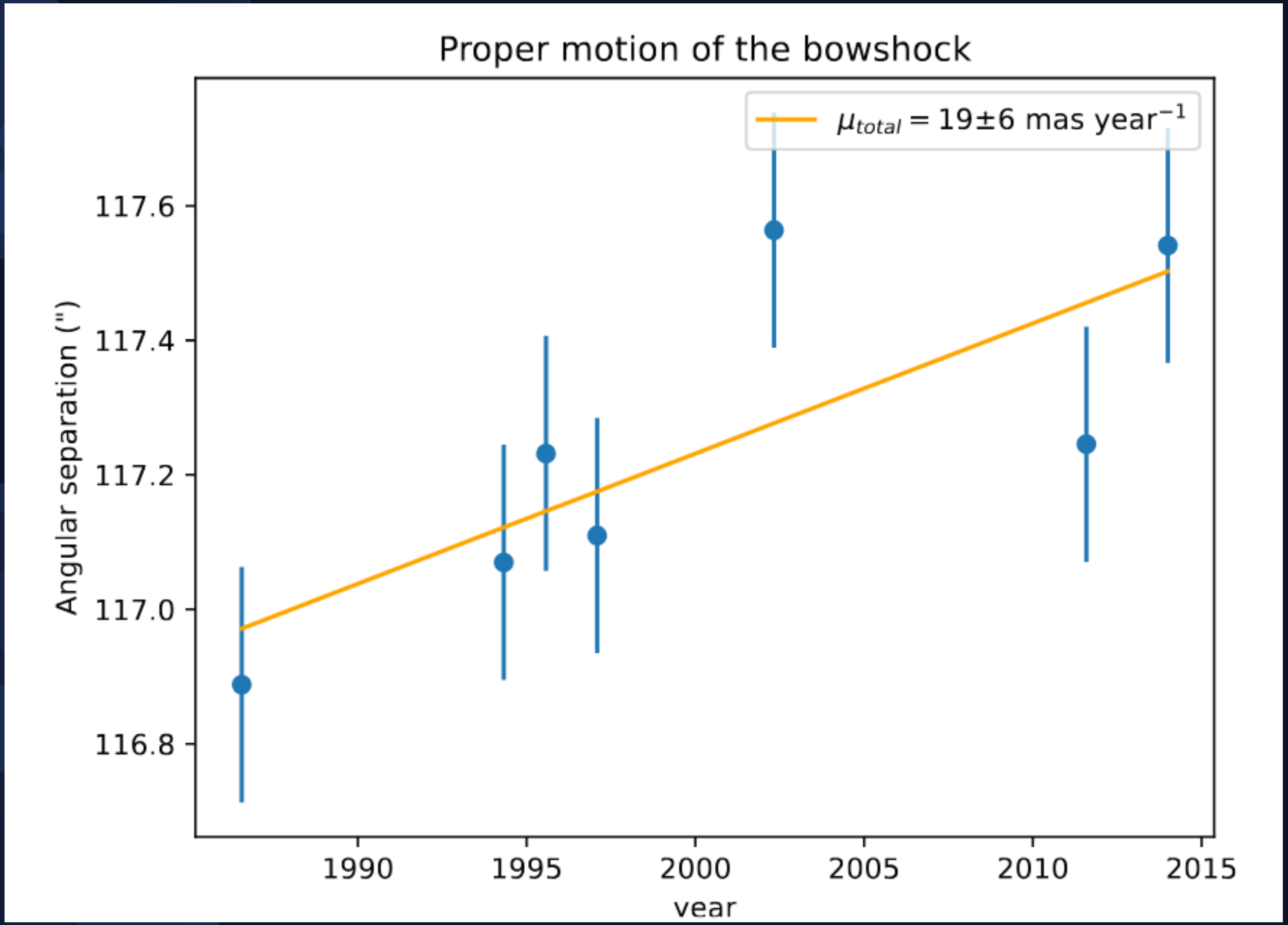


Velocity of the source



Vel=123 km/s +/- 40 km/s

