
Massive star formation
feedback with
e-MERLIN and the SKA
Katharine G. Johnston (University of Leeds)
Melvin Hoare, Wouter Vlemmings
and the MSF e-MERLIN Legacy Project team
e-MERLIN


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MSF = Massive Star Formation
e-MERLIN

# Ionized jets from low-mass stars

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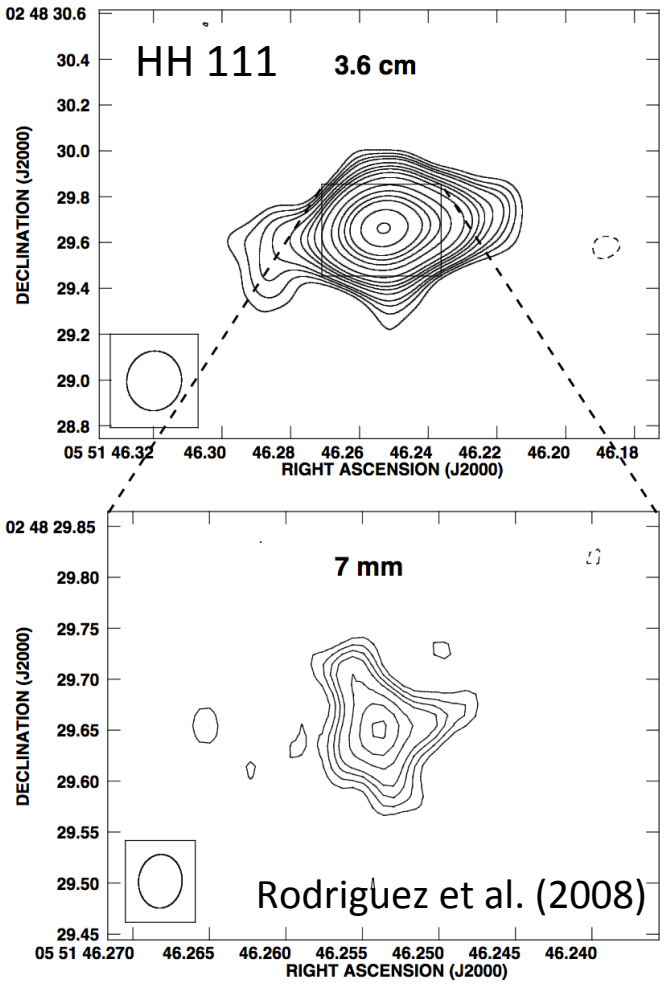


Rodriguez et al. (2008)

Flux density of sources **~1mJy**

Trace the **base of the outflow** phenomenon

Give upper limits to the **jet width / collimation**

**Proper motions** give the velocity of the jet: ~100 km/s

High-resolution observations may be able to distinguish between **disk** (Konigl & Pudritz 2000) **or X wind** (Shu et al. 1994) **models**

