School of Physics & Astronomy
FACULTY OF MATHEMATICS & PHYSICAL SCIENCES

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Galactic Radio Science

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Overview

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- Planet formation
  - Thermal dust emission
- Star formation
  - Ionized thermal and non-thermal gas emission
  - Non-thermal line emission from masers
  - Astrometry and polarization
- Stellar evolution
  - All of the above
- e-Merlin as a valuable test bed for SKA1 Mid science
  - Similar baselines and frequency coverage

Planet Formation

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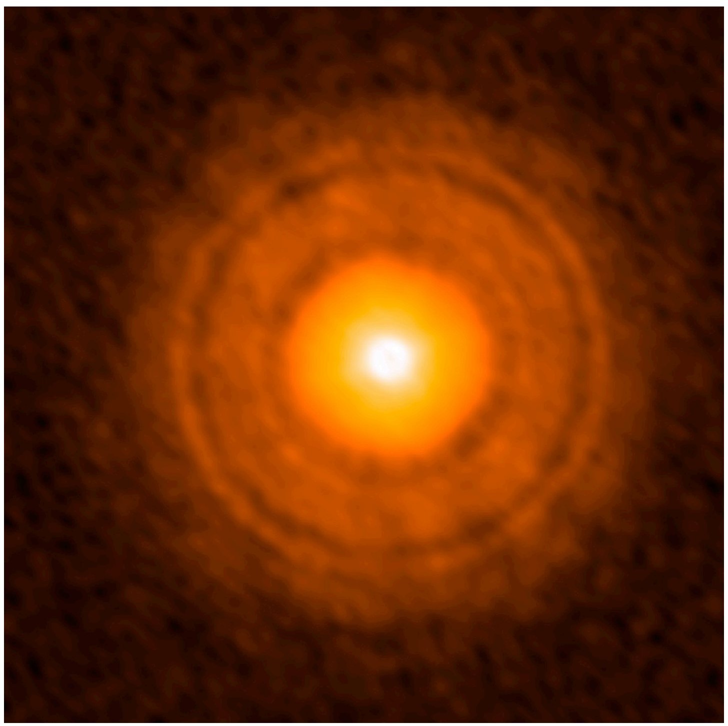
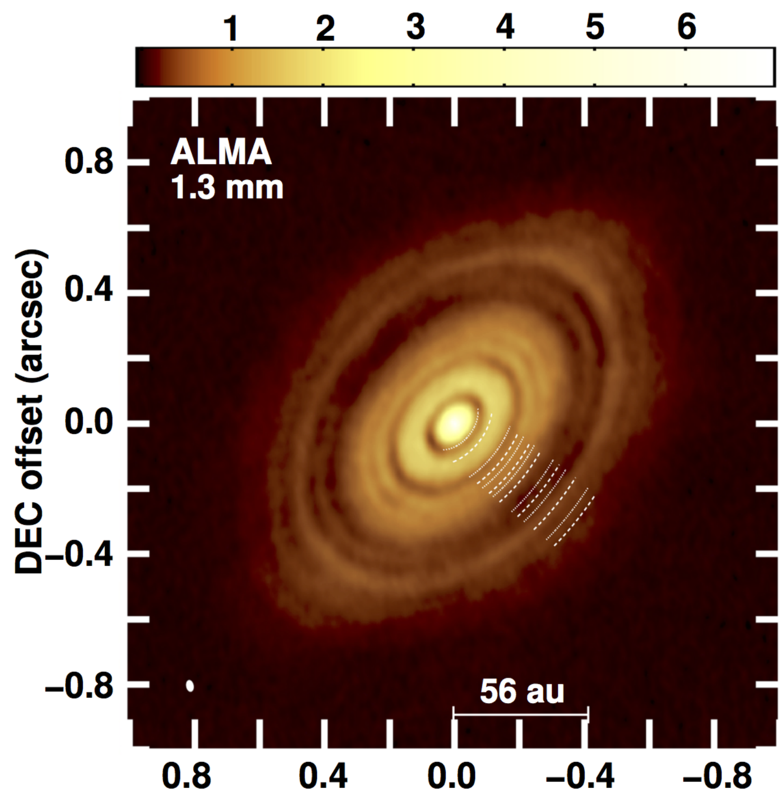
- ALMA observations with resolution ~ 40 mas (4 au @ 100 pc) are revealing significant structures in proto-planetary disc dust emission





Grain Growth

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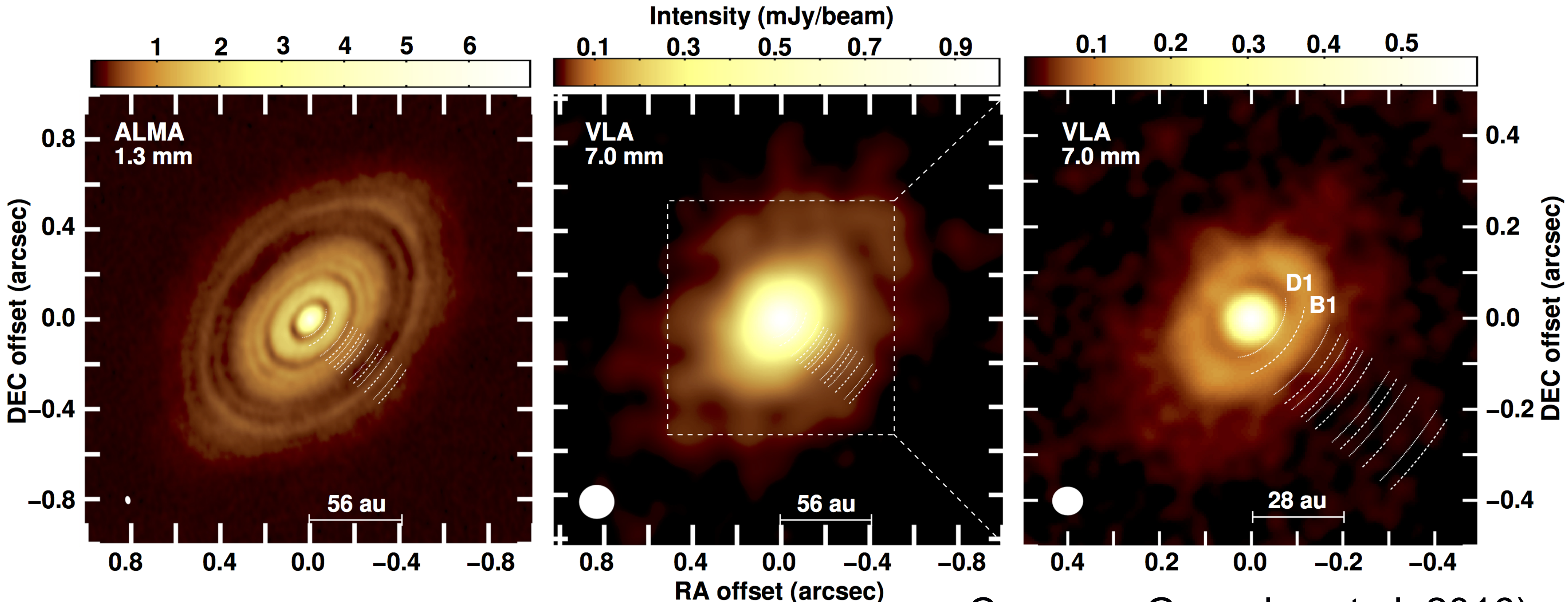
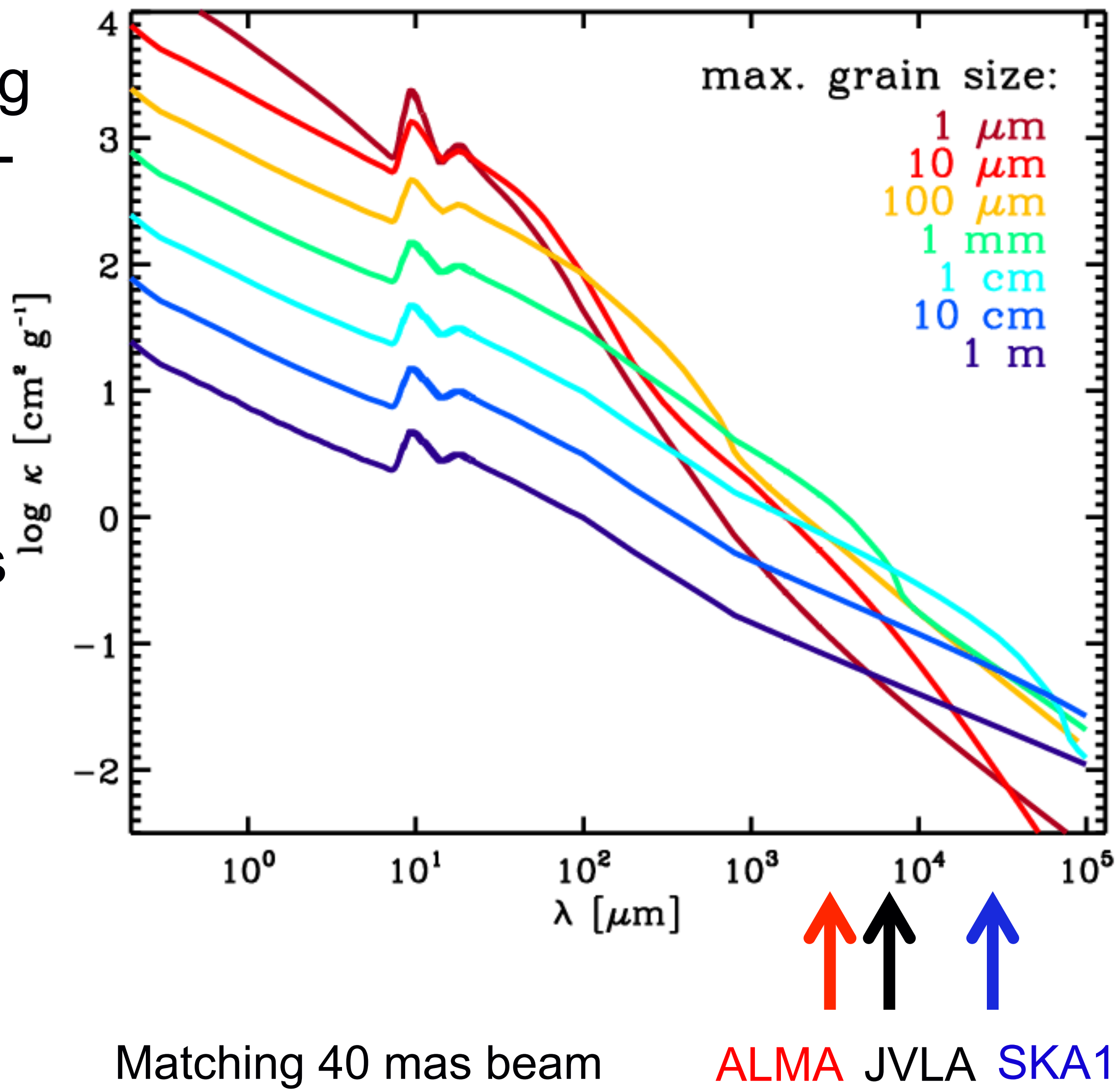
- VLA can achieve resolution ~ 40 mas at 7 mm
- e-Merlin at 5 cm
- SKA1 Mid at 2.5 cm



