Probing high-mass star formation in the outflow source G12.42+0.50

Namitha Issac et al. (in prep)

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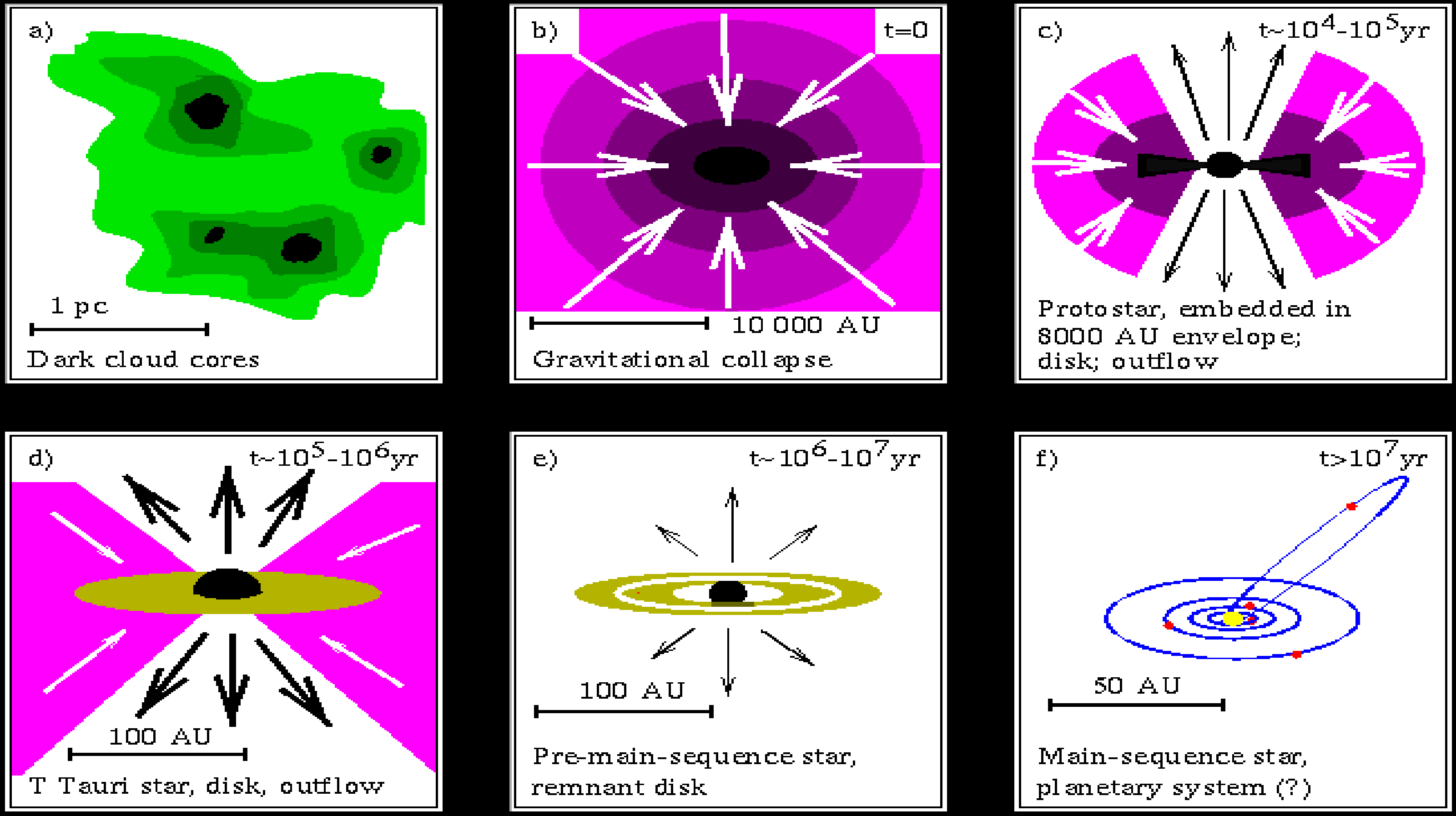
Star formation



M.Hogerheijde1998, after Shu et al. 1987

Processes at work

Accretion onto protostar

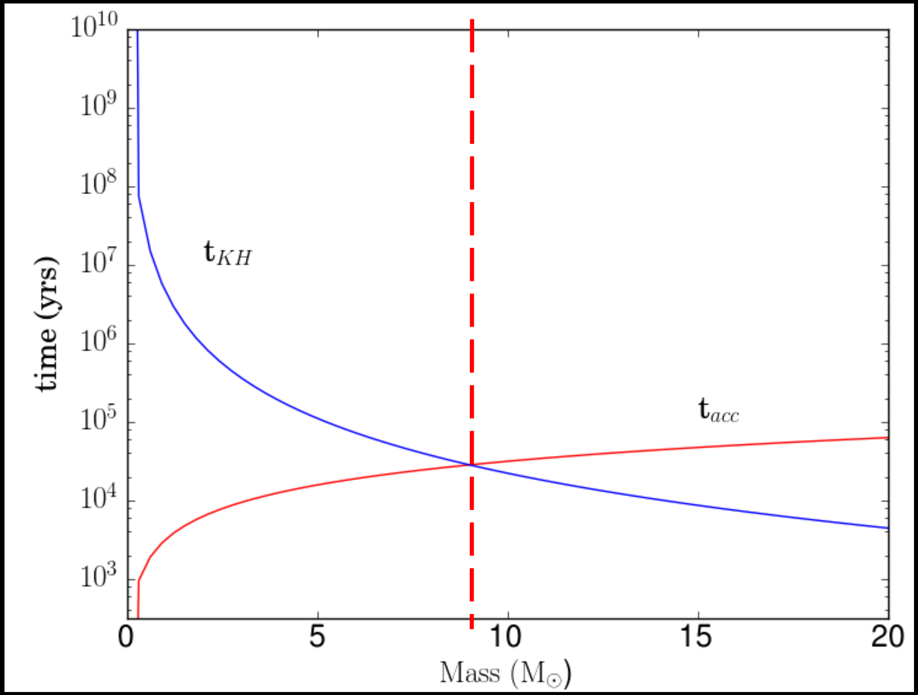
$t_{acc} = M_*/(dM_{acc}/dt)$

Contraction of protostar:

$t_{KH} = GM^2/R_*L_*$

Stars < 8 M_{sun} $t_{KH} > t_{acc}$

Stars > 8 M_{sun} $t_{KH} < t_{acc}$



High-mass stars "switch on" while still accreting

Radiation pressure (+ wind + ionizing flux) inhibits accretion

Can stars > 8 $M_\odot$ then form!?