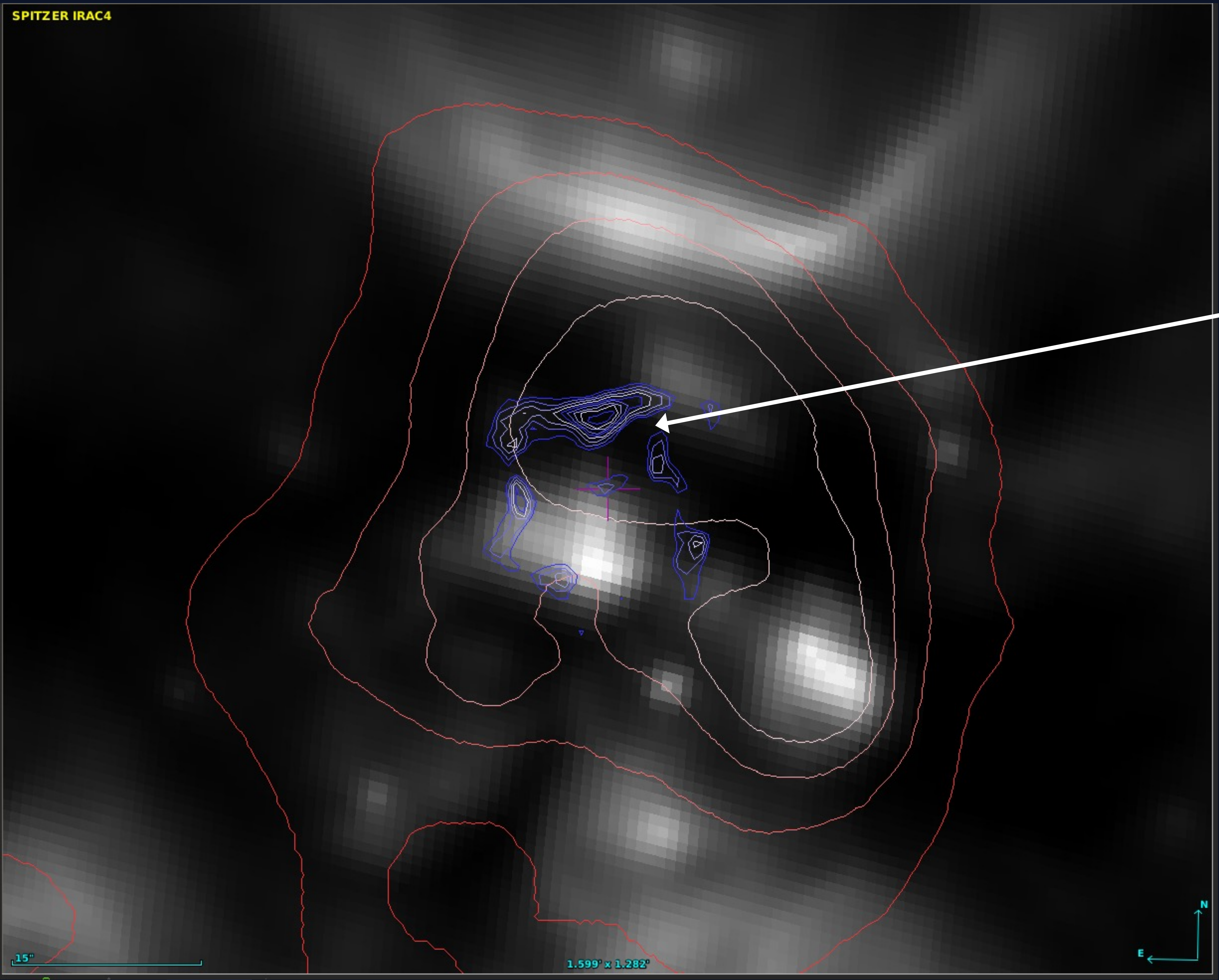
Velocity of the source



Vel=123 km/s +/- 40 km/s

Where is the massive star?