Carrasco-Gonzalez et al. 2016)

Need cm-wave data

- Difficulty in growing grains through cm-sized regime
- Need cm-wave observations to probe cm-sized grains, emission is weak



Matching 40 mas beam

State-of-the-art

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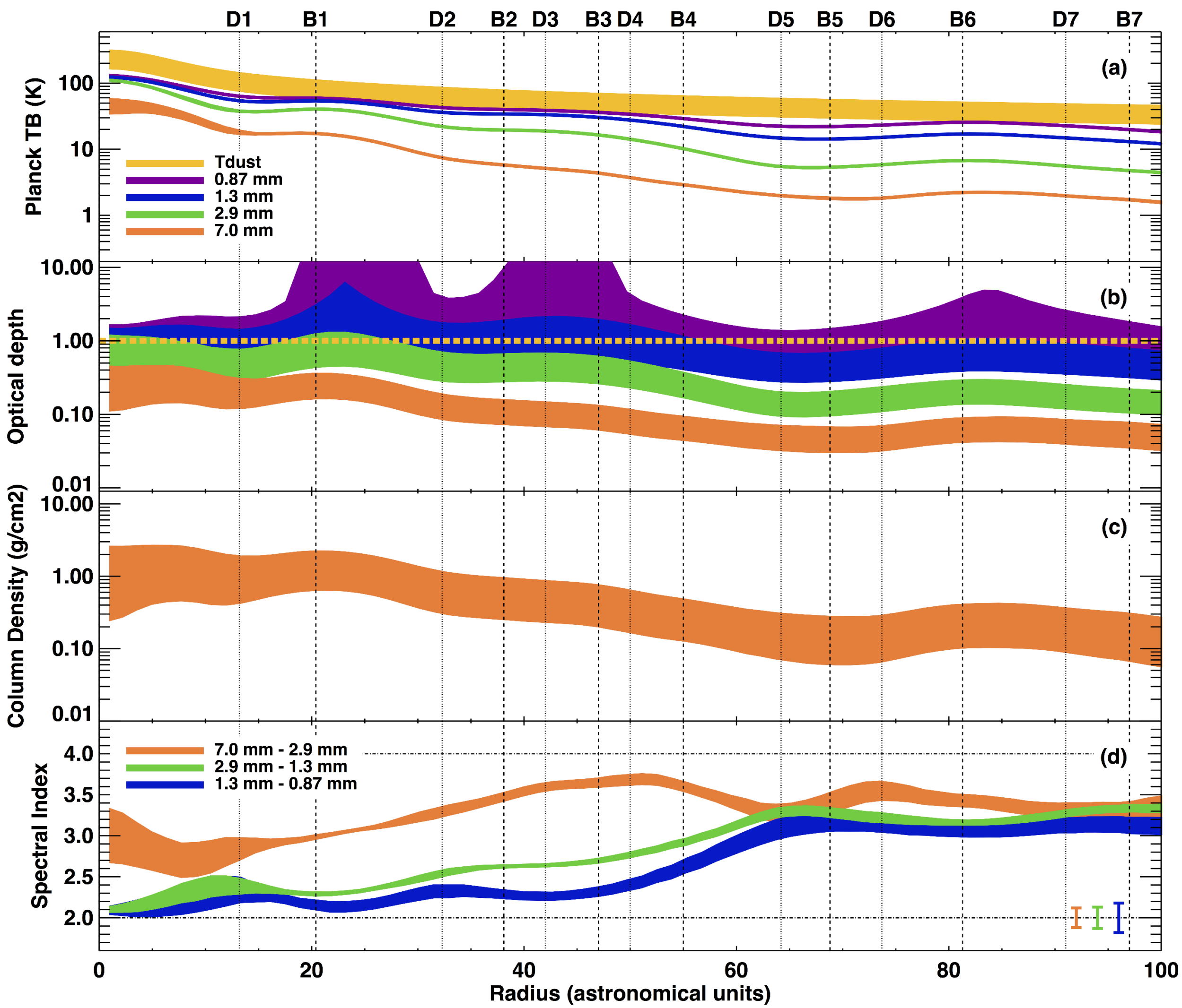

PPDs only optically thin at cm wavelengths

Shallower spectral index indicates grain growth in inner disc (Carrasco-Gonzalez et al. 2016)

Inside the snow line with SKA1

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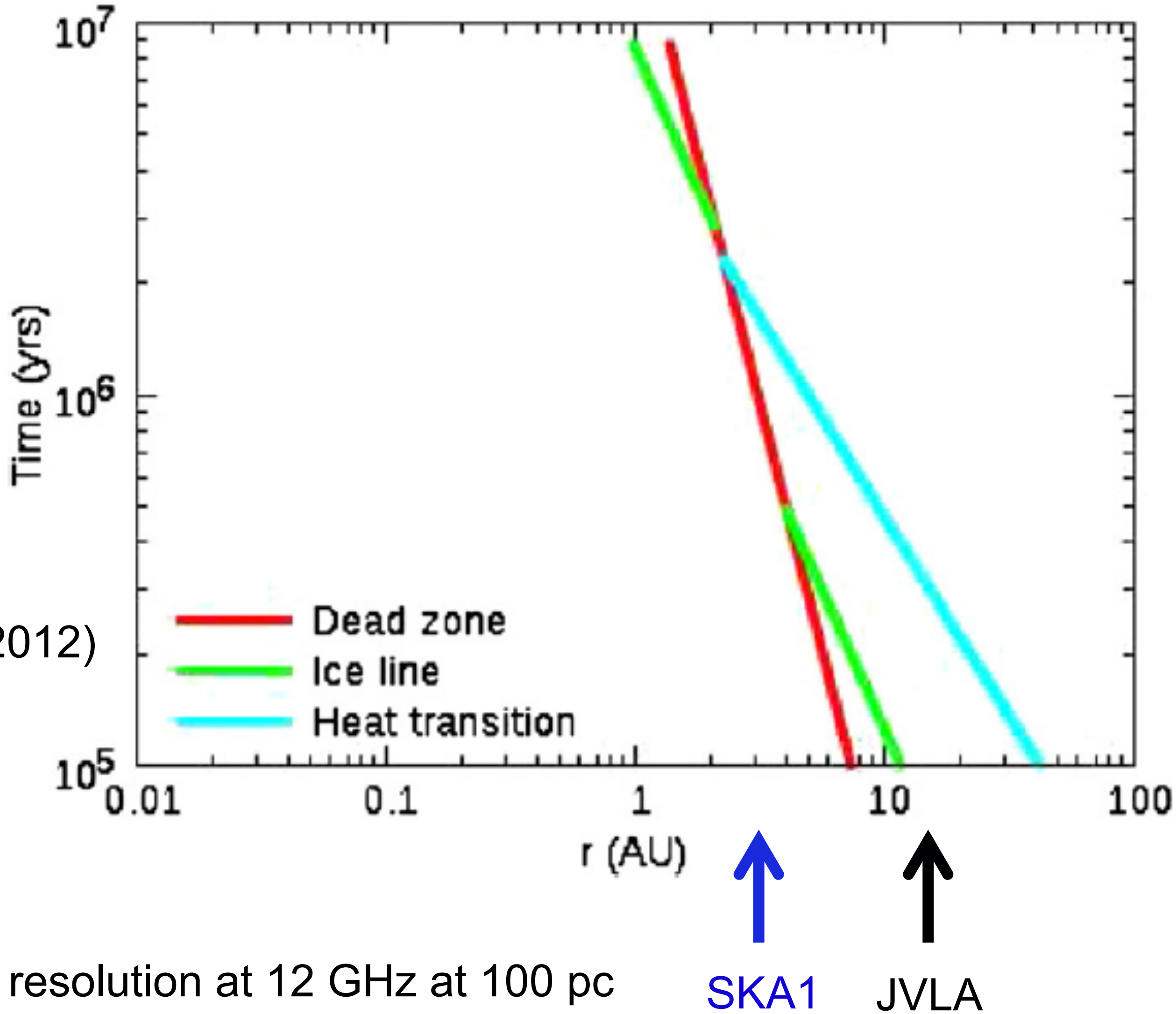
- Need ‘planet traps’ to help grains grow
- E.g. the water snow line



Hasegawa & Pudritz (2012)