Competing theories of high-mass star formation

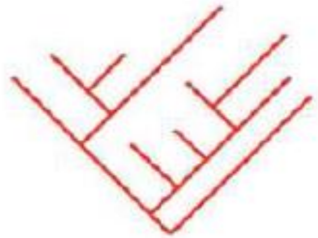
Monolithic Collapse

The mass is gathered **before** star formation

- Increased Accretion rates
- Disk Geometry helps accretion
- Flashlight effect

(Yorke et al. 2002)

Competitive Accretion

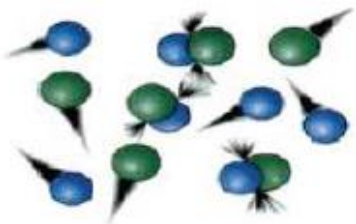


The mass is gathered **during** star formation

- Gas cloud fragments
- Each clump accretes from surroundings
- Largest gravitational potential at centre

(Bonnell et al. 2006)

Collisions & Mergers

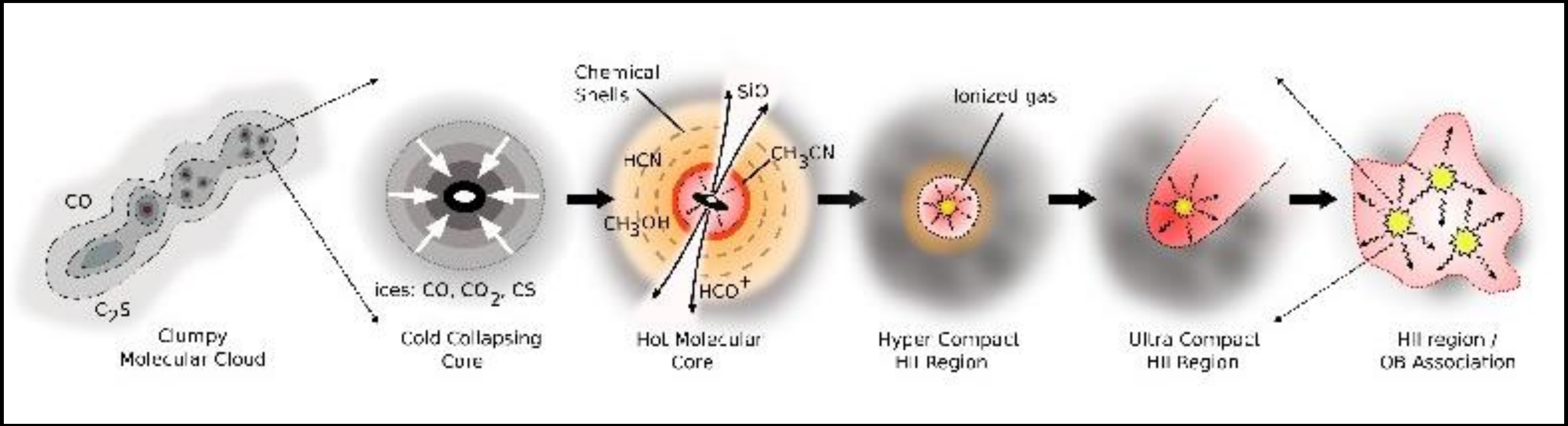


The mass is gathered **after** star formation

- Require high protostellar densities
- Explosive events
- Outflows and jets cannot survive

(Bonnell et al. 1998)

High-mass star formation scheme



(Purcell et al. 2006)

Scenario in infancy due to dearth of observations

- Deeply embedded in dusty clumps
  High extinction
- Initial Mass Function
  High-mass stars are rare $N(1\ M_\odot) = 100\ N(10\ M_\odot)$
- Formation in clusters (swarm of low-mass objects)
  Confusion
- Short evolutionary timescales

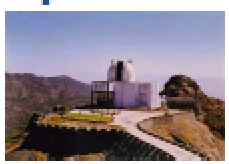
$$t_{\rm acc} = \frac{20 M_\odot}{10^{-3} M_\odot {\rm yr}^{-1}} = 2 \times 10^4 {\rm yr}$$

- Large distances
  > 400 pc, typically a few kpc
- Parental environment profoundly altered

Multiwavelength study

Near and mid-infrared

1.2 - 24.0 μm



- Warm dust
- Young stellar object (YSO) population

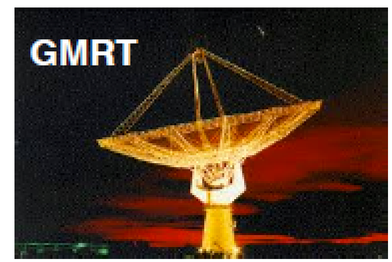
Far-infrared and millimeter

70 μm - 1.2 mm

- Cold dust
- Molecular cloud

Radio

300-1400 MHz

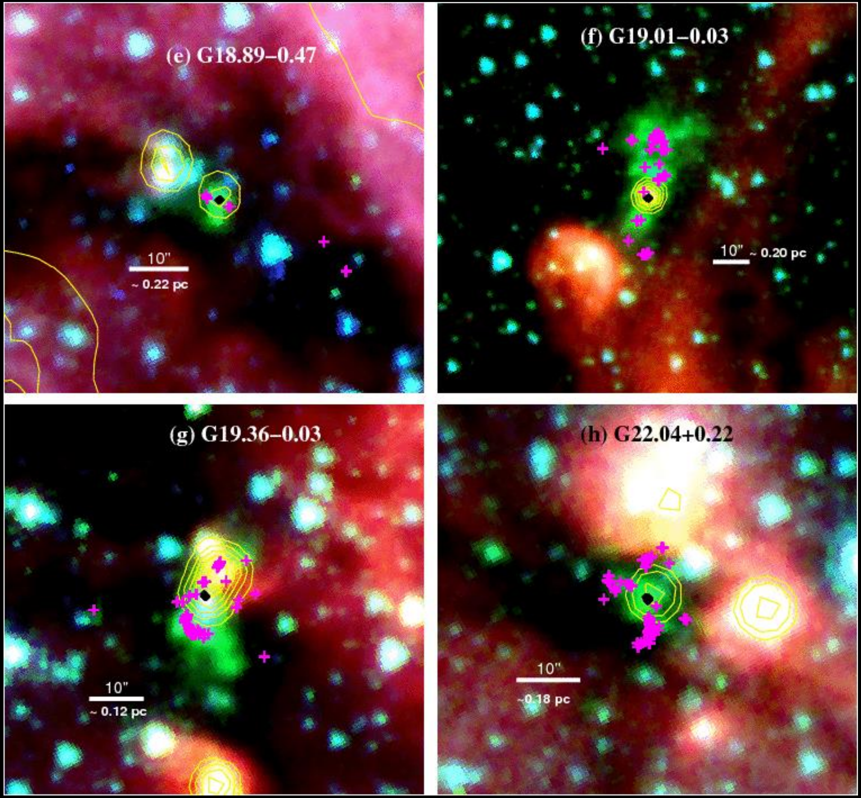


- HII regions

Ionised regions around newly formed massive stars

Evolution, kinematics and star formation activity of the cloud

Extended Green Objects



Enhanced and extended emission in the Spitzer 4.5μm band
(Cyganowski et al. 2008)

