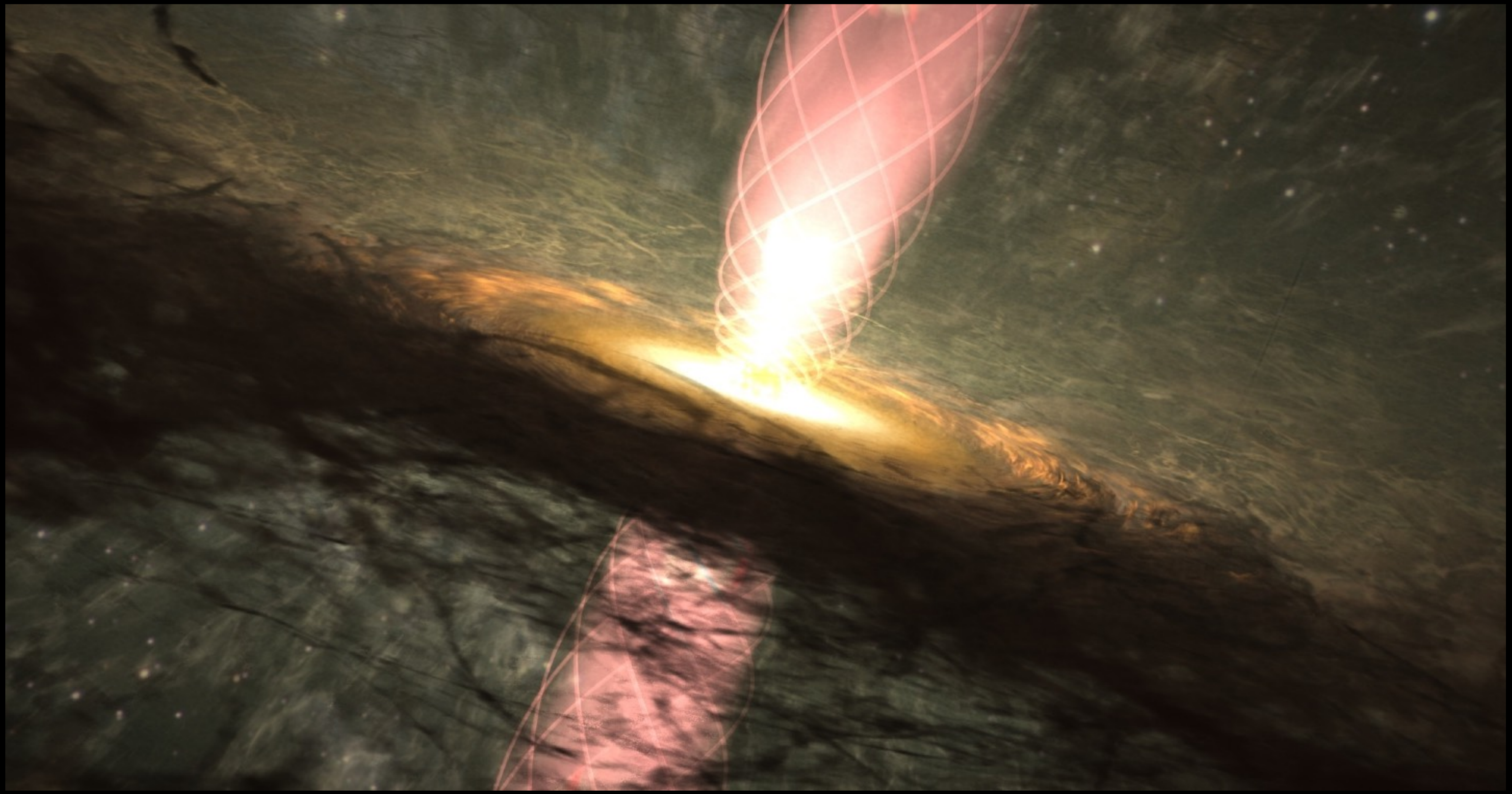
Synchrotron Emission from Protostellar Jets



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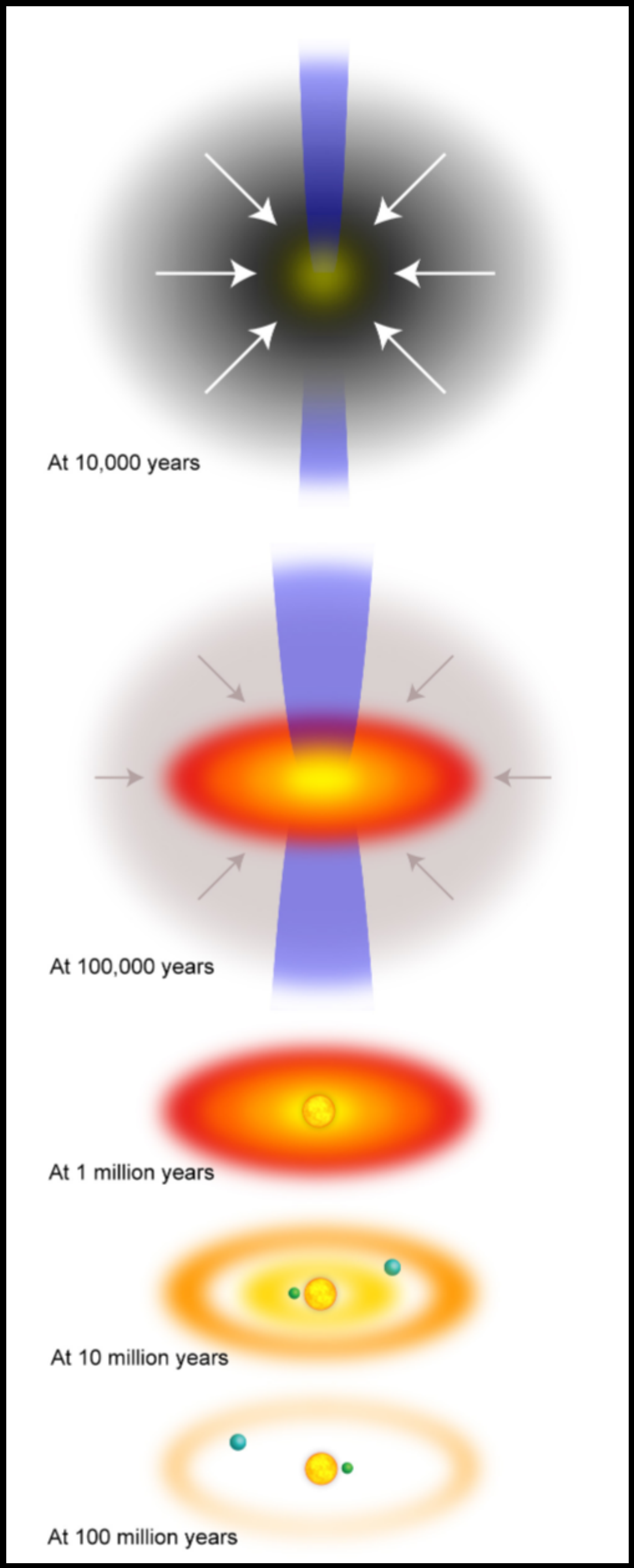
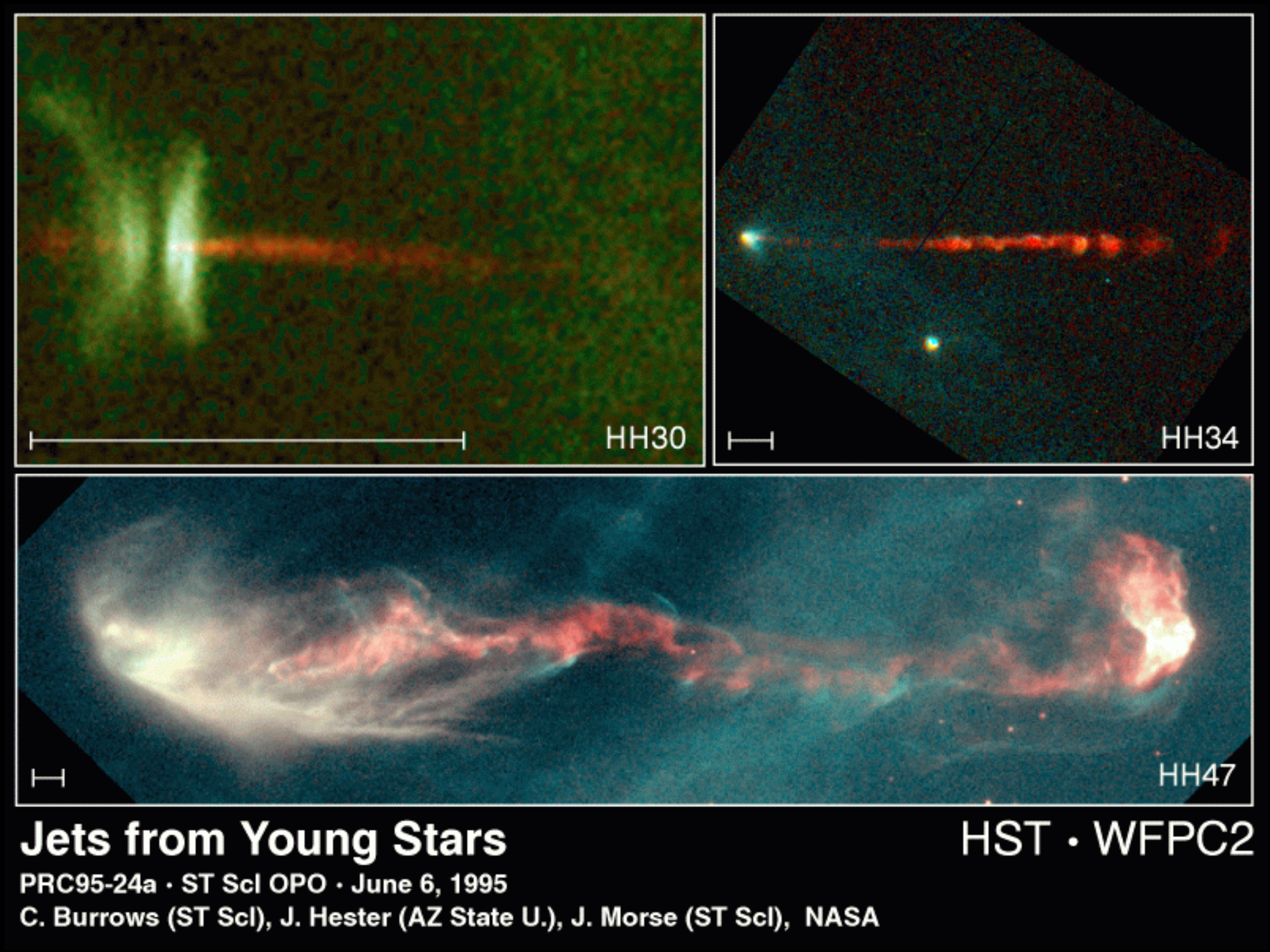
Protostellar Jets

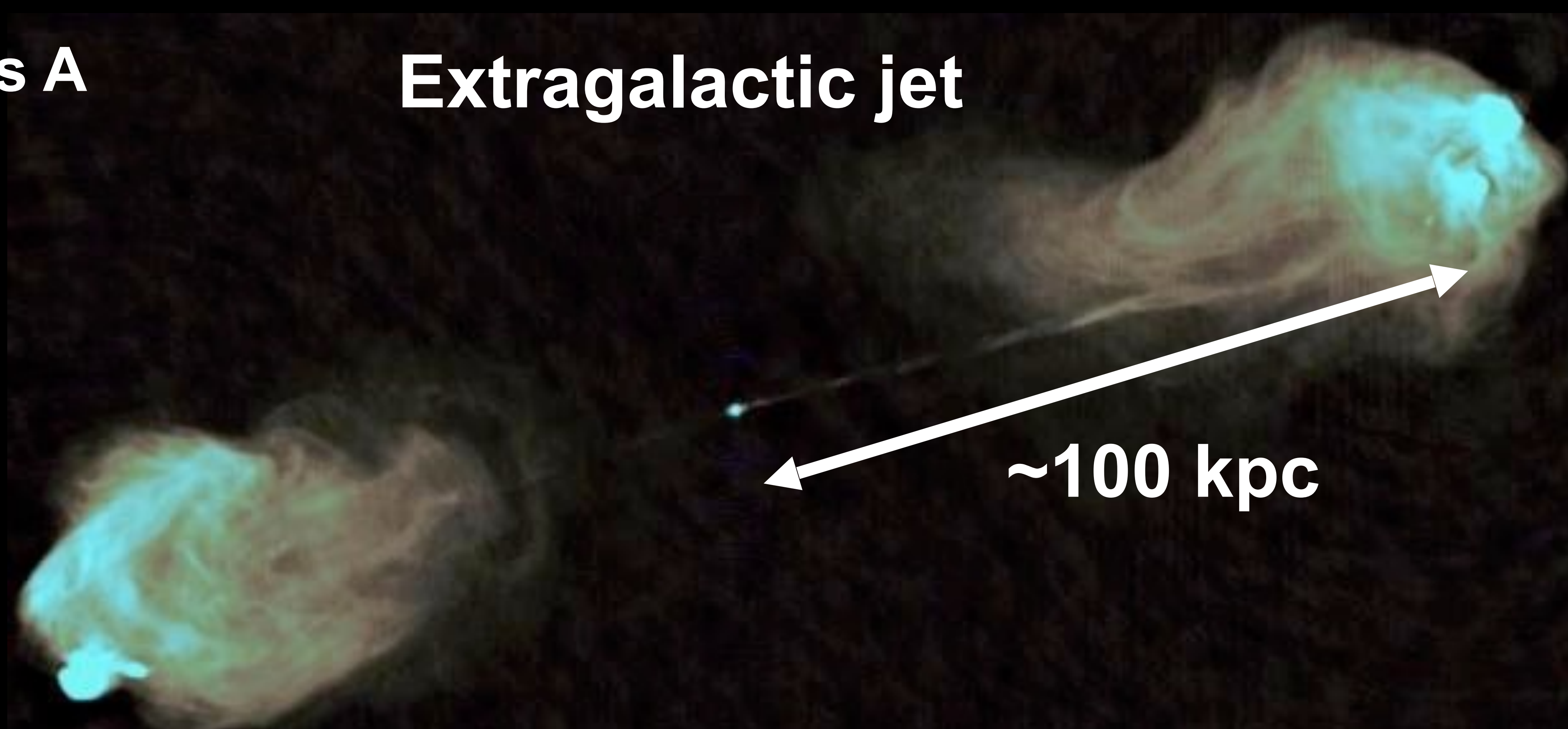




Central Object -> Protostar (~1 Msun)
Jet velocities -> ~100 km/s
Jet lengths -> ~ 1 pc