Spatial resolution at 12 GHz at 100 pc

Ionized Jet Emission

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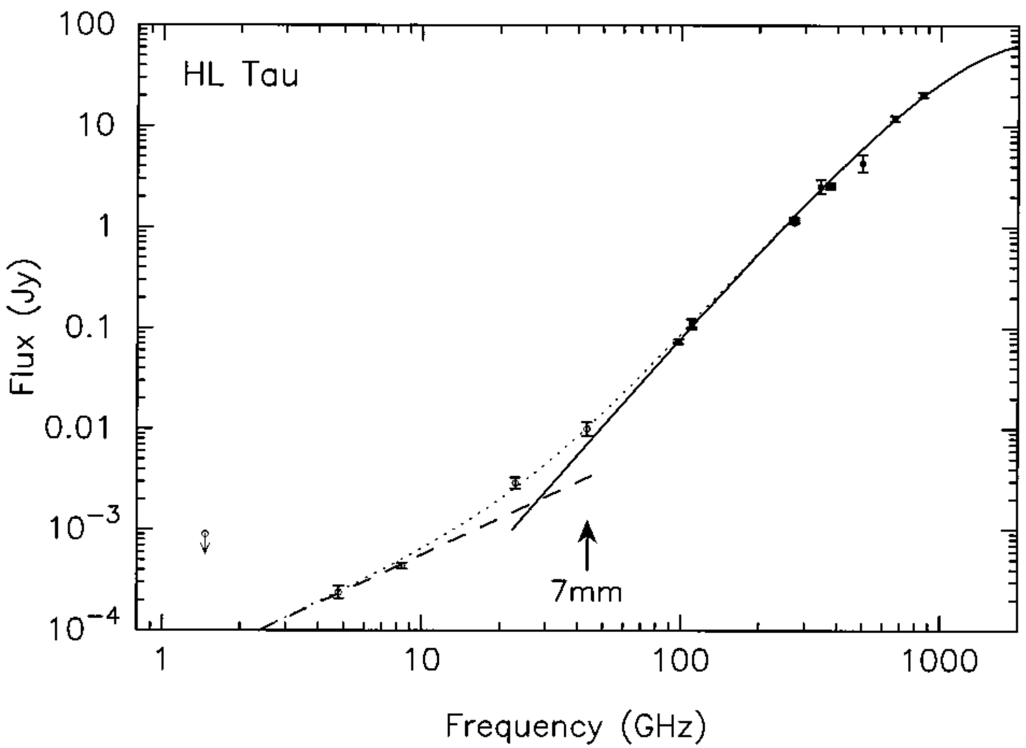
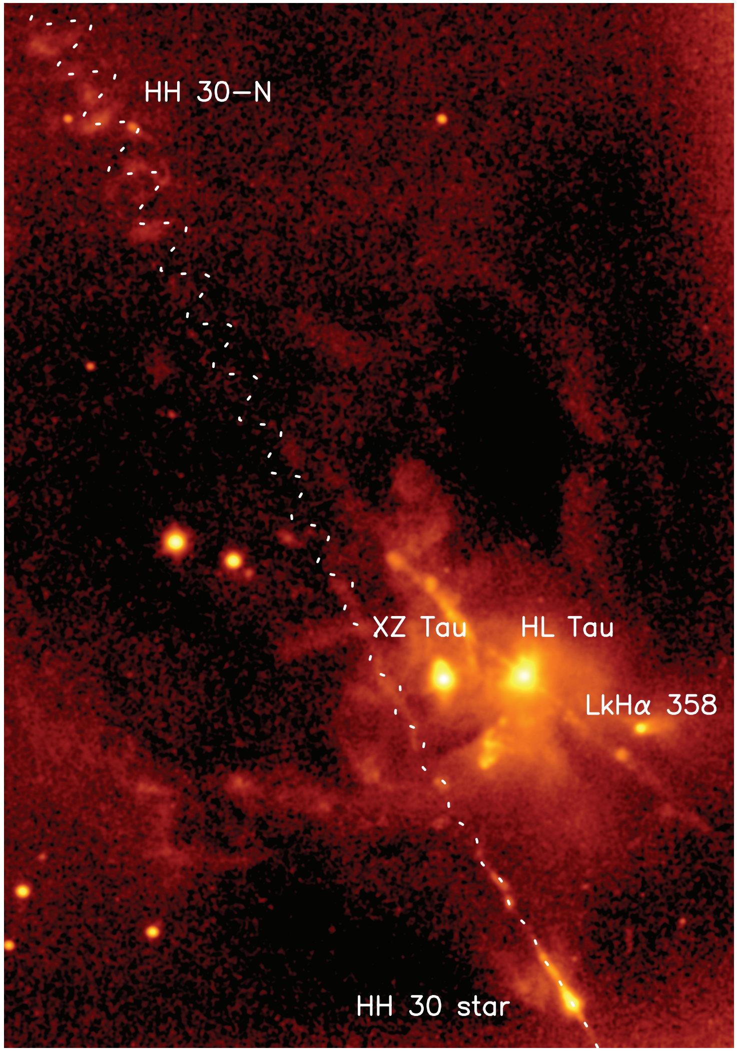
- Need to accurately subtract jet emission seen at longer cm wavelengths





Pre-biotic molecules

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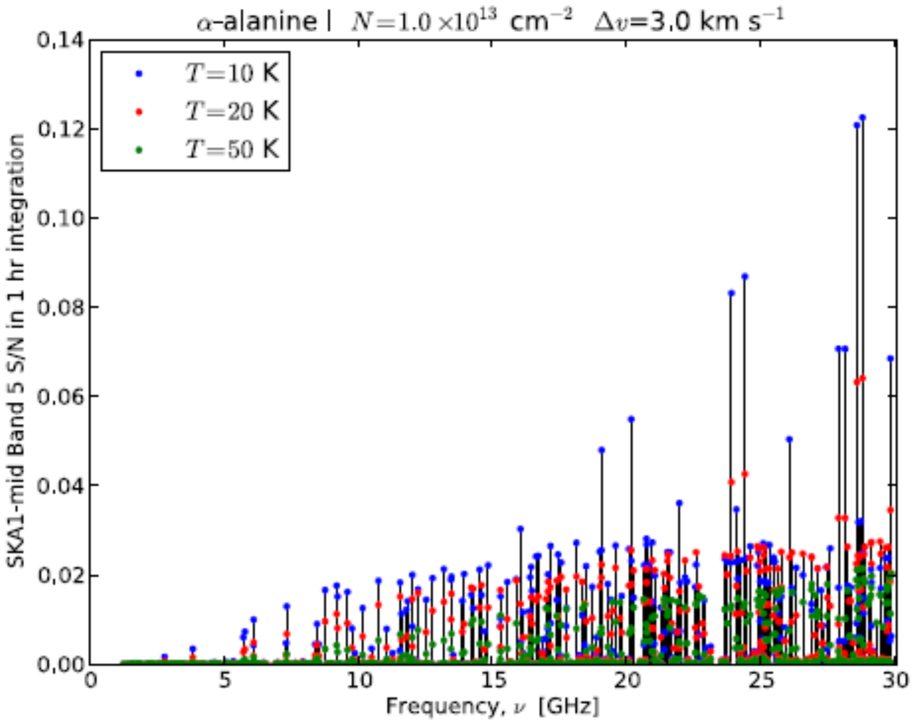
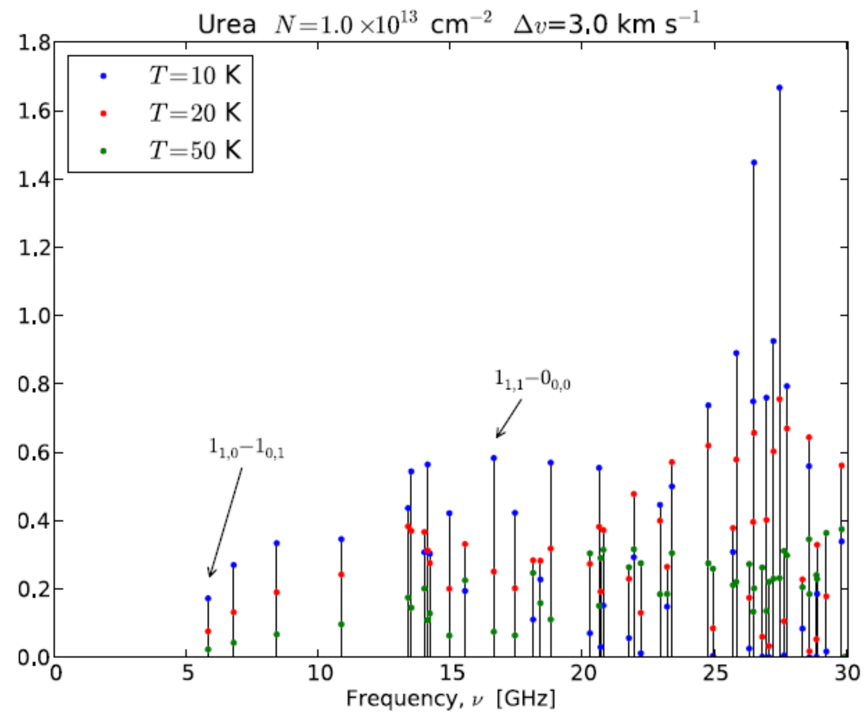
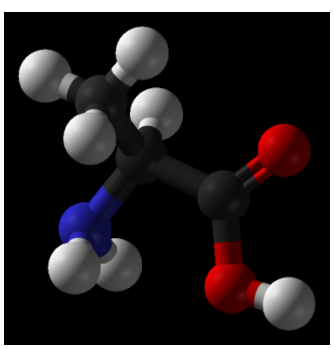
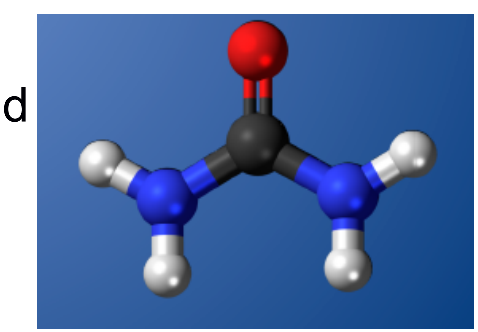