'Green fuzzies' or Extended Green Objects (EGOs)
(Chambers et al. 2009; Cyganowski et al. (2008)

Spectral carriers – shock-excited H2 line and/or CO bandheads

Association with IRDCs, Class II Methanol masers

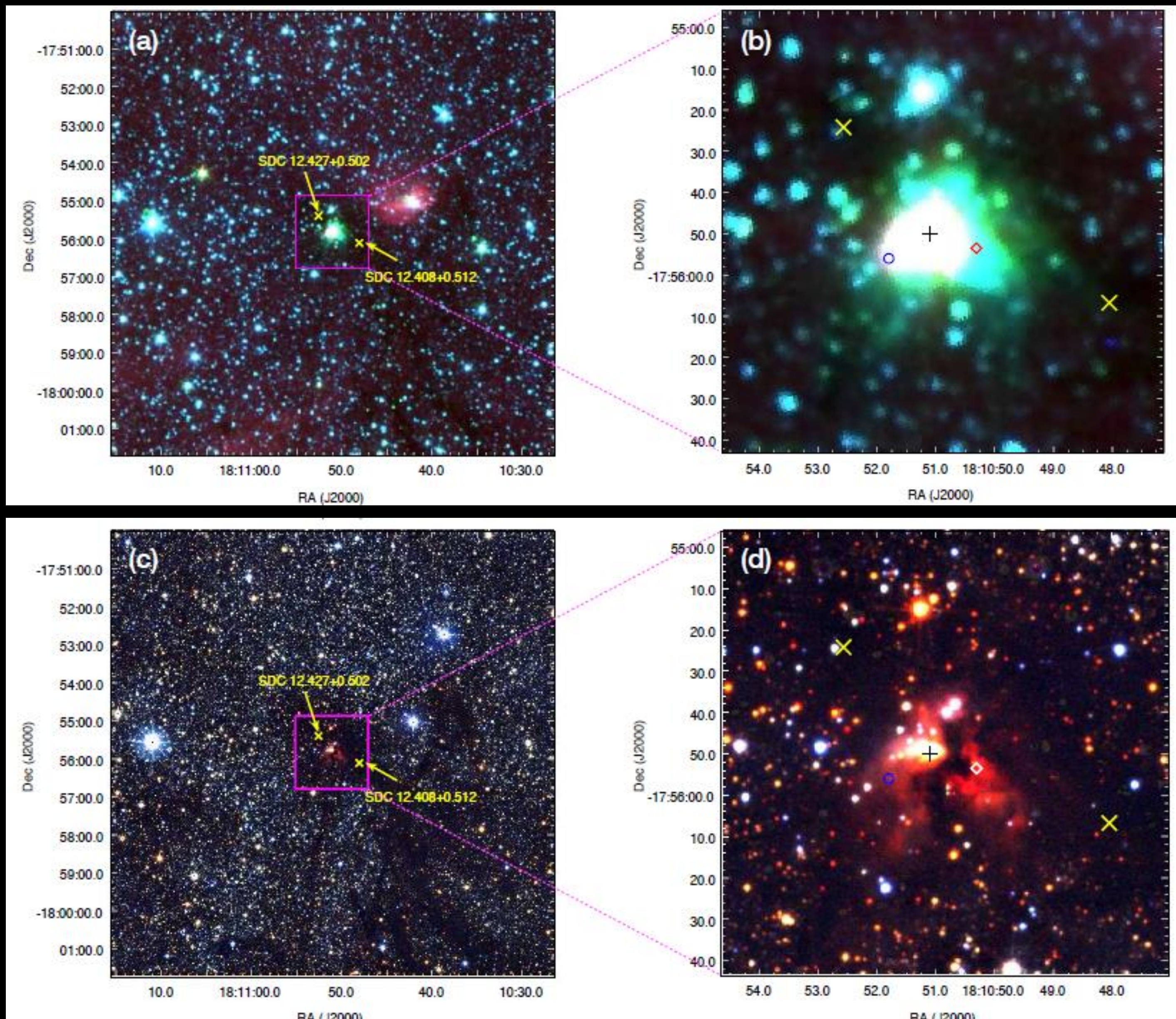
Candidates for outflows from massive YSOs

