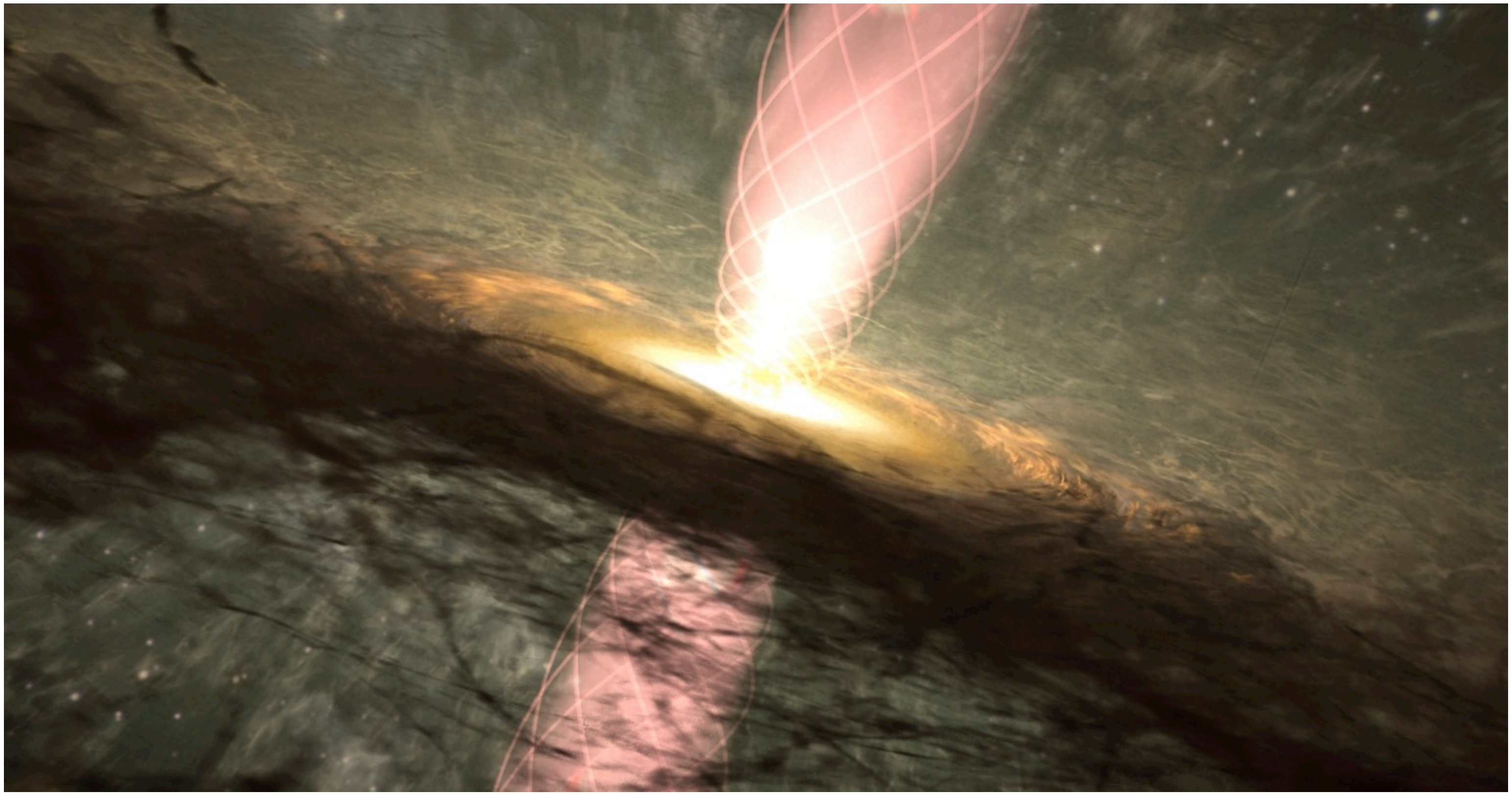
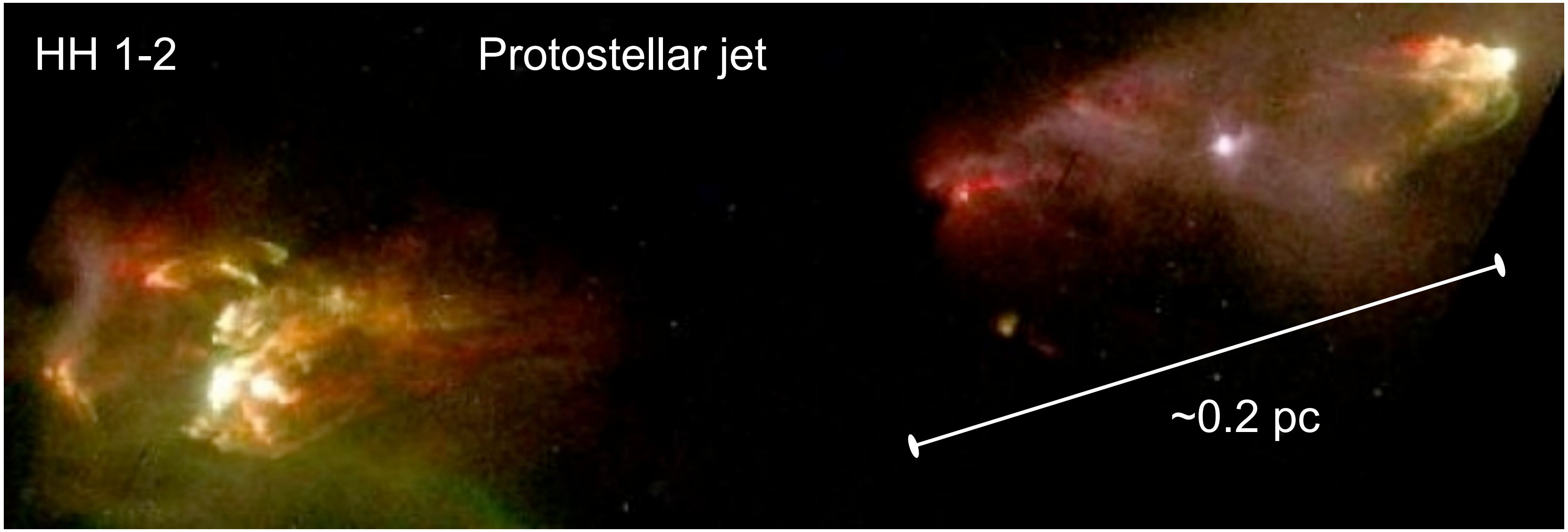
Discovery of Synchrotron Emission from a YSO (non-relativistic) Jet

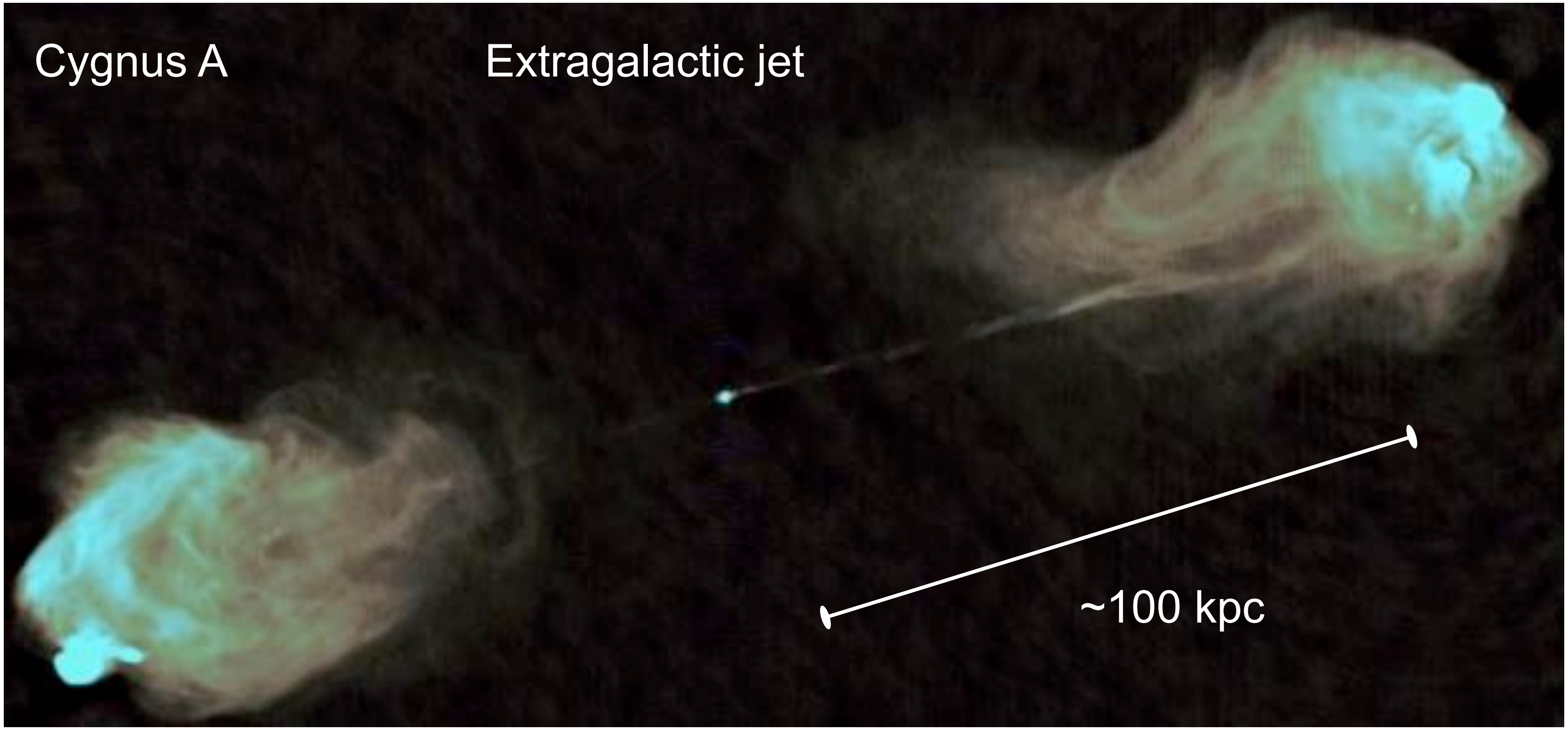


Carlos Carrasco-González
Max-Planck-Institut für Radioastronomie
(Bonn, Germany)

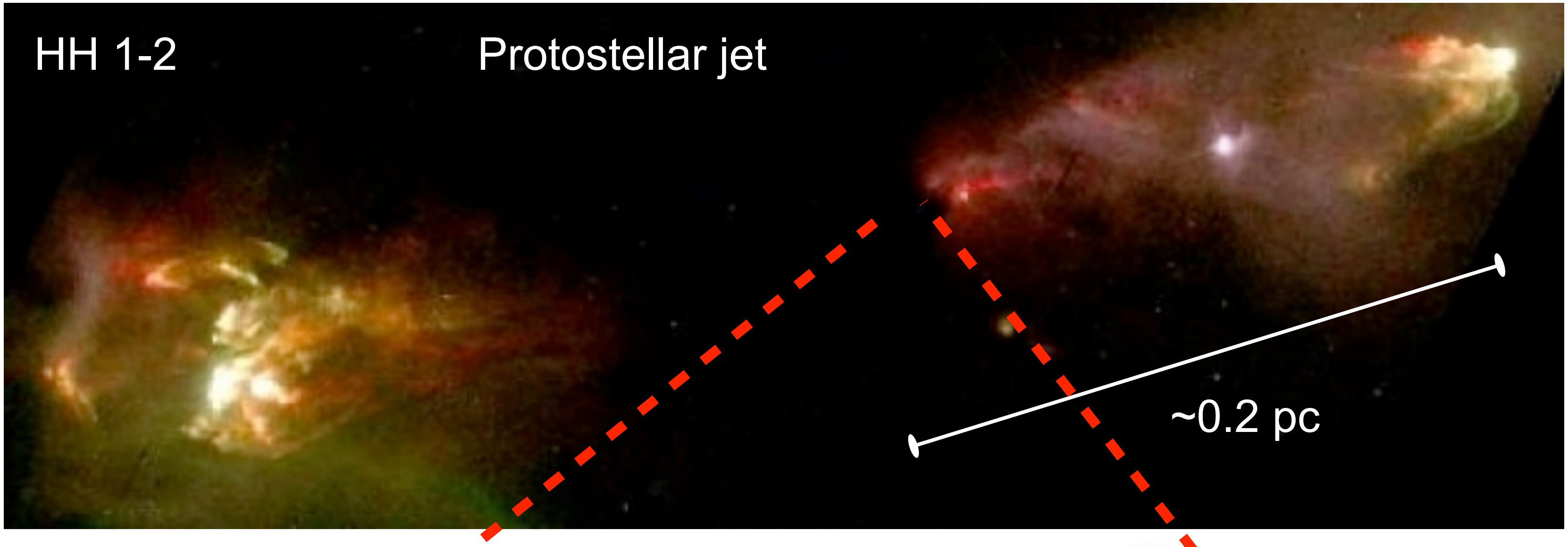
Luis F. Rodríguez (CRyA), Guillem Anglada (IAA),
Josep Martí (University of Jaén), José M. Torrelles (IEEC), Mayra Osorio (IAA)