**Legacy Project**: "Morphology and Time Evolution of Thermal Jets Associated with Low-Mass Young Stars"

# Ionized jets from young massive stars

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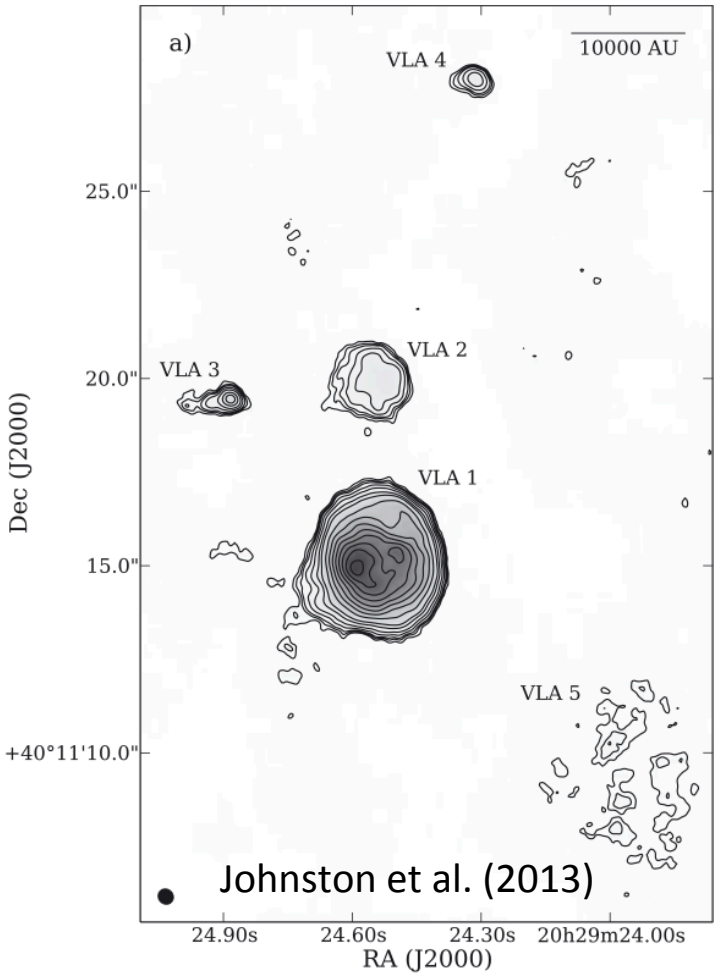
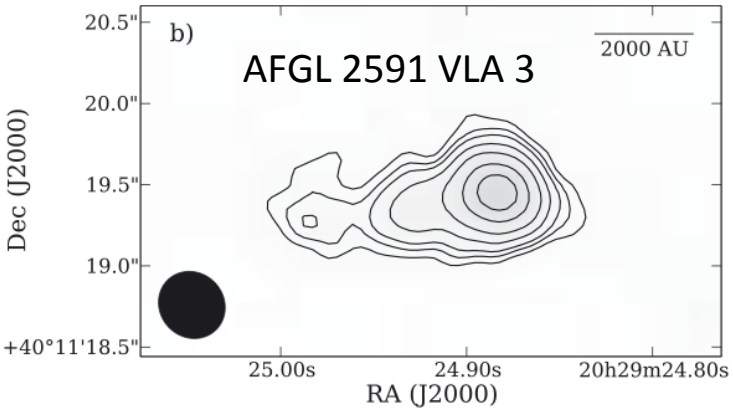
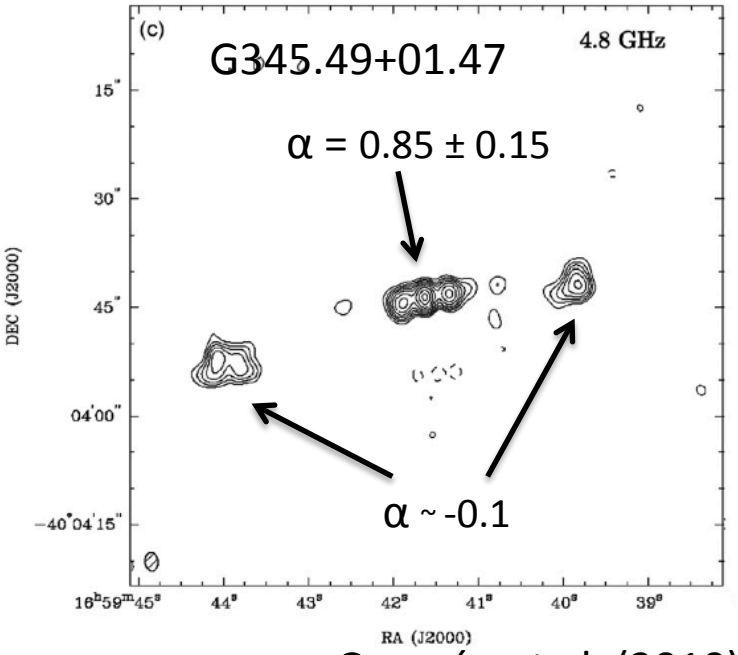
AFGL 2591




Johnston et al. (2013)




Guzmán et al. (2010)

See also ATCA survey by Purser et al. (2016)