Unique sample to probe the early phases of high-mass star formation

G12.42+0.50

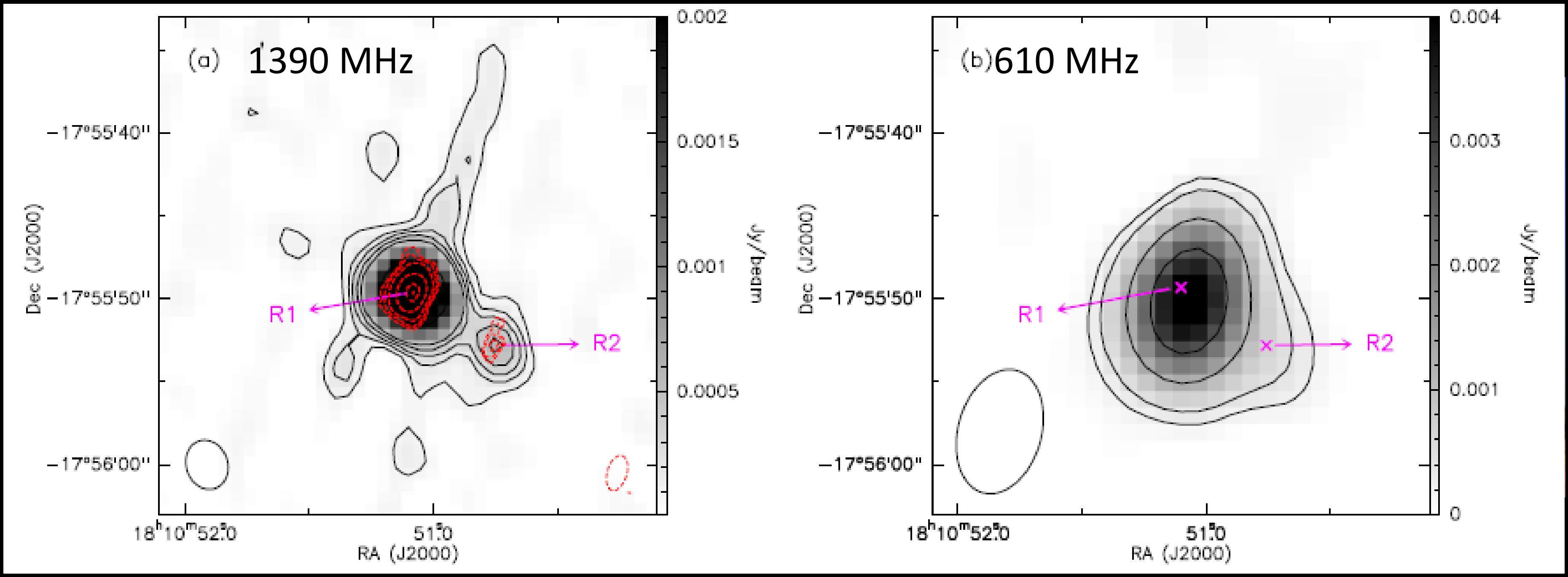
IRAC color composite image

8 μm, 4.5 μm, 3.6 μm



UKIDSS color composite image

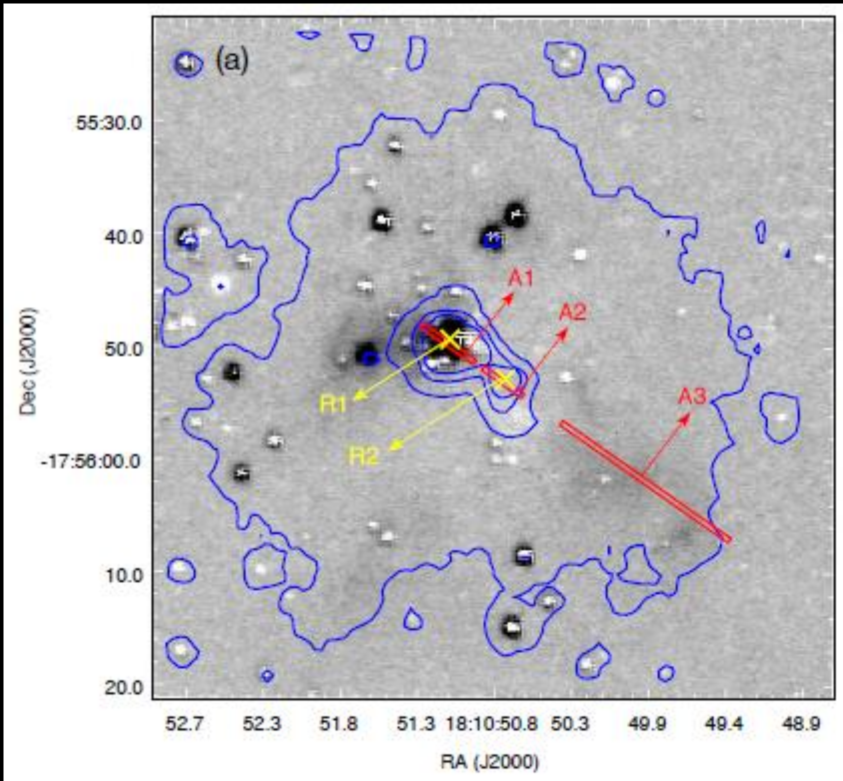
2.2 μm, 1.6 μm, 1.2 μm

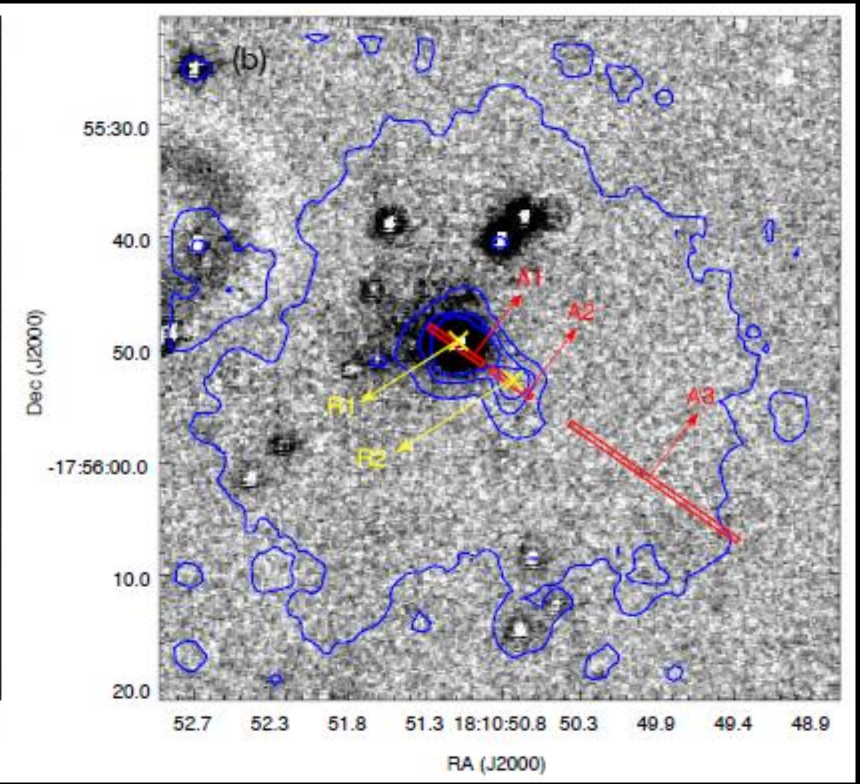


GMRT radio maps of G12.42+0.50

H_2line – UWISH2

FeII line – UKIRT





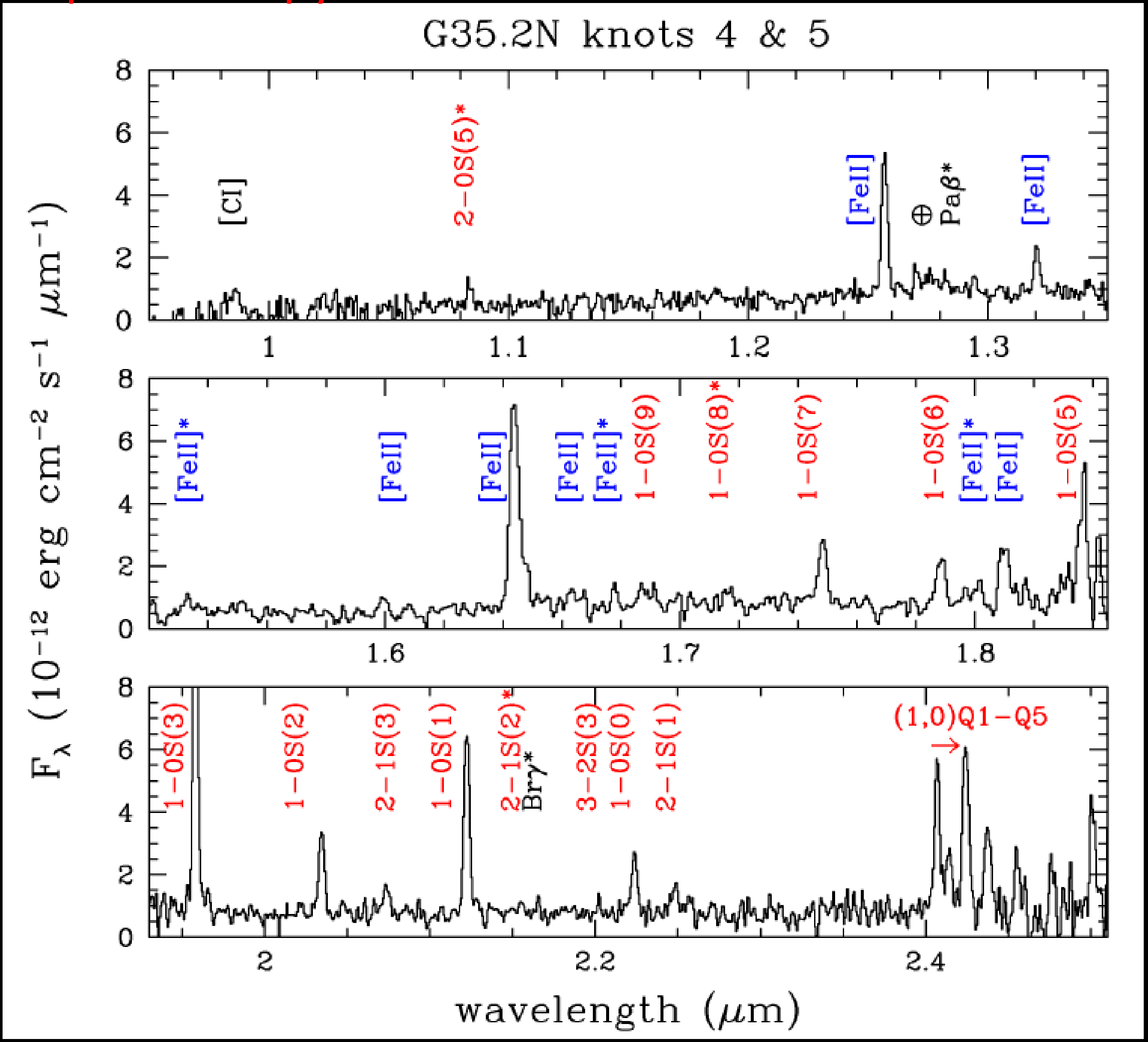
