Non-thermal radio emission from massive protostellar jets

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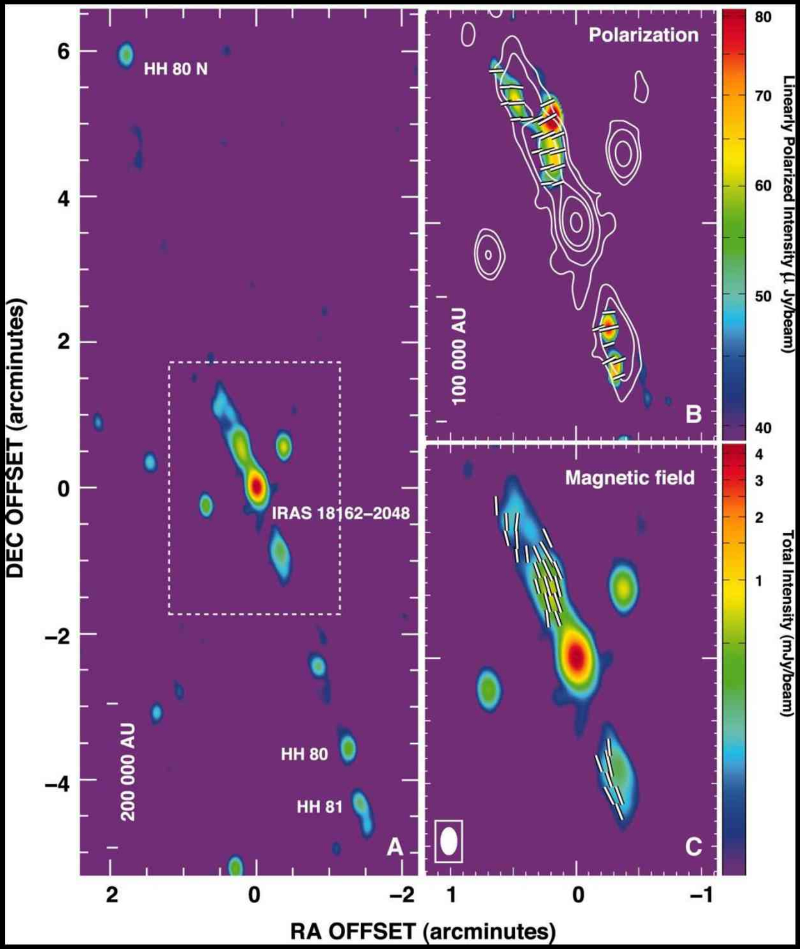
Non-thermal radio emission from massive protostellar jets
HH 80-81

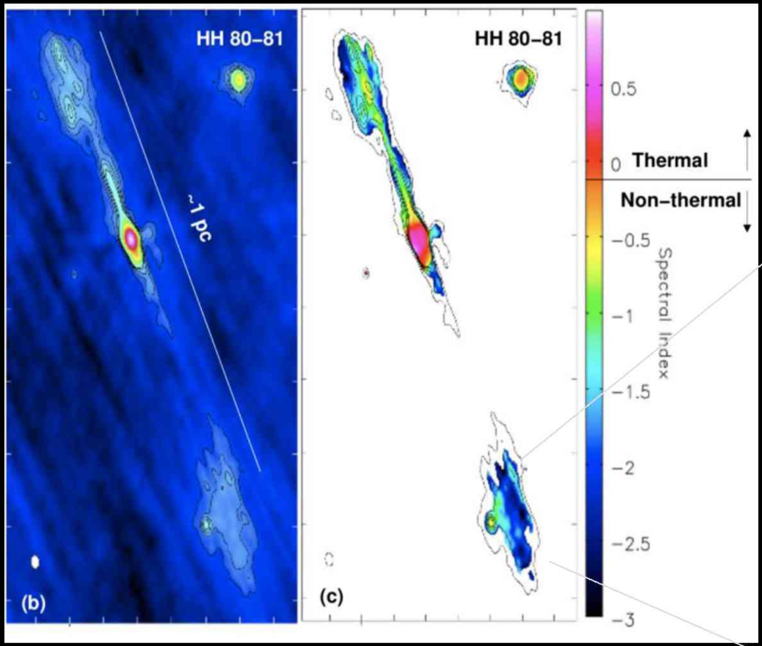


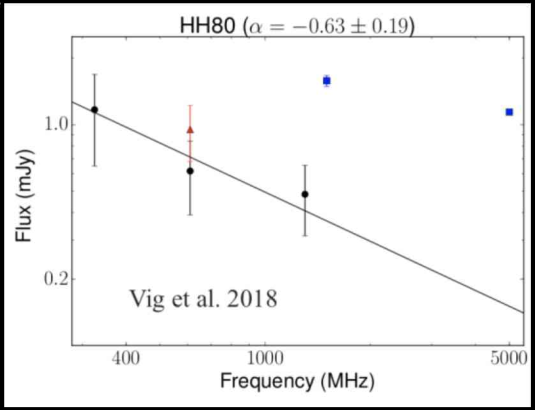
Well studied magnetized Protostellar jet (HH80-81/ GGD27)

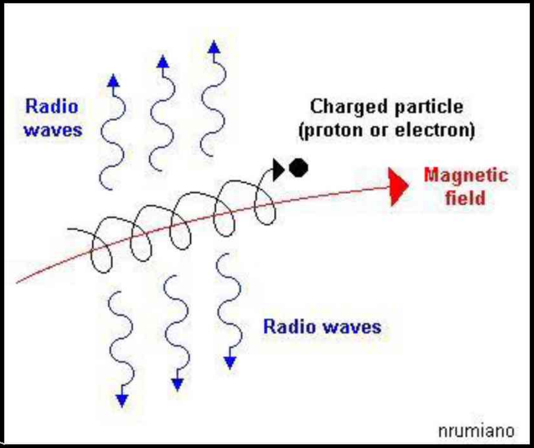
Carrasco-Gonzalez et al. (2010) detected polarized synchrotron emission.

Non-thermal radio emission from massive protostellar jets
HH 80-81

Spectral indexing ($S_\nu \propto \nu^\alpha$)



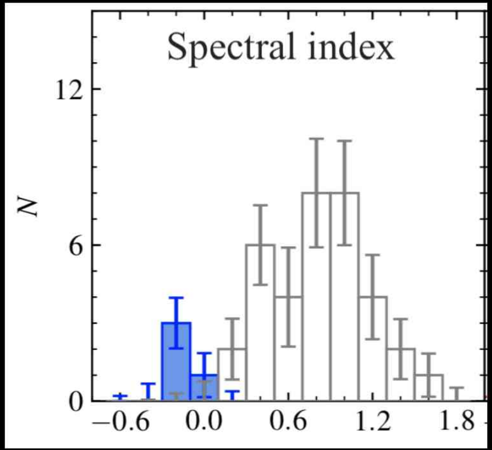




(Rodriguez-kamenetzky et al 2017)

Non thermal emission from massive protostellar jets
A search for more

Sample Selection



60 MYSOs

Radio Survey (Purser 2017)
C- band: 2012, Q-band: 2014/15

L band (1.5 GHz)

15 MYSOs

1. Brightest at 6 GHz
2. Distance < 7kpc
3. $L_{bol} > 2500L_{\odot}$

Observation

- Telescope – JVLA (A configuration)
- Resolution ~ 1.2'' at L-band (1.5 GHz)