Alanine
– simple amino acid

Urea
- peptide bond



Courtesy of Per Bergman

Young Cluster Deep Field SKA KSP

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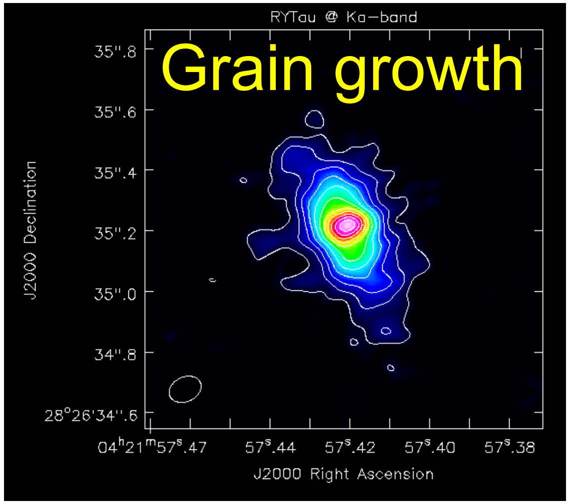
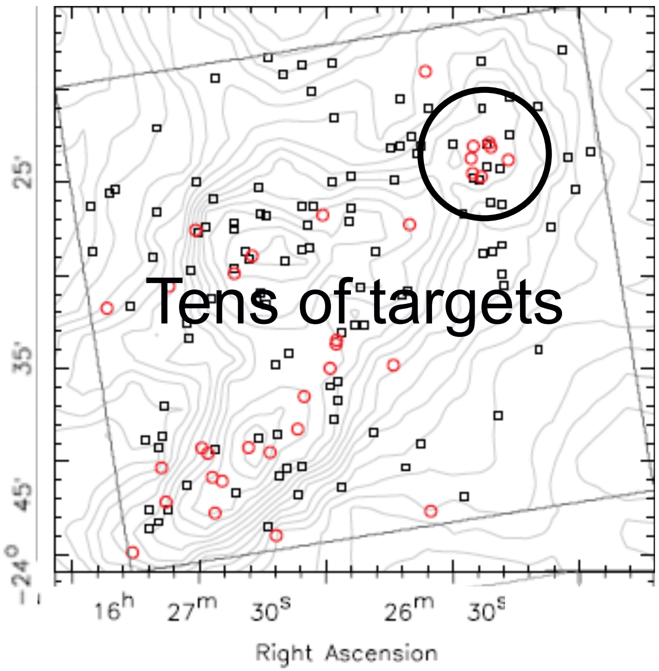
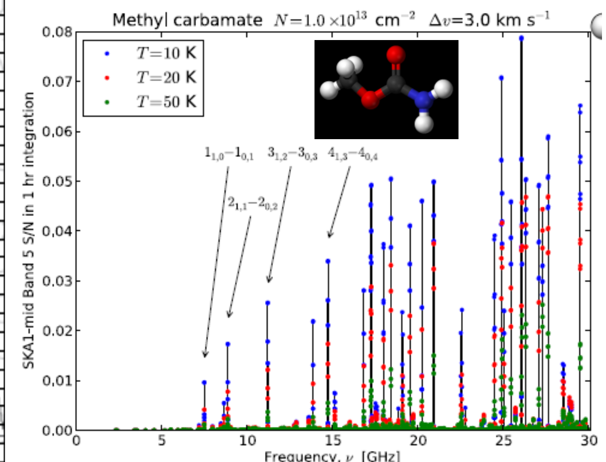
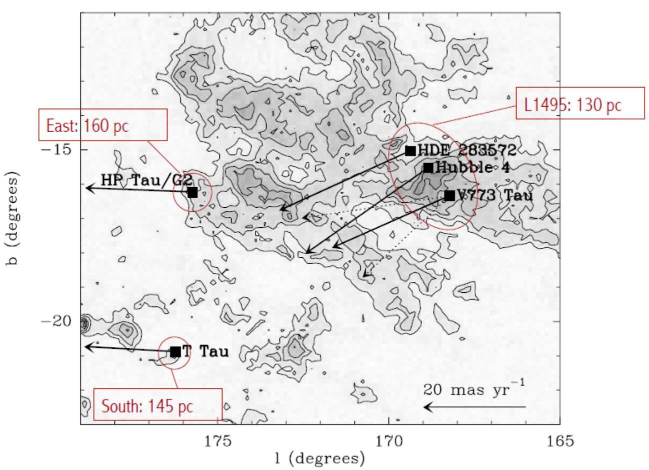


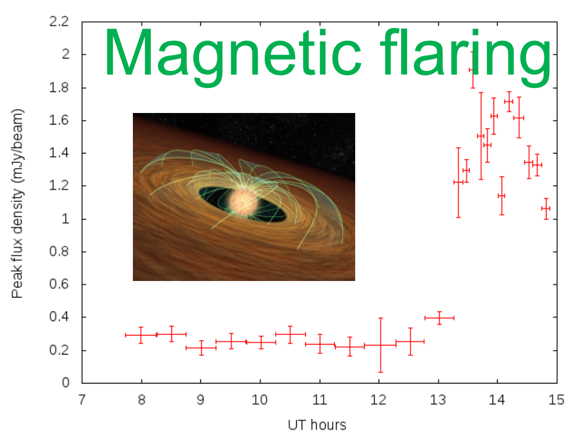


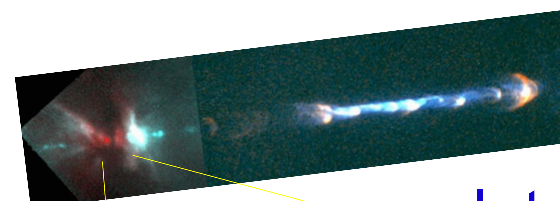
Pre-biotic molecules



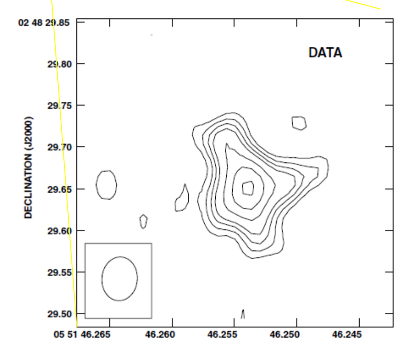
6D tomography







Jets



Dense young clusters

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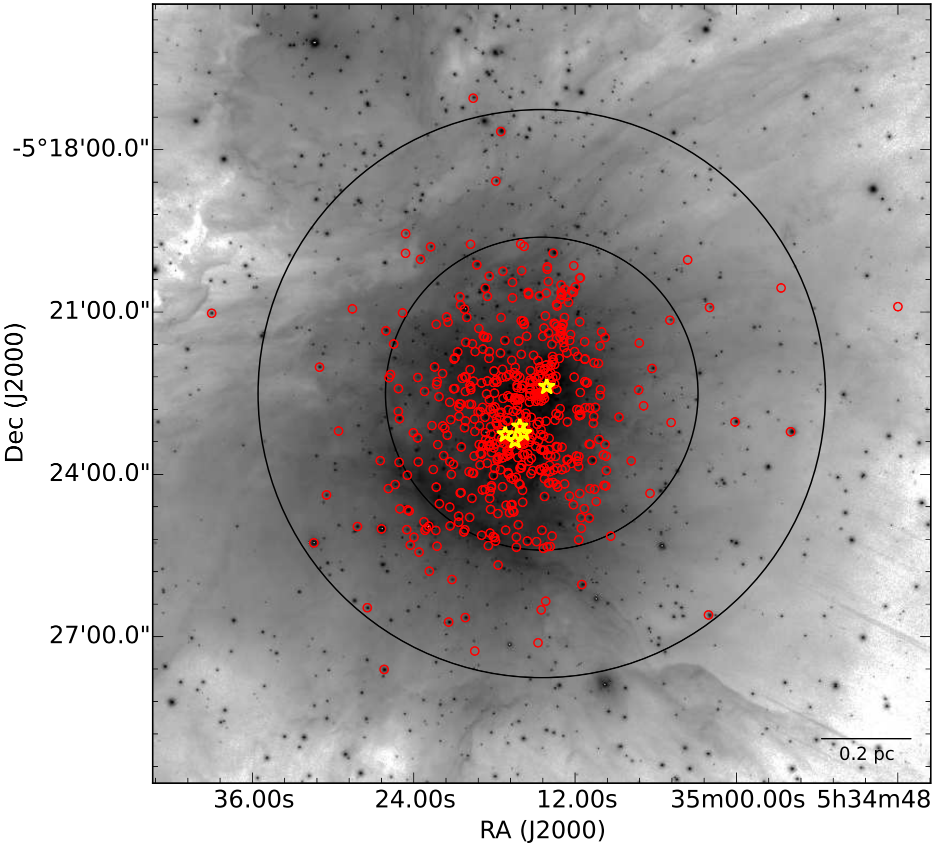
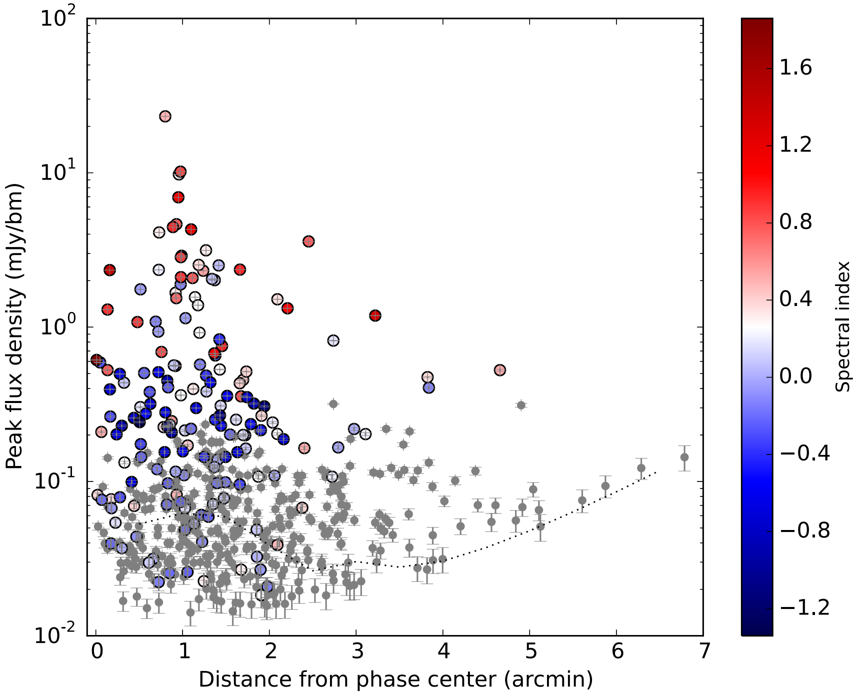
- Orion Nebula Cluster shows over 500 sources in single deep VLA pointing (Forbrich et al. 2016)