NIR line emissions

NIR Spectra with UIST-UKIRT

Lines detected in the spectra extracted from aperture A1.

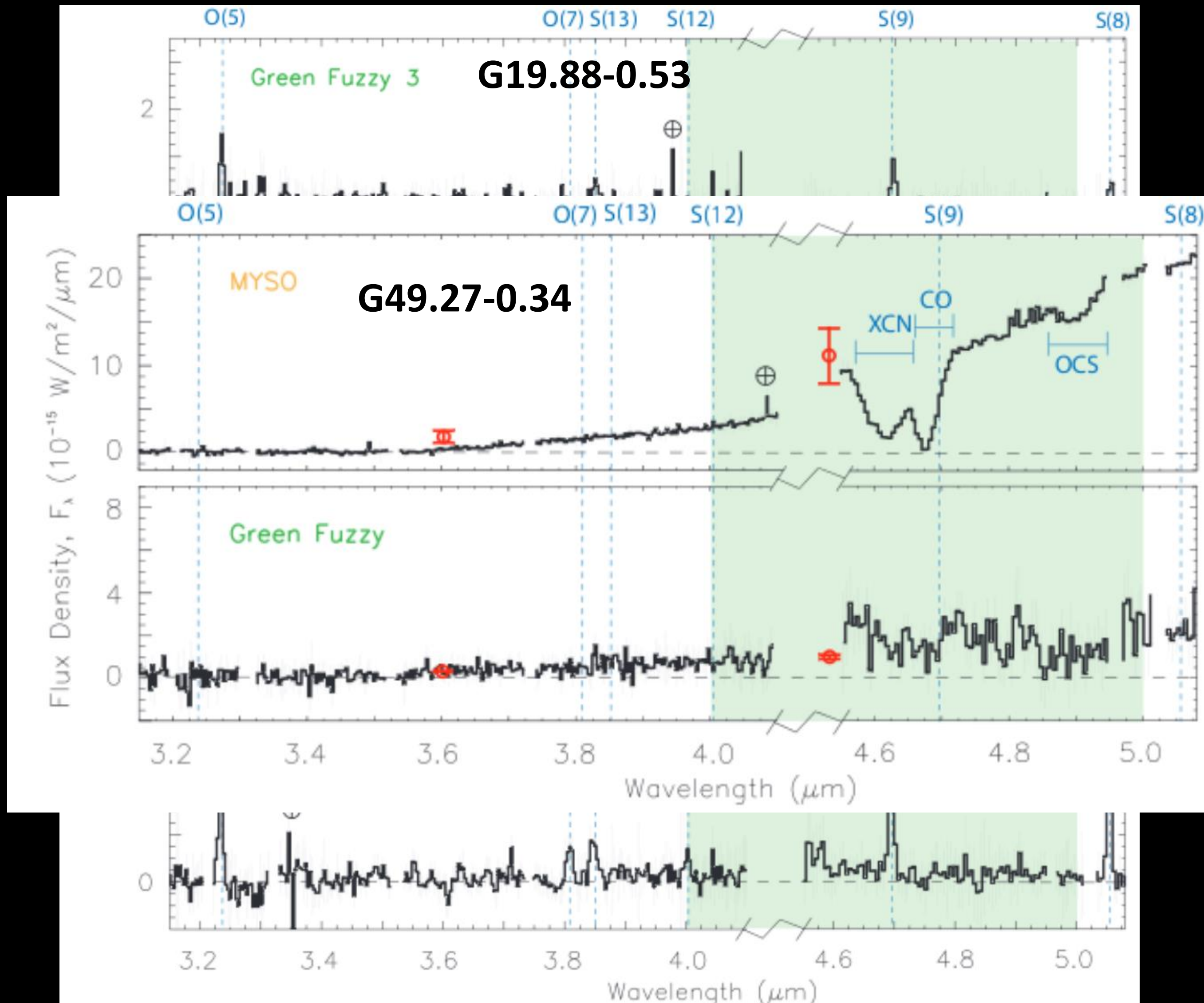
Line	Wavelength (μm)
[Fe II]	1.644
H_2 1-0 S(3)	1.958
He I	2.059
H_2 1-0 S(1)	2.122
H_2 1-0 S(0)	2.224
H_2 1-0 Q(1)	2.407
H_2 1-0 Q(2)	2.413
H_2 1-0 Q(3)	2.424

NIR spectroscopy of outflow sources with ESO-NTT



Caratti O Garatti et al. 2015)