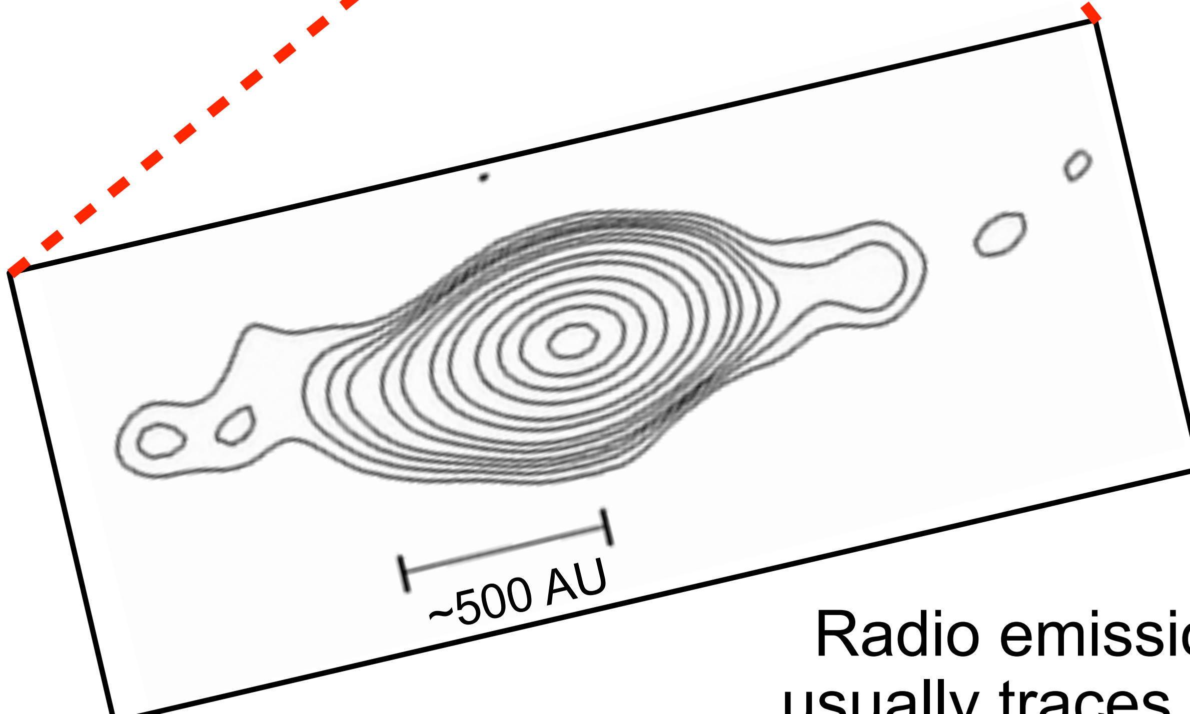
Not so different...





The Innermost Regions of Non- Relativistic Jets





Radio emission from YSOs usually traces the base of the large scale optical jets

Jet Formation and collimation

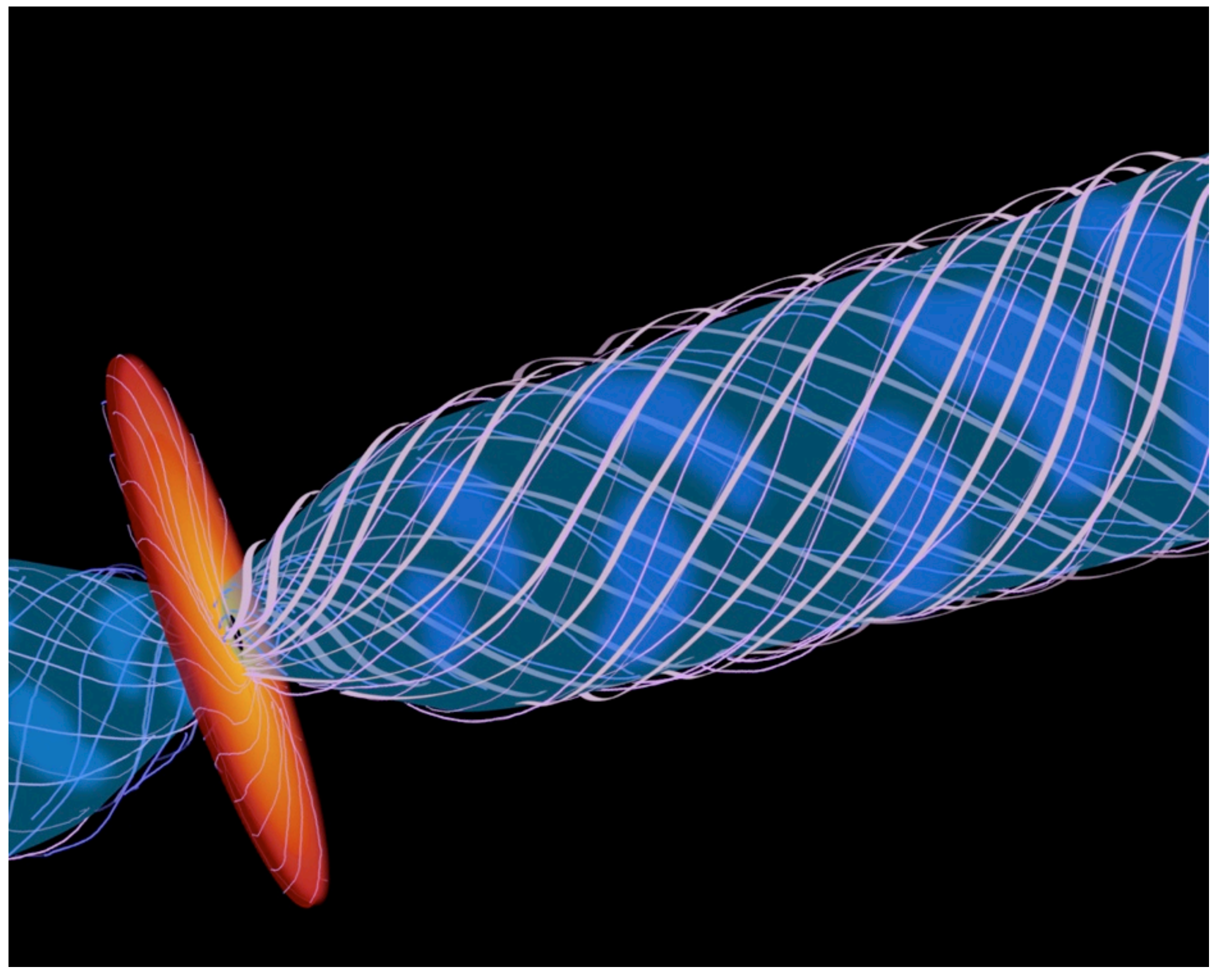
Fundamental ingredients → Accretion disk + Magnetic field

Rotation + acretion → B is twisted in the disk

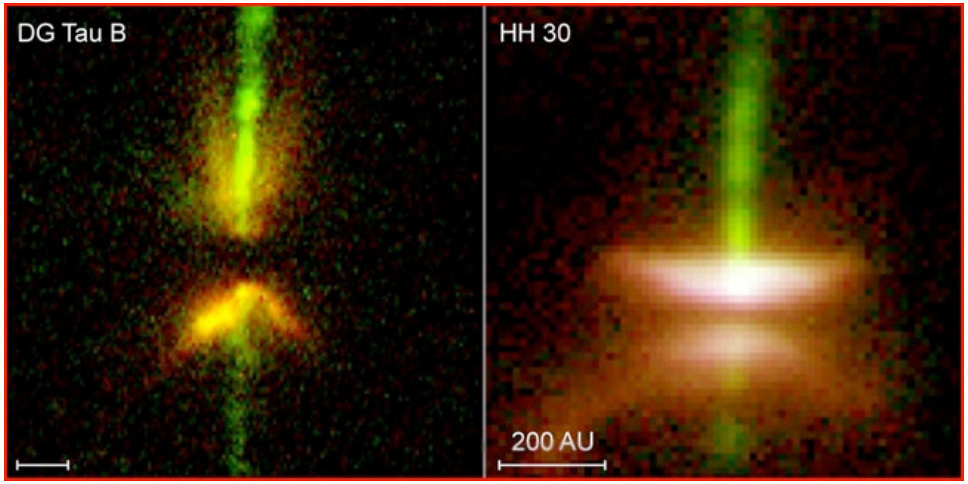
Large distances → helical B → confines the material

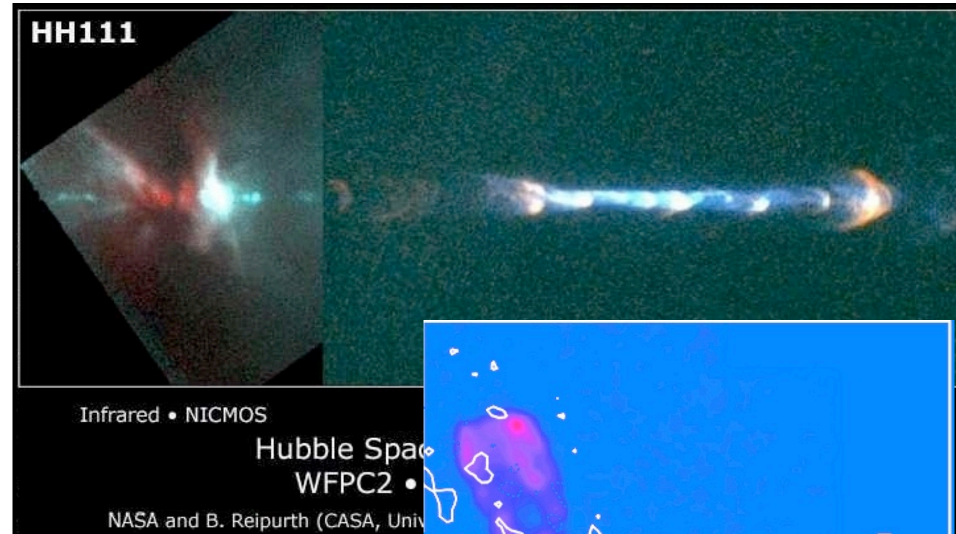
Similar mechanism for all kind of jets:

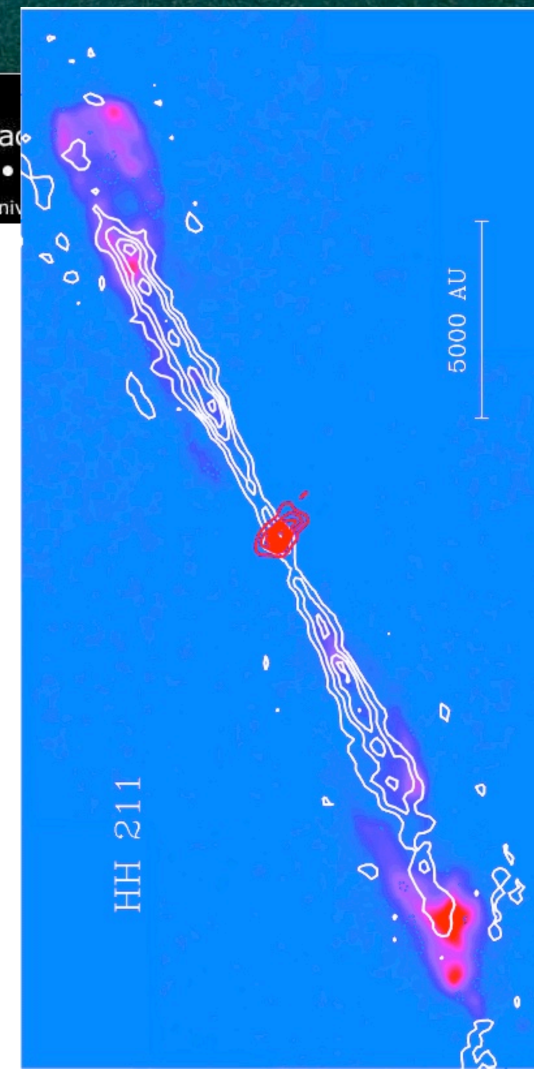
- AGNs
- Microquasars
- PNe
- YSOs
- …



YSO: Excellent targets for the study of the jet phenomenon







Large number of known YSOs, nearby and lot of information can be obtained from observations at different wavelengths