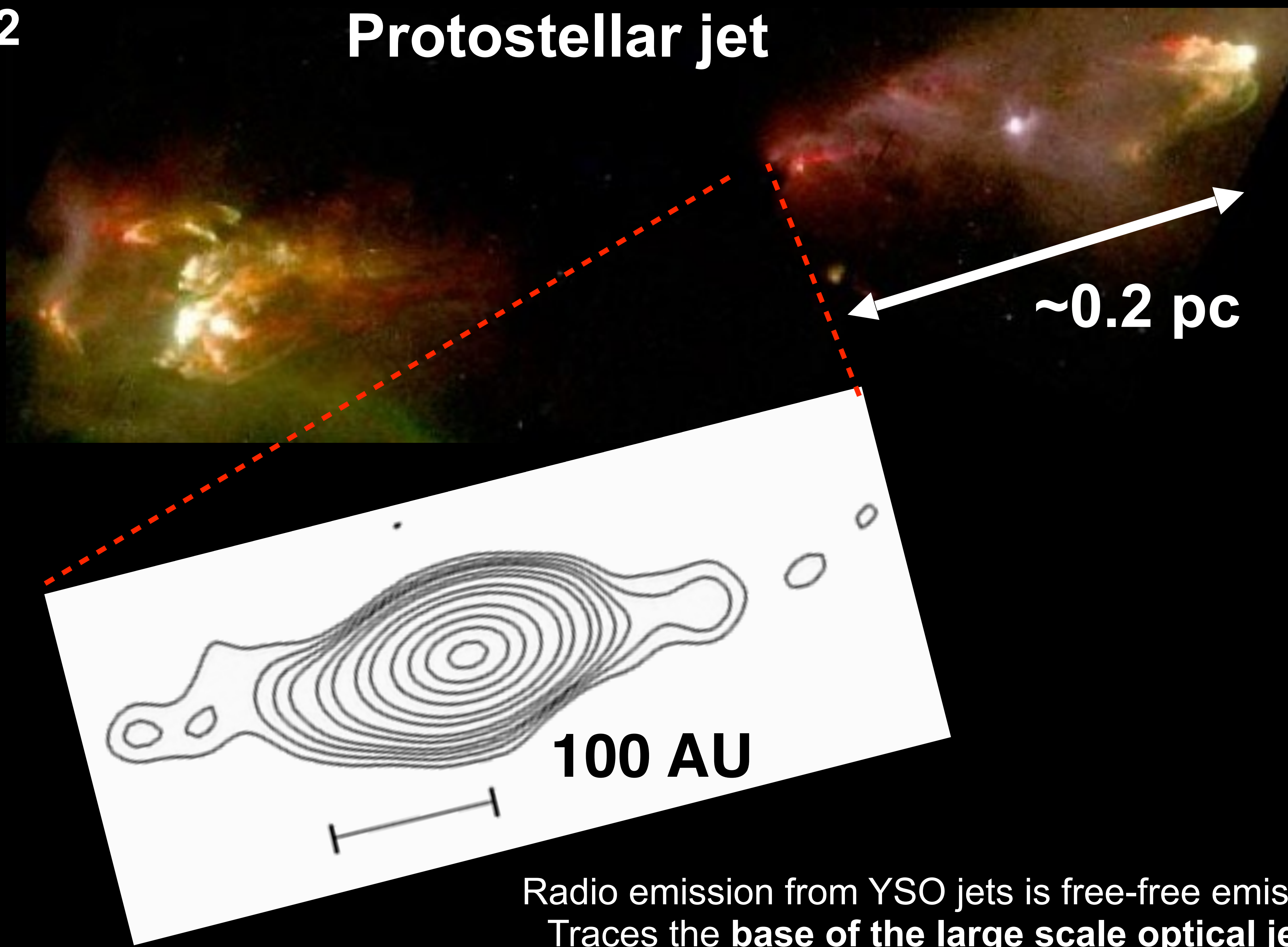
HH 1-2

Cygnus A



HH 1-2

Protostellar jet



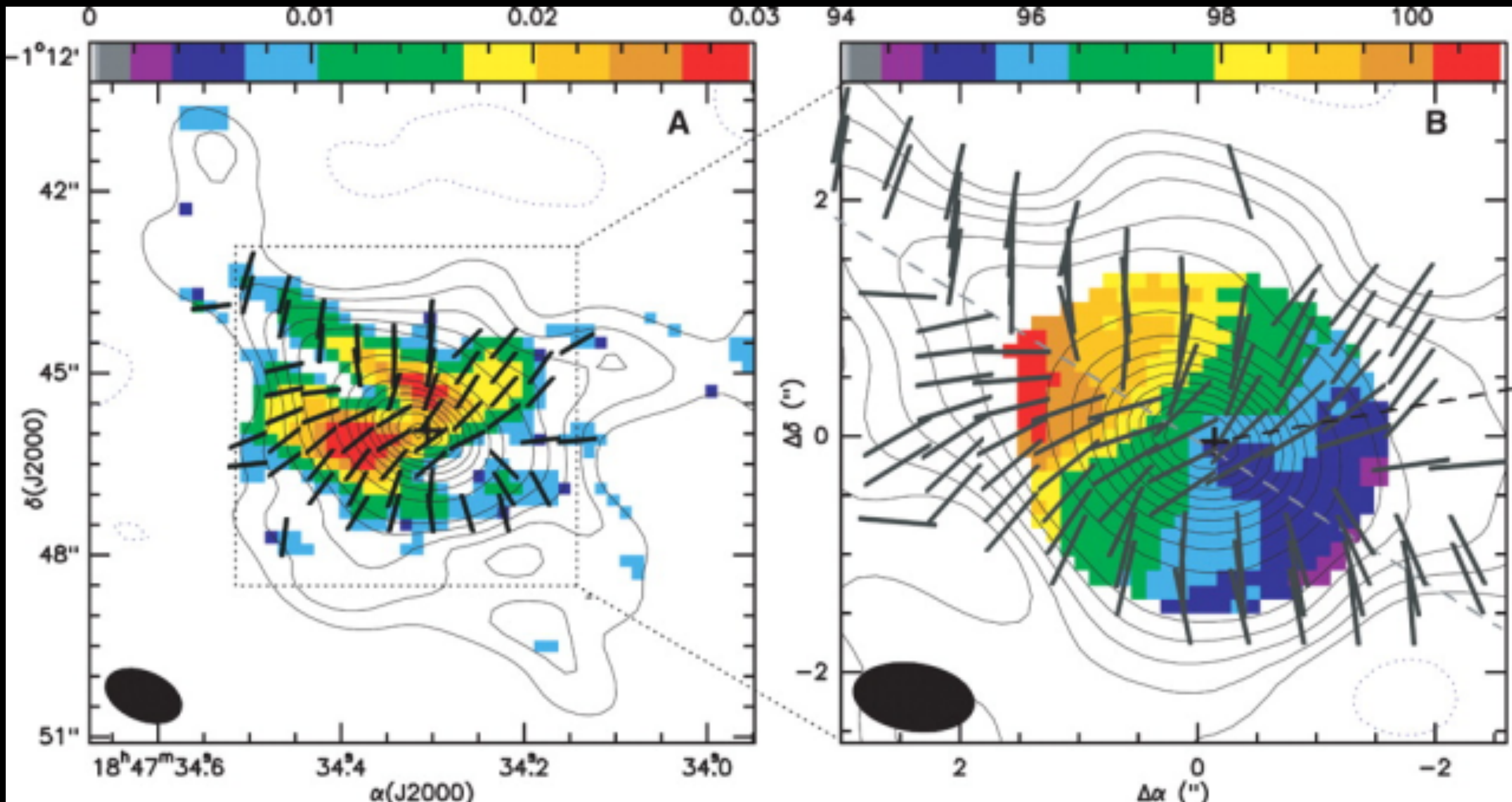
Radio emission from YSO jets is free-free emission
Traces the **base of the large scale optical jets**

These are called **THERMAL RADIO JETS**

NO INFORMATION ABOUT MAGNETIC FIELD IN THE JET

Dust Polarization

Traces magnetic field around the protostar (disk, envelope)

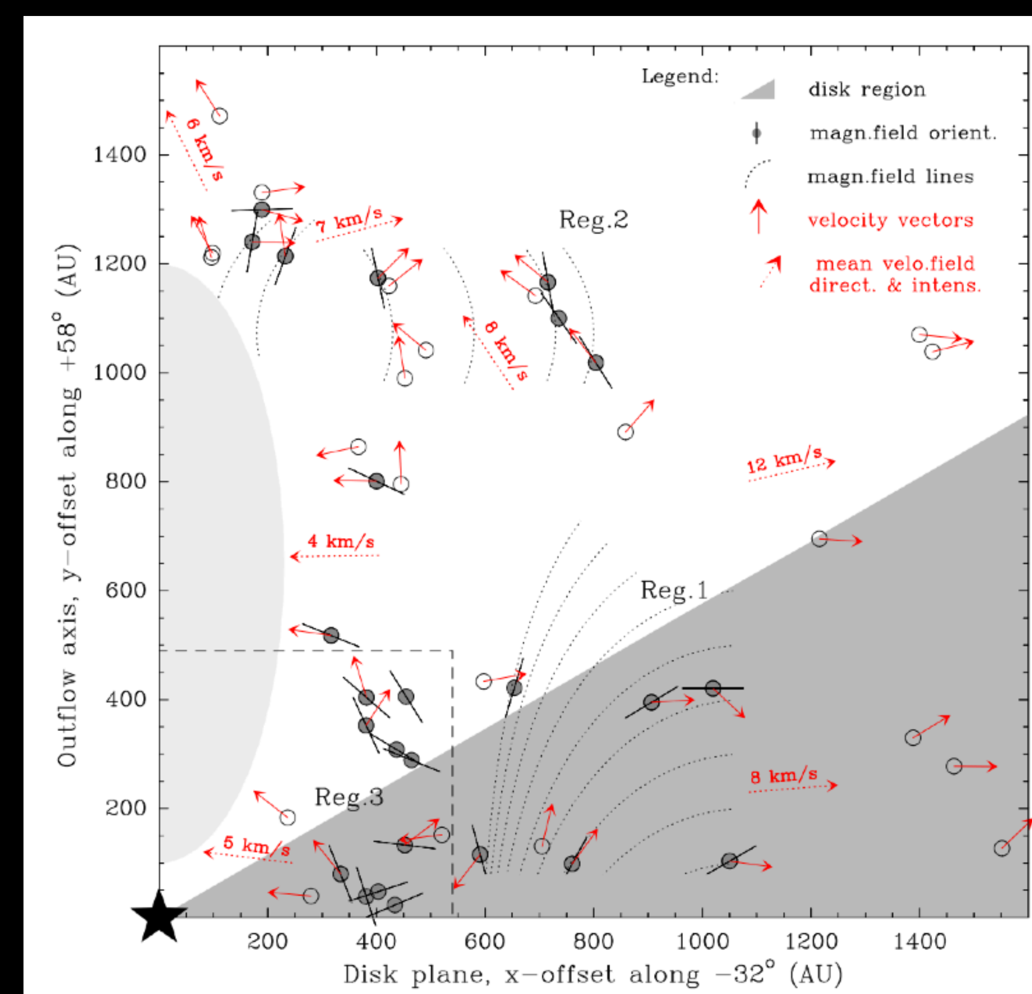


Girart et al. (2009)

Maser Polarization

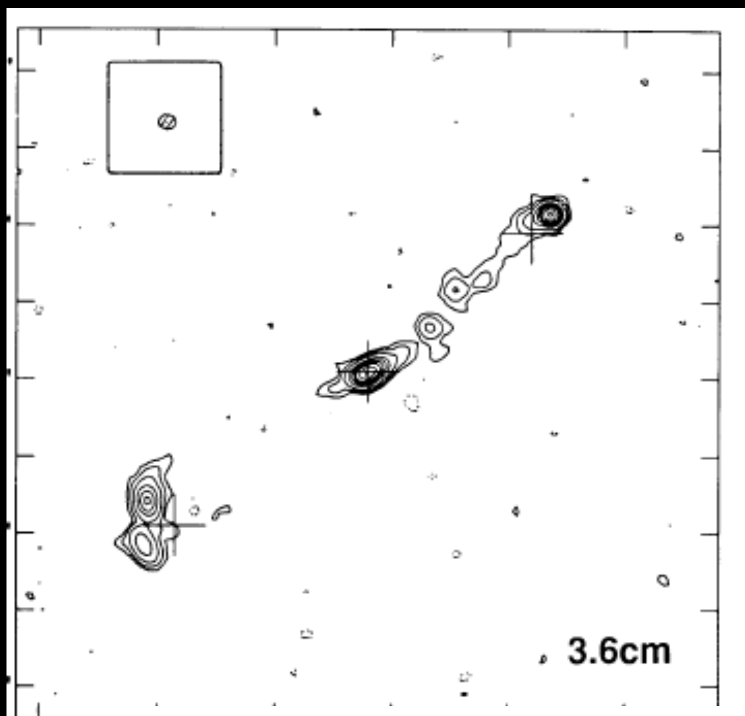
Traces magnetic field in molecular gas

Sometimes outflow
Sometimes envelope

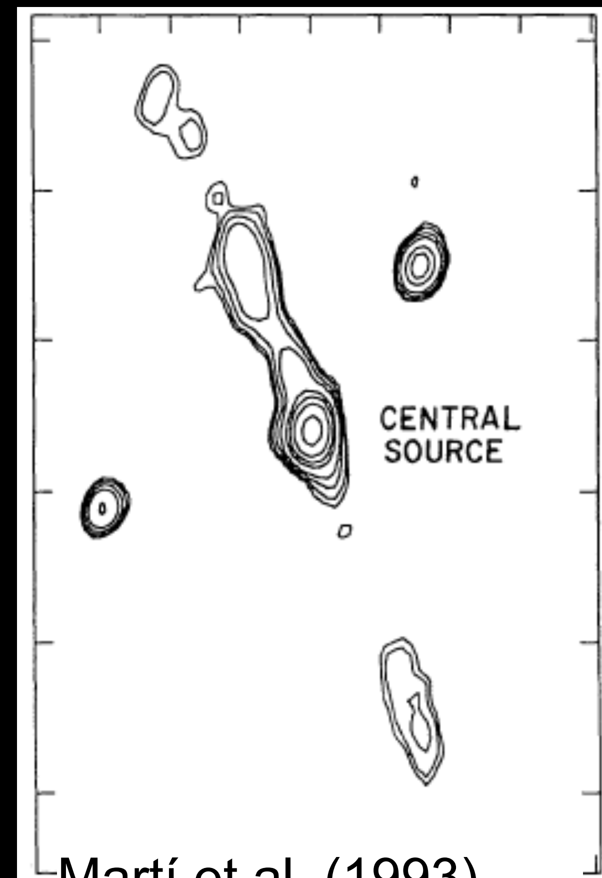


Sanna et al. (2015)