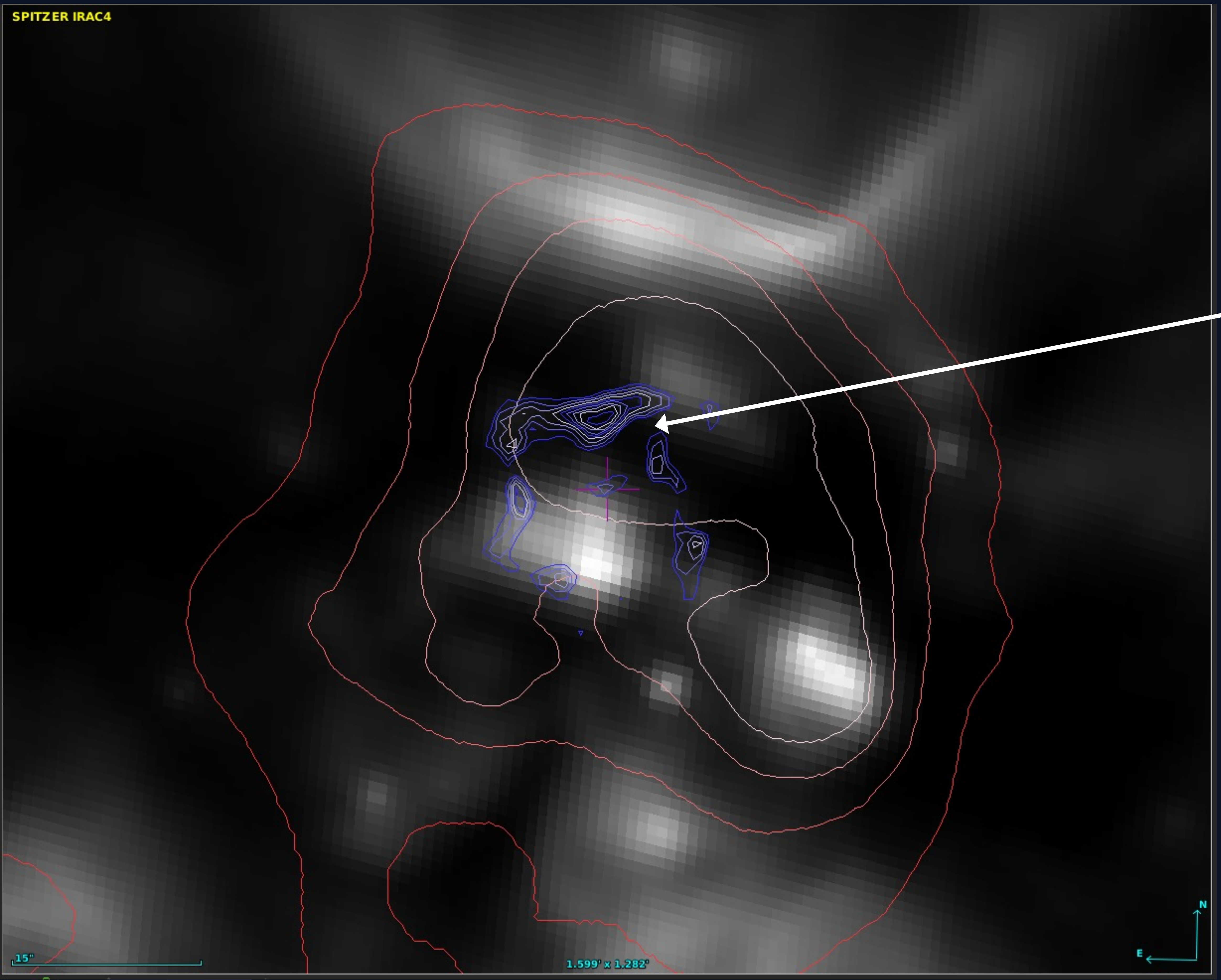
Preliminary result



Using Herschel 70um, we calculate a Lbol ~ 15000-20000 Lsun

This is a B0 star

Preliminary result

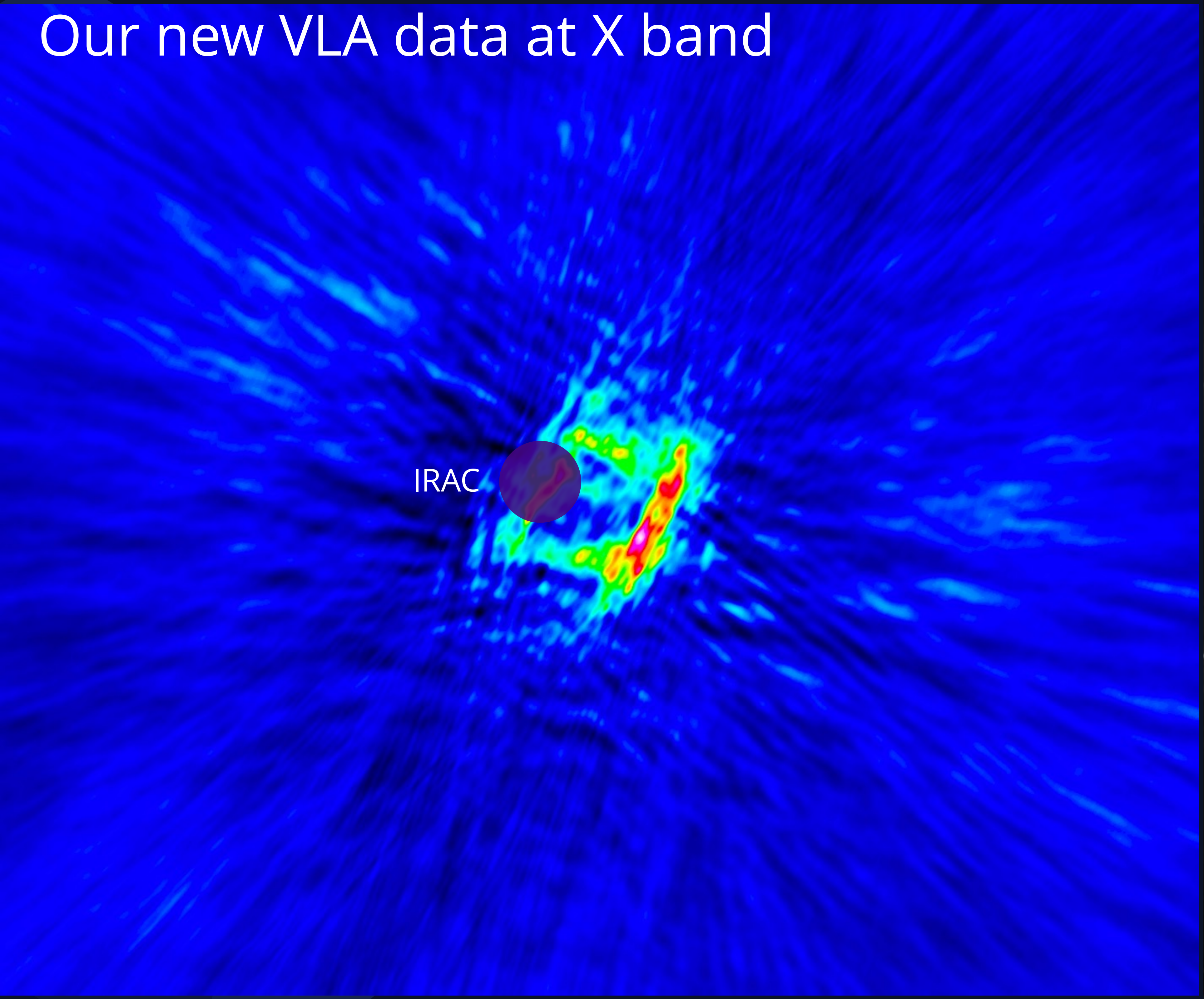


Using Herschel 70um, we calculate a Lbol ~ 15000-20000 Lsun