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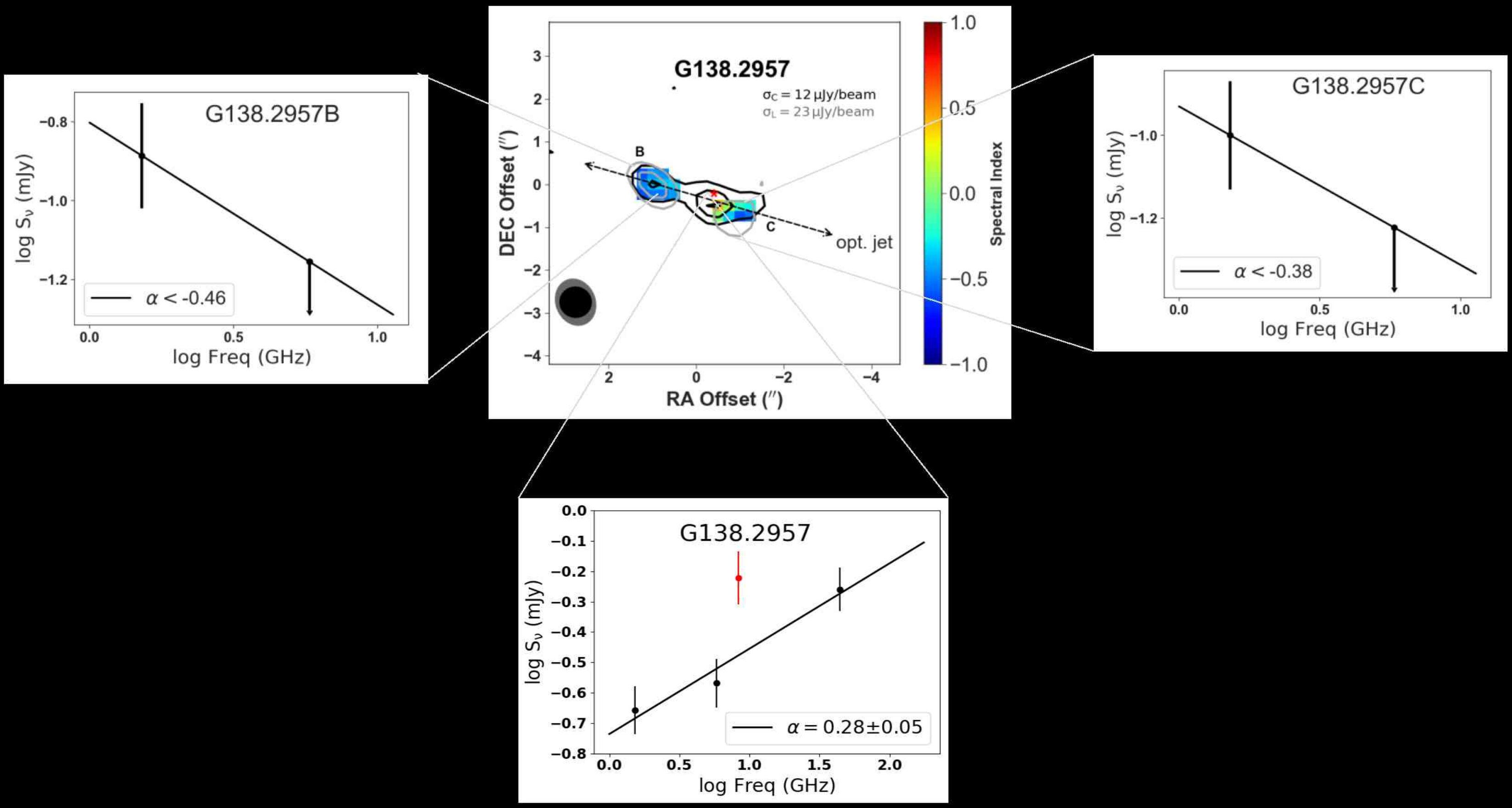
Technique: Spectral indexing

G138.2957+01.5552 (AFGL 402d)



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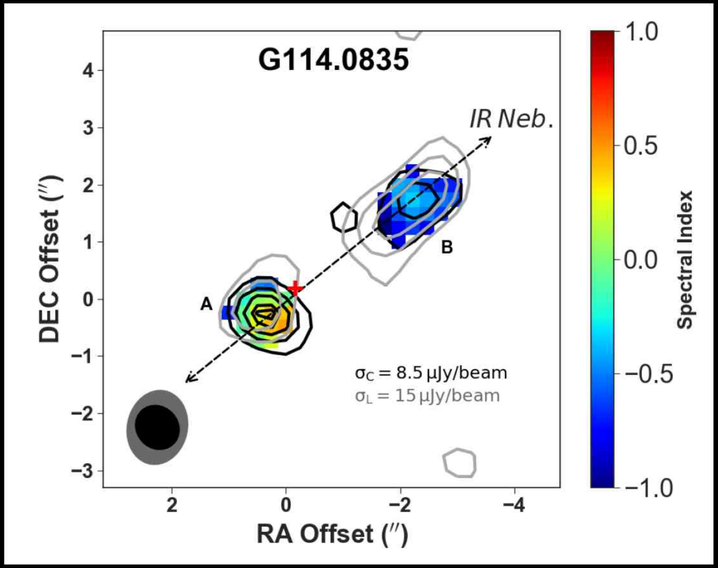
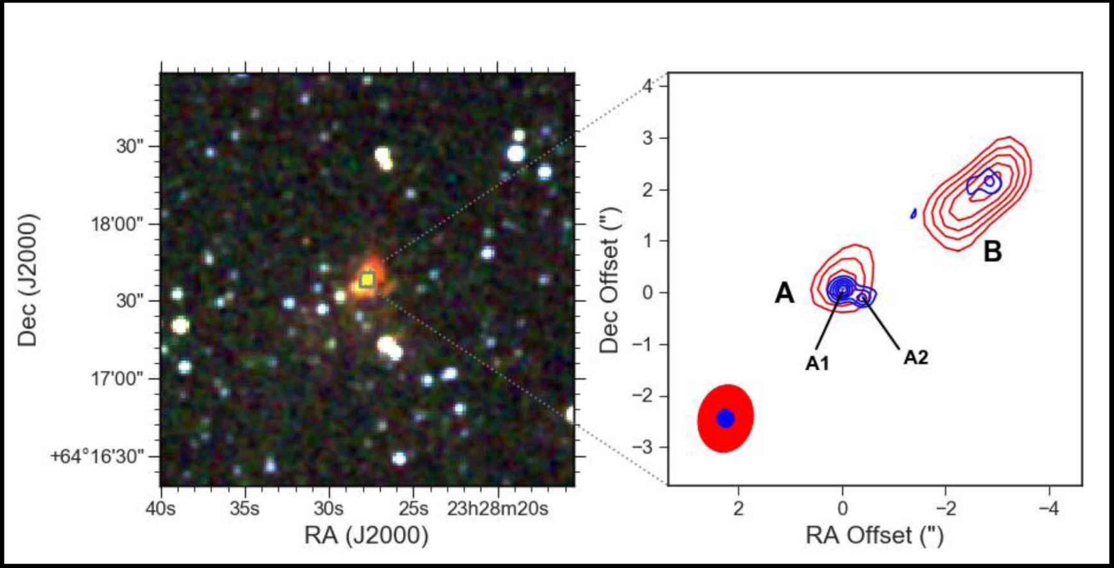
Results: Non-thermal lobes

G114.0835+02.8568 (IRAS 23262+6401)





Radio jet aligned with IR reflection nebula tracing outflow cavity.