Jets in Young Stellar Objects

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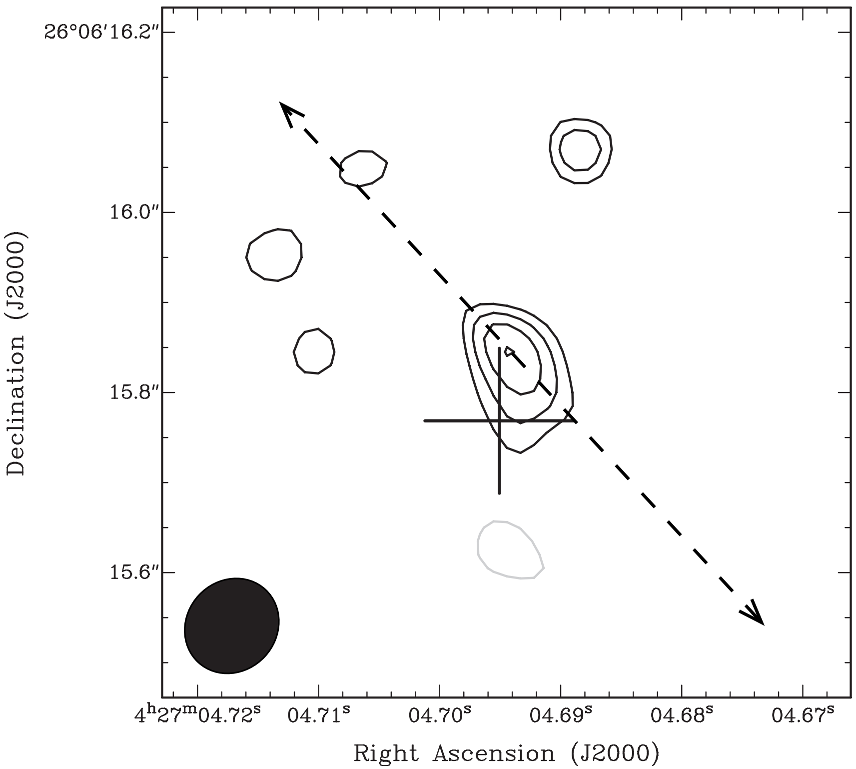
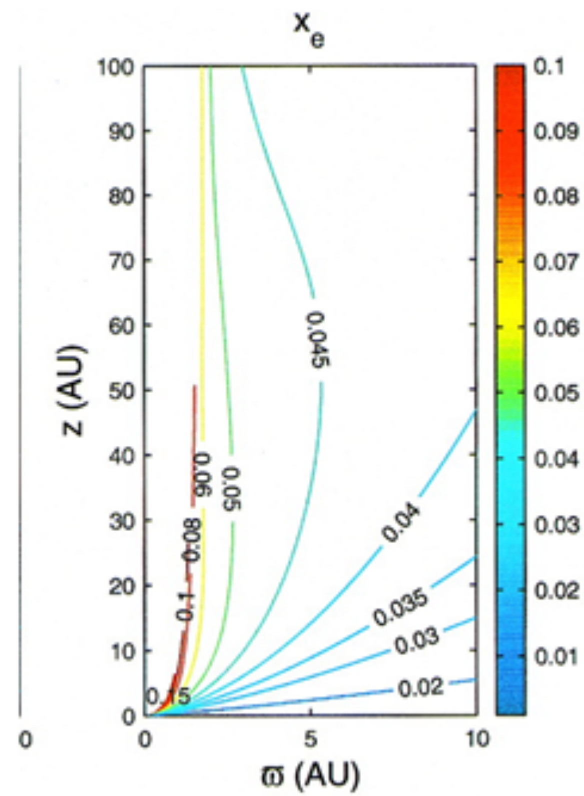


Early e-Merlin 5 GHz map of low-mass YSO jet (Ainsworth et al. 2013)



Potential to test jet driving mechanisms at K-band (~ 1 au resolution)

Magnetic Fields in Star Formation

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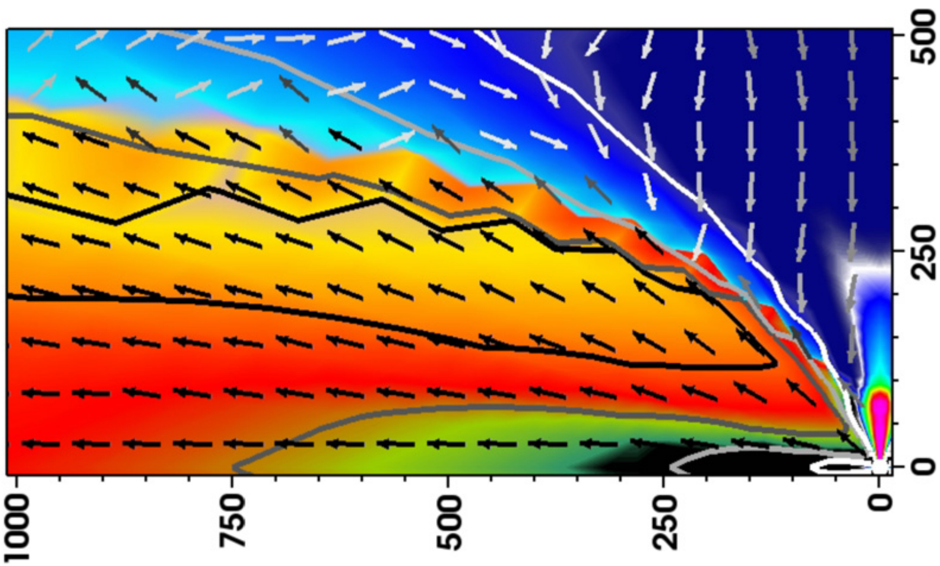
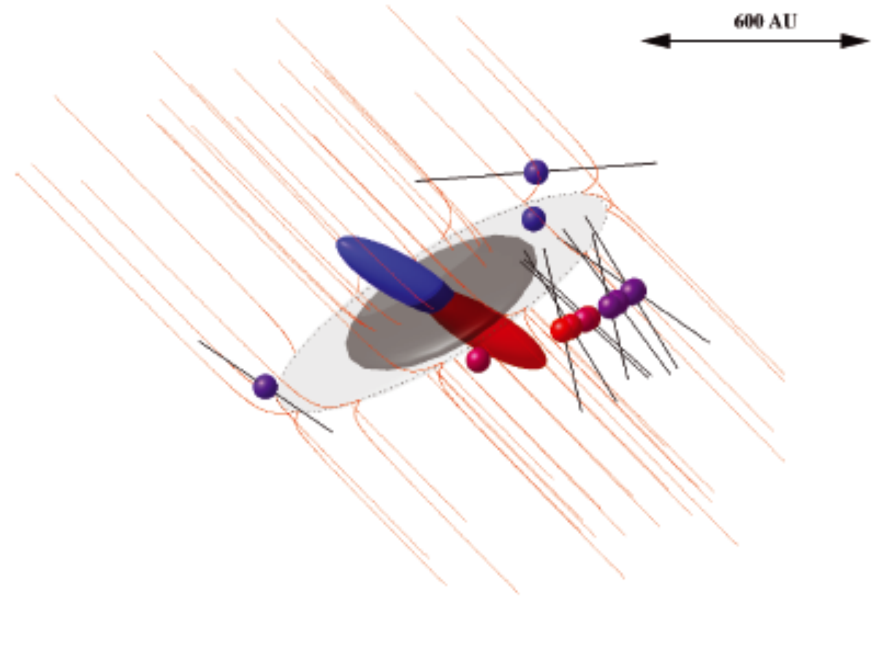


au

MHD jet interaction (Kuiper et al 2015)



Methanol maser polarization giving 3D B field

(Vlemmings et al. 2010)

Magnetized YSO Jets

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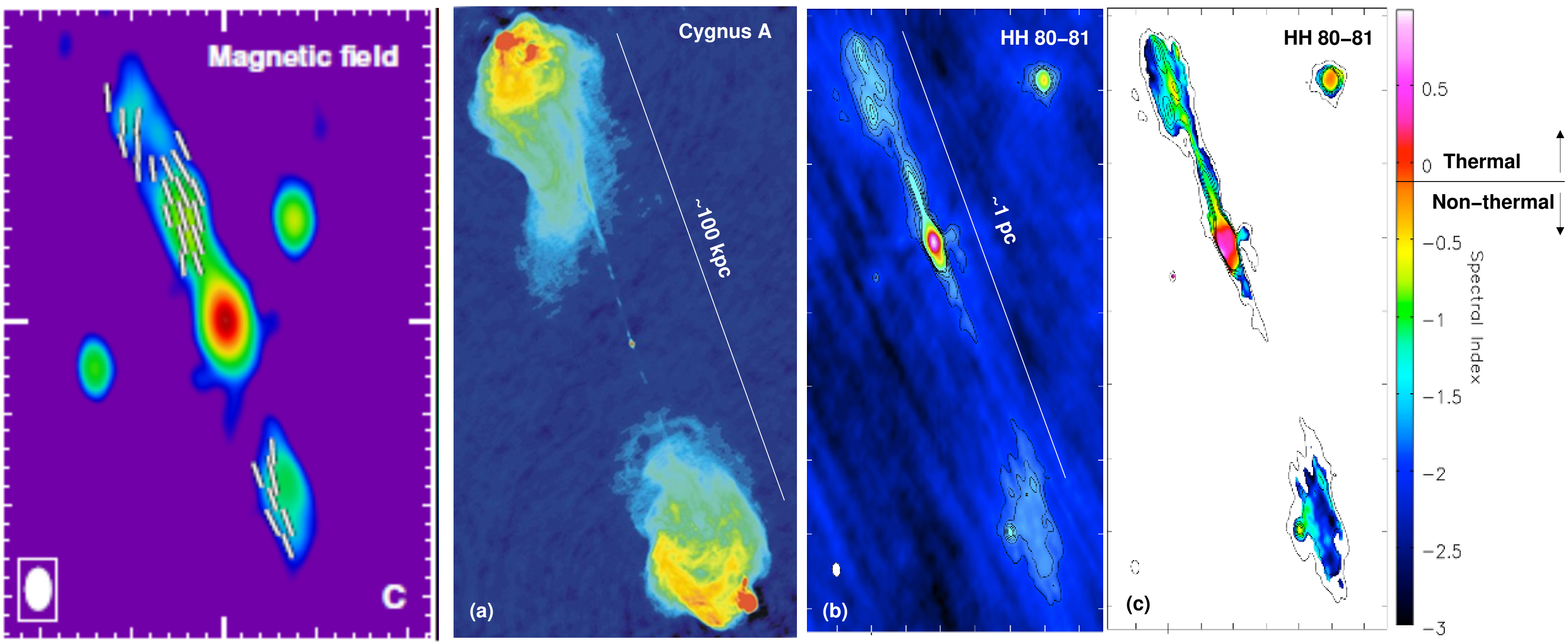
- Linear polarization now detected