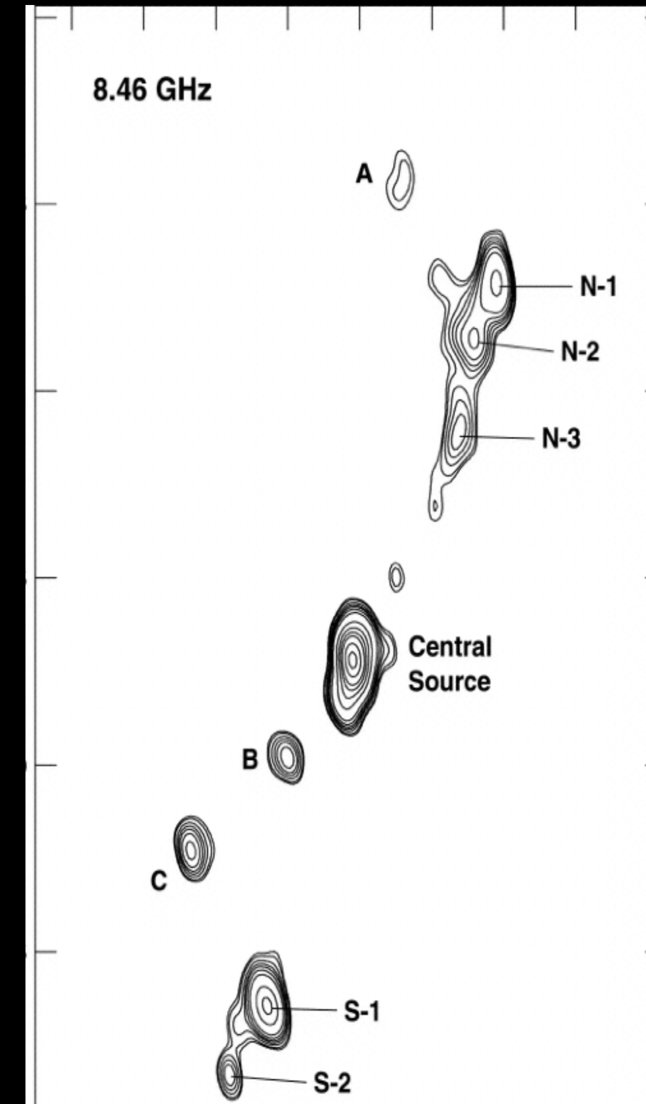
Negative spectral indices -> Non-thermal emission



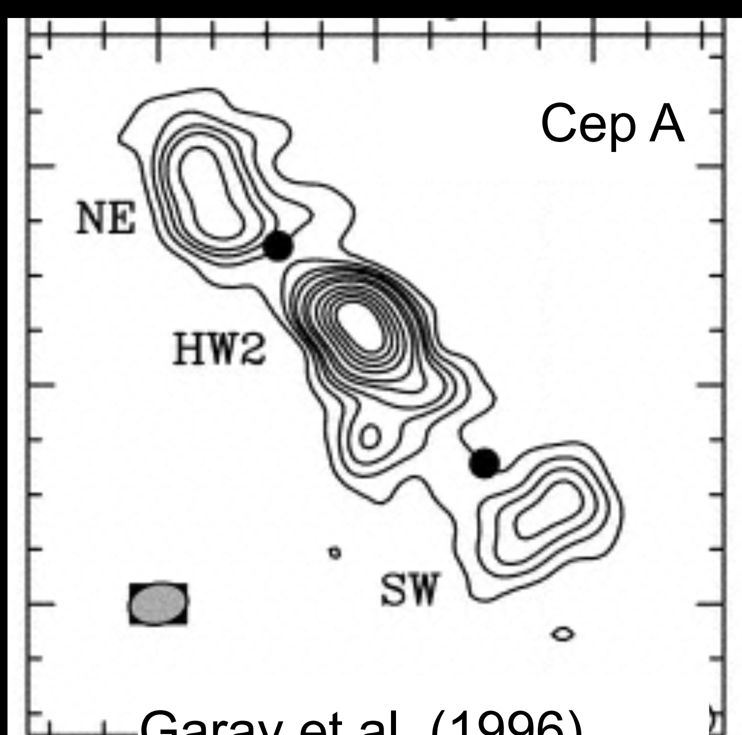
Rodríguez et al. (1989)



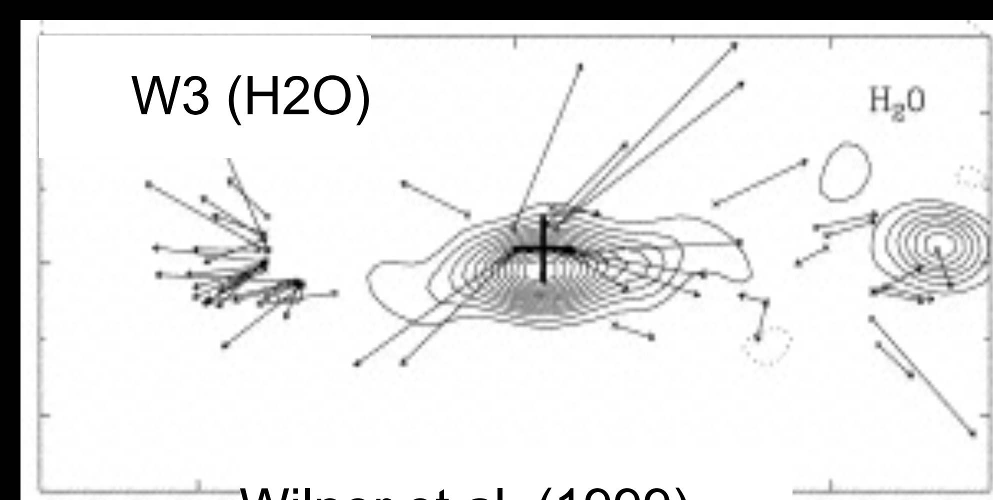
Martí et al. (1993)



Rodríguez et al. (2005)

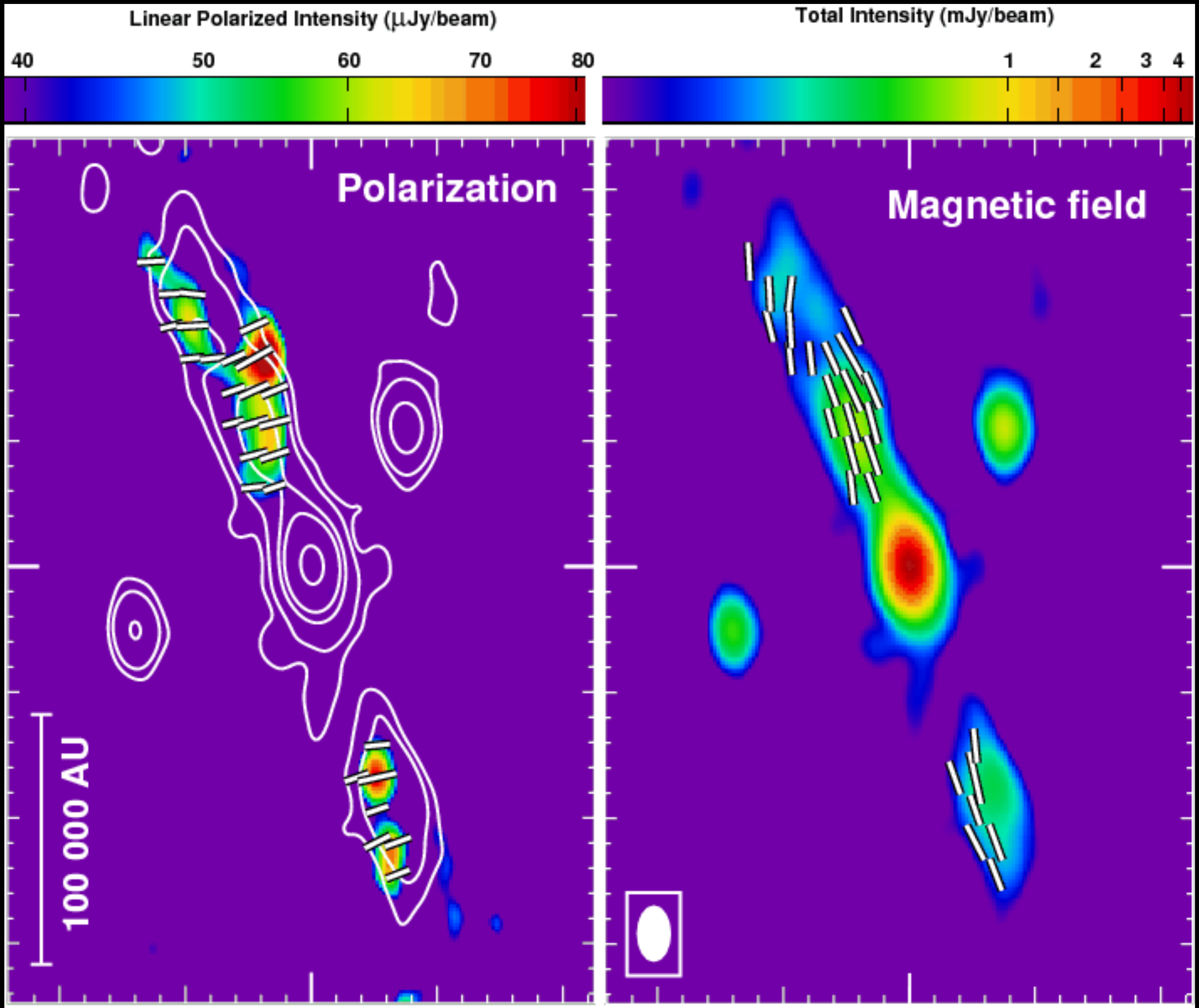


Garay et al. (1996)



Wilner et al. (1999)

First (and still unique) detection of linearly polarized emission at cm wavelengths in a protostellar jet



"Massive" protostar (~10 Msun)

"Fast" Jet -> 1000 km/s

Jet very well embedded in dense material

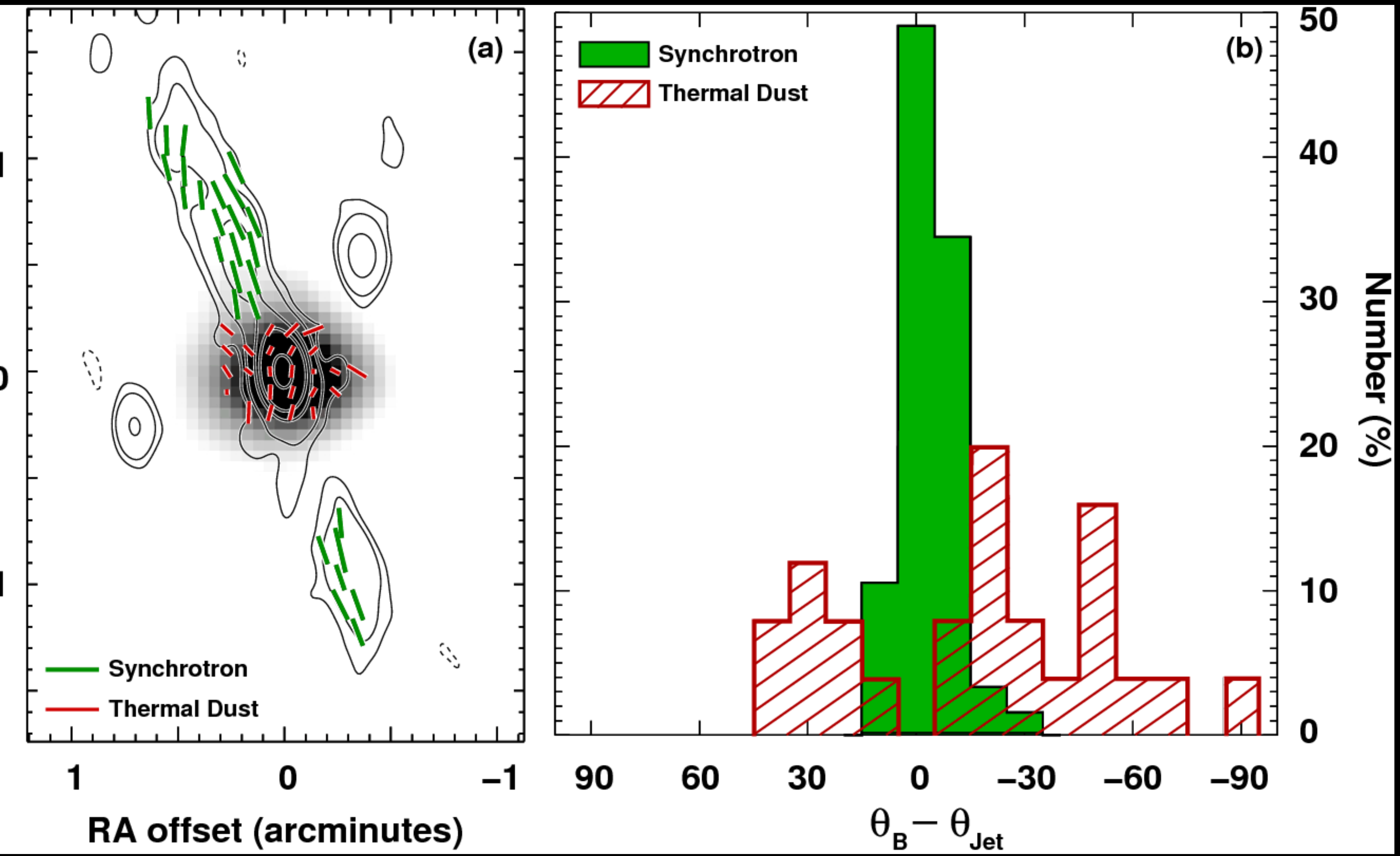
Linear polarization at 6 cm after 12 hours of VLA observation