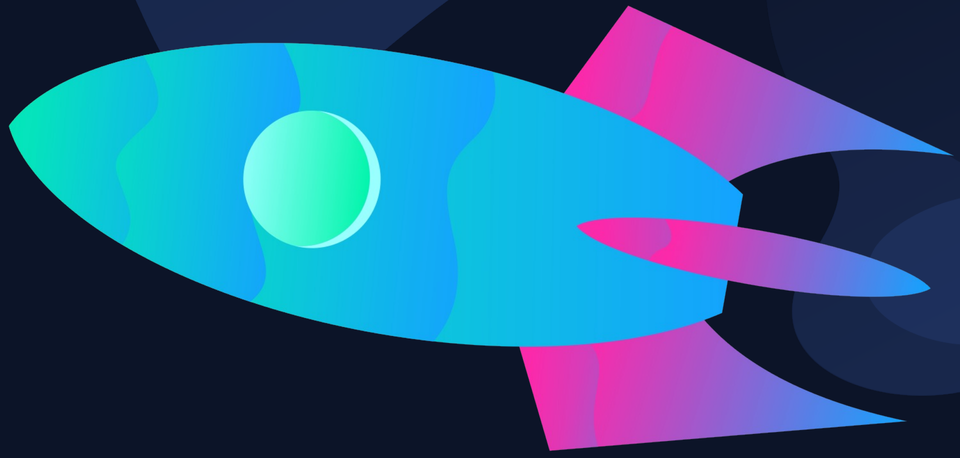
This is a B0 star

The Peak at the north could be the ionizing star that it is also a runaway star, but was moved from the center by the dynamical scenario

G5.89


Our new VLA data at X band
IRAC


SPITZER IRAC4
315.1
1'
20.13' x 17.6'
N
E



Thank you!