# Ionized equatorial disc winds

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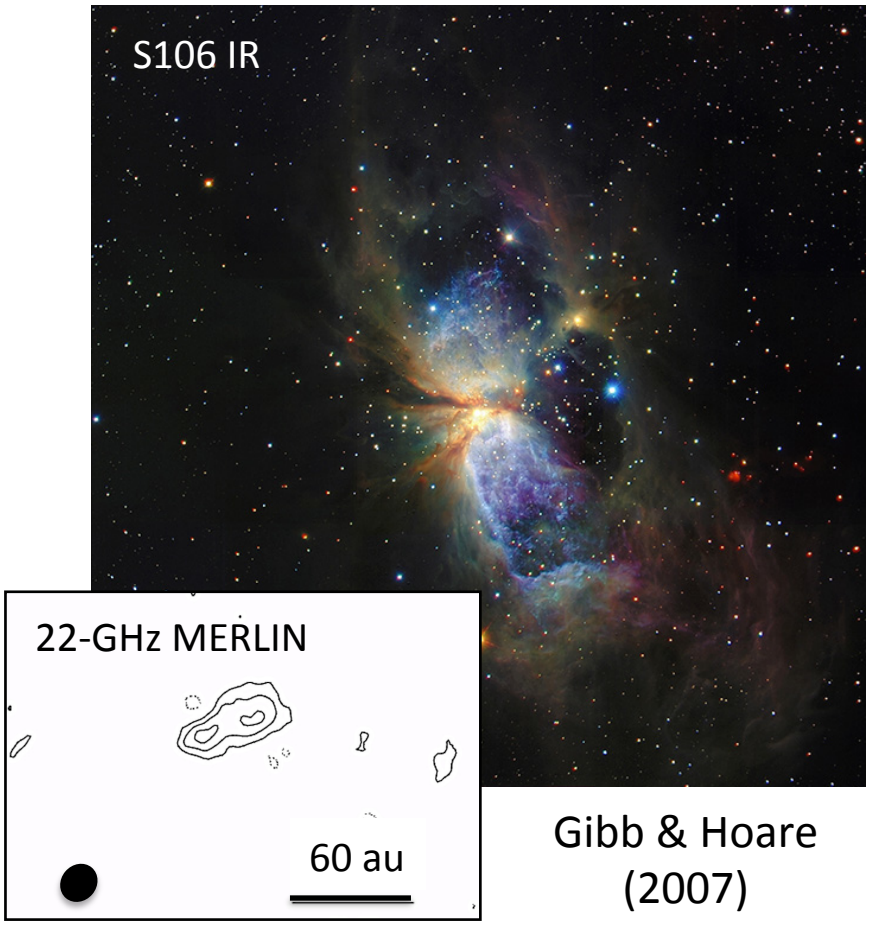
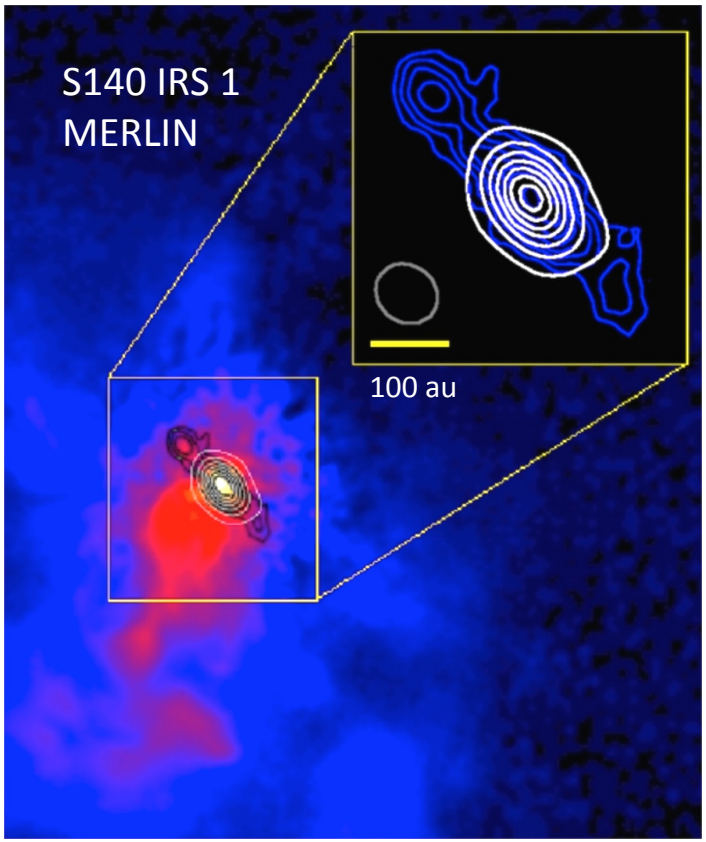
## Radiatively-driven equatorial disc wind sources