Confirmation of synchrotron emission in protostellar jets

1. Particle acceleration mechanism
2. Possibility of studying magnetic field

Carrasco-González et al. (2010)

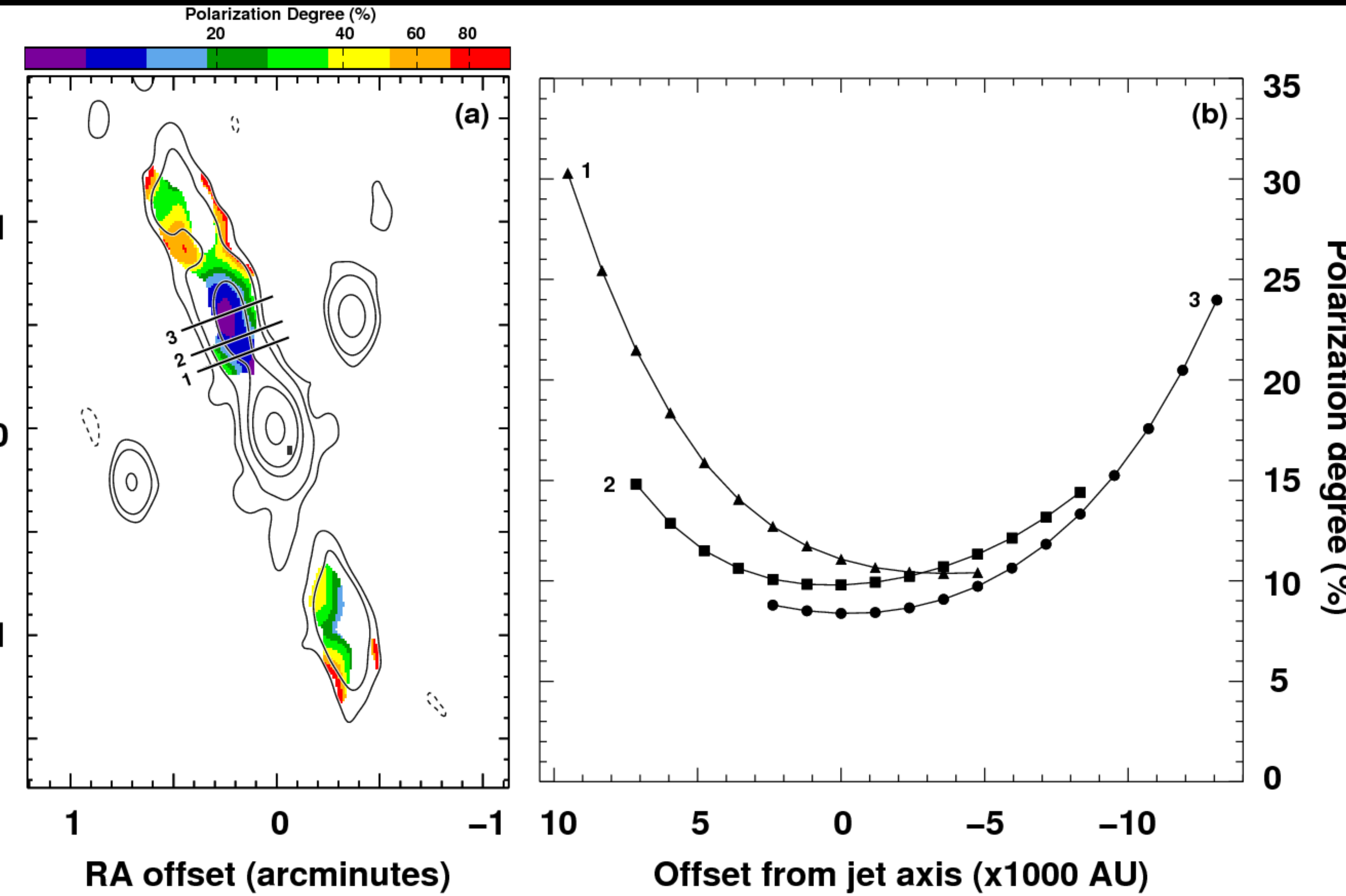
Apparent magnetic field is parallel to the jet direction



Polarized dust emission → envelope/disk

Synchrotron emission → jet

There is a gradient in the polarizarion degree across the jet width



Consistent with helical magnetic field

(Extended) Very Large Array (VLA)

High **sensitivity** (~microJy/beam)
High angular **resolution** (0.1-1”->10 - 100 AU)
Allows simultaneous observations of **large bandwidths** (4 - 8 GHz)

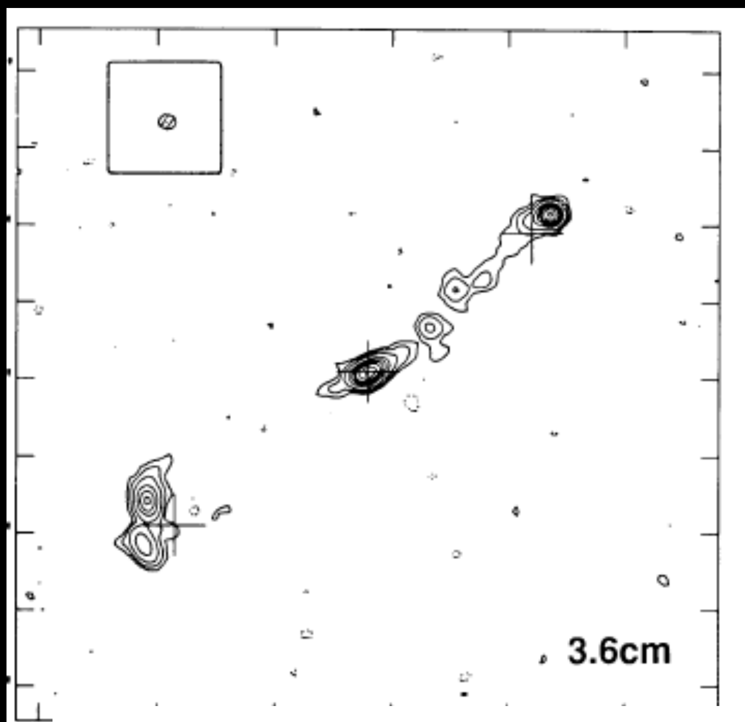
We started a project to observe several non-thermal protostellar radiojets with the VLA

Two objectives:

- Study magnetic field configuration (multi-wavelength polarization)
- Study particle acceleration (resolved spectral indices maps)

Adriana Rodriguez-Kamenetzky PhD Thesis

Synchrotron protostellar jets candidates



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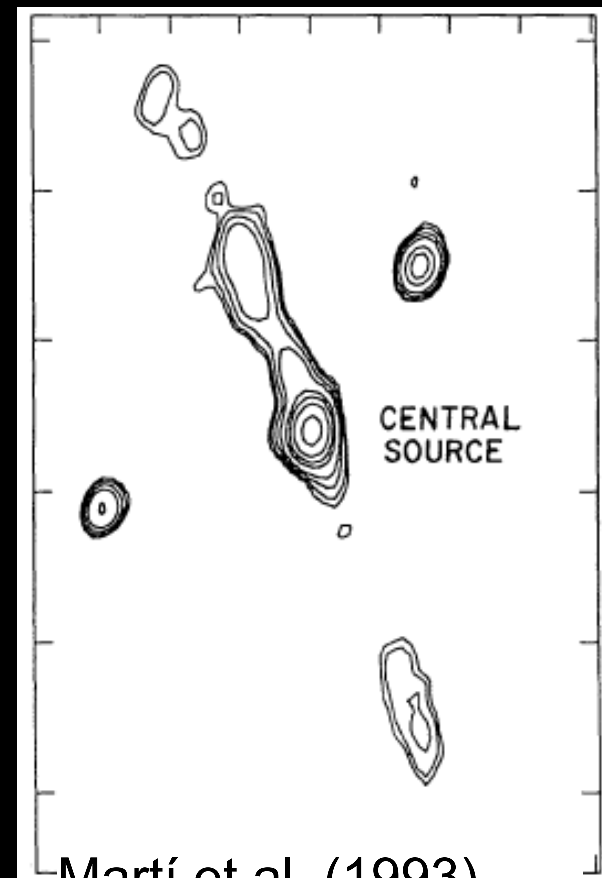

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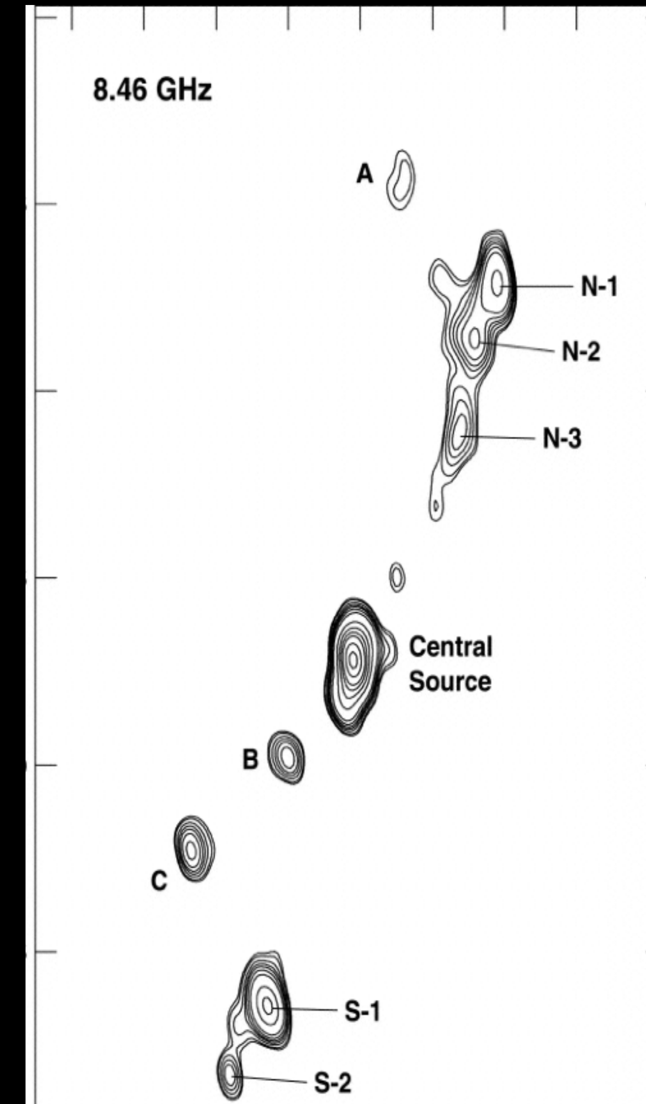

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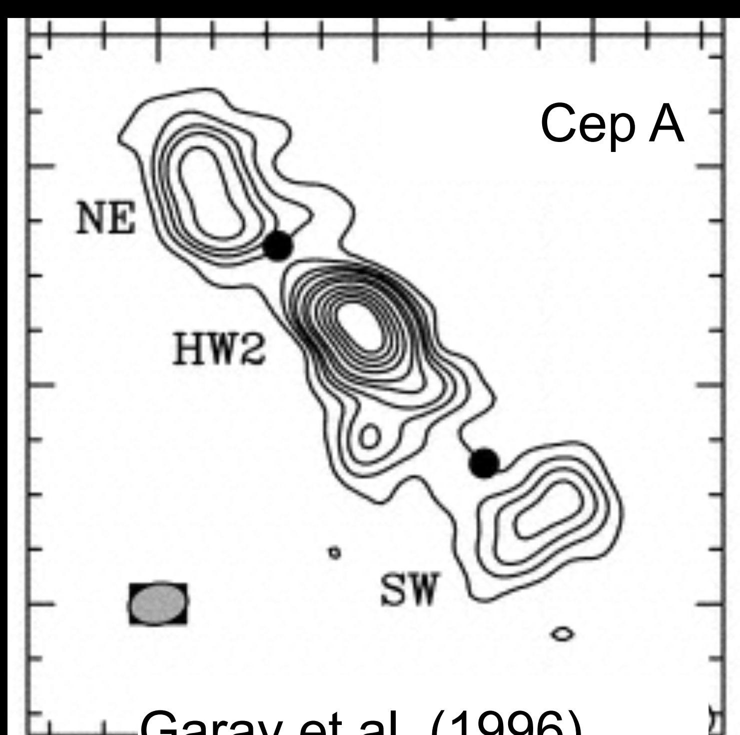