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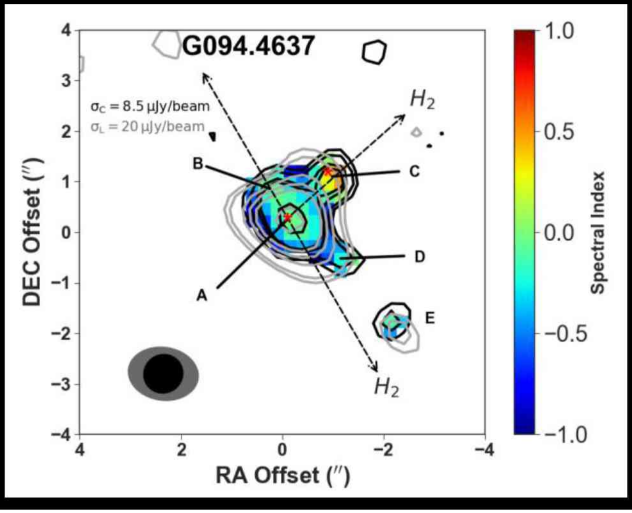
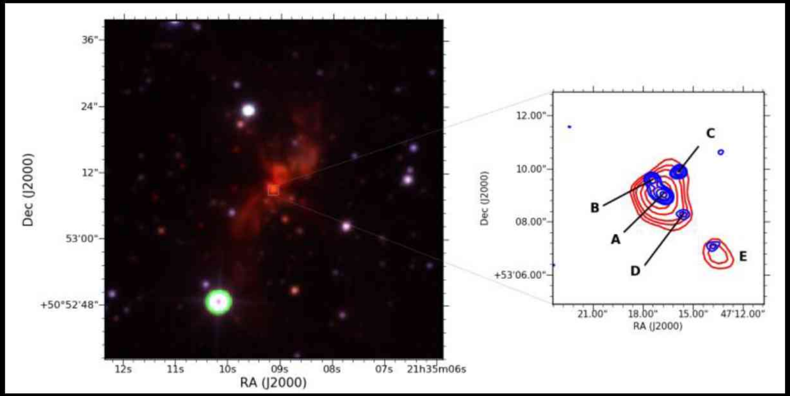
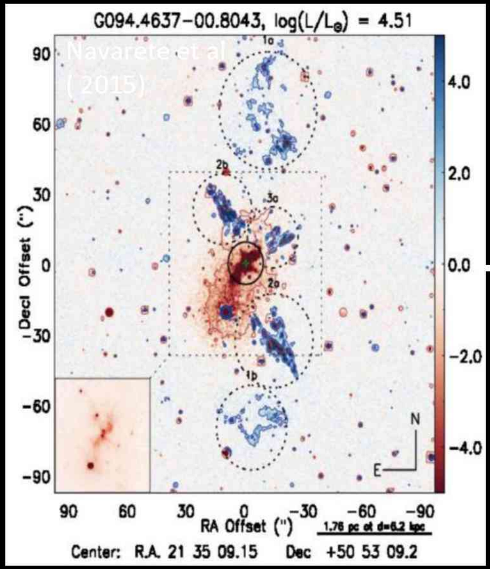
Results: Non-thermal lobes

G094.4637-00.8043 (IRAS 21334+5039)





UKIRT K band



2.12μm H_2

Continuum

Navarete et al. 2015

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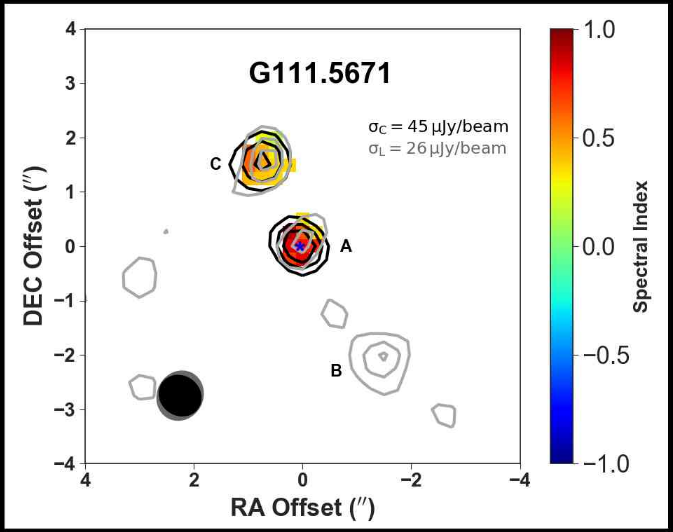
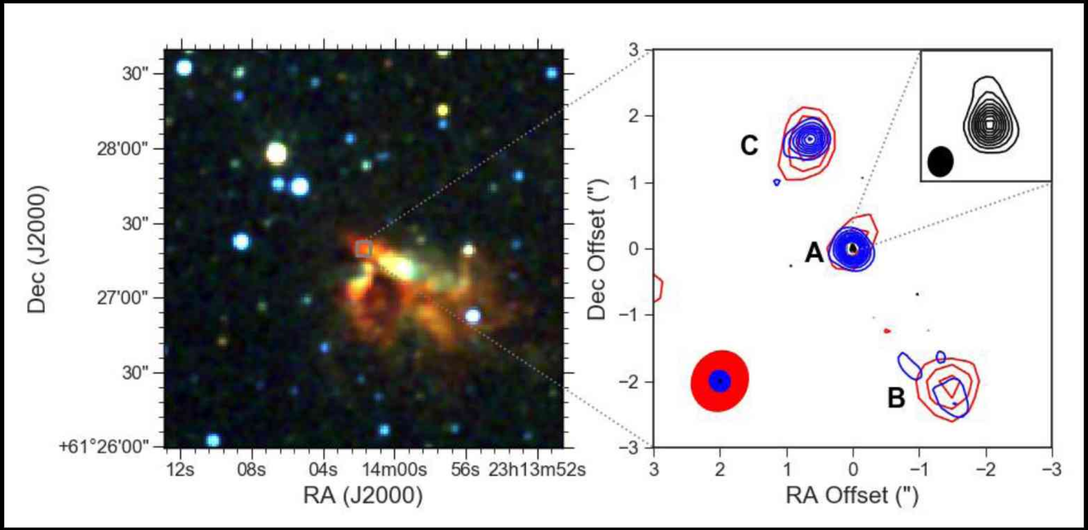
Results: Non-thermal & thermal lobes

G111.5671+00.7517 (NGC 7538 IRS 9)



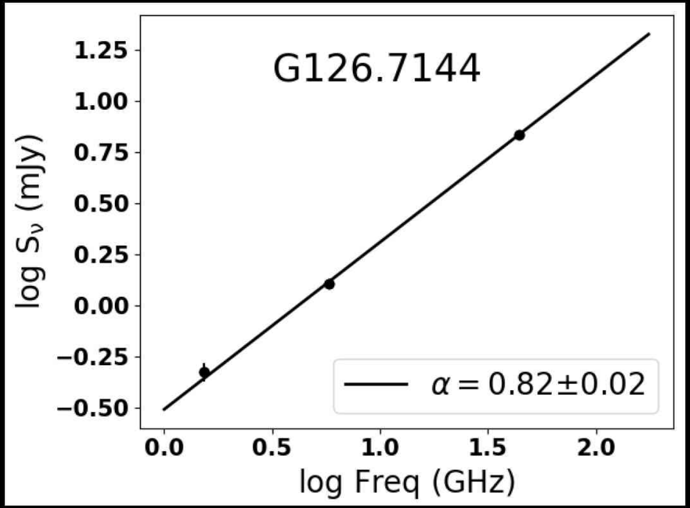


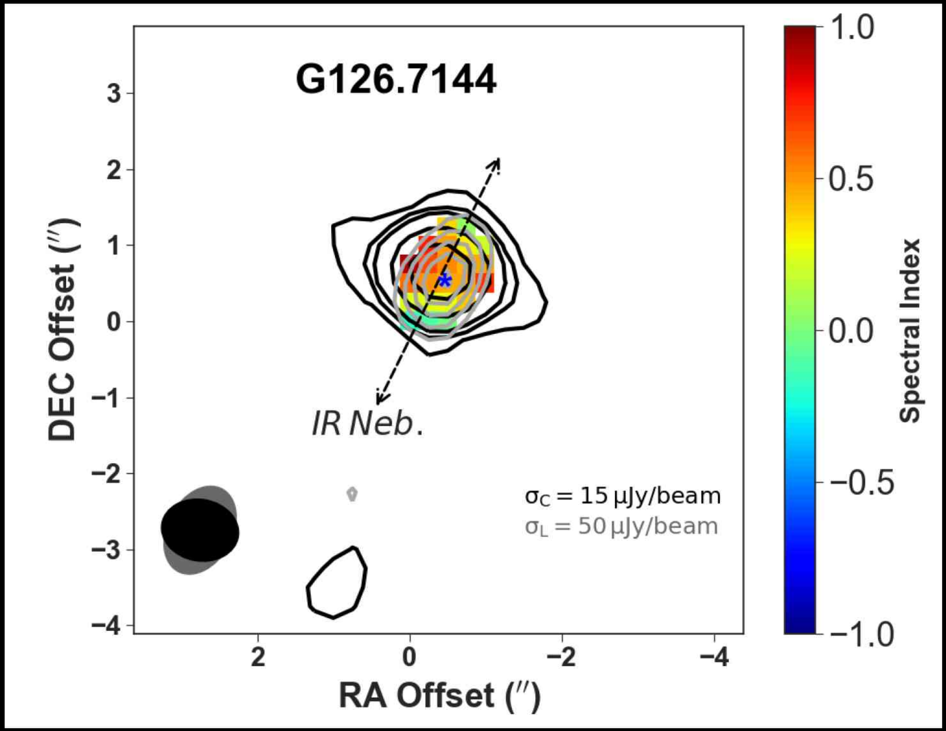
Non thermal emission from massive protostellar jets
A search for more