Gibb & Hoare (2007)




**Black/blue contours:** MERLIN 5 GHz emission from ionized disc wind
**White contours**: compact dust disc
**Colourscale:** near-IR reflection nebula

Maud et al. (2013)

Theoretical modelling: Drew et al. 1998, Douglas et al. in prep

# Magnetic fields in massive star formation

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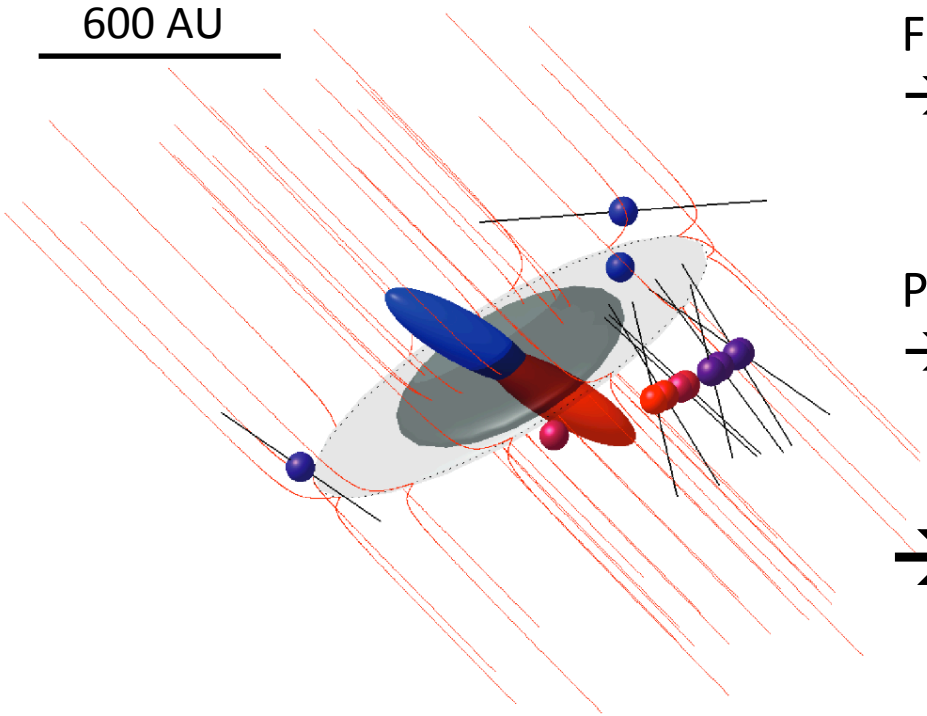
**Cepheus A HW2**




Vlemmings et al. (2010)

Full polarisation of $CH_3OH$ and OH masers
→ Direction of magnetic field in the plane of the sky

Polarisation fraction + maser modelling
→ Magnetic field angle compared to the line of sight

→ **Magnetic field 3-D morphology**

For bright sources:
total magnetic field strength
from Zeeman observations

# e-MERLIN MSF Legacy Project

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## *Feedback in Massive Star Formation Legacy Project*

*PIs: M. Hoare & W. Vlemmings*

1) **Test evolutionary models of massive star formation:**

   to determine, as a function of stellar mass, when MHD-driven jets turn on and when they give way to HII regions or radiatively driven equatorial disc winds

2) **To test the physics of the feedback mechanisms:**

   to map the 3D magnetic field structure in a number of sources through methanol and excited OH maser polarization to test current models of MHD driven jets