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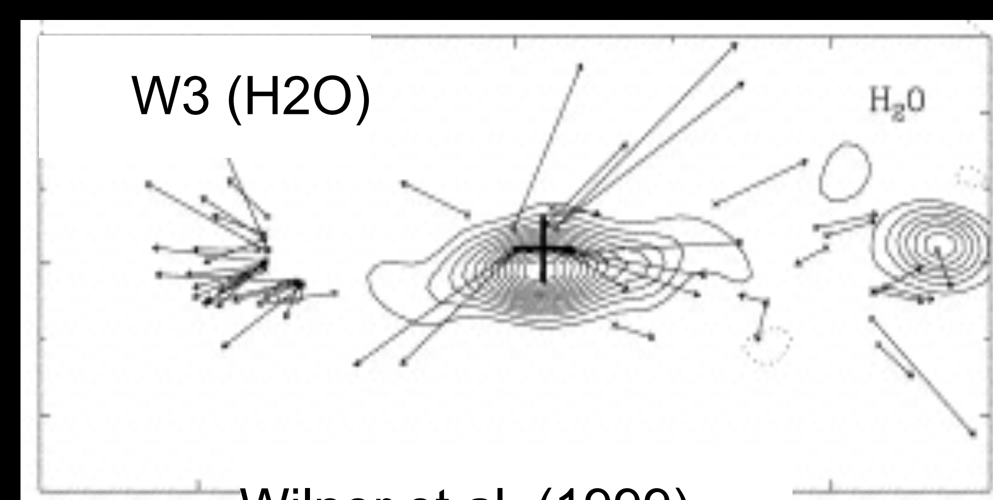

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Our new observations have higher angular resolution
Polarization in HH 80-81 were detected in a very extended structure

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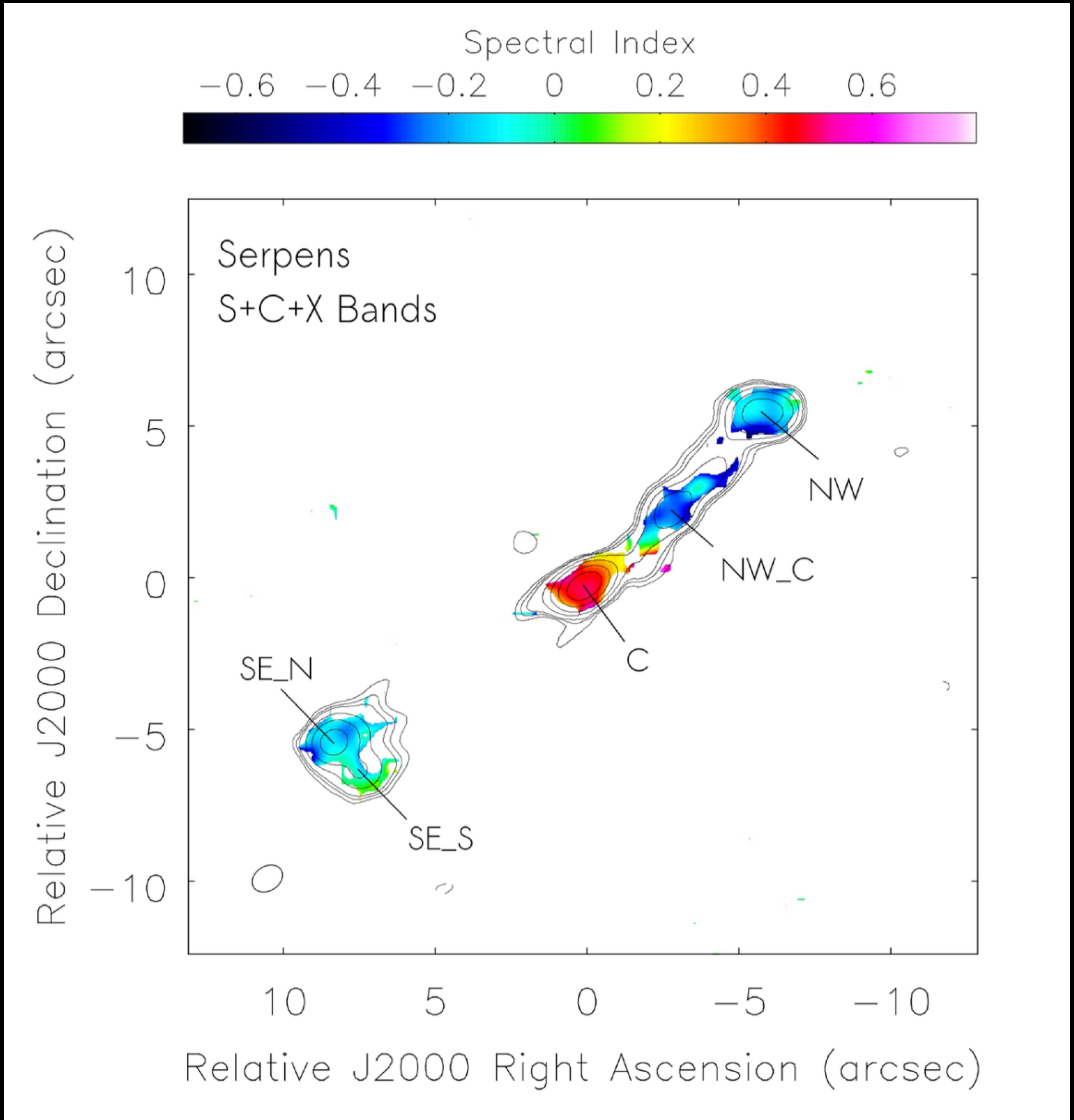
BUT, we could study particle acceleration in some jets

Triple Source in Serpens

Intermediate-mass protostar (~5 Msun)



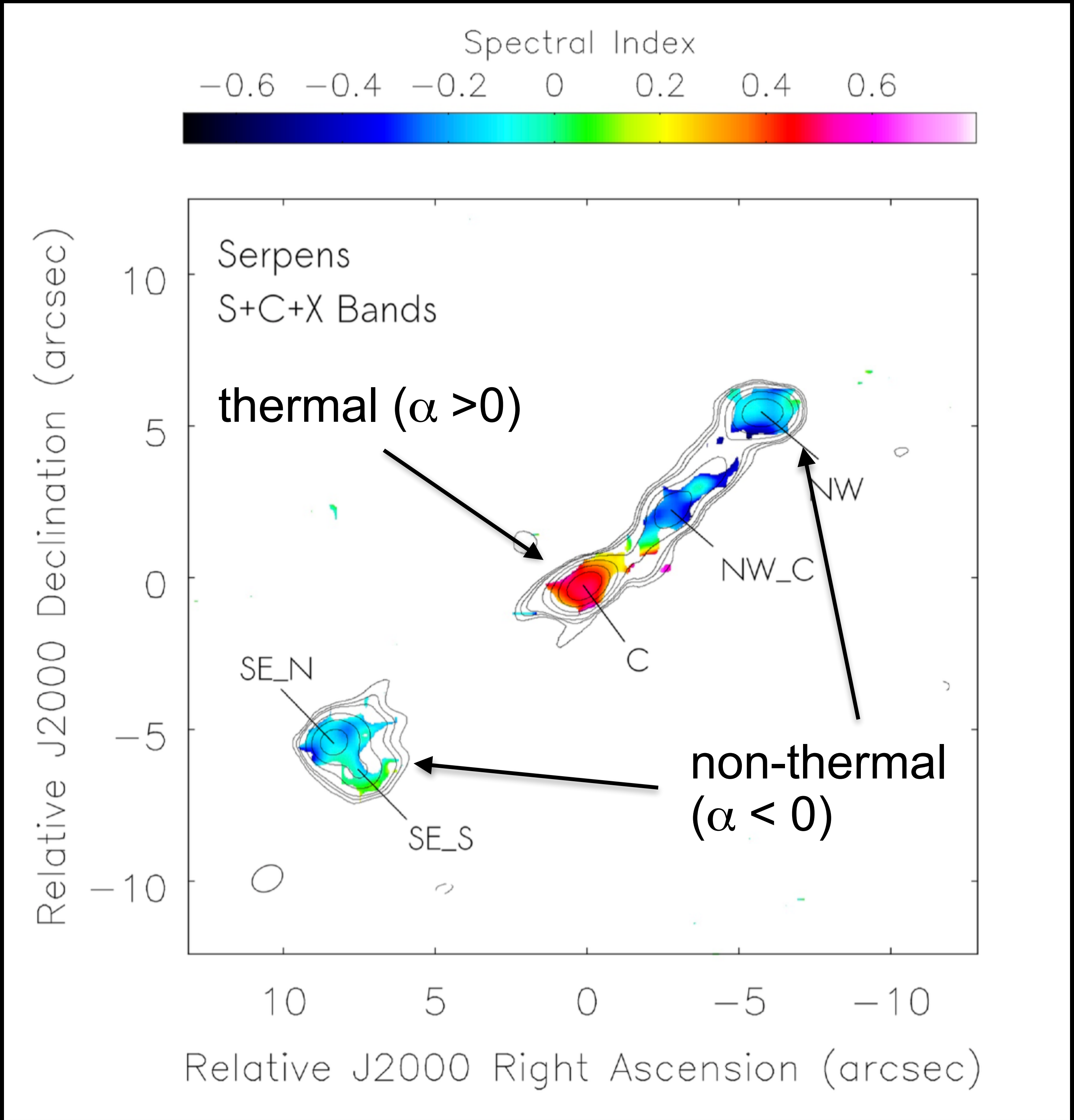
Non-thermal emission from shocks

Also "fast" jet (>300 Km/s)

Periodic ejections + Jet precession

Rodriguez-Kamenetzky, Carrasco-Gonzalez et al. (2016)

Triple Source in Serpens



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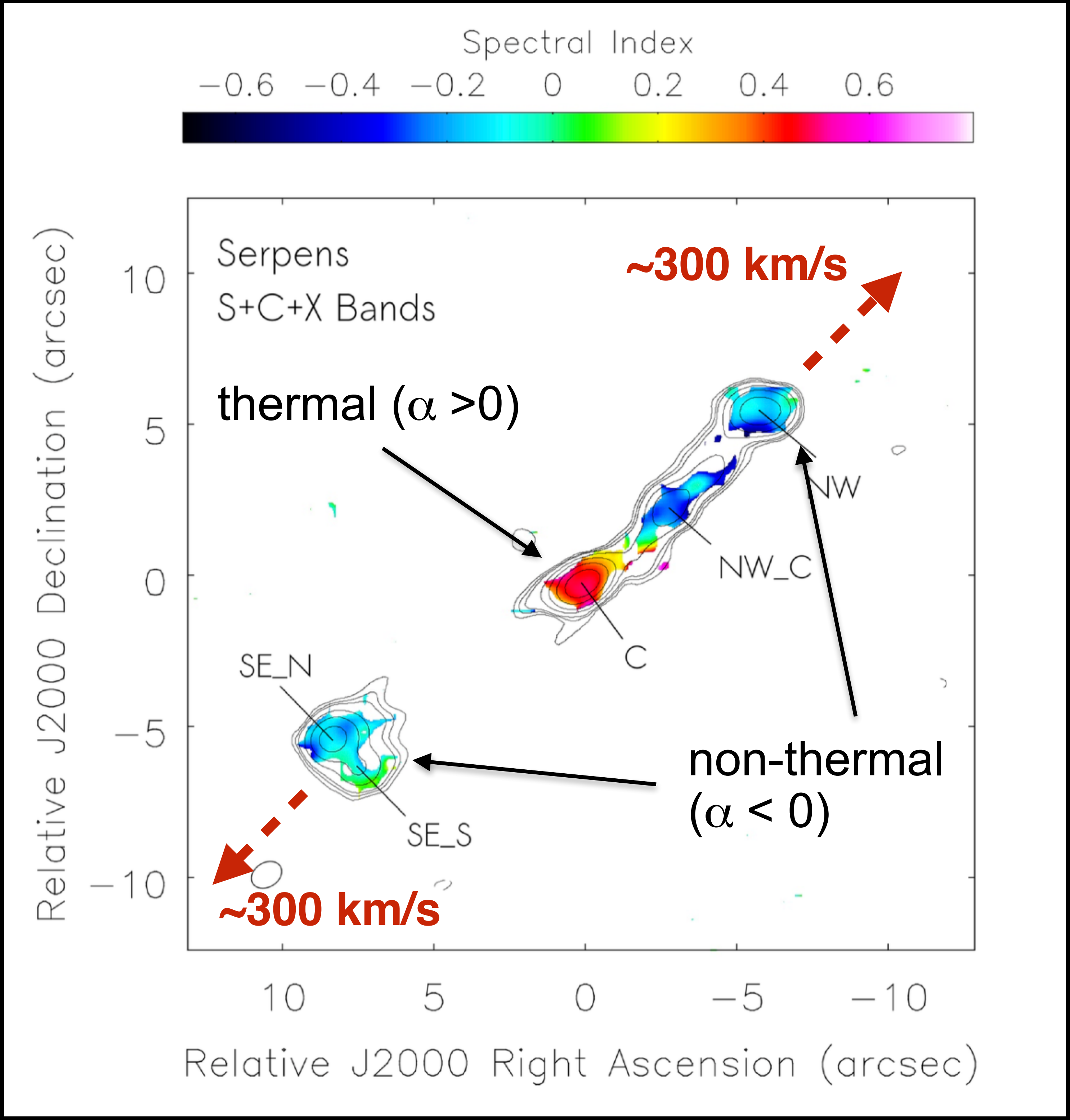