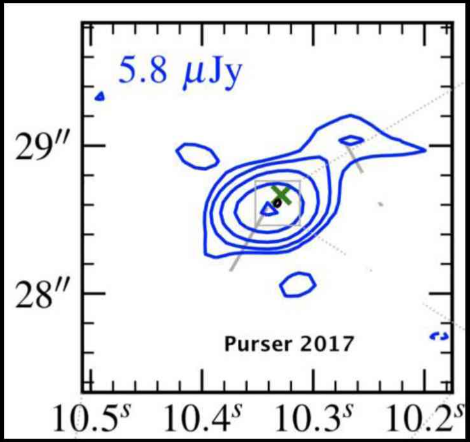
Results: Core properties

All cores are thermal

Example:G126.7144-00.8220 (S187 IR)







Purser (2017)

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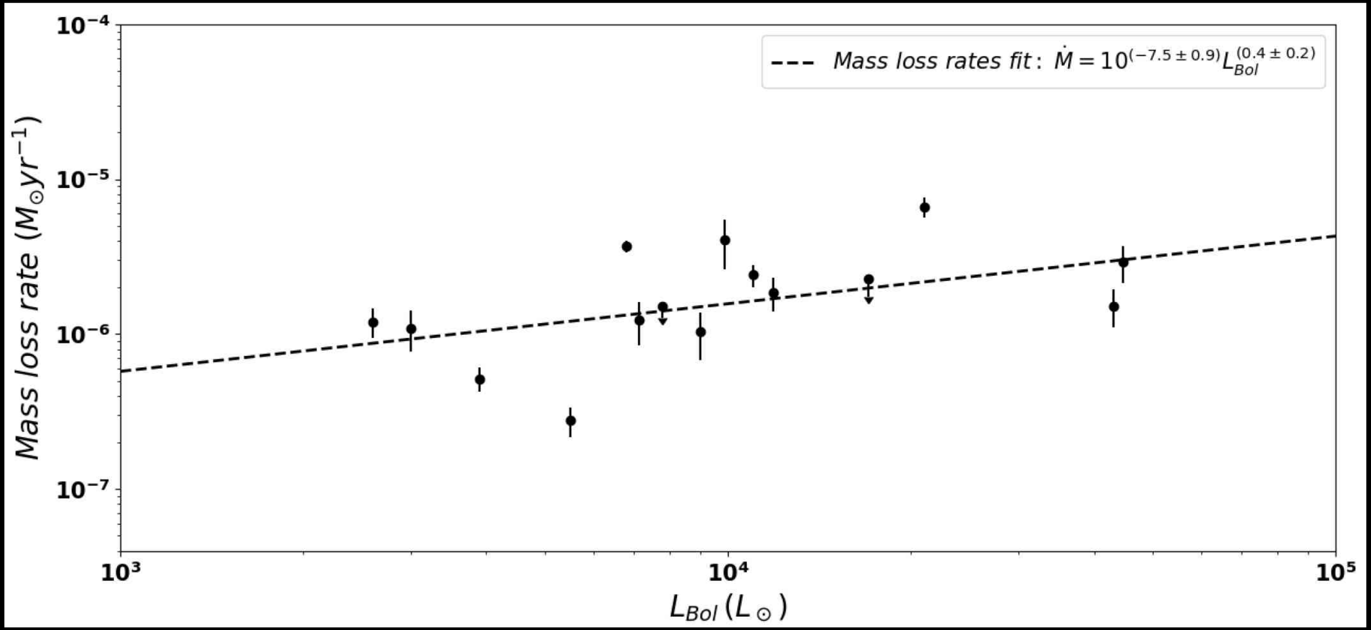
Results: Core properties

Cores drive out mass the rate $\dot{M}$ ~ 10^{-7}– 10^{-6} $M_\odot yr^{-1}$



Mass-loss-rate ~ 10^{-7}- 10^{-5} $M_\odot yr^{-1}$
Accretion-rate ~ 10^{-5}- 10^{-4} $M_\odot yr^{-1}$
Assumption
$\frac{M_{out}}{M_{acc}}$ $\sim 1\%$ (Hartigan et al. 1995)

Theoretical predictions of Accretion rates ~ 10^{-4}- 10^{-3} $M_\odot yr^{-1}$ (Hosokawa et al 2010, Krumholz et al. 2009)

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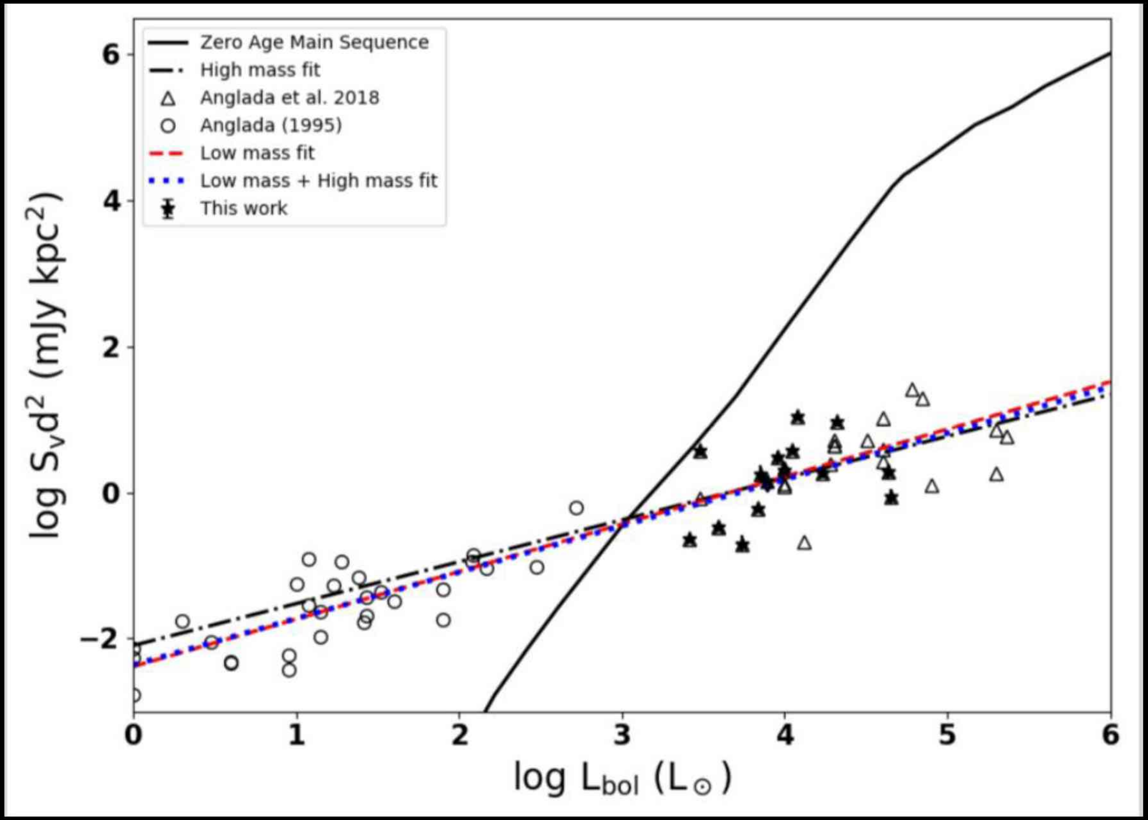
Results: Core properties