LM band spectroscopy of EGOs with NIRI-GEMINI



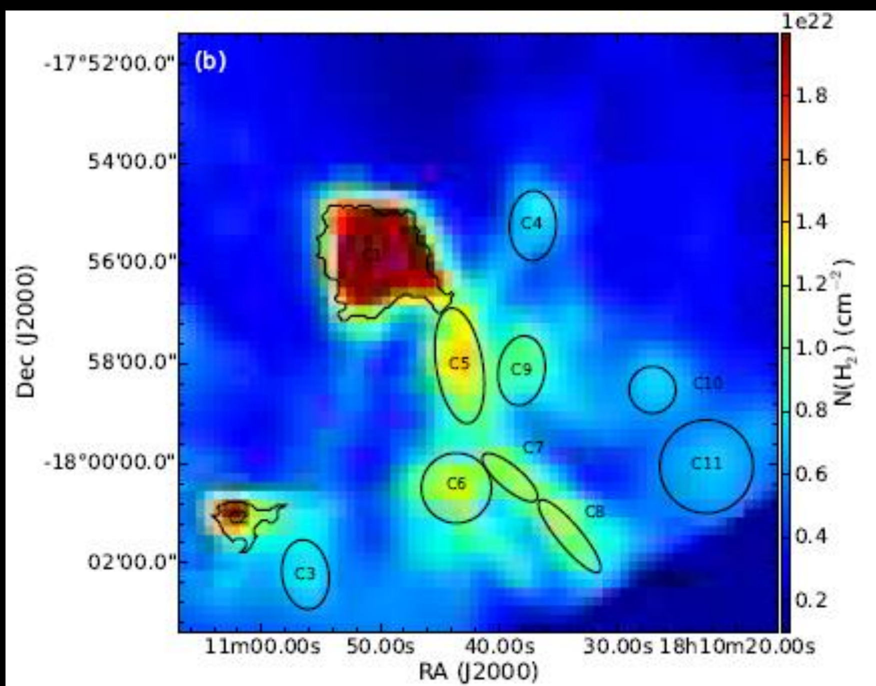
(DeBuizer & Vacaa 2010)

Cold dust emission

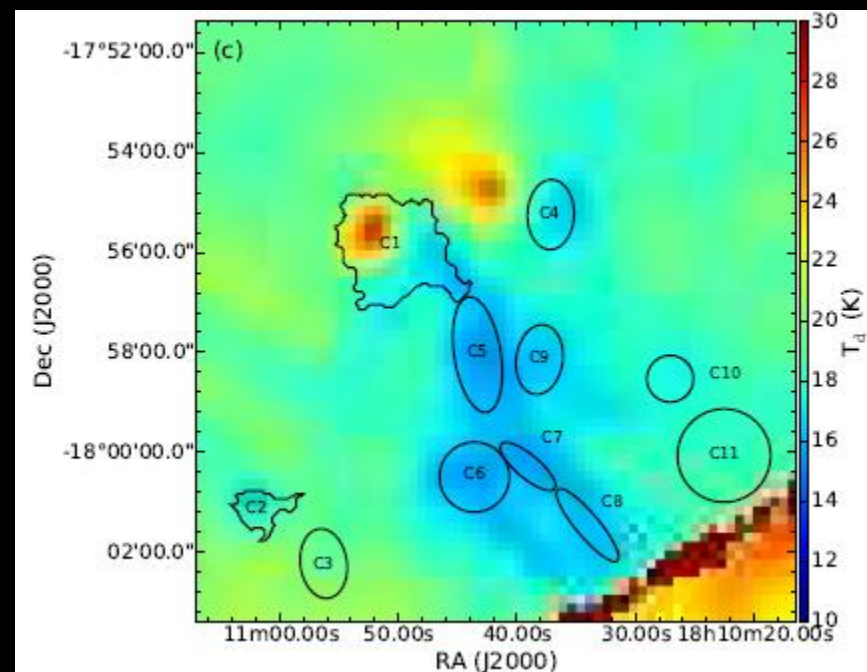
Pixel wise modelling of the dust emission with a modified blackbody using the Herschel and ATLASGAL-Planck FIR data (160 – 870 μm)