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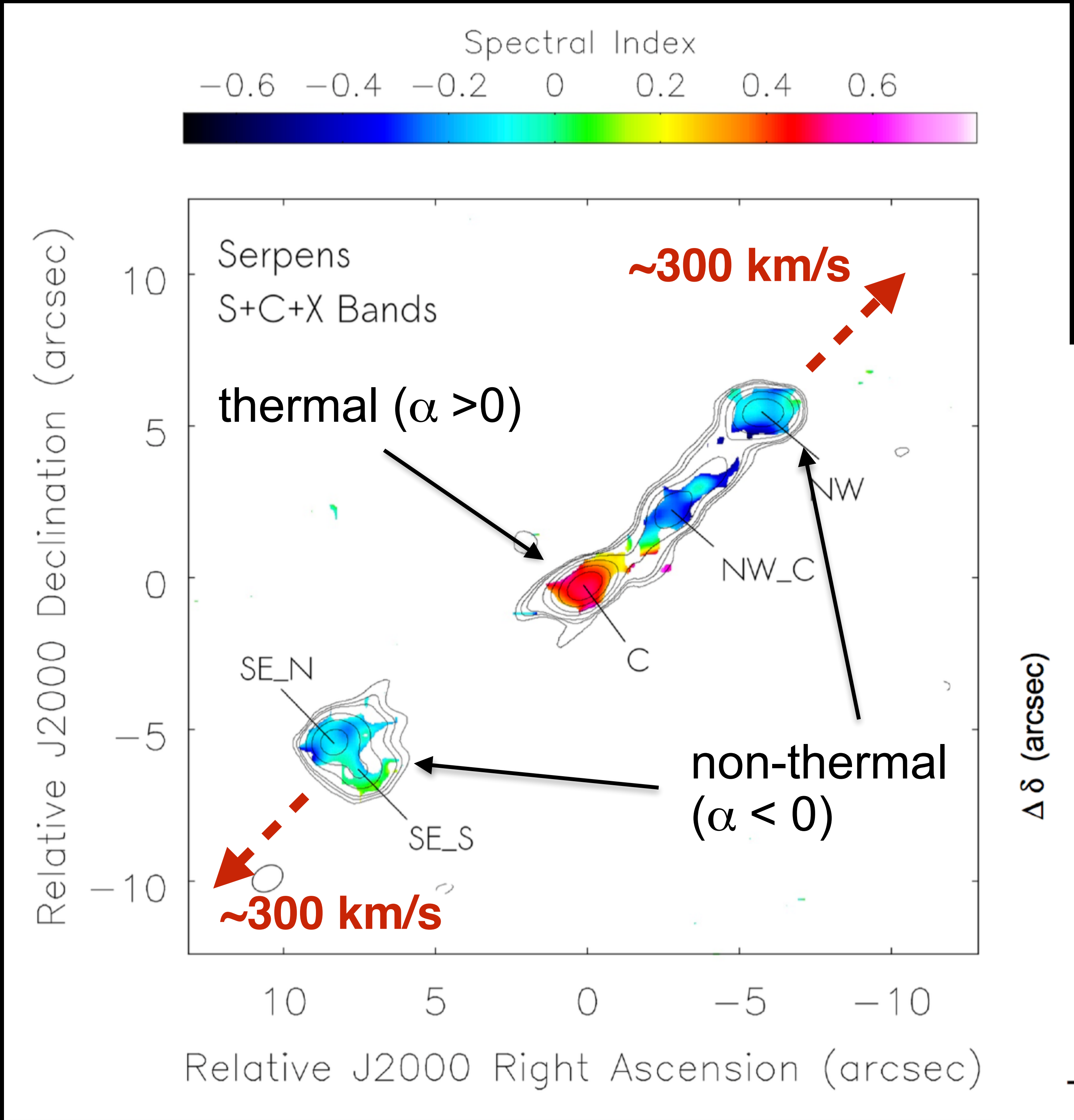

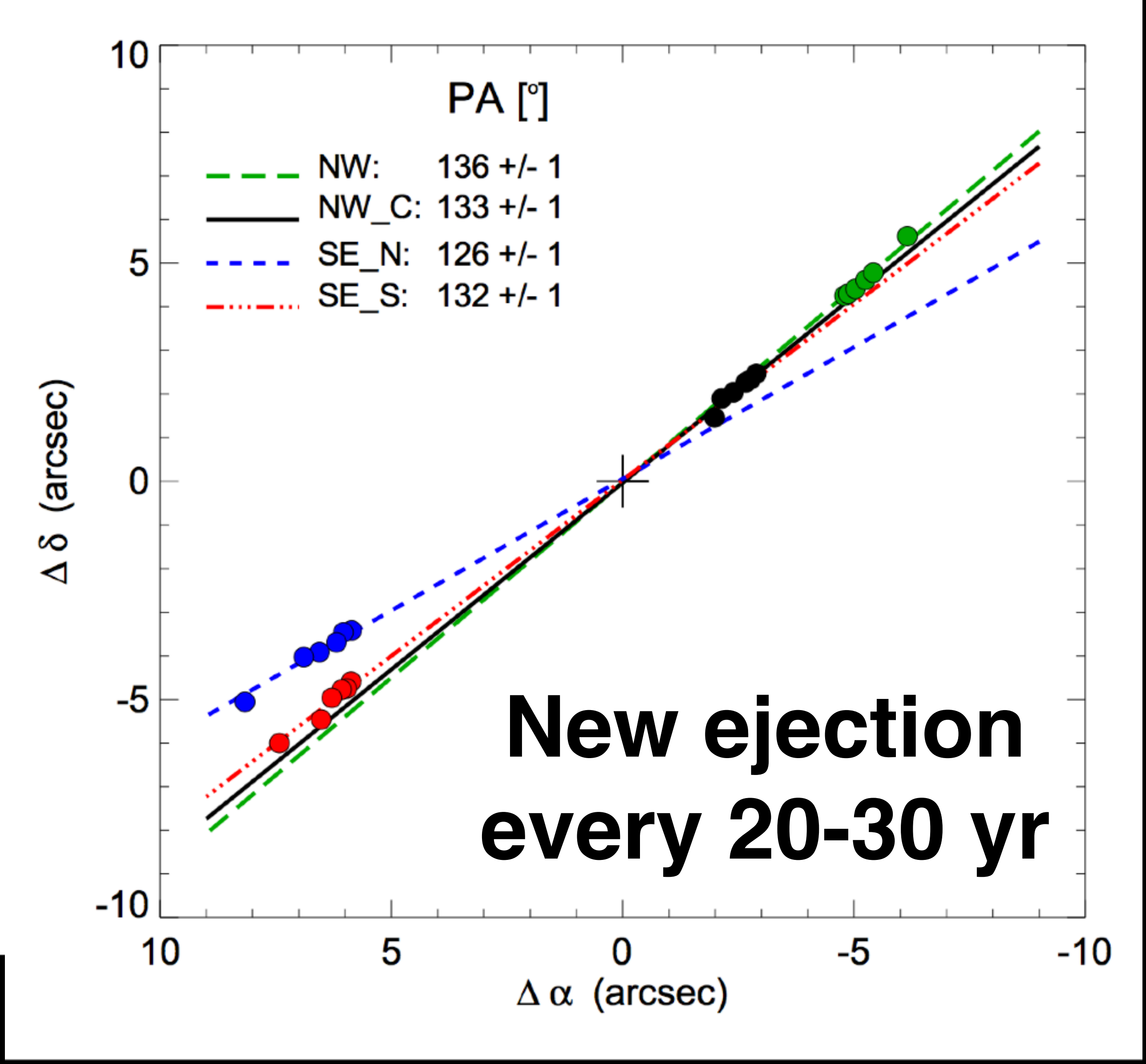

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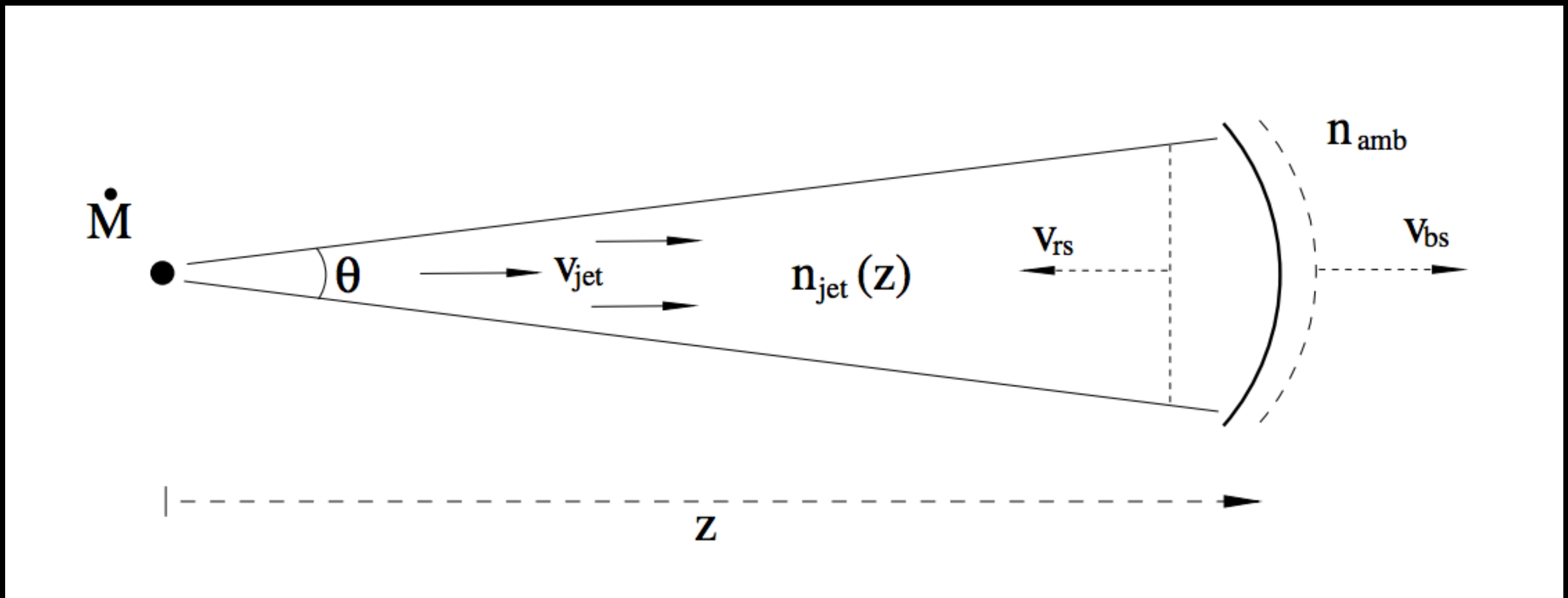
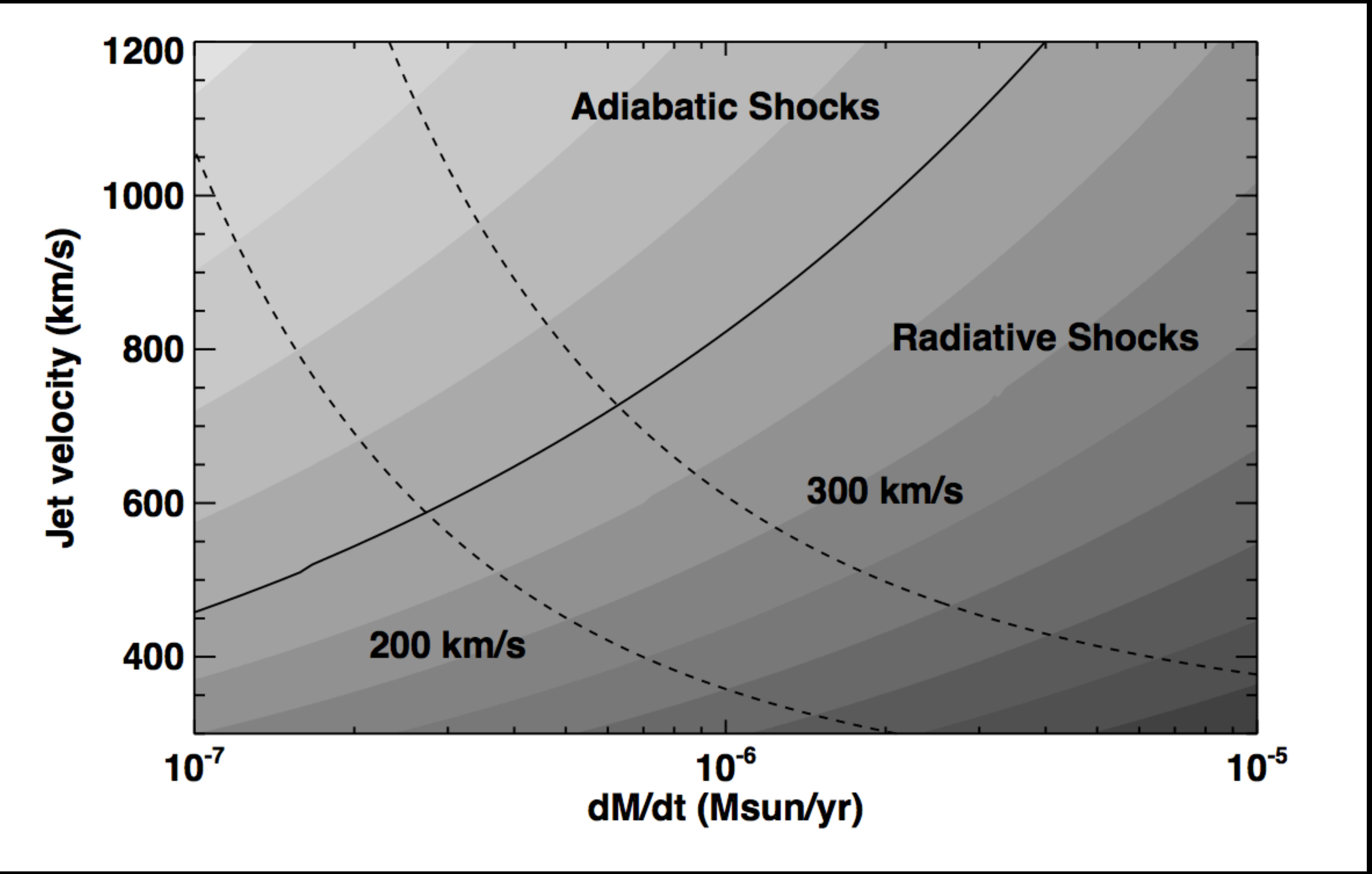