# Selected targets

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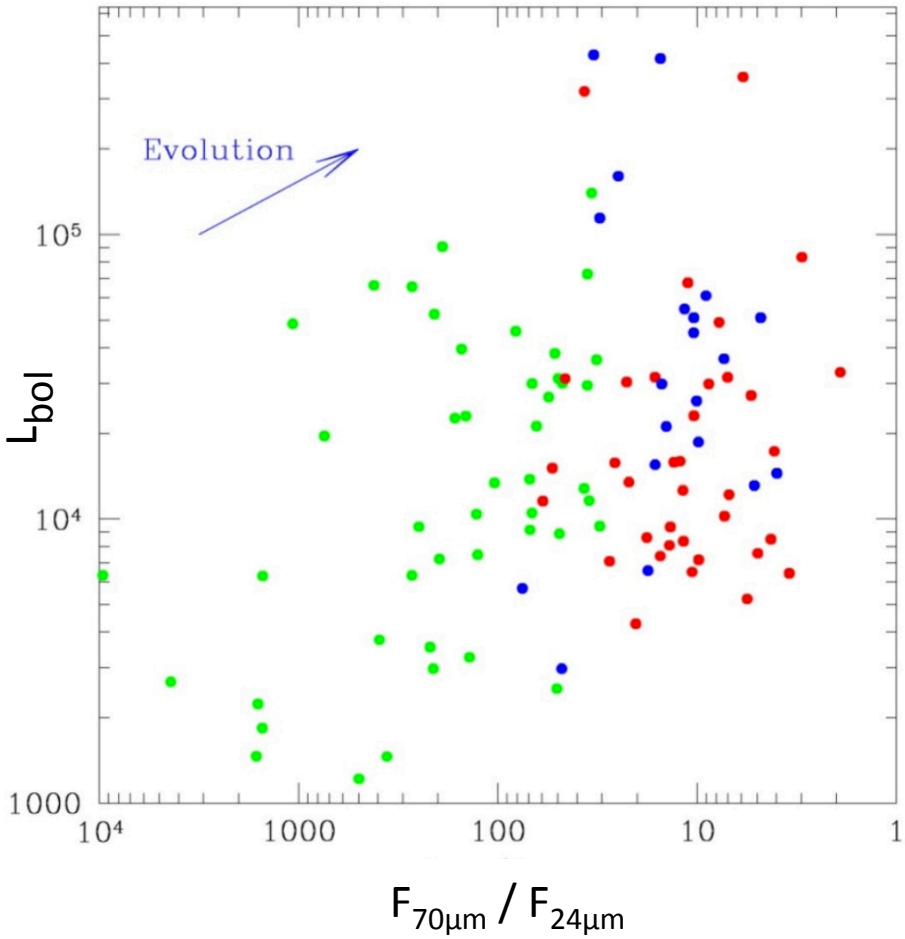
**75** sources at different evolutionary stages (IRDCs and MYSOs):

**L > 2000 $L_\odot$** (B3V and earlier)
**d < 7 kpc**

- IRDCs: Infrared Dark Cloud sources
- MYSOs: Massive Young Stellar Objects
- Ultracompact HII regions



# Observational setup

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- **450 hr** Legacy Programme
- **Continuum** at 5-7 GHz (1.8 GHz BW)
- **Spatial resolution:** ~0.05”

  (350 au at 7 kpc)
- **Expected noise**: ~2 μJy/beam

  (with Lovell)


- **Class II methanol maser** at 6.668 GHz
- **OH maser** at 6.035 GHz
- **Bandwidth and channel width**: 83 and <0.1 km $s^{-1}$
- **Maser sensitivity**: 22 and 11 mJy/beam (methanol / OH)
- **Full polarization**