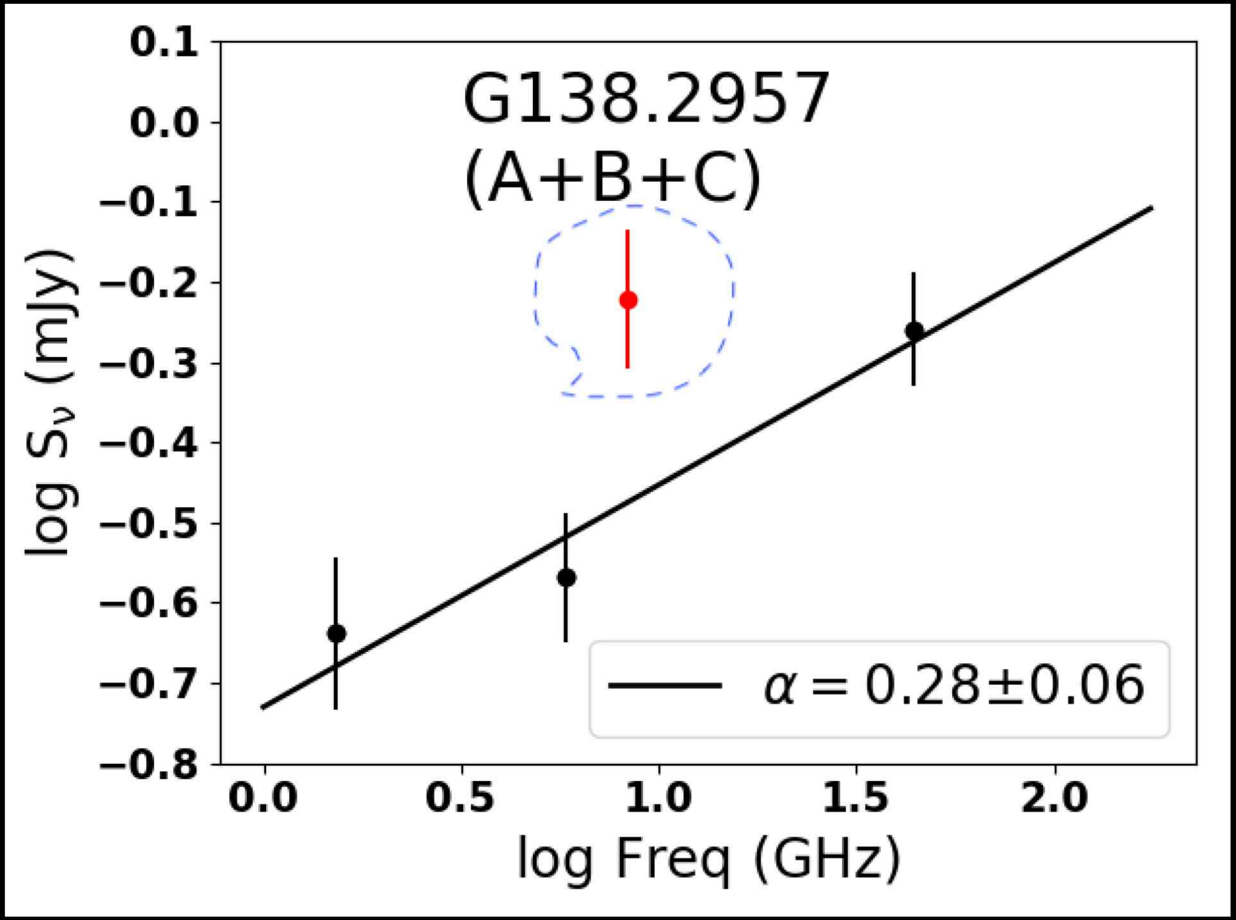
Ionization mechanism



Collisional ionization in G35.20- 0.74N i.e ~ 5-12% (Fedriani et al. 2019)

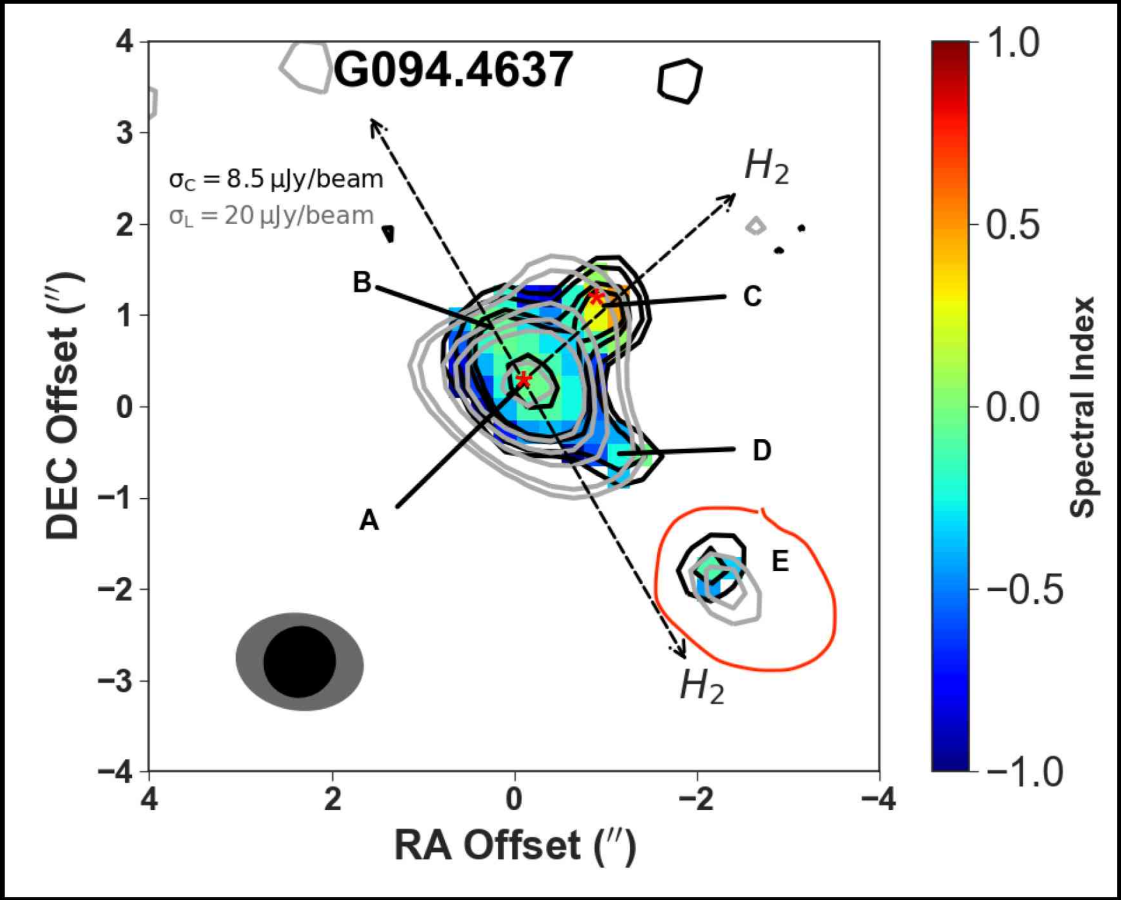
But?

Uncertainties in spectral indexing - Flux Variability



But?