Adiabatic shocks against the ambient medium

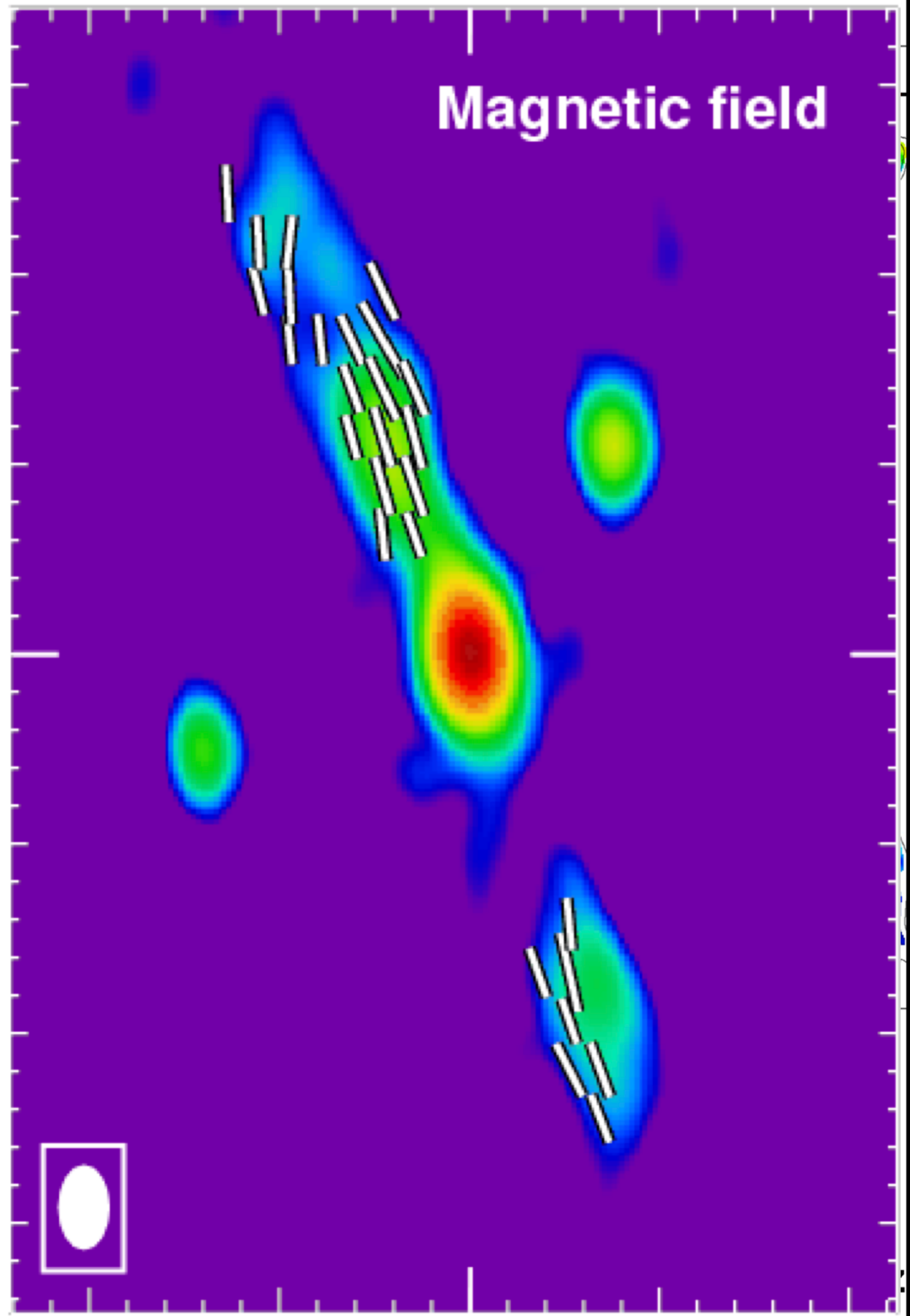


No special properties

Only fast jet + Dense medium

Rodriguez-Kamenetzky, Carrasco-Gonzalez et al. (2016)

HH 80-81



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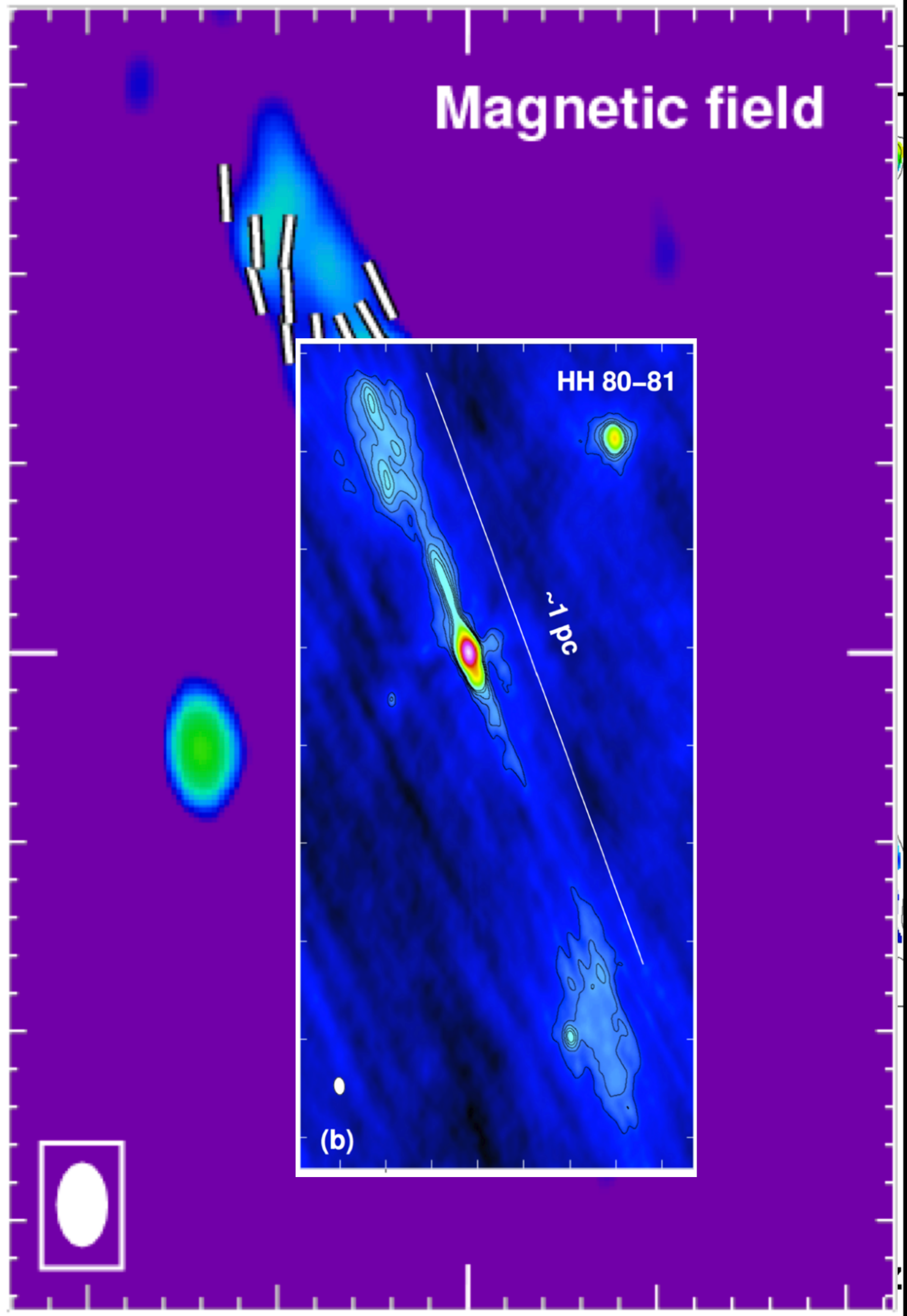
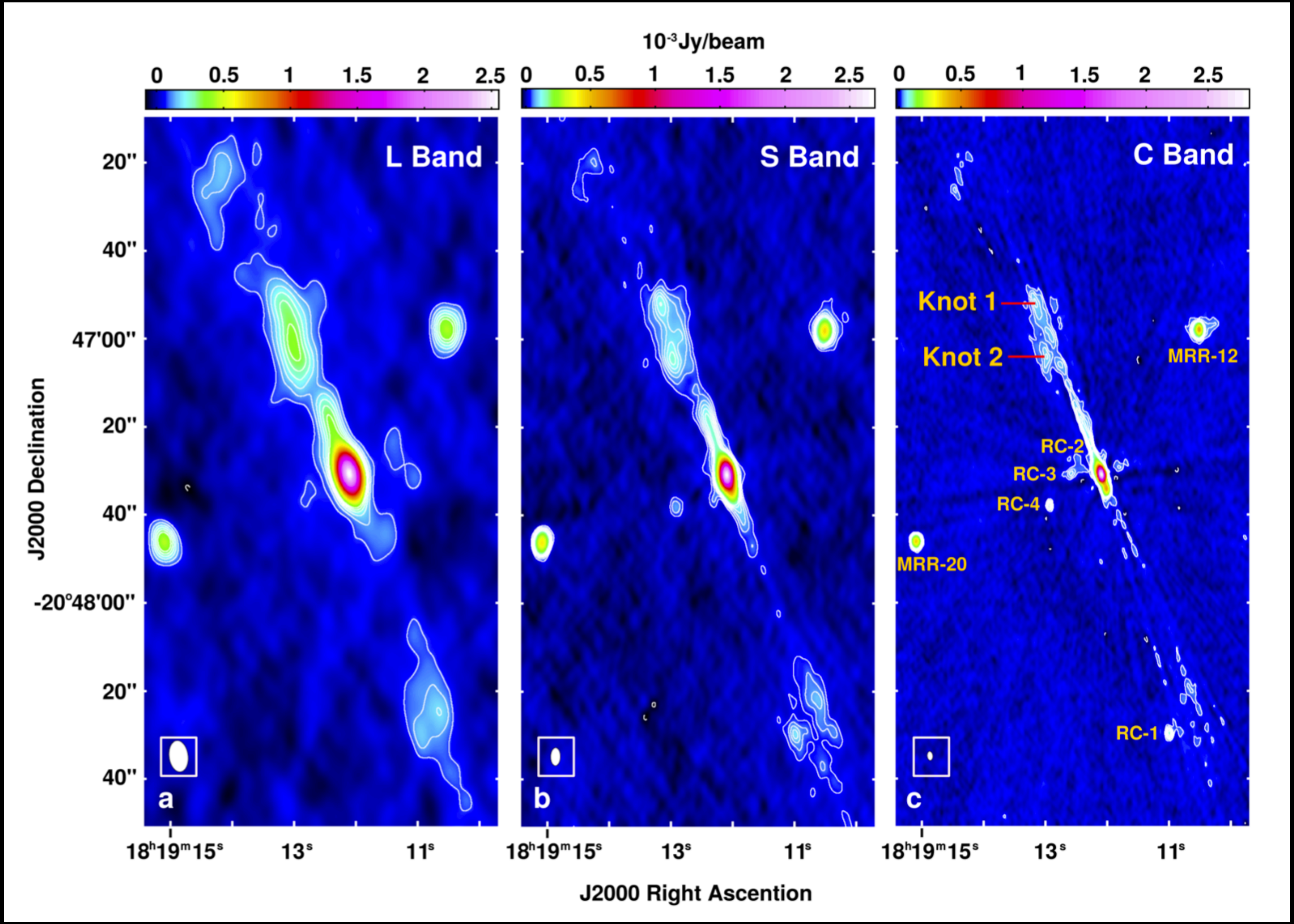


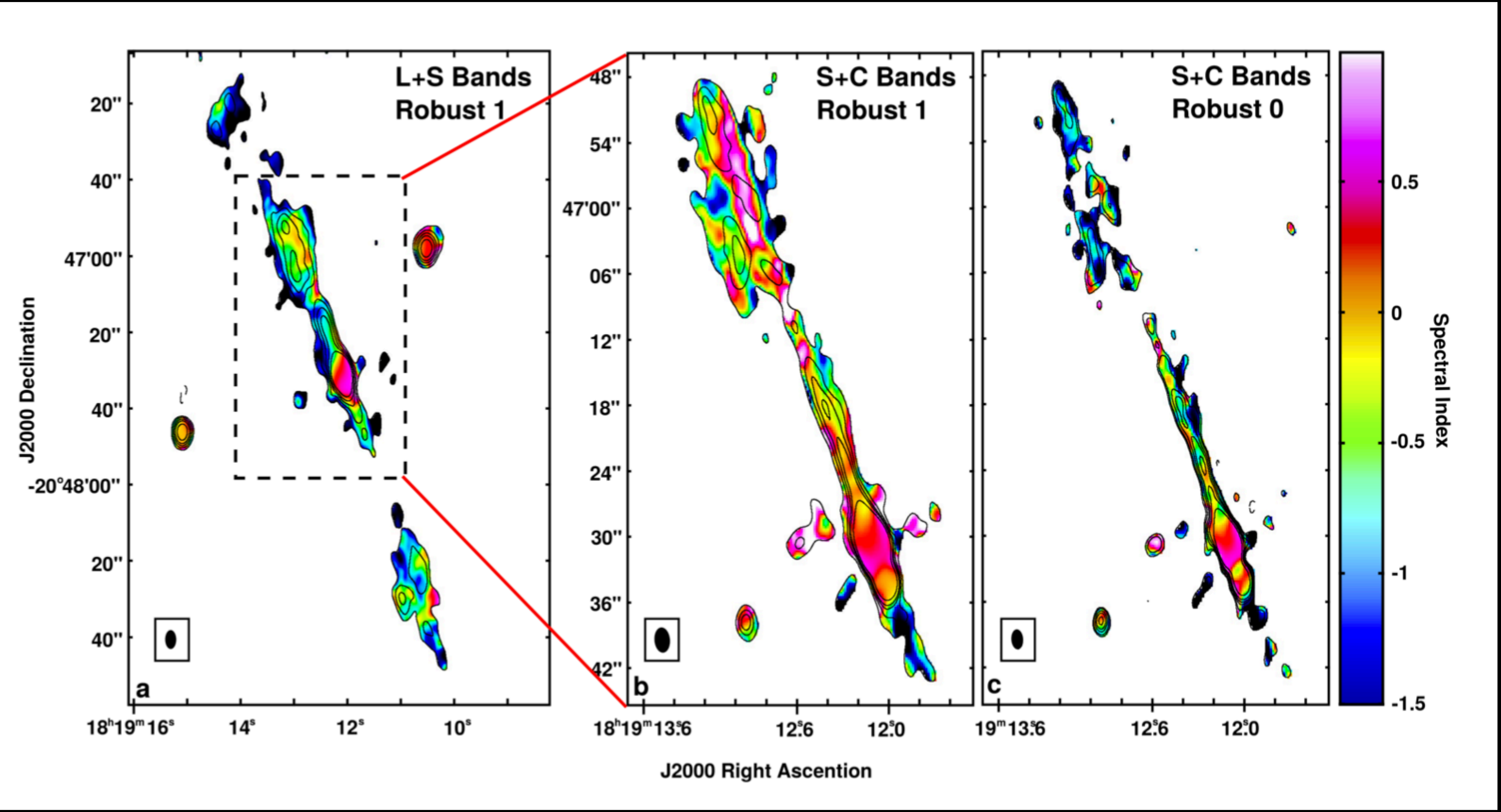
HH 80-81

Nice images showing different structures



Rodriguez-Kamenetzky, Carrasco-Gonzalez et al. (submitted)