VLA observations of HH80-81 (Carrasco-Gonzalez et al. 2010; 2013)

Non-thermal Lobes

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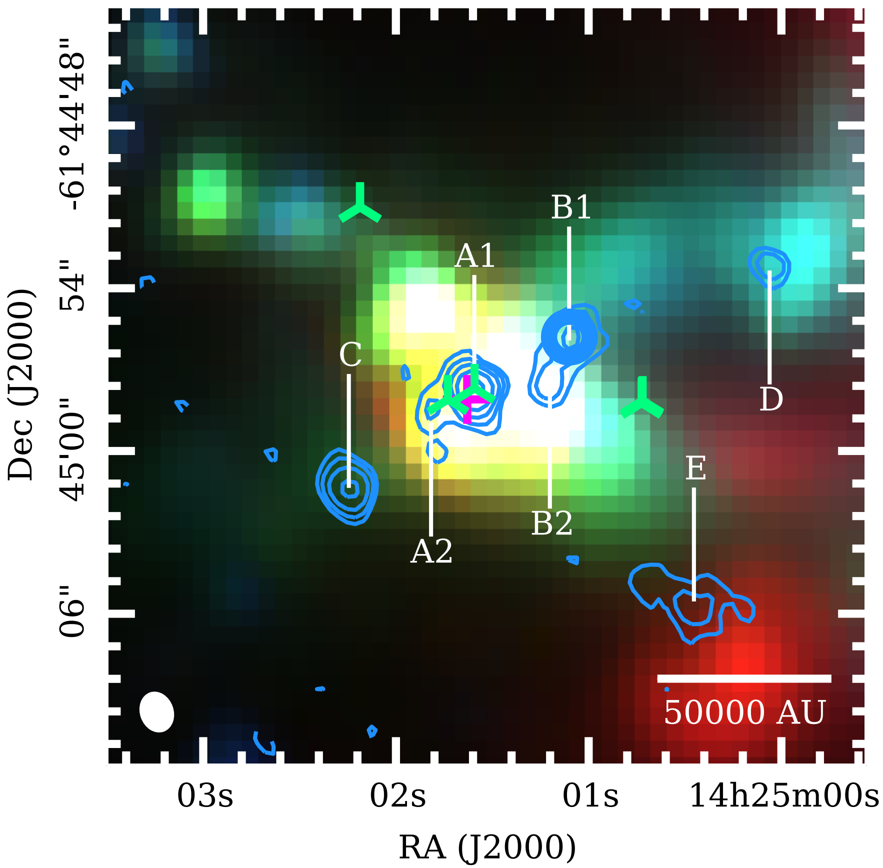
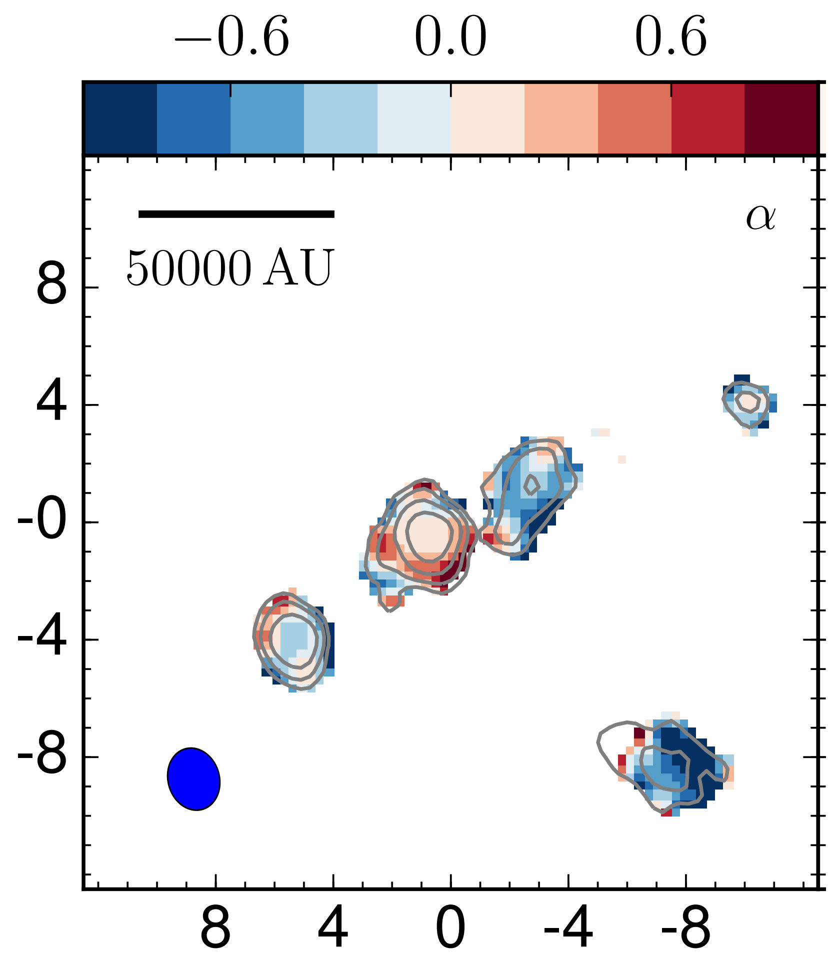


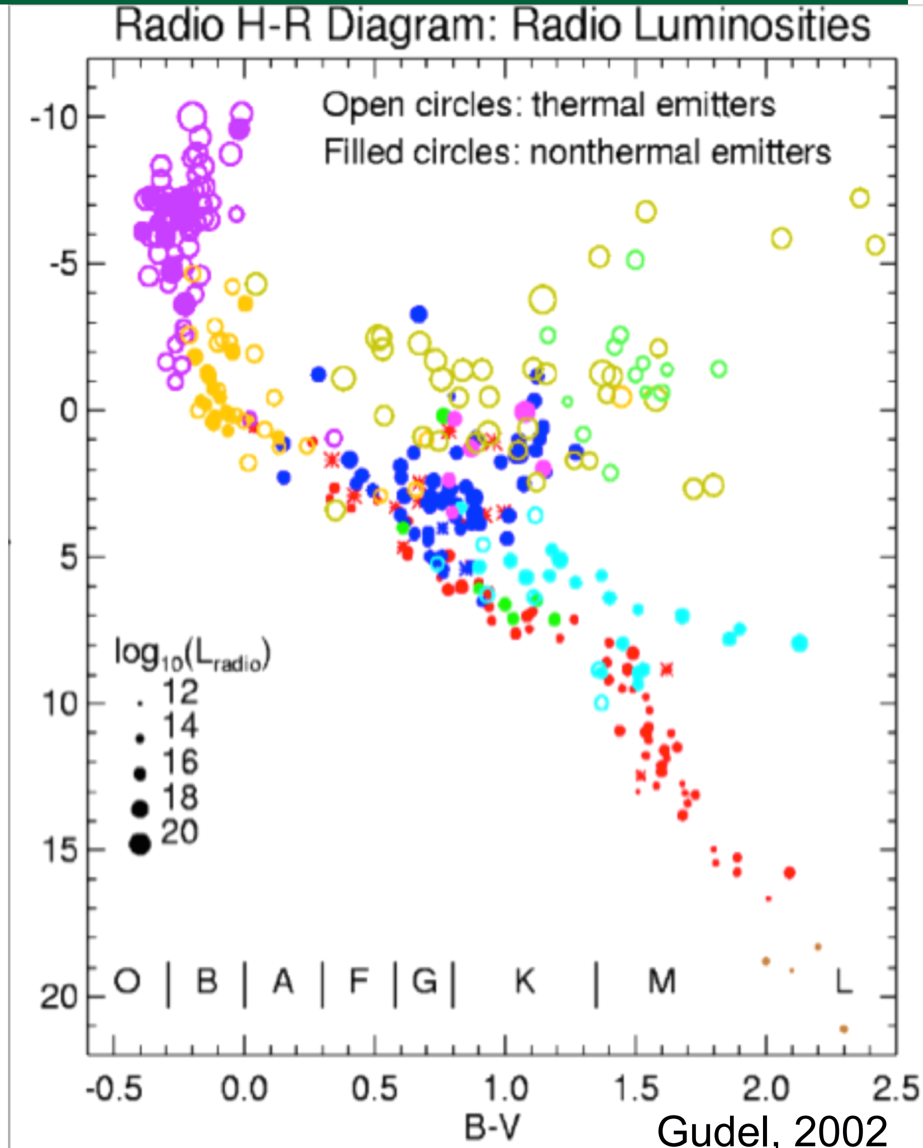
ATCA 9 GHz continuum on Spitzer IRAC image (Purser et al. 2016)



Spectral index map

Radio Stars

- GAIA will usher in a new era of precision stellar astrophysics
- Radio studies will address many important issues