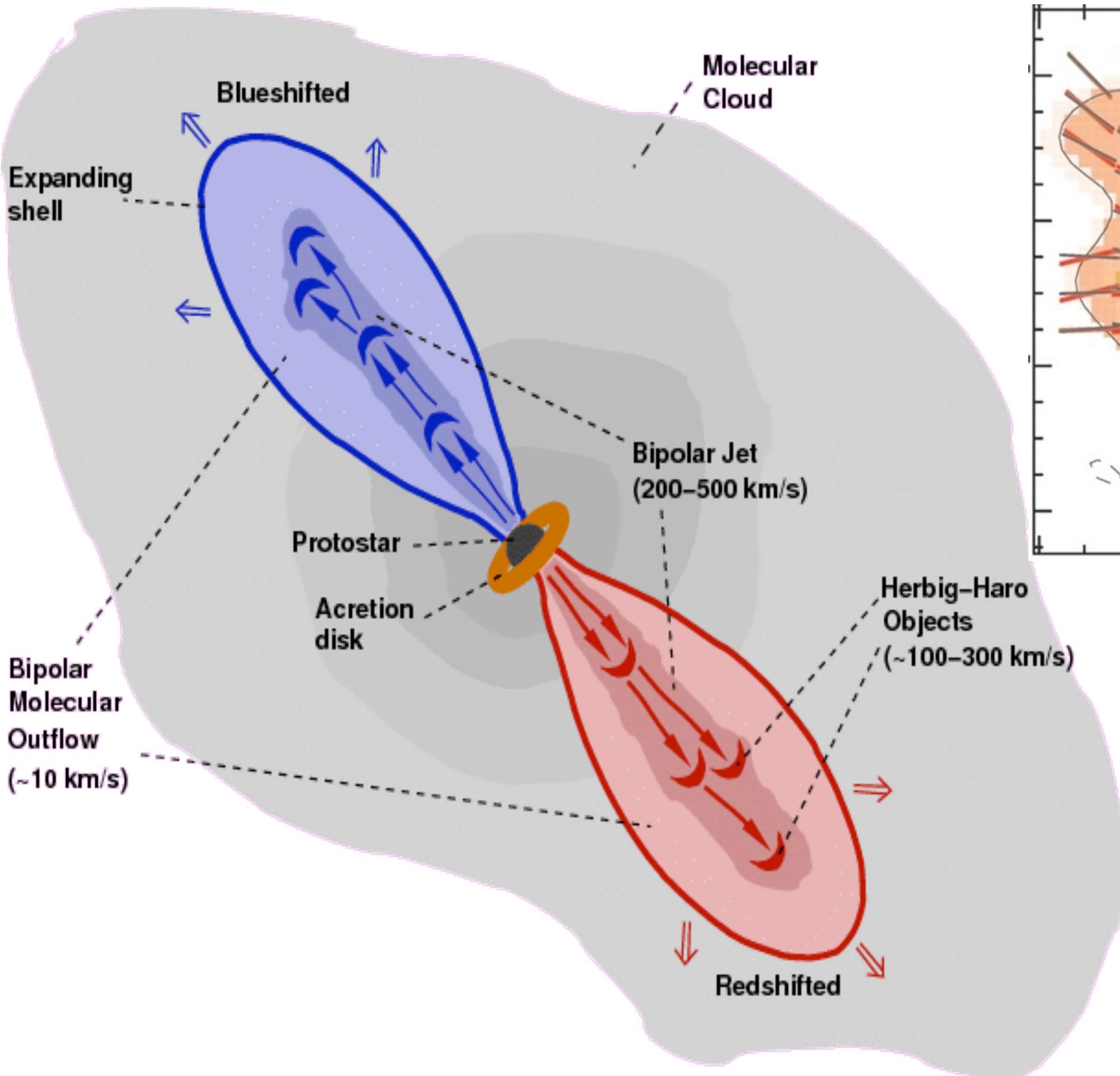
Optical & IR → Temperature, density, mass

Radio → ionized gas, base of the jet, velocity

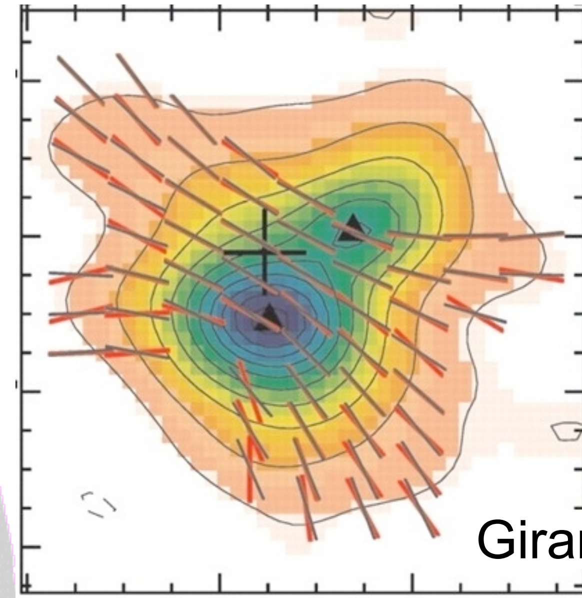
mm/submm → Disk, molecular outflow

But **magnetic field**, very difficult to observe, specially in the jet, and we do not know very much about it

Magnetic Fields in YSO Jets

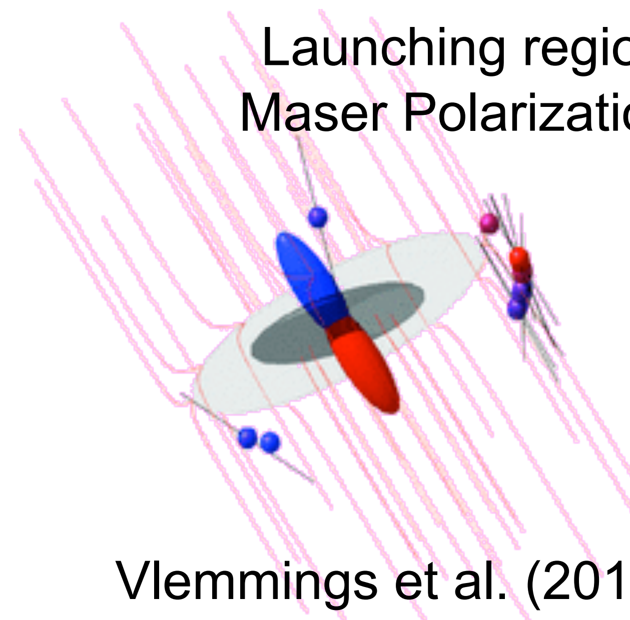


Dust Polarization
Cloud's Magnetic Field

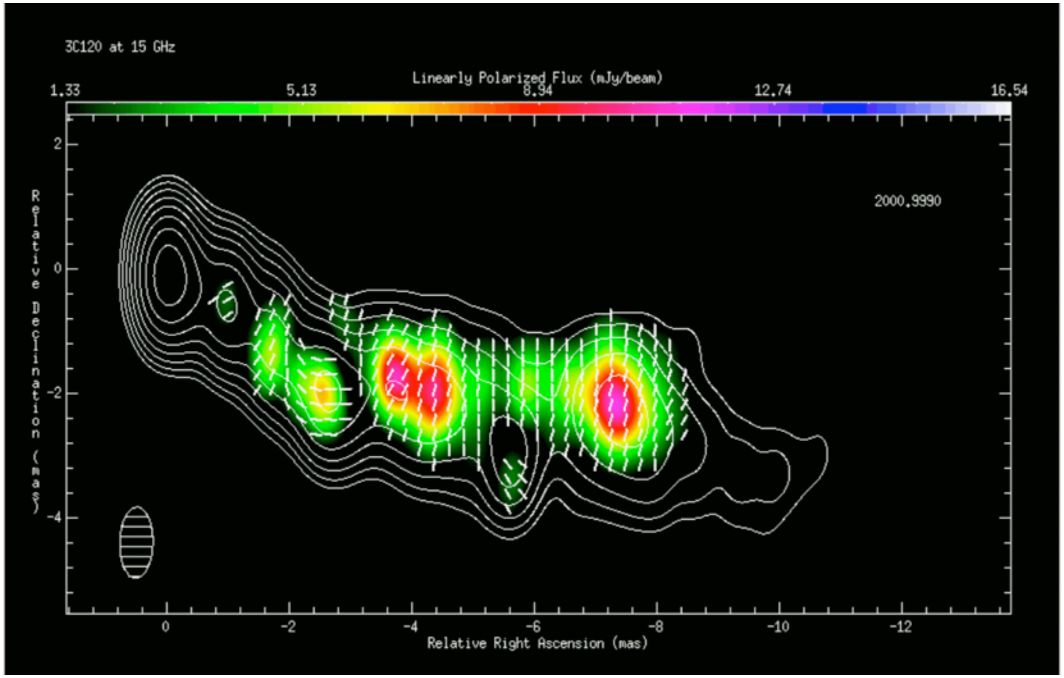


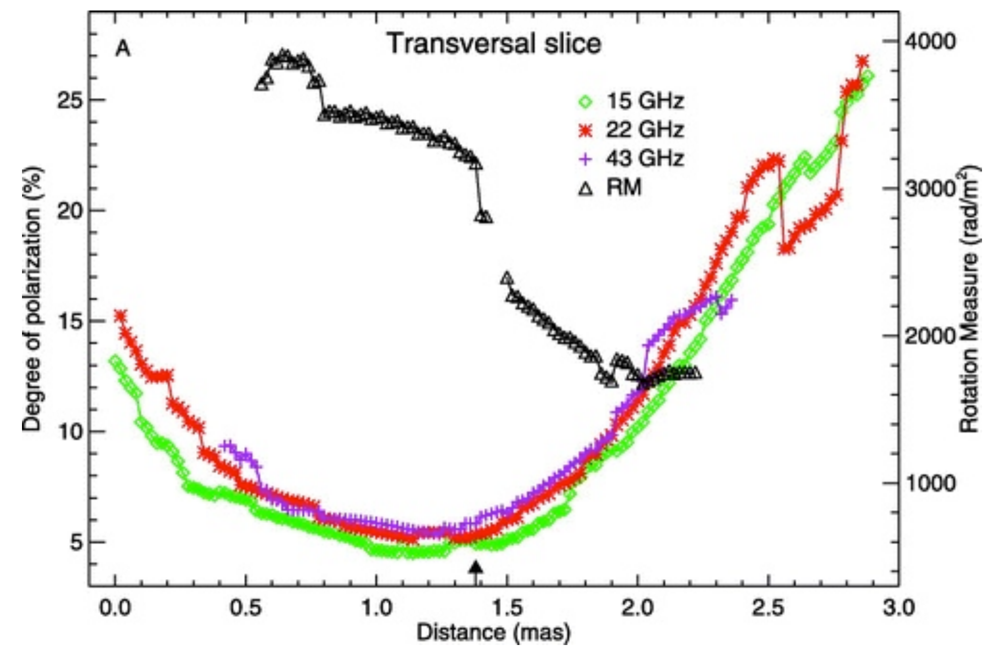
Girart et al. (2006)

Launching region
Maser Polarization



Vlemmings et al. (2010)





In contrast to YSO jets, magnetic fields are "easy" to study in relativistic jets through their synchrotron emission at radio wavelengths

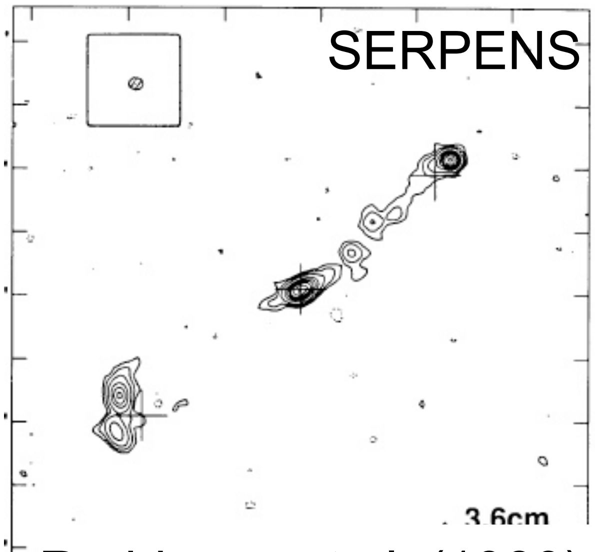
Intensity of radio emission → Intensity of **B**

Linear Polarization → Direction of **B**

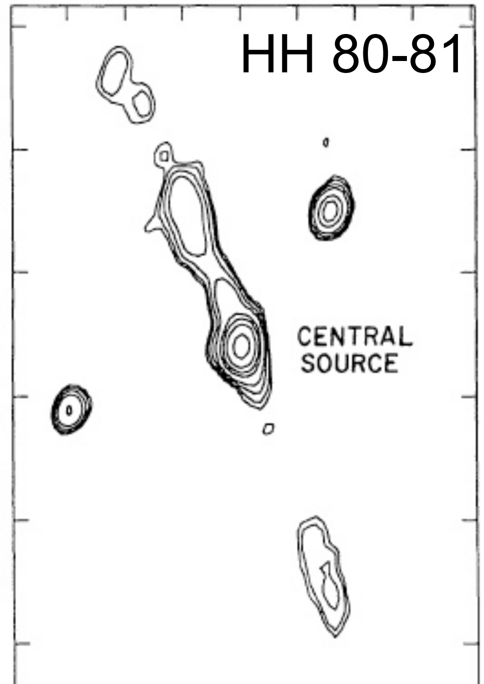
Pol. Deg and Faraday Rotation → 3D structure of **B**

But cannot use the same method for the thermal radio emission from YSO jets

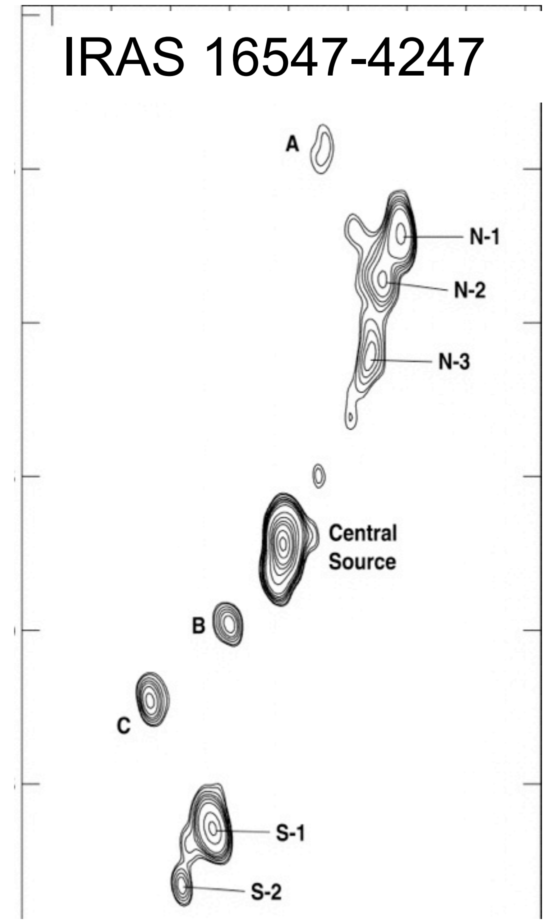
Synchrotron Emission in YSO Jets???