HH 80-81 Spectral index maps



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HH 80-81

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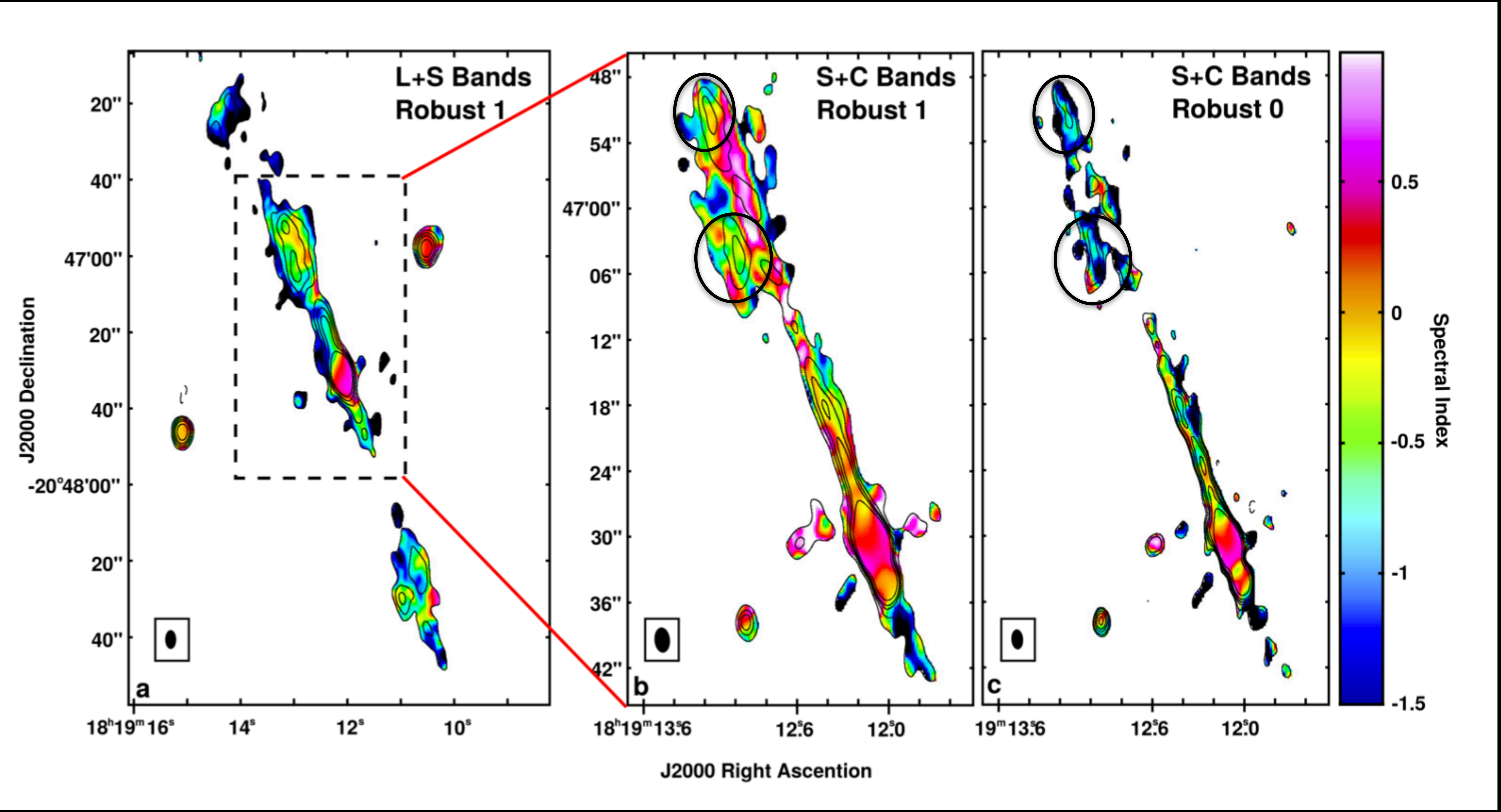

Non-thermal emission from shocks against the ambient medium

Rodriguez-Kamenetzky, Carrasco-Gonzalez et al. (submitted)

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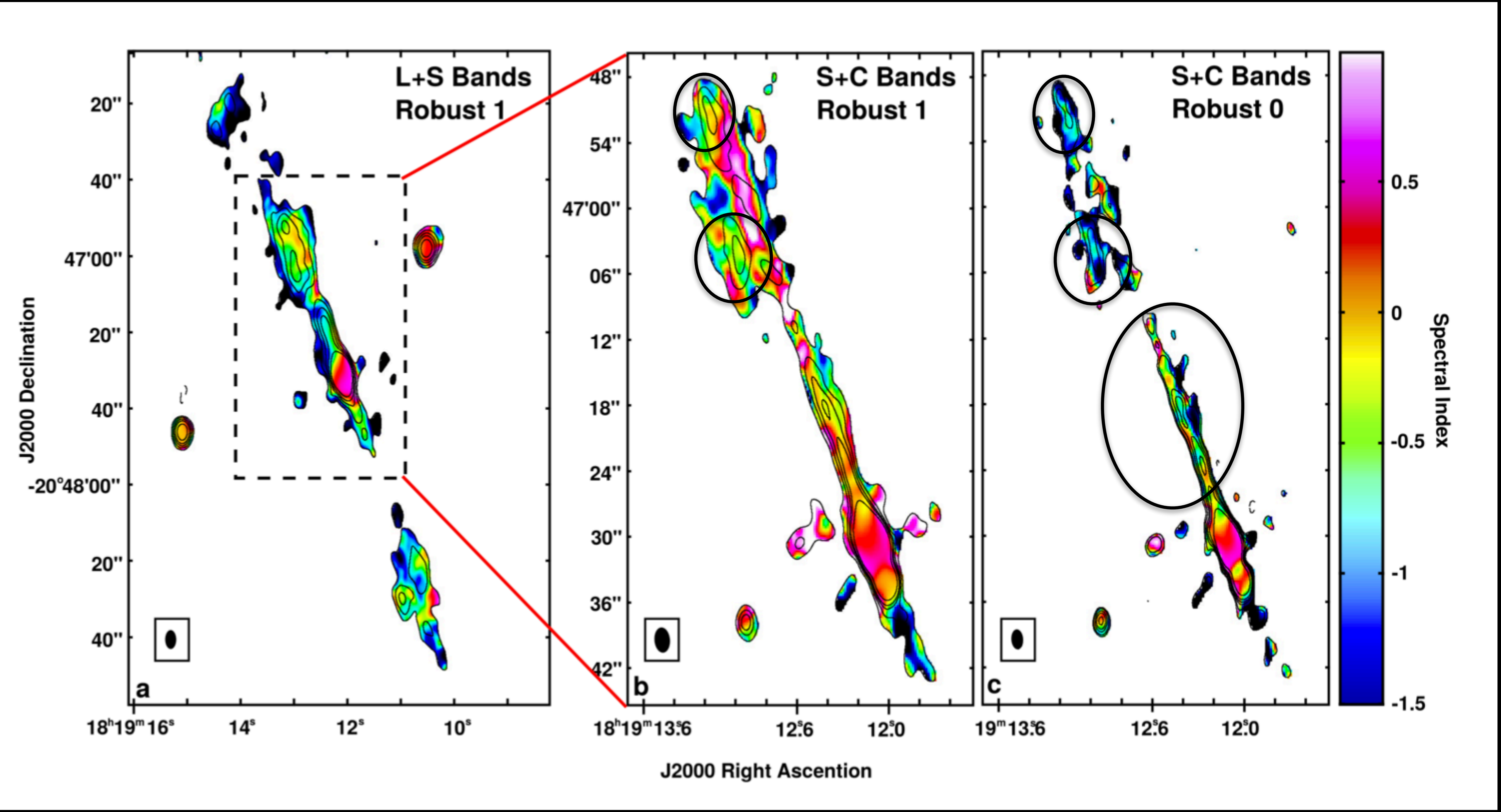
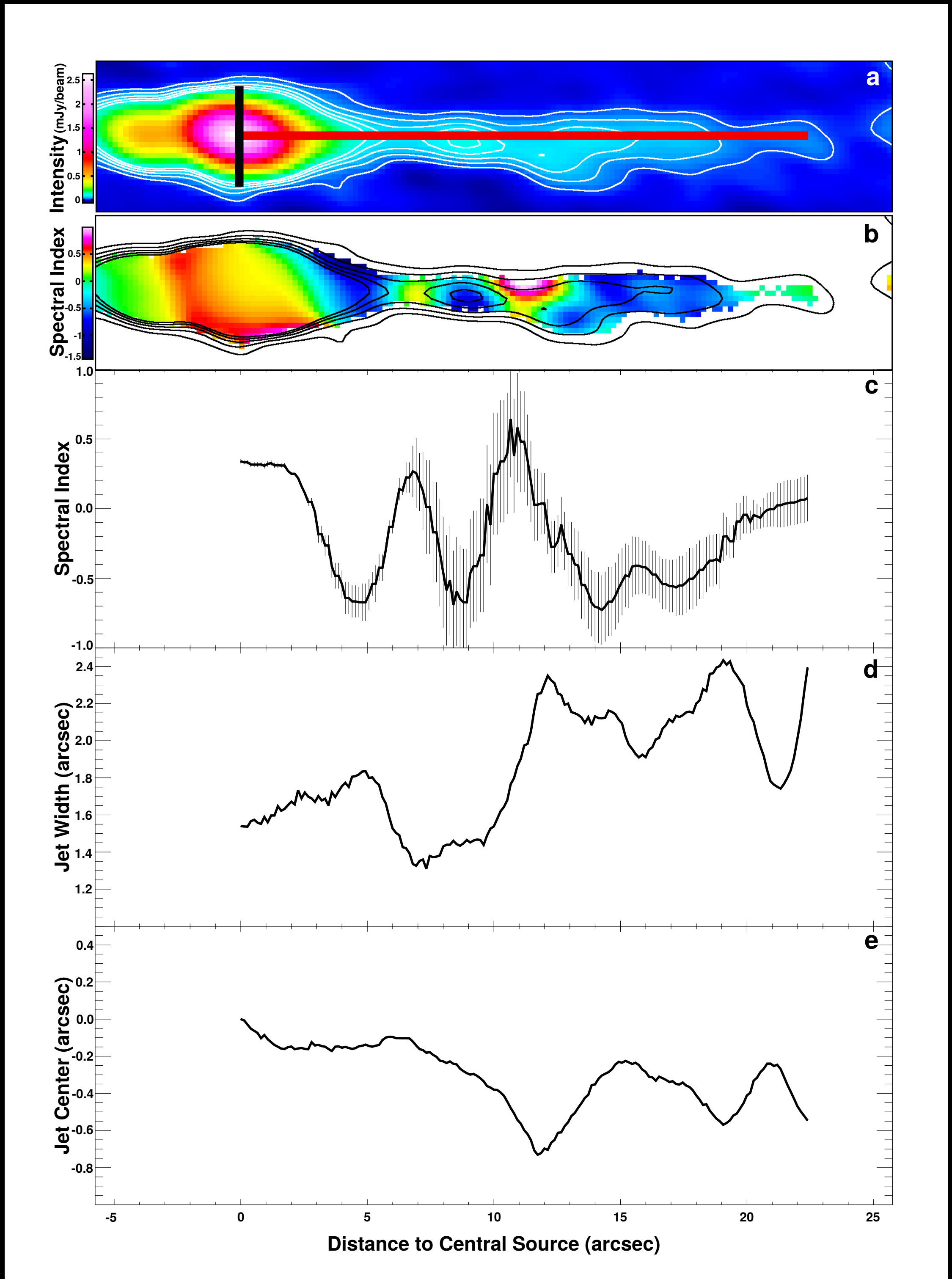


Non-thermal emission from shocks against the ambient medium

But also from the “collimated” part of the jet (internal shocks?)

Rodriguez-Kamenetzky, Carrasco-Gonzalez et al. (submitted)

HH 80-81



Changes in the spectral index along the jet

Changes in the jet width

Changes in the jet direction

Rodriguez-Kamenetzky, Carrasco-Gonzalez et al. (submitted)

SUMMARY

Protostellar jets can **accelerate particles** and emit **synchrotron emission**

Mainly, they accelerate particles in **strong shocks** against the ambient medium

Jet properties to accelerate particles:
"**high" jet velocities** and **high densities** of the ambient medium
(young embedded protostars)

In some cases, also **internal shocks** seems to be able to accelerate particles and emit synchrotron

Possibility of study the **magnetic field** through linear polarization

But emission is **very weak** in these guys:
we need very **high sensitivity** and very **high angular resolution**