$$S_\nu(\nu) - I_{bkg}(\nu) = B_\nu(\nu, T_d)\Omega(1 - e^{-\tau_\nu})$$

$$\tau_\nu = \mu_{H_2} m_H \kappa_\nu N(H_2)$$

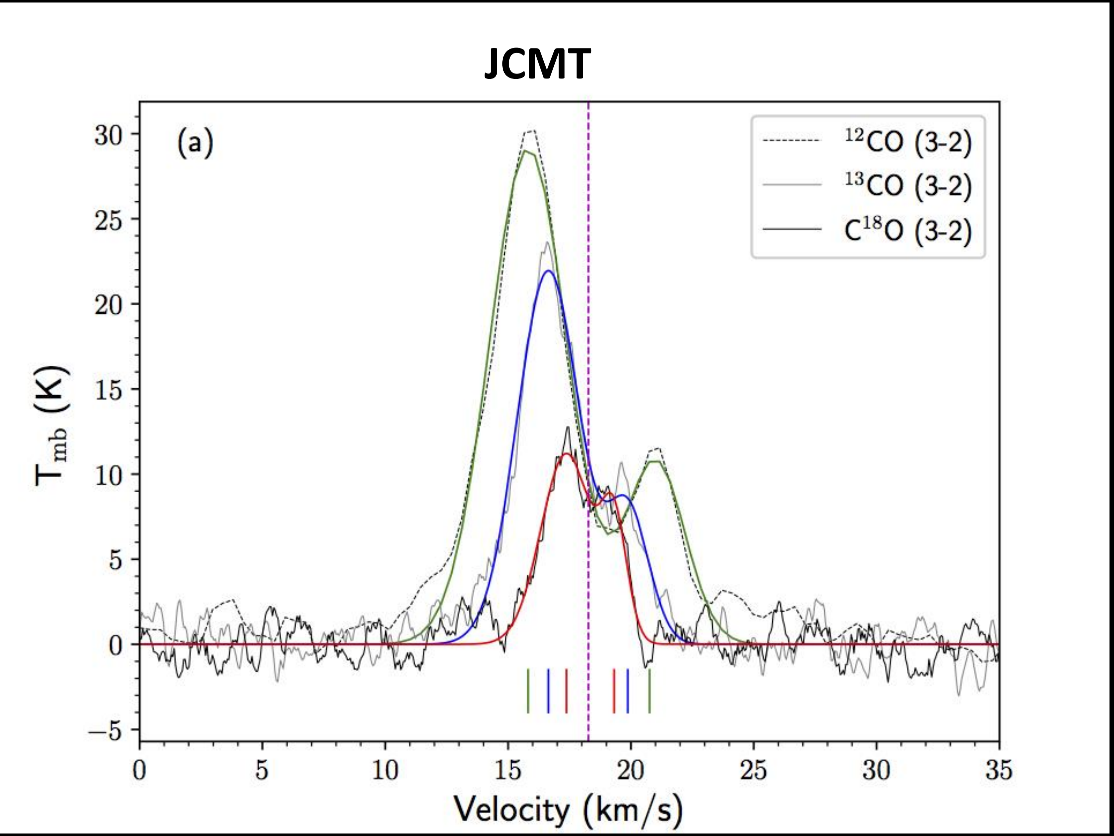


H_2 column density



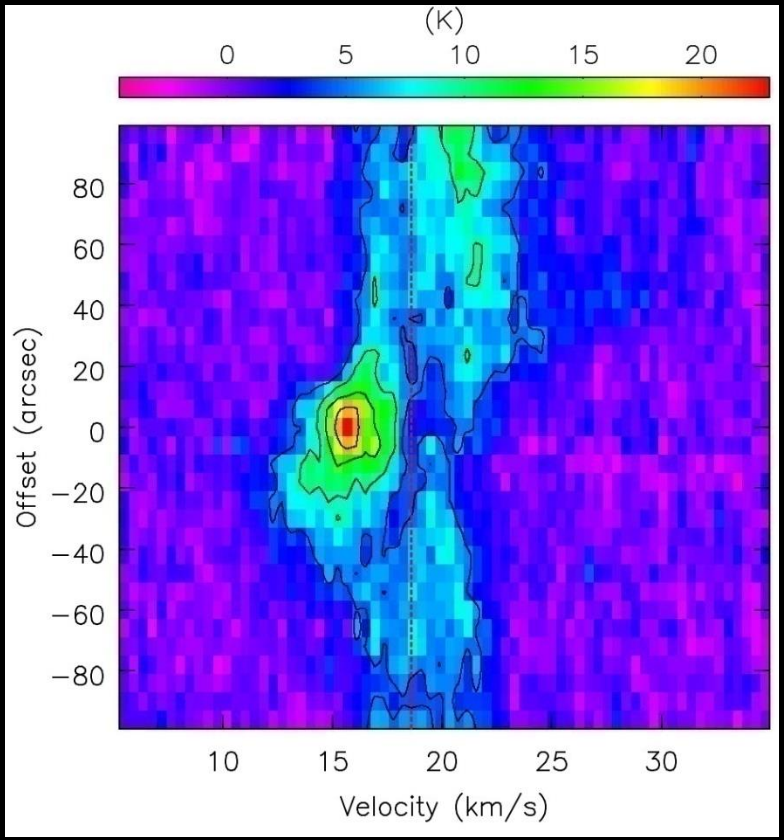
Cold dust temperature

Molecular Outflow



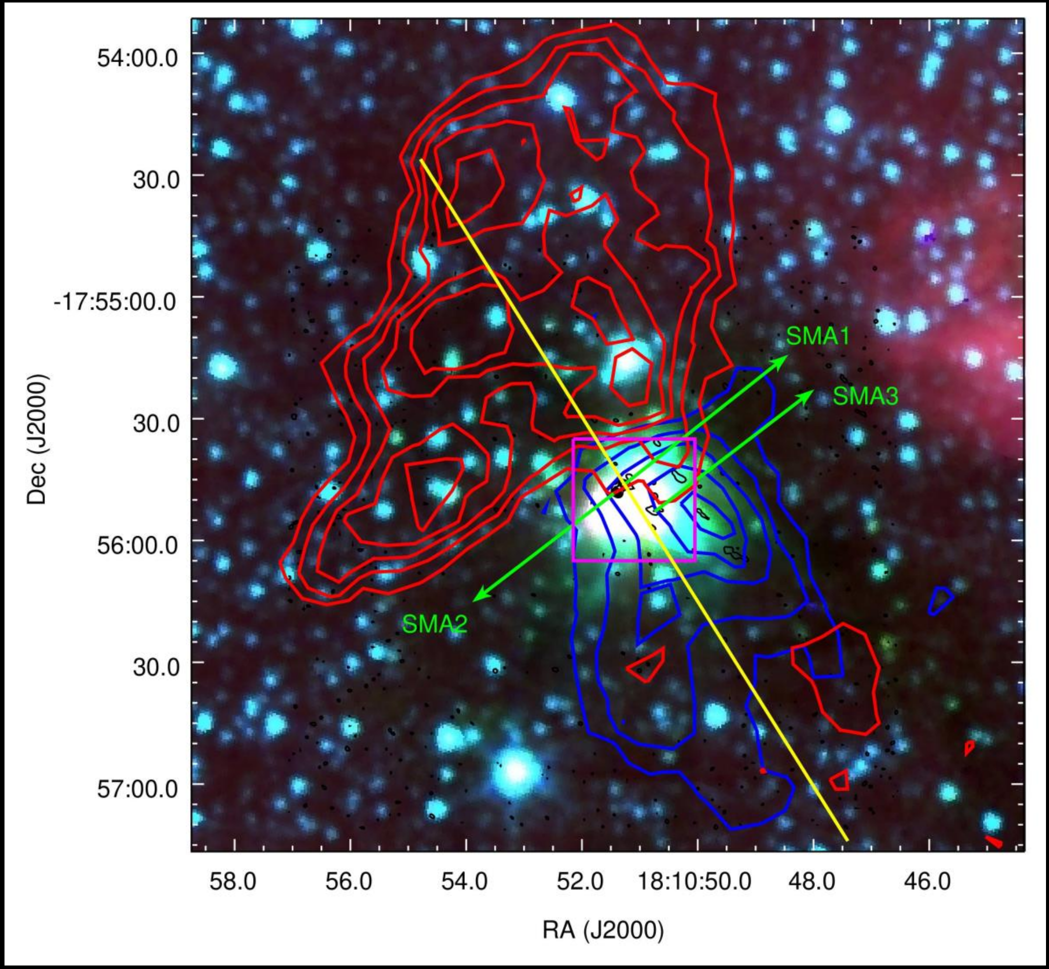
Rotational transition lines of isotopologues of the CO (3-2) observed towards G12.42+0.50.