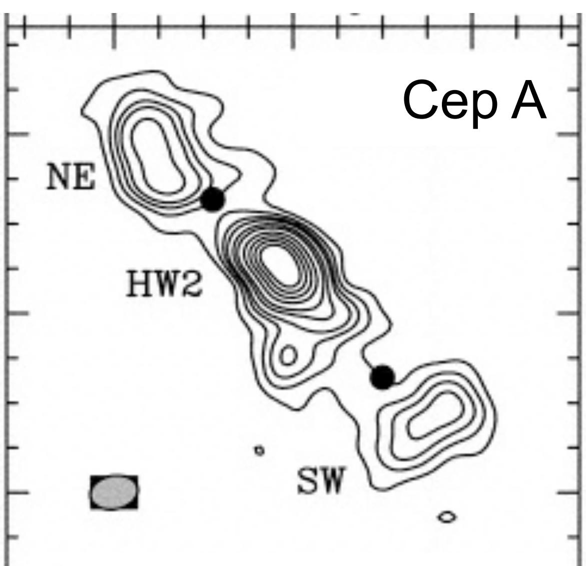
Rodriguez et al. (1989)



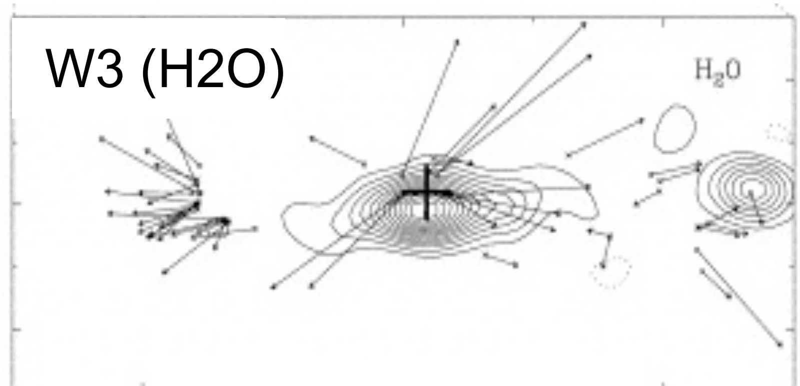
Marti et al. (1993)



Rodriguez et al. (2005)

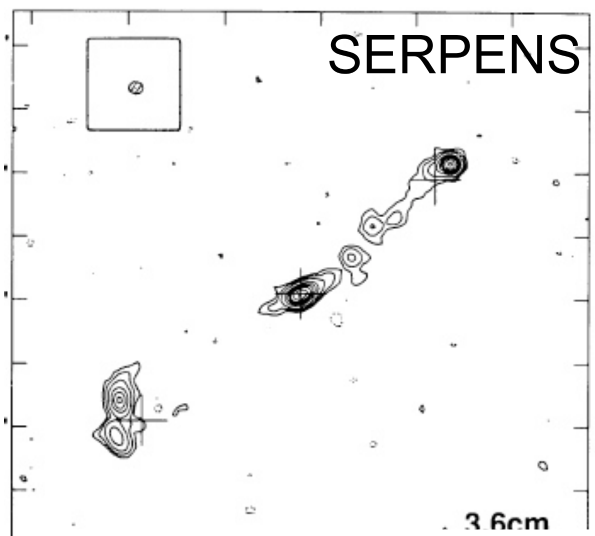


Garay et al. (1996)

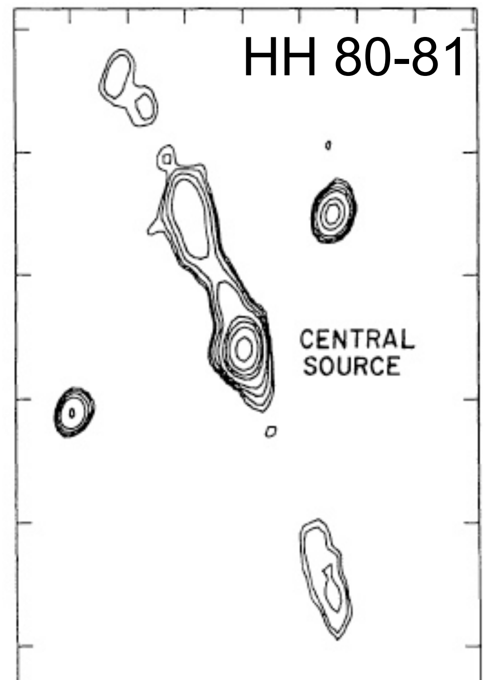


Wilner et al. (1999)

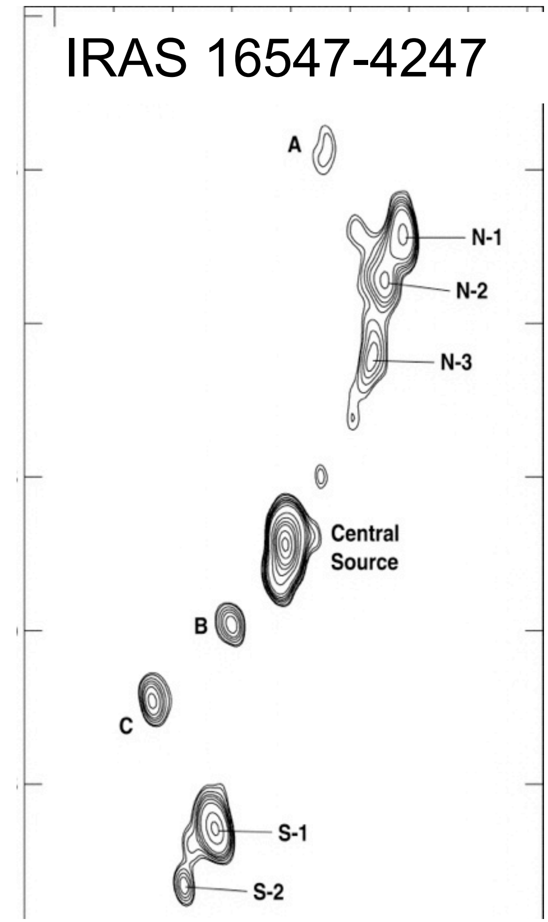
Synchrotron Emission in YSO Jets???



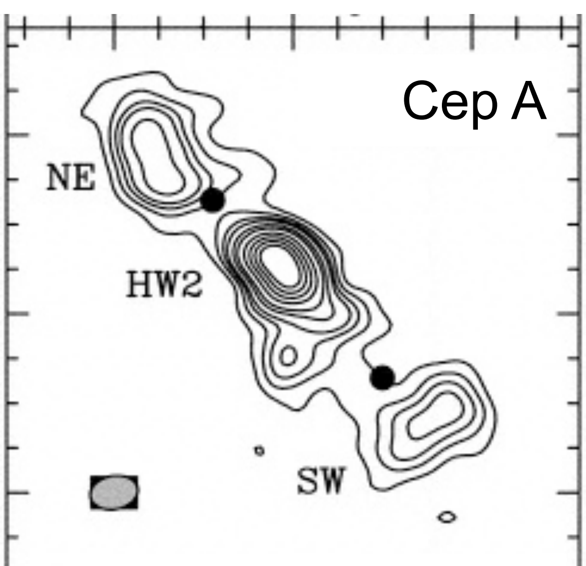
Rodriguez et al. (1989)



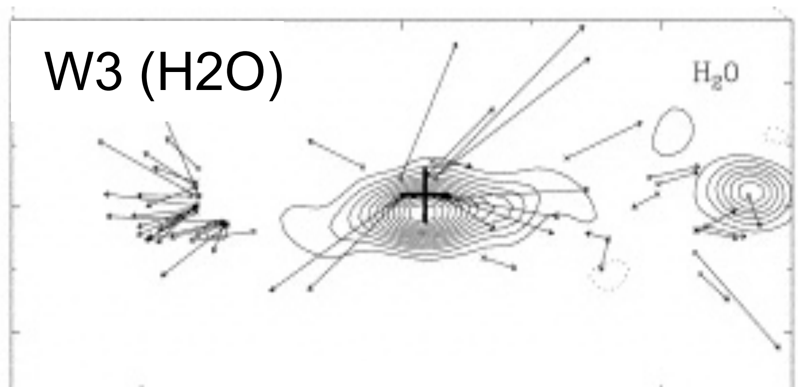
Marti et al. (1993)



Rodriguez et al. (2005)

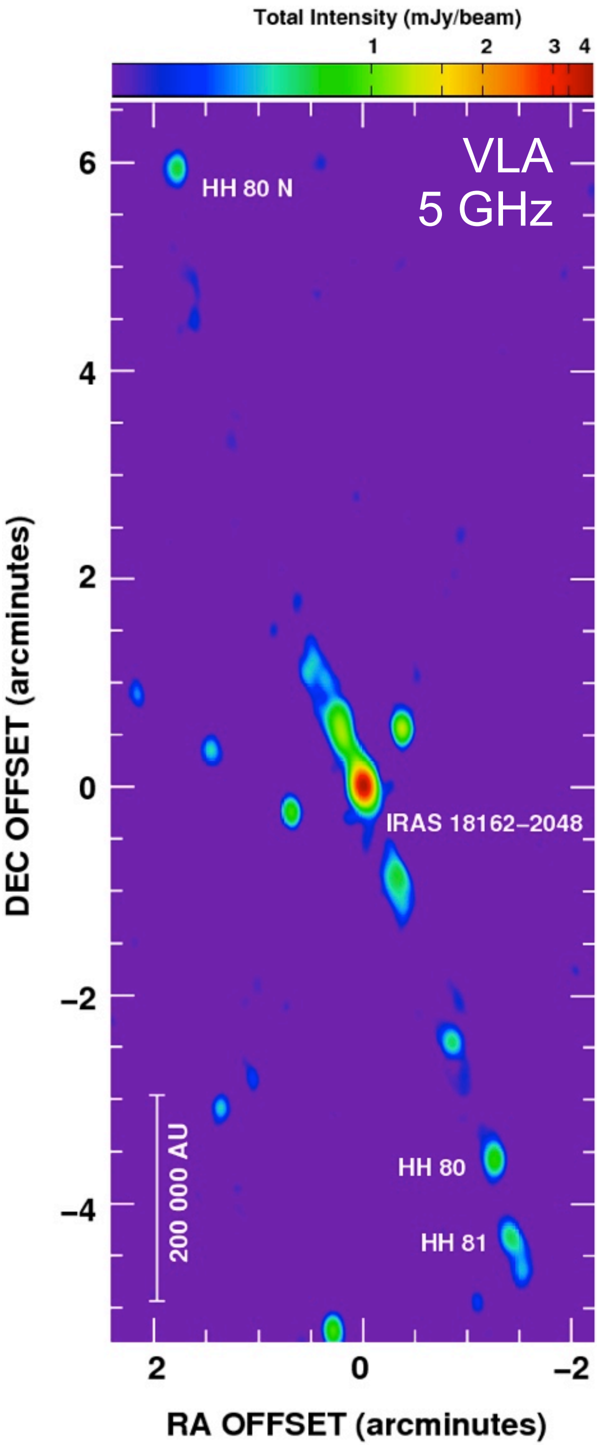


Garay et al. (1996)



Wilner et al. (1999)