Uncertainties in spectral indexing - Positional Variability



Part 2: Search for Variability in massive protostars

Four massive protostars

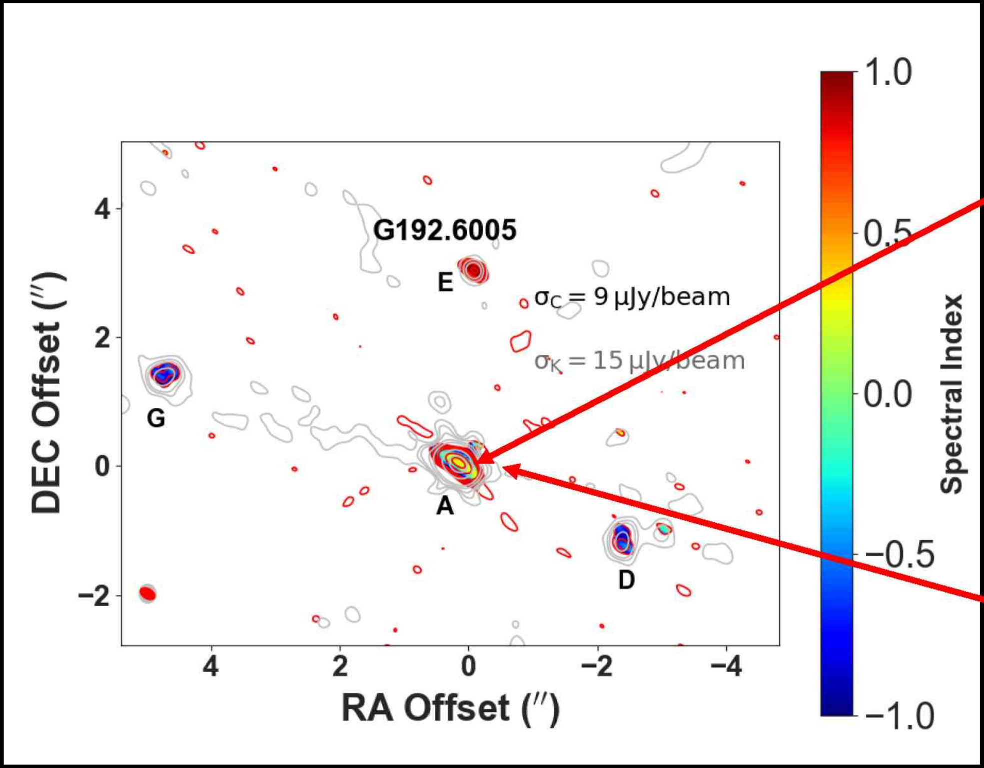
- Observed in 2012 at 6 GHz (Purser 2017)
- Spatially resolved at 6 GHz

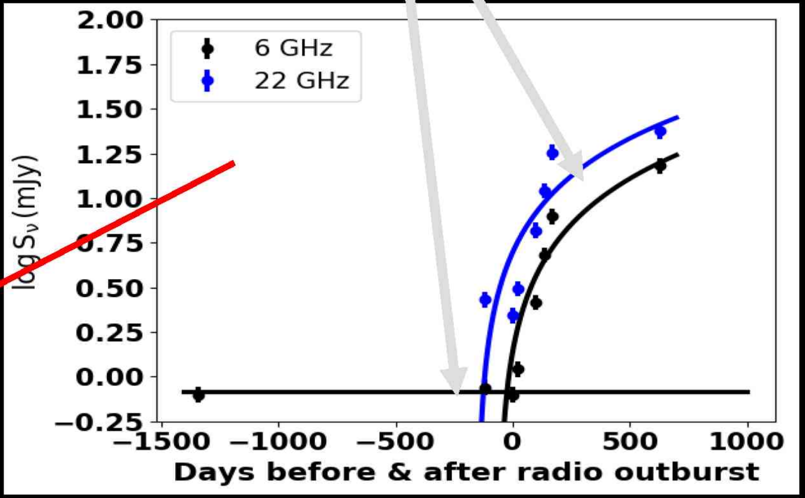
- Re-observed in 2018 at 6 GHz
- Two of them also observed at 22 GHz
- Telescope – JVLA , A configuration
- Resolutions 0.33'' and 0.09''

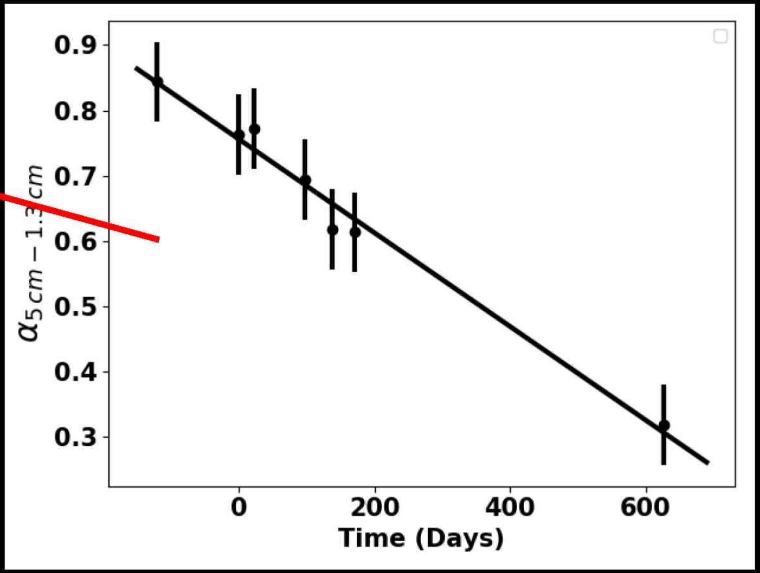
Two of the objects, **S255 NIRS3** and **W3 IRS5** show evidence of **flux** and **positional** variability respectively.