Gudel, 2002

Wide Range of Processes

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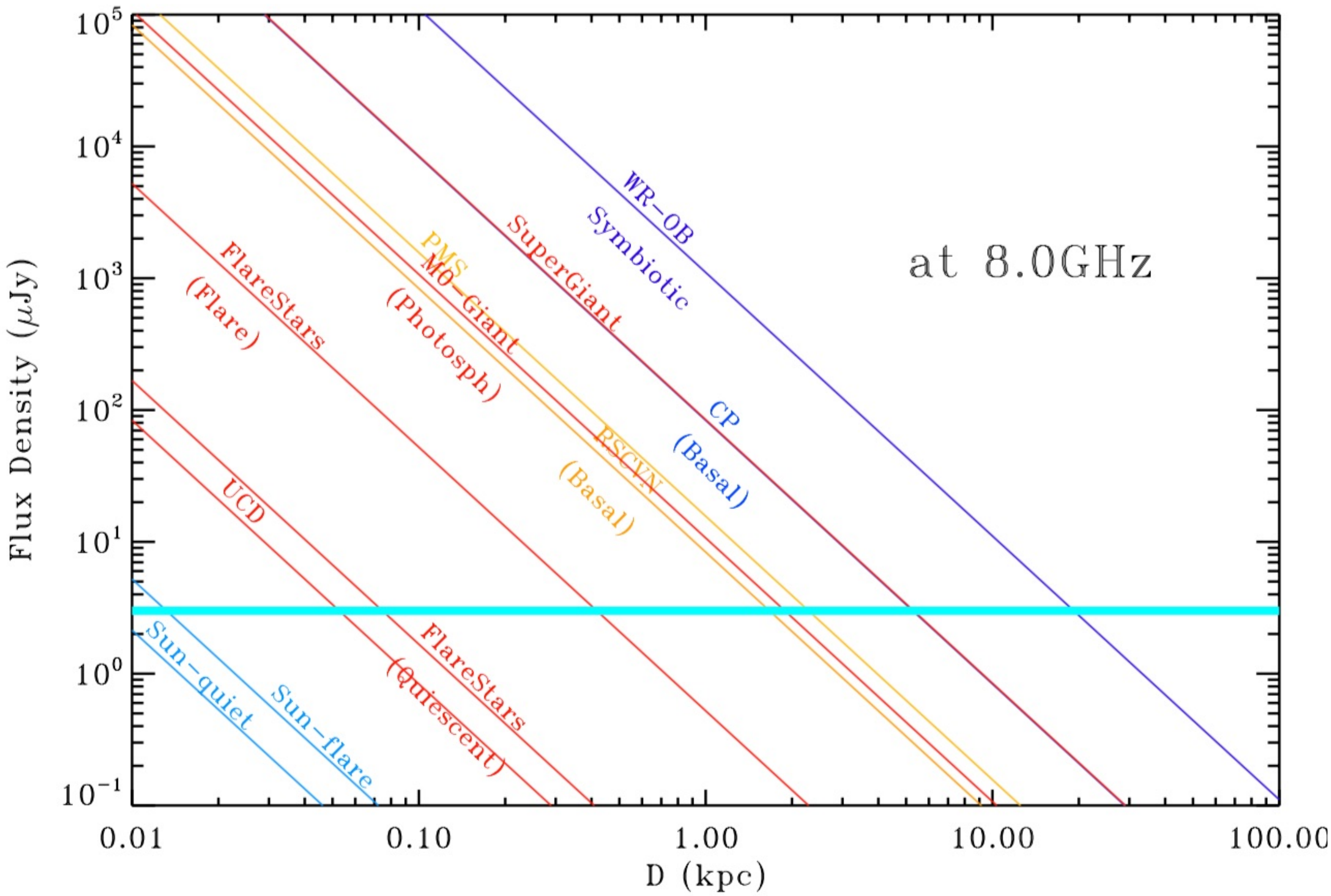

Stellar Winds

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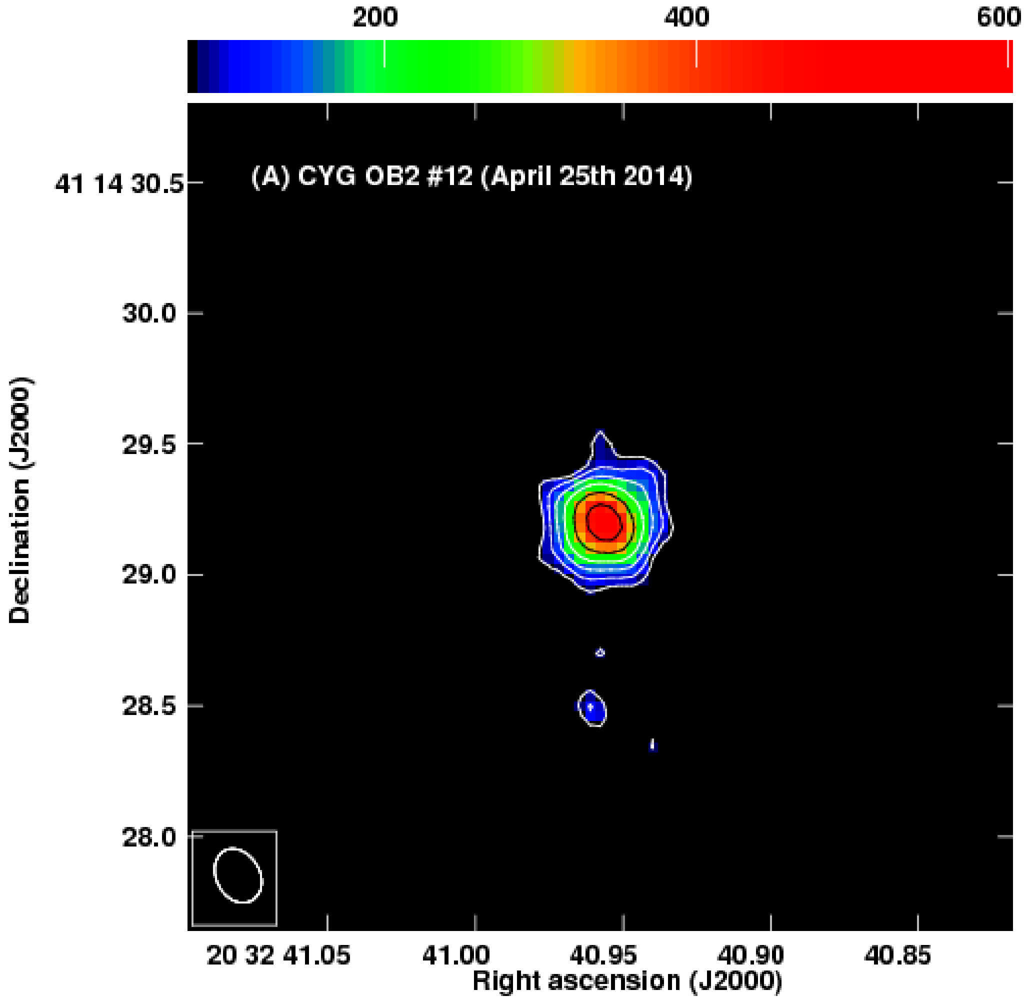
- Accurate mass-loss rates from clumpy, radiatively driven winds from OB stars
- Needed for stellar evolution models and endpoints – NS and BH



e-Merlin L-band map of blue hypergiant wind (Morford et al. 2016)

Colliding Wind Systems

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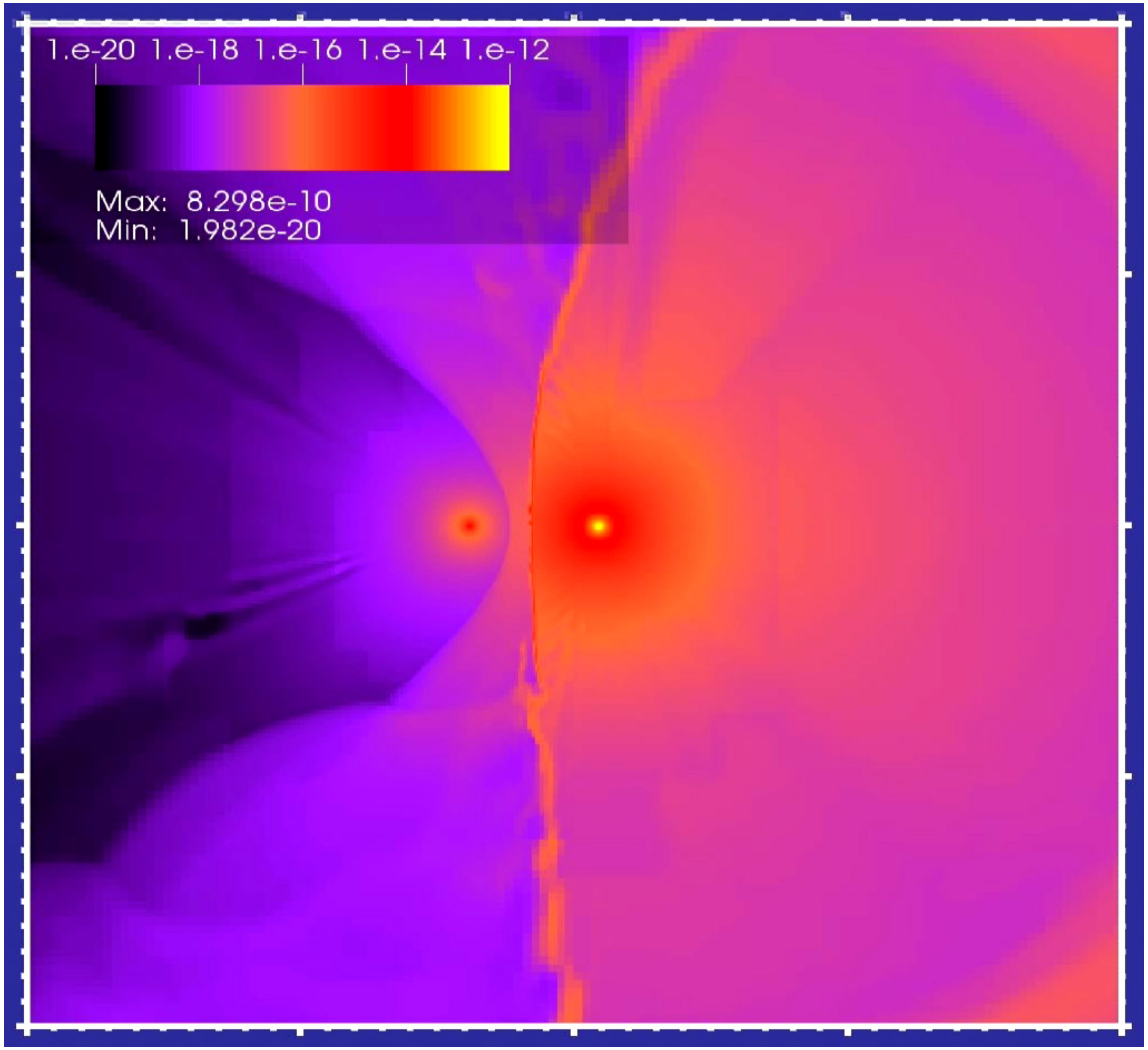
- Non-thermal emission from interacting winds in massive binaries
- Progenitors of NS and BH binaries and GW sources