HH 80-81



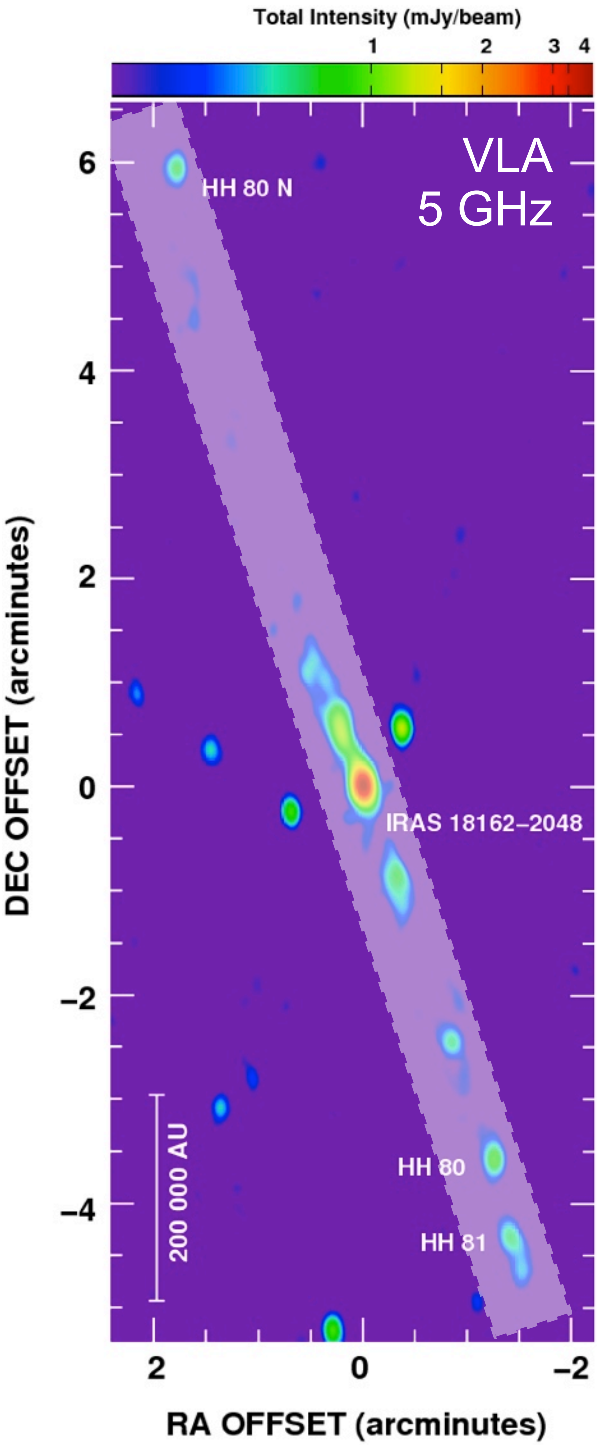
Distance: 1.7 kpc

IRAS 18162–2048 ; 17,000 Lsun (B0; 10 Msun)

HH 80, HH 81, HH 80 N (Martí et al. 1993)

Largest (~5.3 pc) and most collimated (<1º) YSO radio jet known

HH 80-81



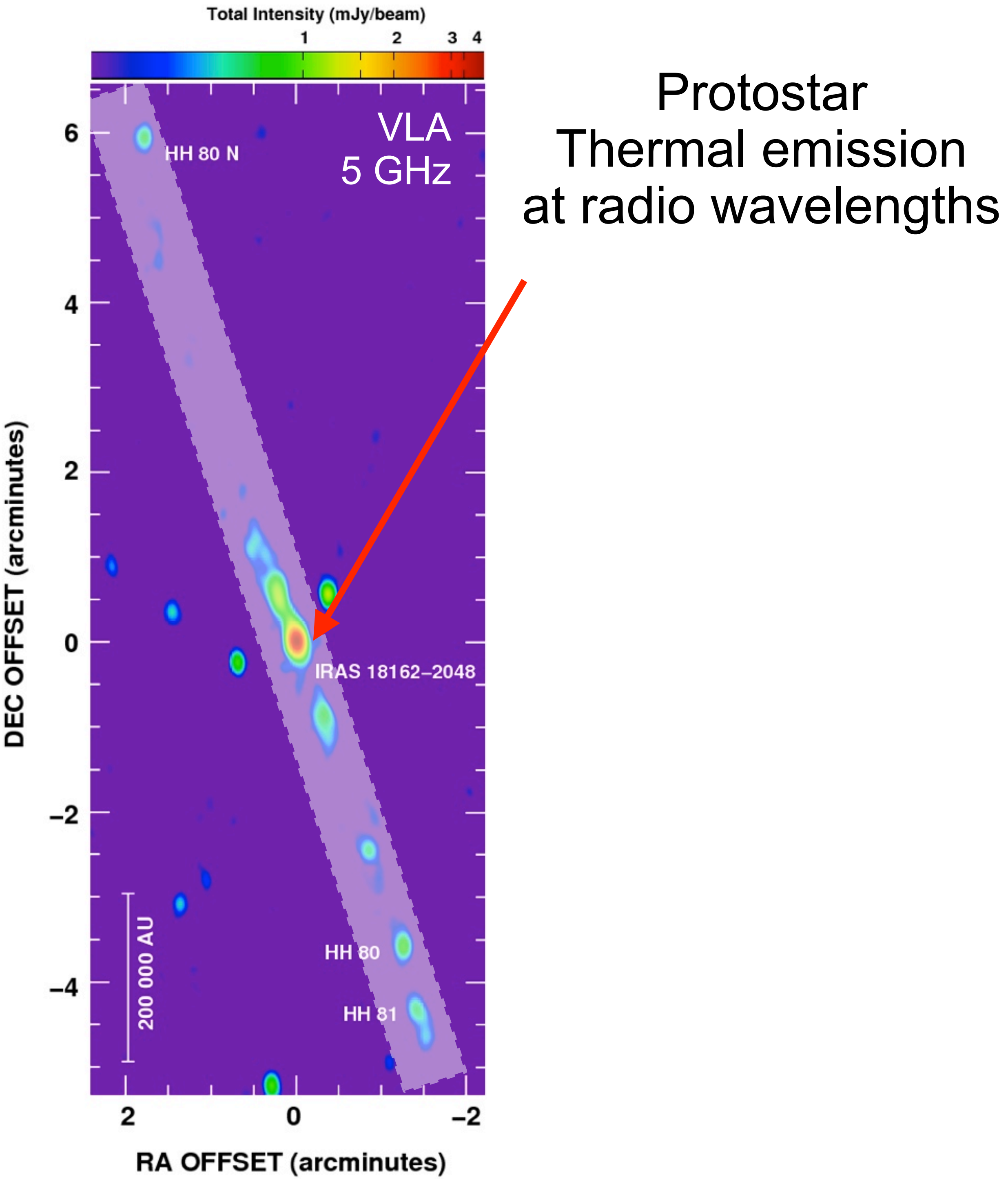
Distance: 1.7 kpc

IRAS 18162–2048 ; 17,000 Lsun (B0; 10 Msun)

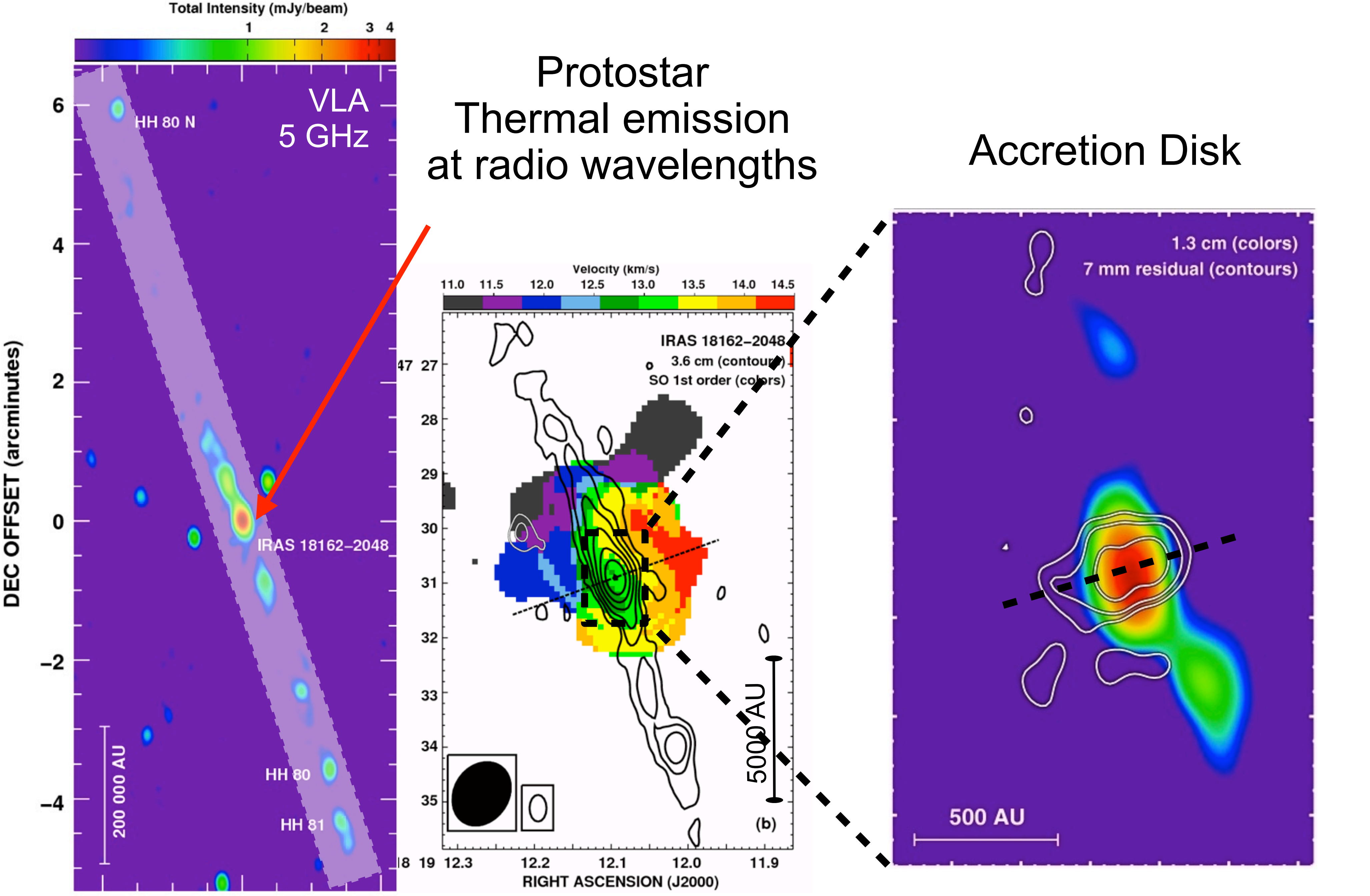
HH 80, HH 81, HH 80 N (Martí et al. 1993)

Largest (~5.3 pc) and most collimated (<1º) YSO radio jet known

HH 80-81

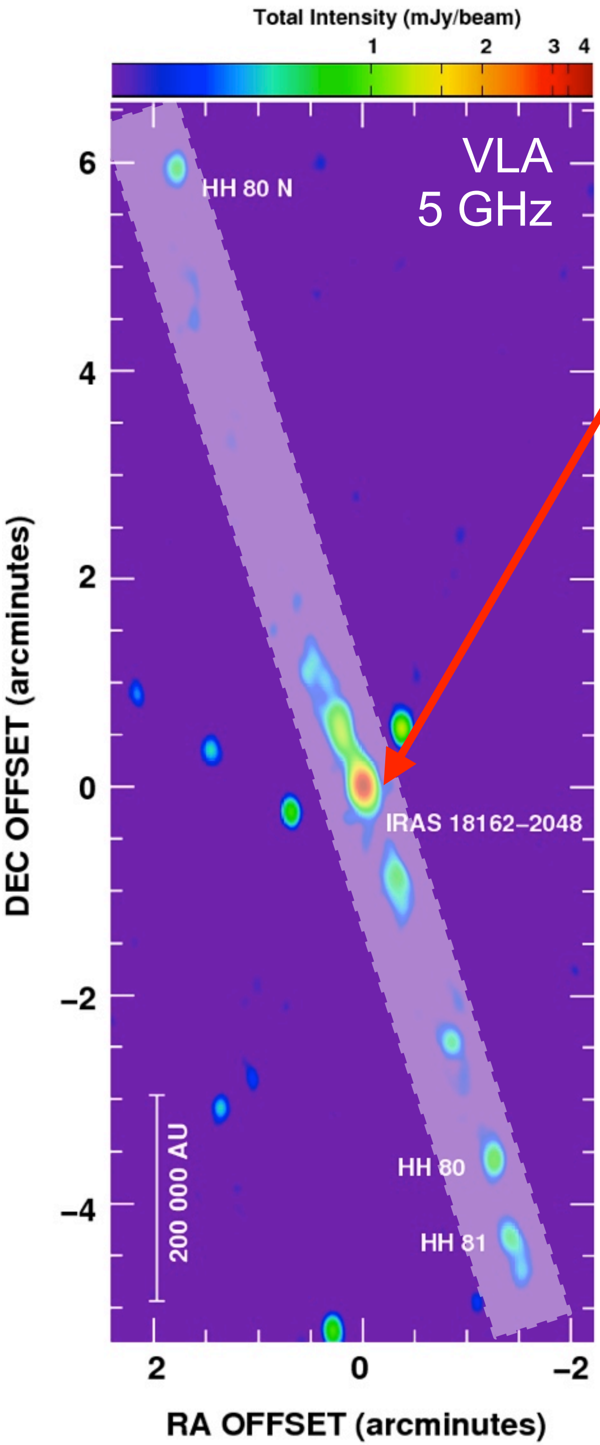

Total Intensity (mJy/beam)
1
2
3
4
VLA
5 GHz
HH 80 N
IRAS 18162–2048
HH 80
HH 81
200 000 AU
6
4
2
0
−2
−4
DEC OFFSET (arcminutes)
2
0
−2
RA OFFSET (arcminutes)
Protostar
Thermal emission
at radio wavelengths