S255 NIRS 3: Flux variability

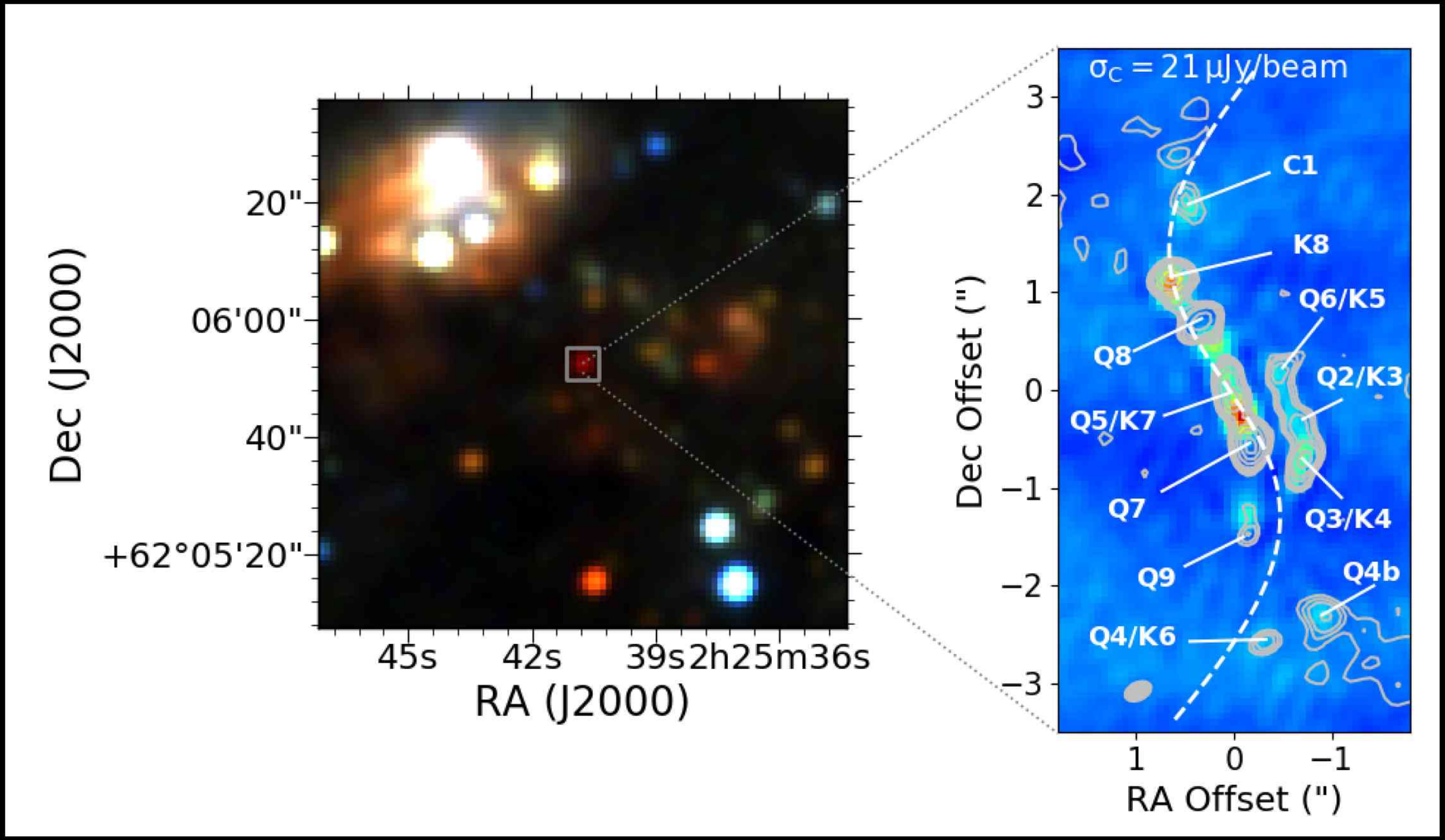
Cesaroni 2018







W3 IRS5: Positional variability



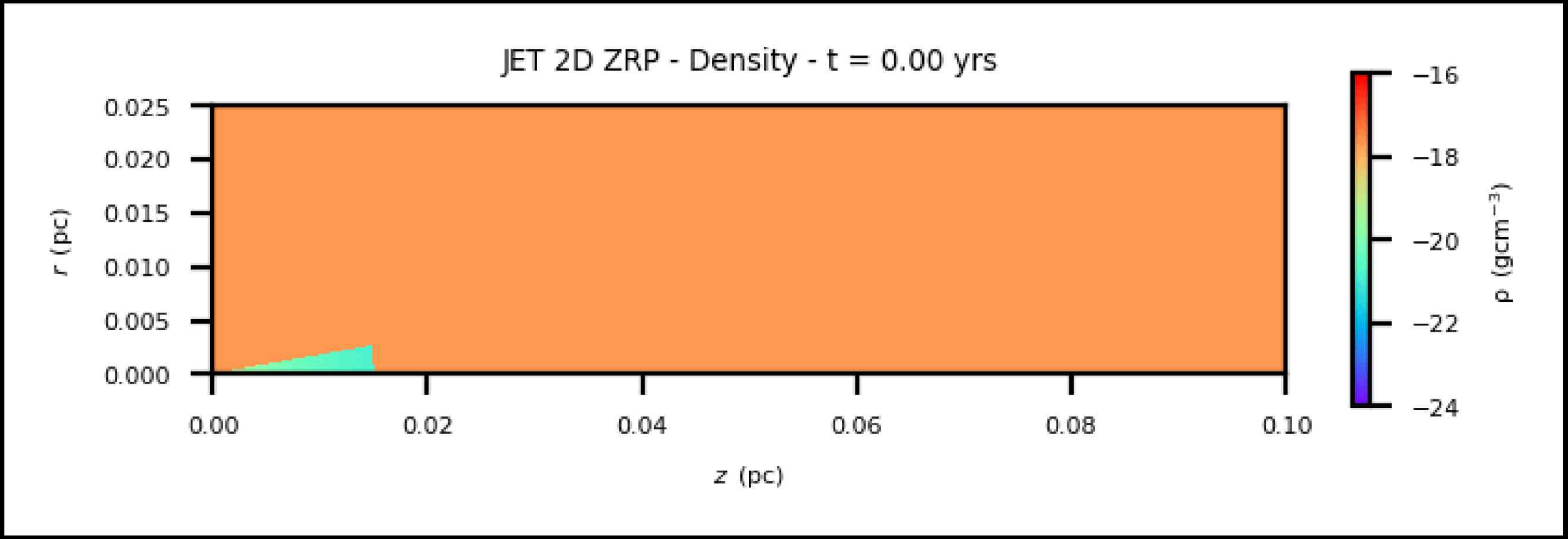
Precessing jet: Lobes and the core fits equation of the form y= $-\sin(\frac{2\pi}{9}\theta_s)$

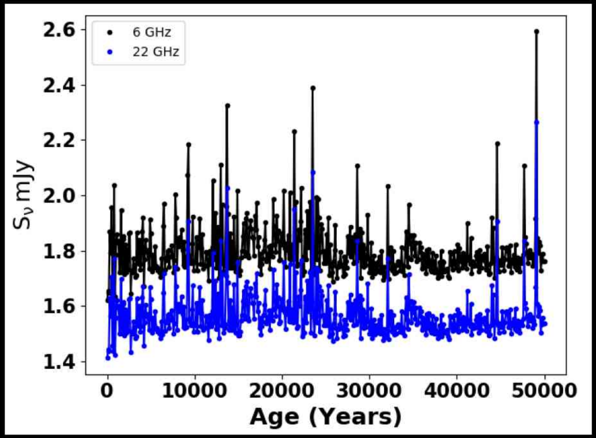
Precession angle: 30±8°; Precession period: 164 years

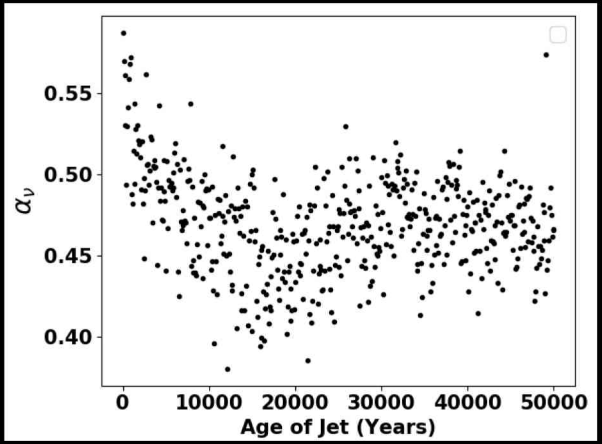
Proper motion: Average velocities 460±60kms^{-1}

Radio emission from Variable Protostellar jets

A steady jet (T = 10^4K; Vel=500 kms^{-1}; $\dot{M} = 10^{-6}\ M_{\odot}yr^{-1}$)