Photospheric Studies

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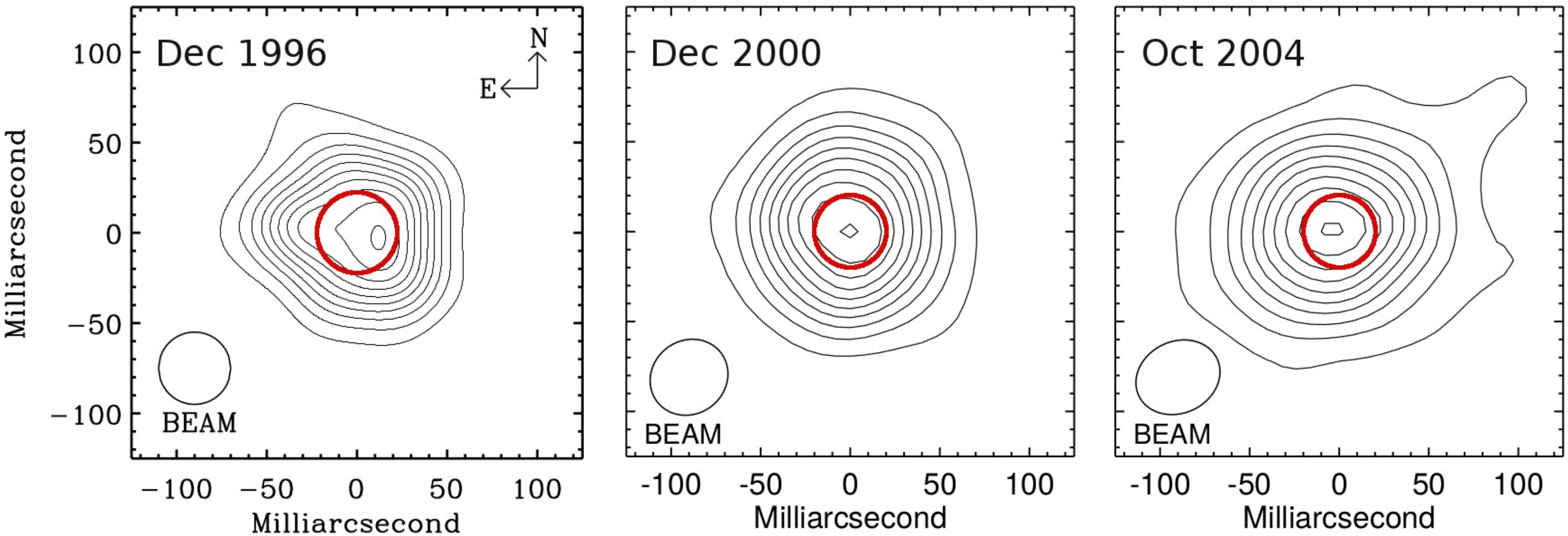
- Resolved photospheres of red supergiant stars probe atmospheric structure and role of giant convection cells



VLA Q-band images of Betelguese (Gorman et al. 2015)

Novae

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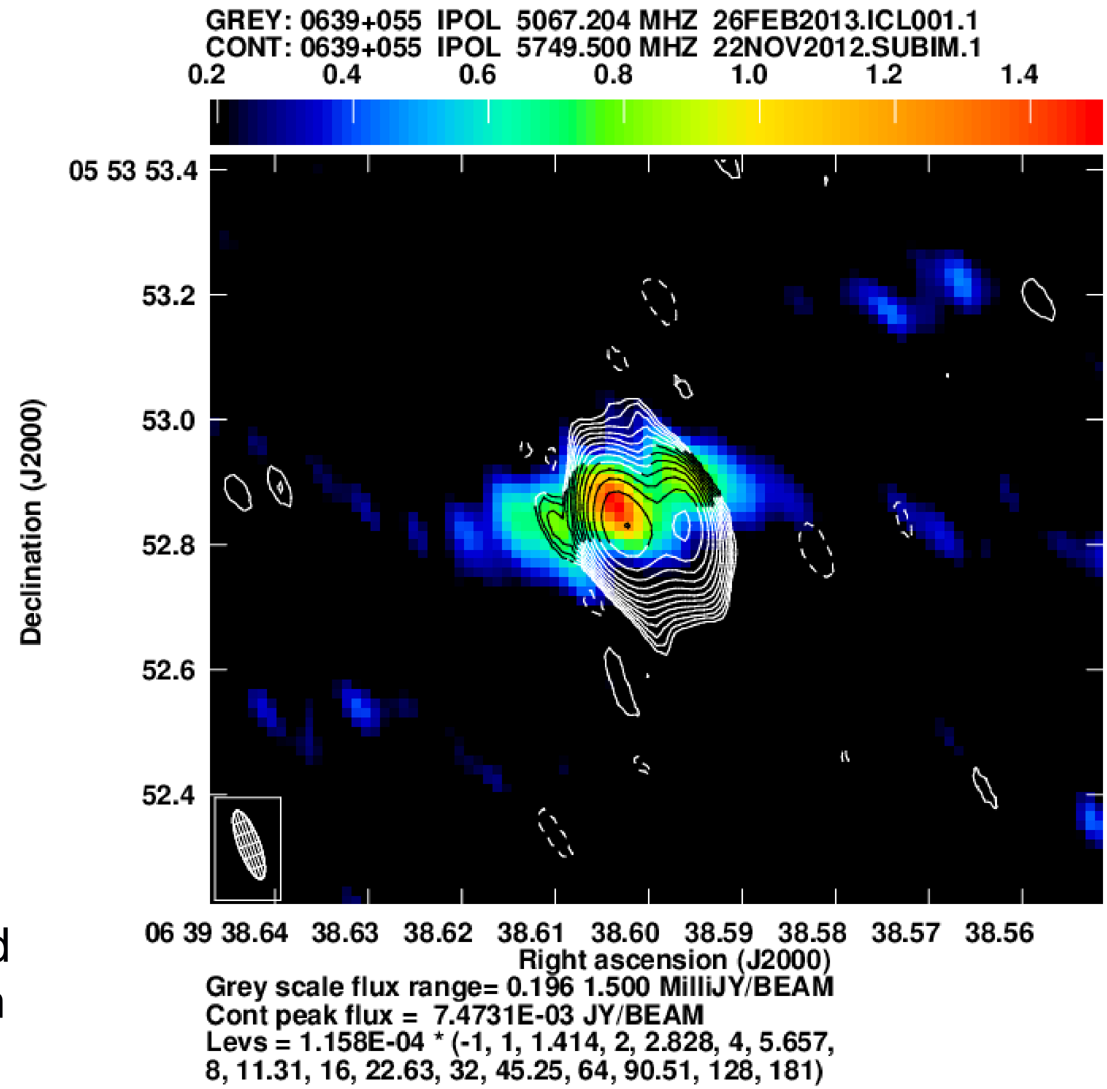
- Multi-epoch spatially resolved studies of novae explosions to ascertain role as Type 1a SN progenitors



Two epochs of e-Merlin C-band emission from nova V959 Mon (O'Brien et al. 2014)

Other Ventures

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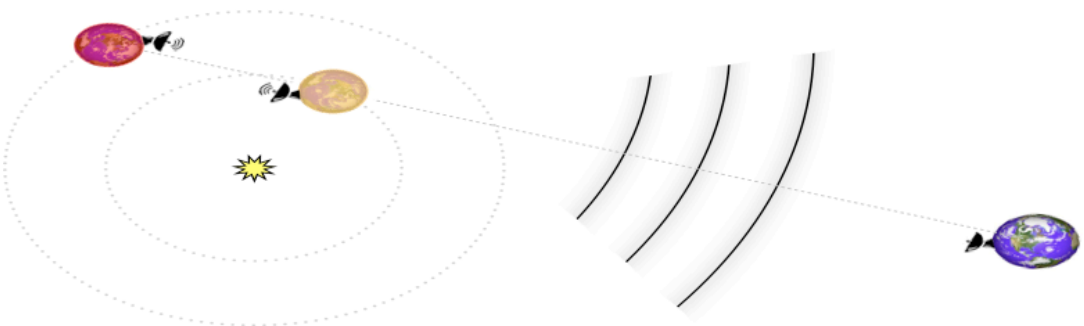
- SETI searches of particular northern targets
    - E.g. alignments in multi-planet systems found by Kepler



- Support to space missions
    - E.g. VLBI tracking of probe entries into planetary atmospheres

Summary

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- Sensitive, high resolution radio studies of thermal and non-thermal emission from Galactic sources addresses many big questions and underlying astrophysics
  - Planet formation
  - Star formation
  - Stellar evolution
- Matching 40 mas resolution of ALMA (1 mm), VLA (7 mm) and e-Merlin/SKA1 Mid (5/2 cm) is a powerful combination (also JWST at 1 μm)