HH 80-81

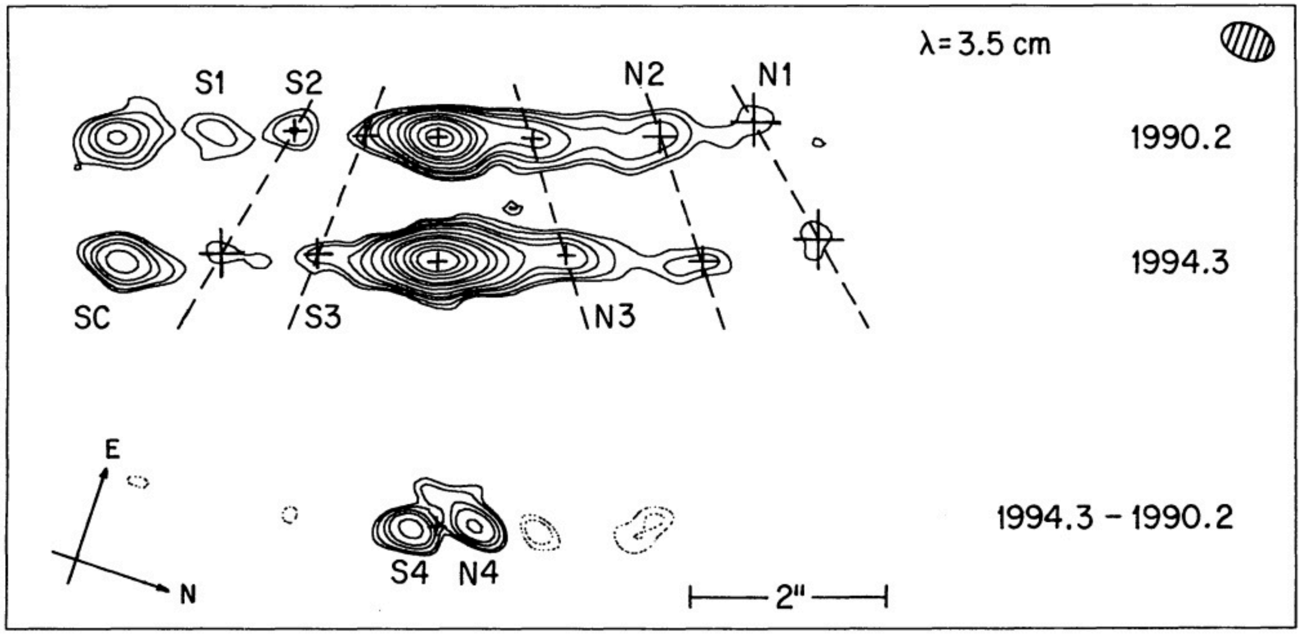


Carrasco-González et al. (2012)

HH 80-81

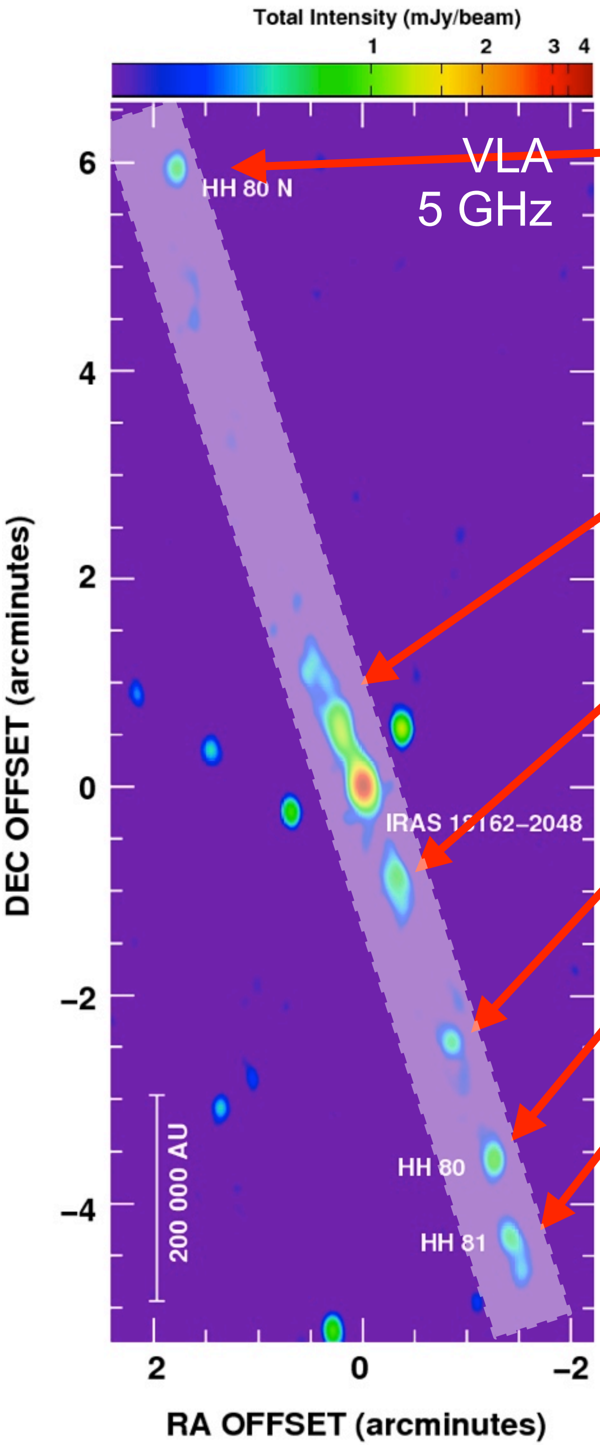


Protostar
Thermal emission
at radio wavelengths



Radio knots near the protostar are thermal (radiative internal shocks), and move away at ~700-1000 km/s (Martí et al 1995)

HH 80-81

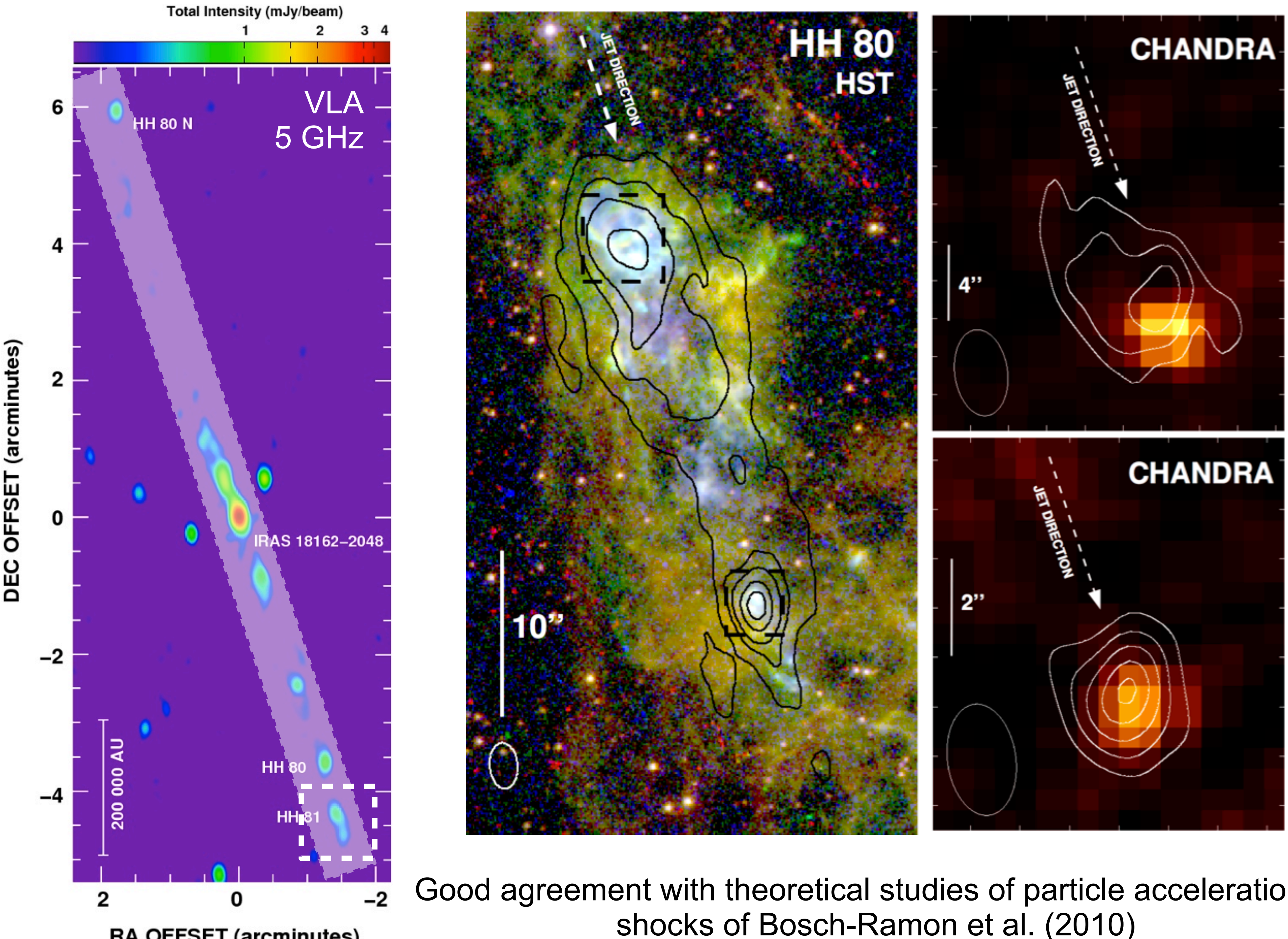


Several non-thermal radio knots along the jet (negative spectral indices at cm)

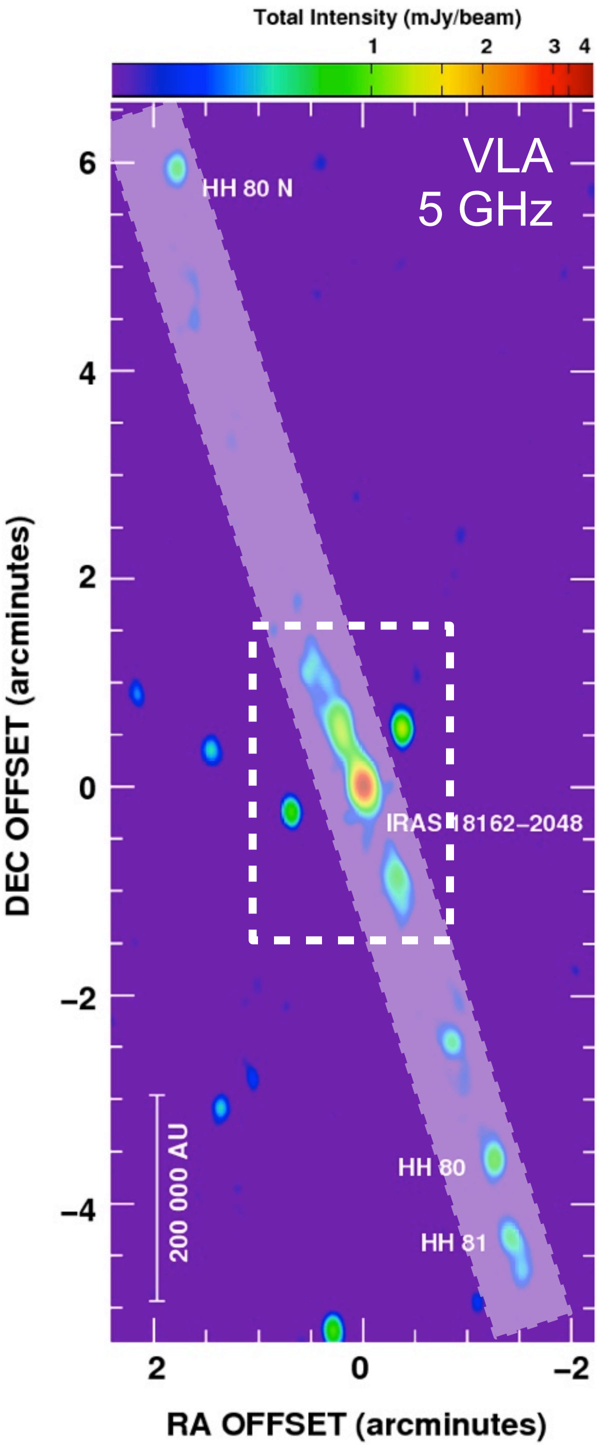
Is this synchrotron emission?