# e-MERLIN MSF Survey Status

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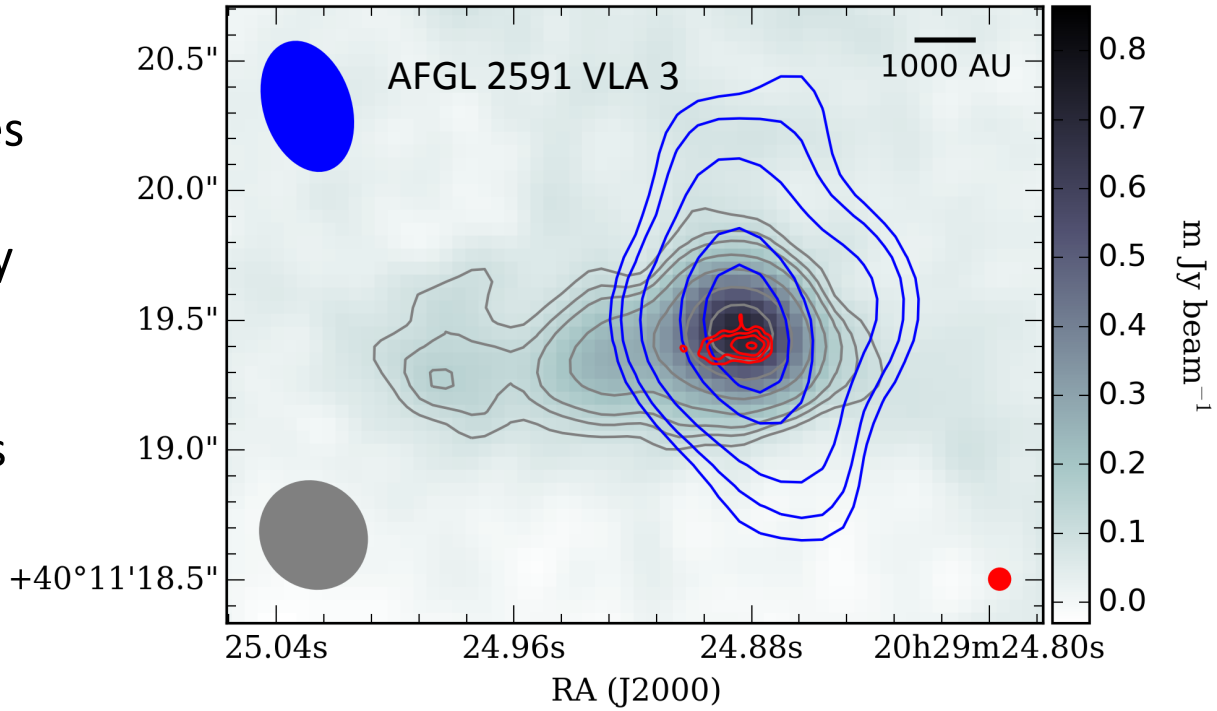
**Status:** Several test sources recently observed with 512 MHz bandwidth

**AFGL 2591 VLA 3**:
Jet is collimated on scales of a few hundred au
→ indicates magnetically controlled driving and collimating mechanism similar to low-mass YSOs




Grey: VLA 8.4 GHz continuum, **Blue:** PdBI 203.4 GHz continuum (Wang+12), **Red:** e-MERLIN C band

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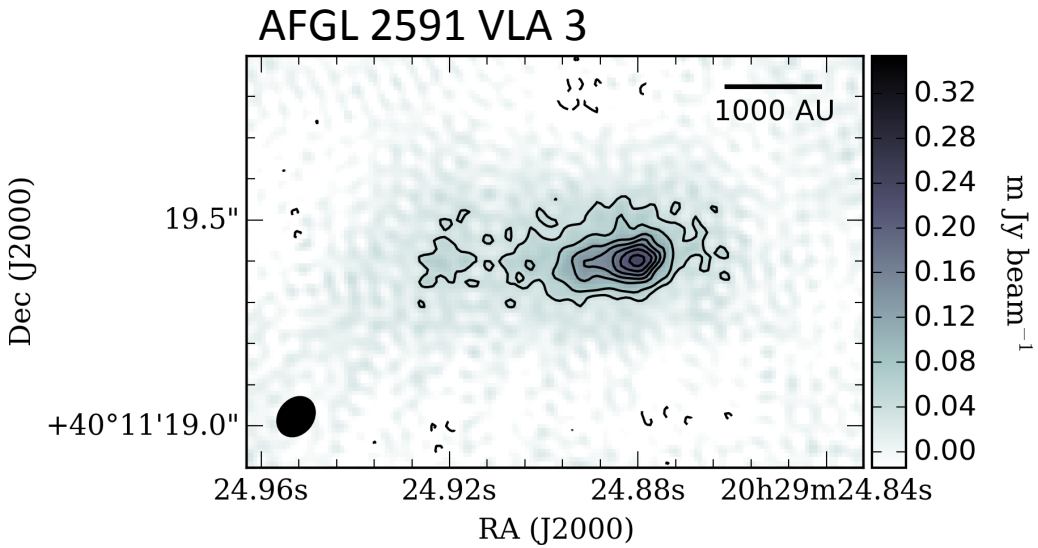