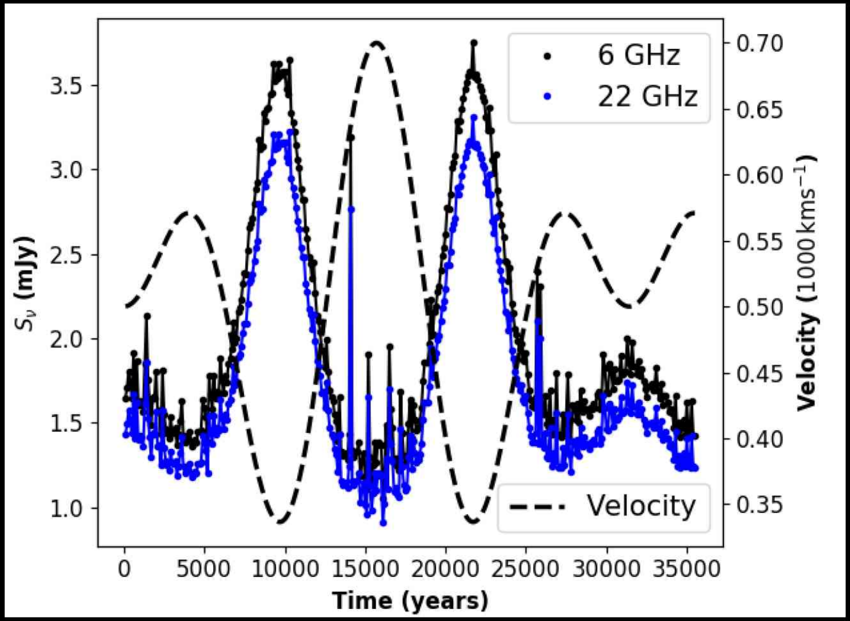


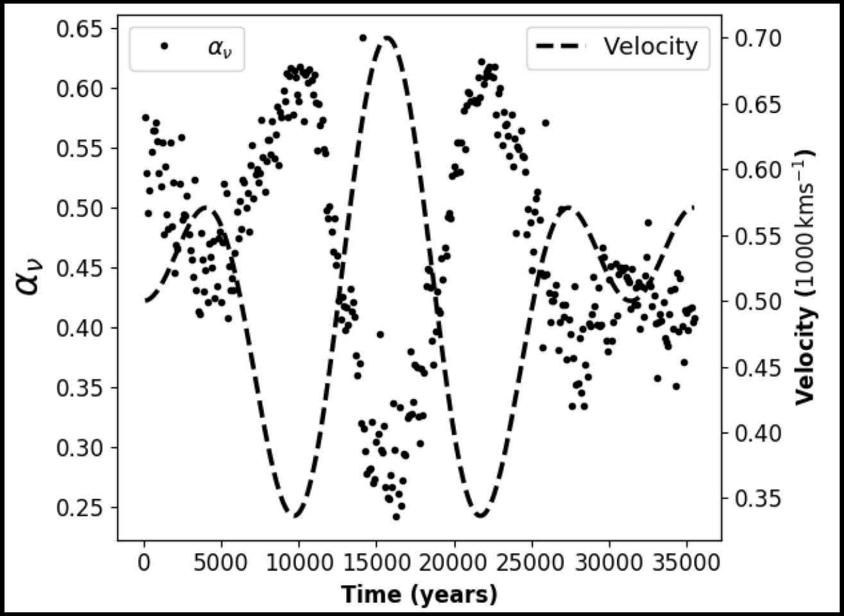




Radio emission from variable Protostellar jets

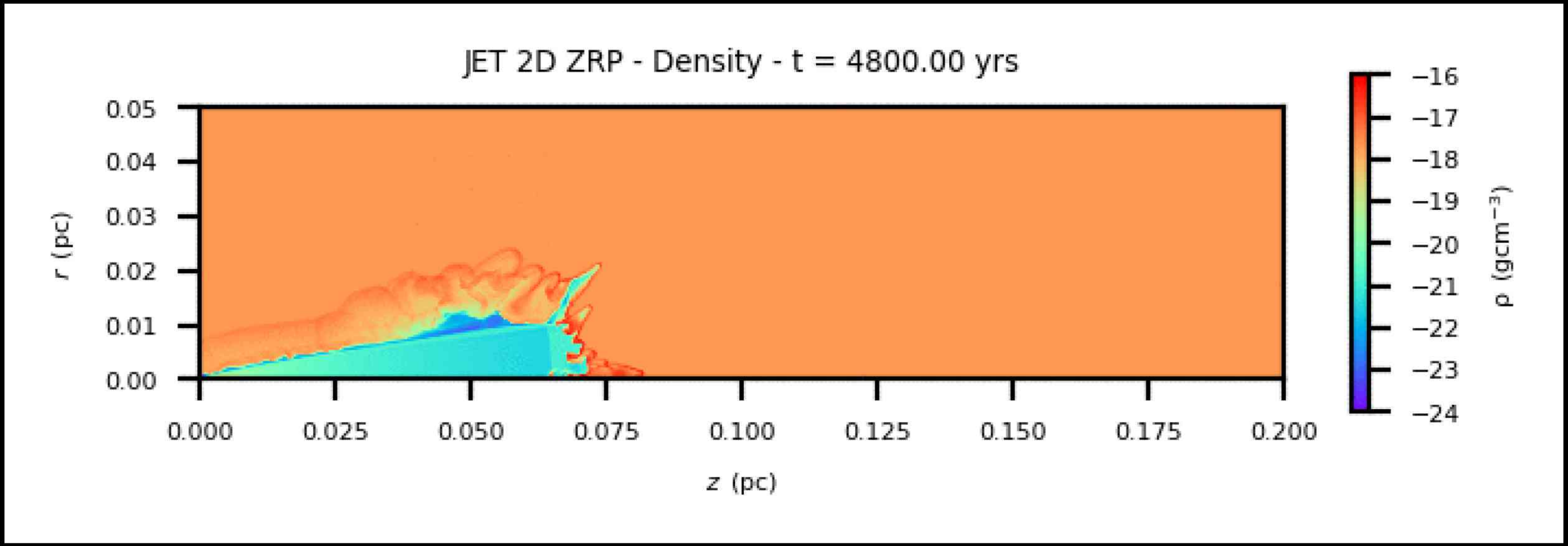
Variable velocity (T = 10^4K $\dot{M} = 10^{-6}$ $M_{\odot} yr^{-1}$)

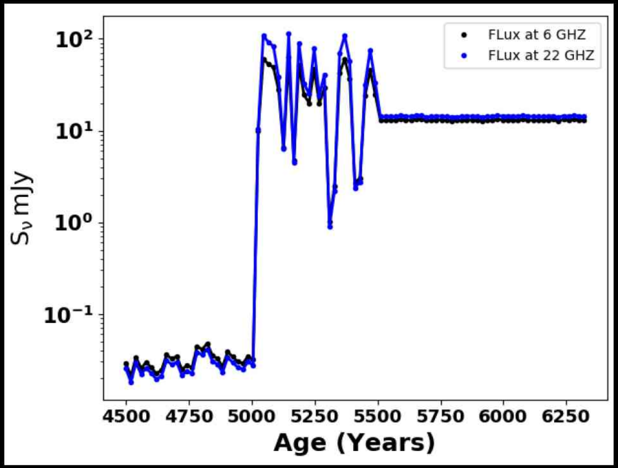




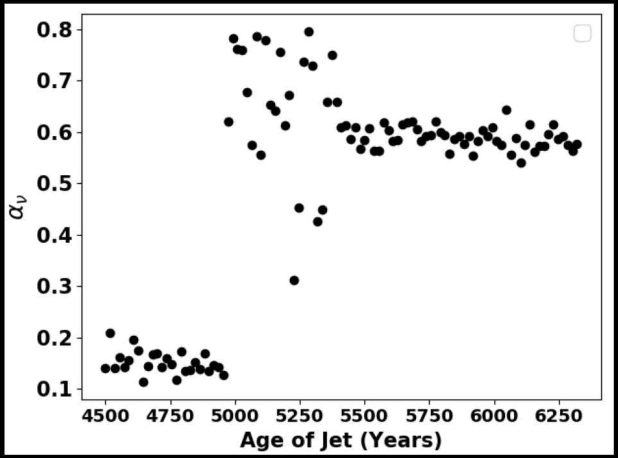
Radio emission from variable Protostellar jets

Variable mass-loss rate





Evolution of Flux



Evolution of spectral index

Conclusion

- Massive protostellar jets exhibit thermal radio emission from their cores.
- Some massive protostellar jets exhibit non-thermal emission from jet lobes whose B-field and energies ~ 0.5±0.2mG and 10^{41}-10^{42} ergs respectively.
- Magnetic fields play a significant role in massive protostellar jets
- MYSOs have high accretions rates and undergo accretion bursts at times, potential solution to the required high accretion rates.
- Some MYSO jet precess.

Future work

- 3D simulation of massive protostellar cores
- High resolution follow up with e-MERLIN.
- Follow up observations with the SKA