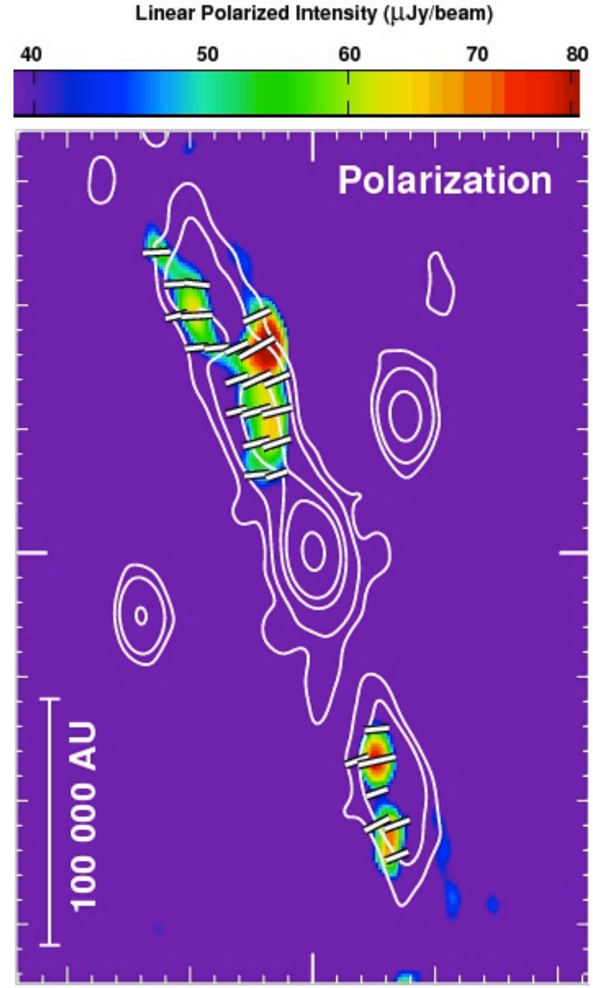
We need
relativistic particles+magnetic field

HH 80-81



Good agreement with theoretical studies of particle acceleration in shocks of Bosch-Ramon et al. (2010)





After long VLA observation at 5 GHz, we detected linear polarization in the non-thermal radio knots at 0.5 pc from the protostar.

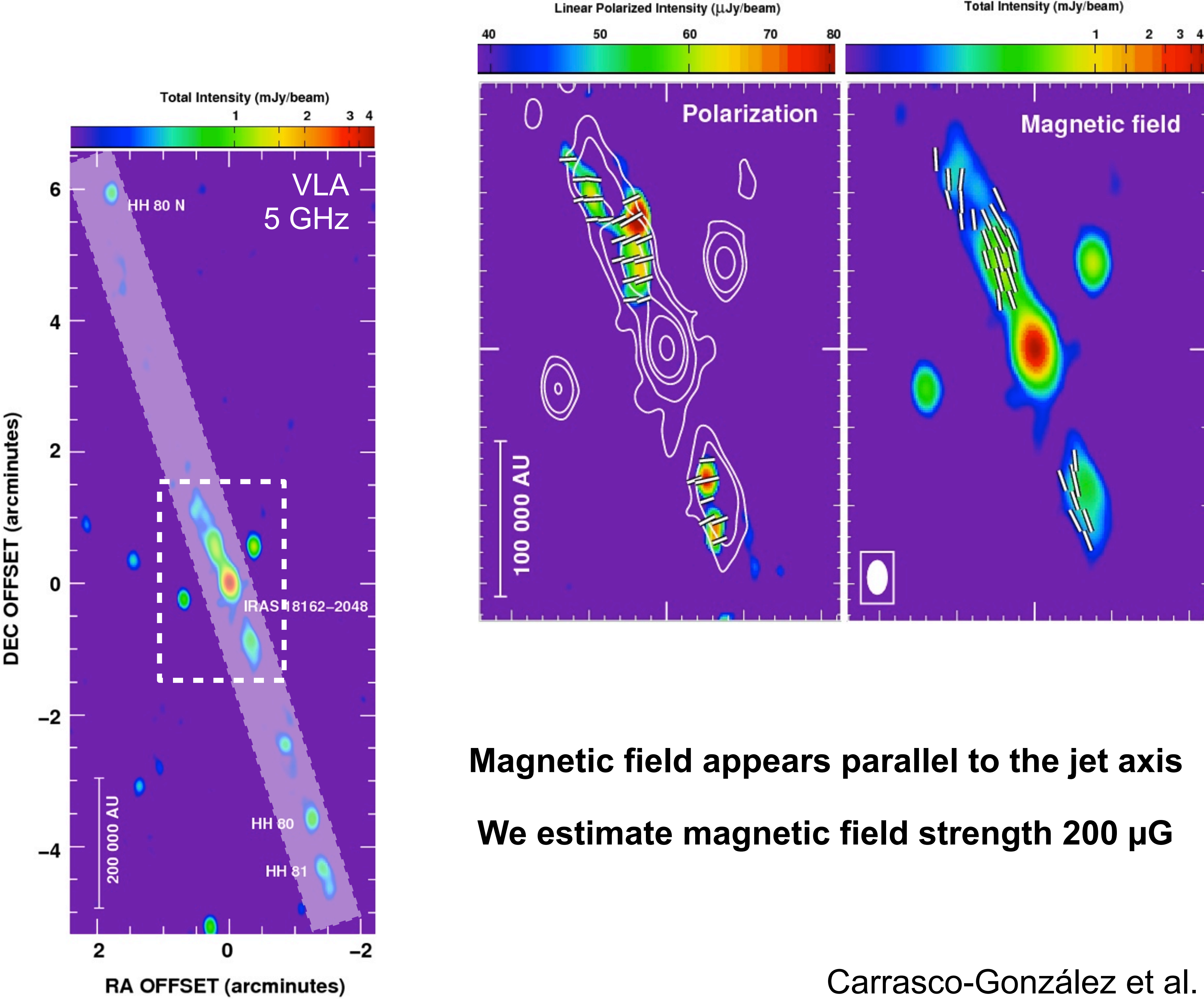
THIS CONFIRMS SYNCHROTRON NATURE OF THE NON-THERMAL RADIO KNOTS

Two important implications:

1. It is possible to accelerate particles to relativistic velocities even in these "slow" jets

2. Finally, we can study the magnetic field in the jet!!!

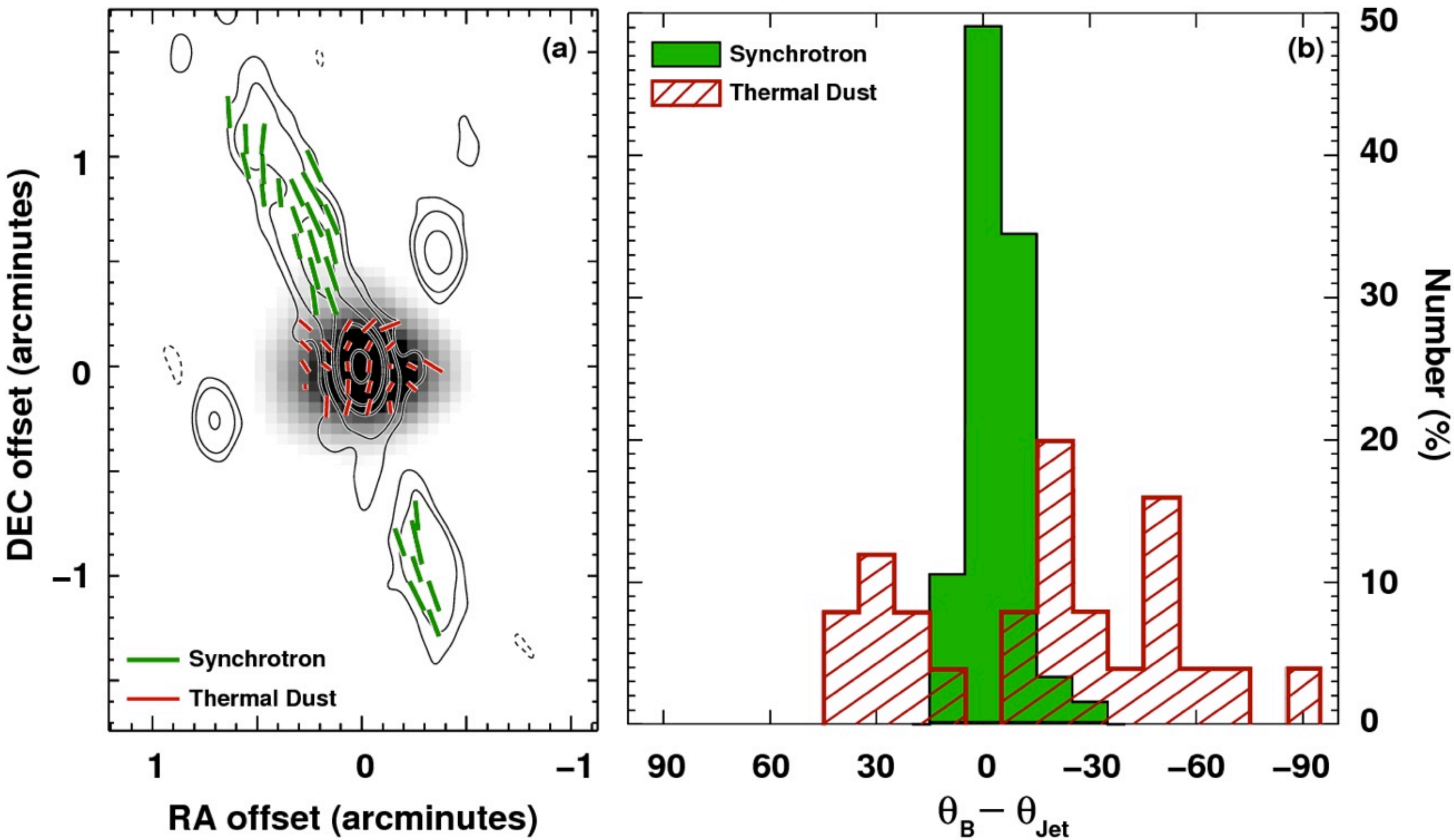
Carrasco-González et al. (2010)



Magnetic field appears parallel to the jet axis

We estimate magnetic field strength 200 μG

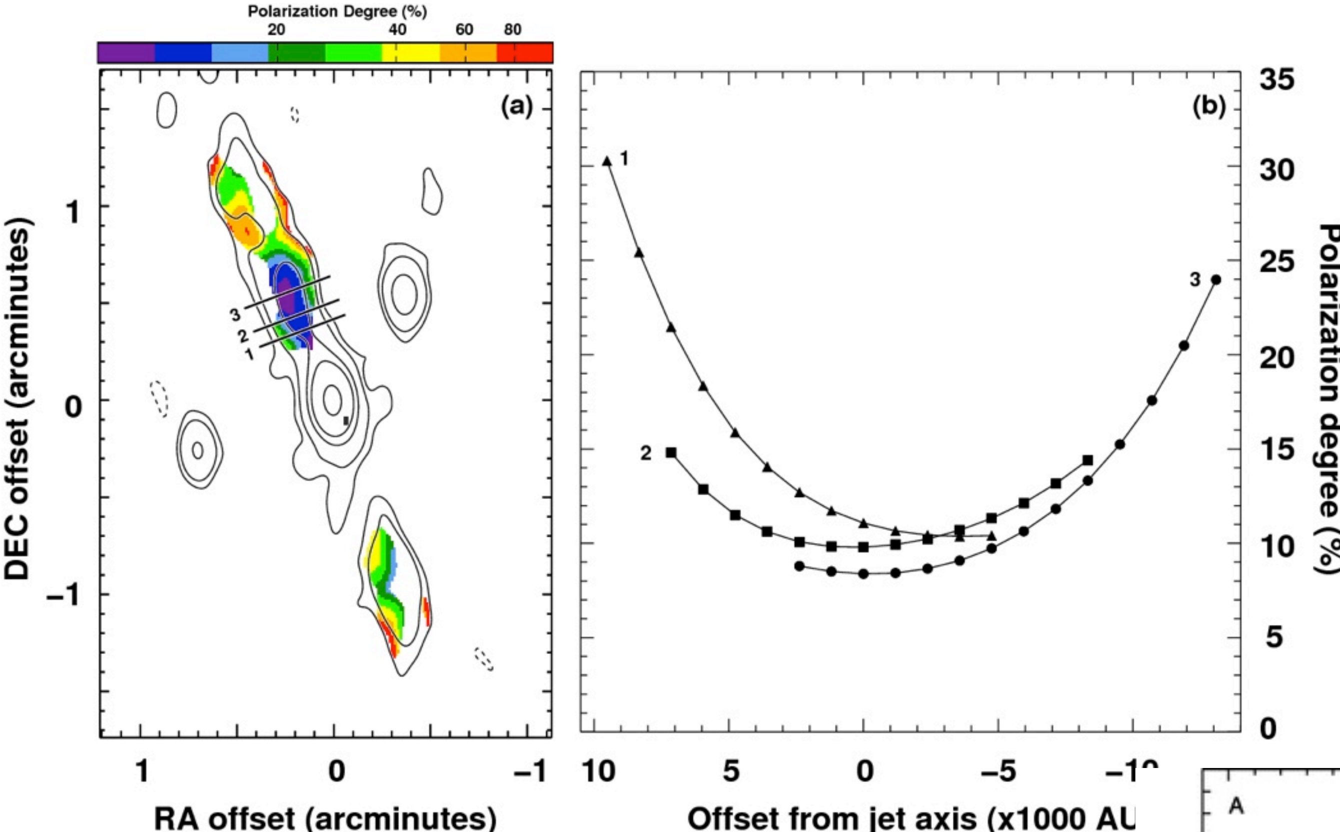
Carrasco-González et al. (2010)