Noise: 13.7microJy/beam (ROBUST=2.5)

Grey: VLA 8.4 GHz continuum, **Blue:** PdBI 203.4 GHz continuum (Wang+12), **Red:** e-MERLIN C band

# e-MERLIN and SKA1-mid

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- Use SKA/e-MERLIN band 5 for free-free continuum due to positive spectral index of many ionized jets/winds
- SKA1: 0.04” resolution at 14 GHz

  (matched to e-MERLIN at 6 GHz)
- SKA1: at 9 GHz 20min integration:

  RMS = 2.4 μJy/beam
- Can survey all massive young stars in Galaxy and their jets efficiently

# e-MERLIN and SKA1/2

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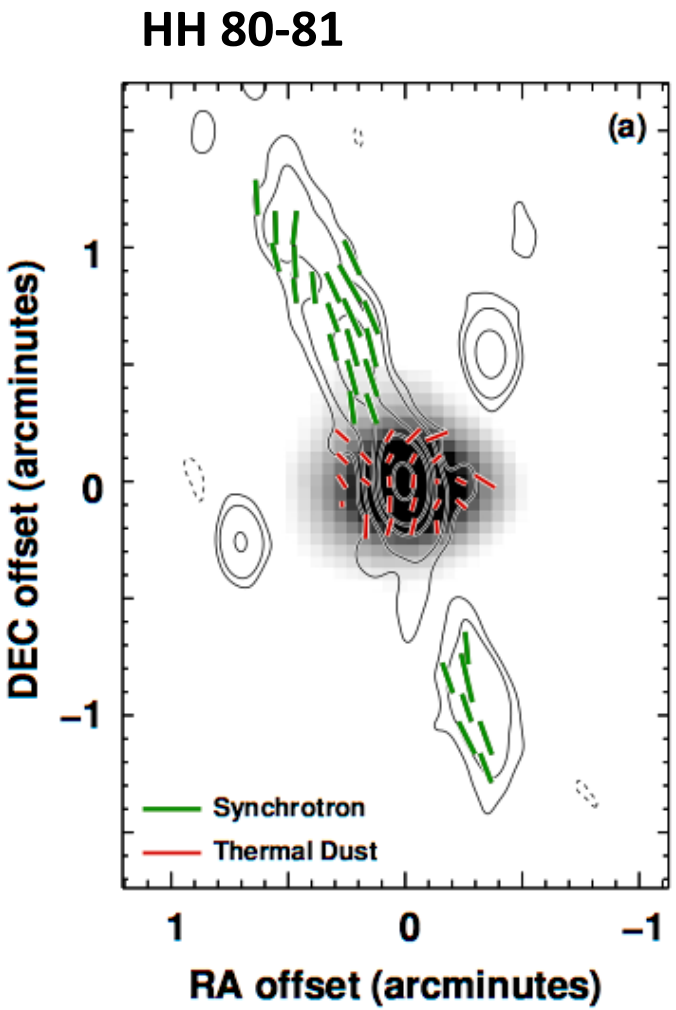
- Spectral index maps
- Polarization
- Zeeman-splitting of masers
- Recombination Lines
- Proper motion studies




Carrasco-Gonzàlez et al. 2010

# Take away points

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- Massive star formation feedback legacy programme with e-MERLIN at C band
- Determining evolutionary sequence and magnetic fields in massive star formation
- Pilot sources observed with 512 MHz BW
- Future is bright (e.g. polarisation, RRLs and proper motion studies) with upgraded e-MERLIN and SKA