Polarized dust emission direction shows considerable scatter with respect to the jet direction (Curran et al. 2007) → envelope/disk

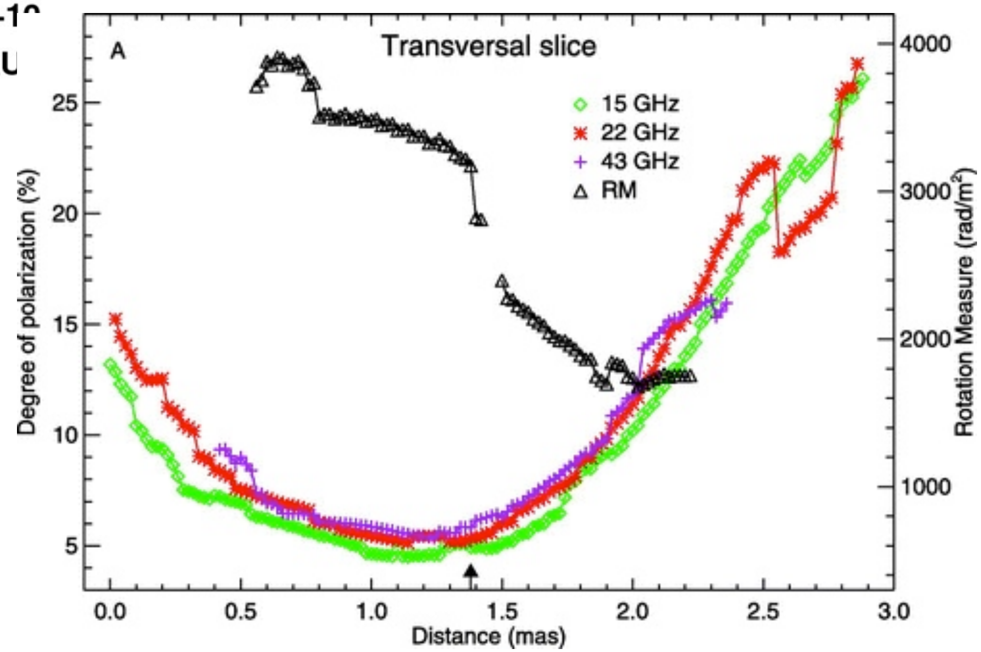
Magnetic field traced by synchrotron emission is intrinsic to the jet

We measure similar values for the magnetic field strength at 0.5 pc from the star



Polarization degree increases towards the edges of the jet

Similar to what is commonly found in extragalactic jets
and
what we would expect to observe in a helical magnetic field
(e.g. Lyutikov et al. 2005)



Gómez et al. (2008)

Summary

1. YSO jets (non-relativistics) are morphologically very similar to relativistic jets.

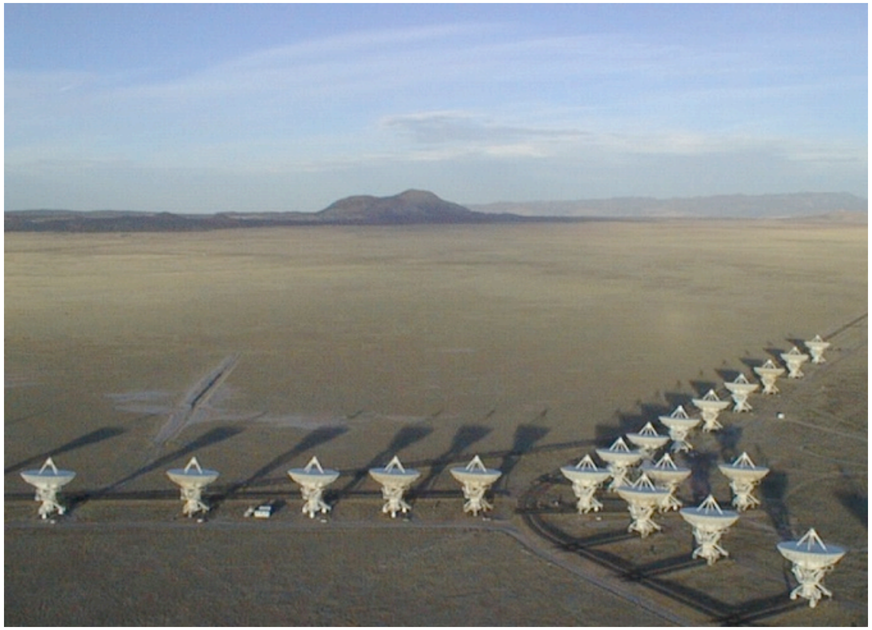
2. Magnetic fields are also though to play a fundamental role in the YSO jet phenomenon, similar to relativistic jets. But magnetic fields are very difficult to observe in YSOs.

3. Radio observations suggested the presence of non-thermal emission in some YSO jets.

4. High sensitive radio observations of HH 80-81 confirmed presence of linearly polarized synchrotron emission in HH 80-81.

5. YSO jets CAN accelerate particles up to relativistic velocities

6. With high sensitive radio observations, we can study the magnetic field in YSO jets in a similar way than in relativistic jets.



<u>Expanded Very Large Array</u>

Higher Sensitivity

Observations of a sample of protostellar jets

<u>ALMA</u>

High angular resolution and sensitivity at (sub)mm wavelengths

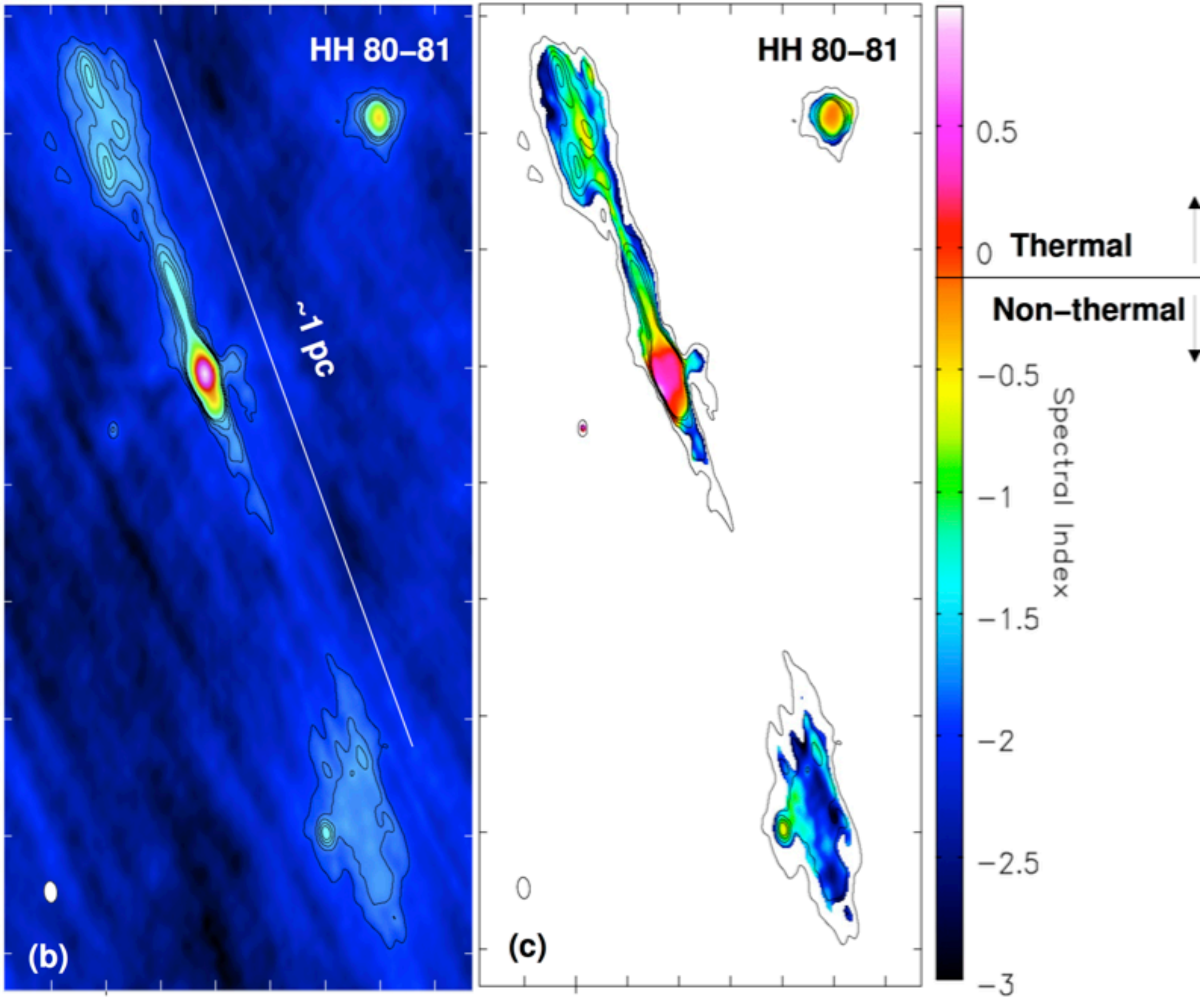
Disk's magnetic field

Using these techniques and combining with others (optical/IR) we can obtain full description of the magnetic field in YSO jets

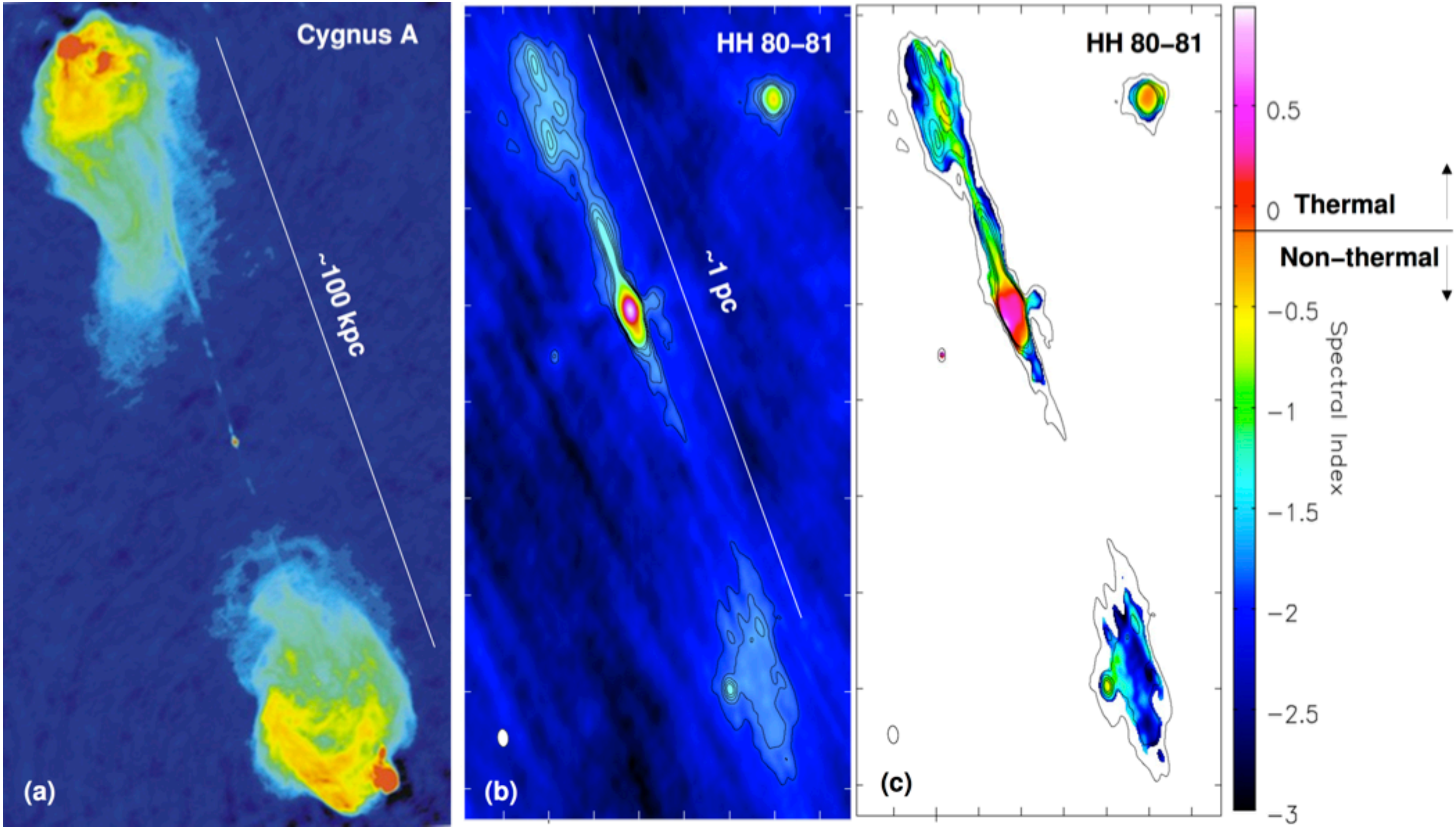
New,
higher sensitive
and
higher resolution
observations at
C and S bands
with the **EVLA**

Resolved non-thermal structures:

Highly collimated jet ending in two extended lobes



Carrasco-González et al. (in prep.)



After all, they are not so different...

Carrasco-González et al. (in prep.)