Molecular Outflow

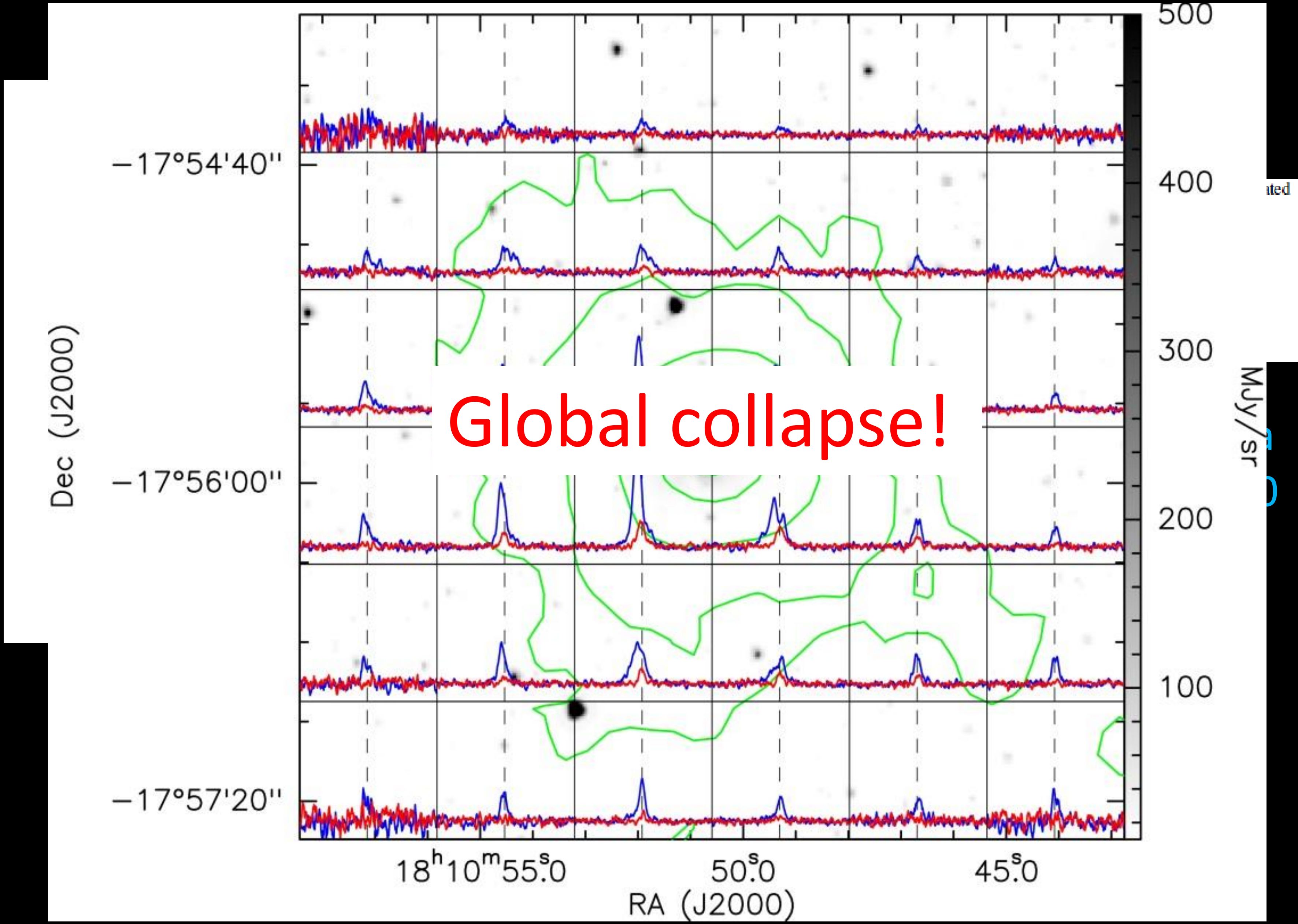


Position-velocity (PV) diagram of ^{12}CO

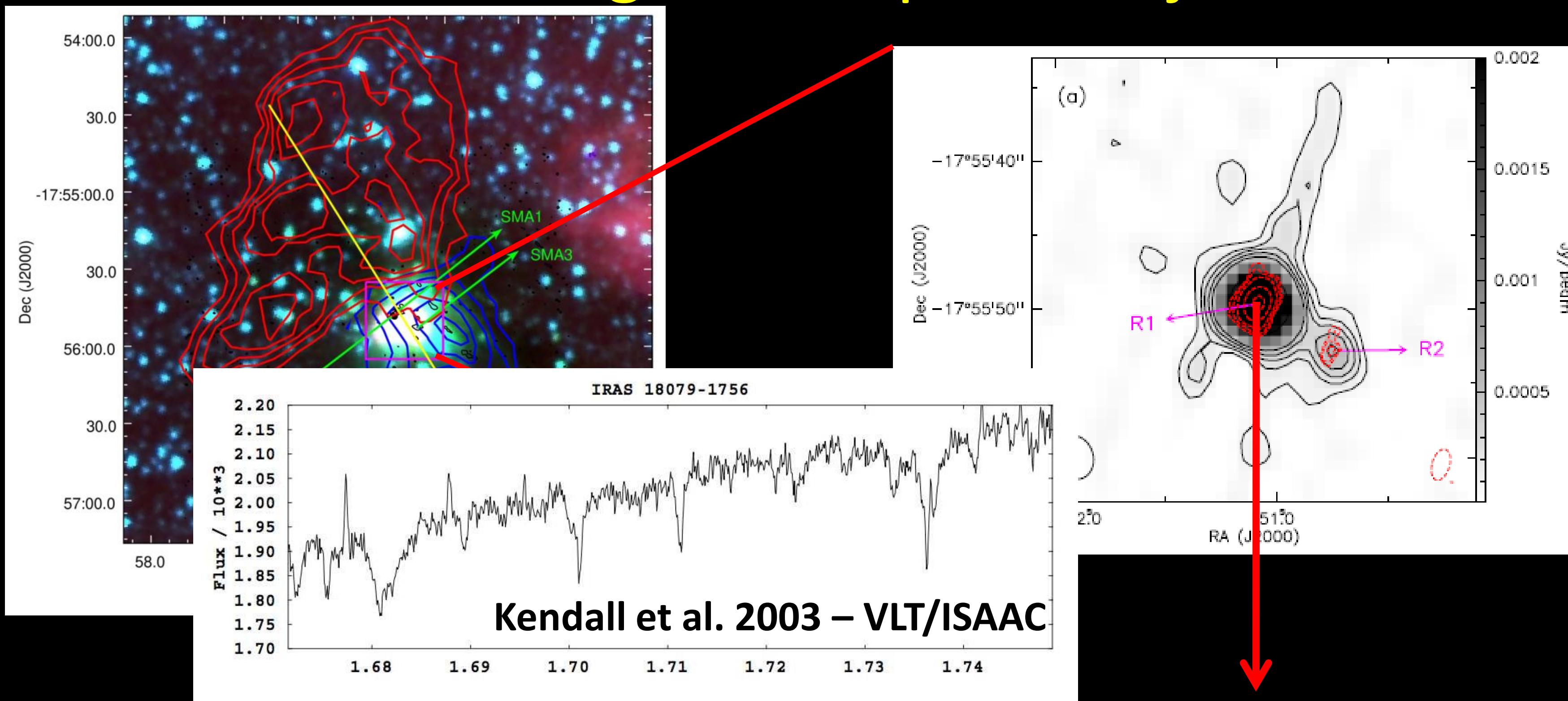
^{12}CO (3-2) emission line overlaid on the Spitzer IRAC colour composite image



Infall signature



UC HII region or a possible jet?

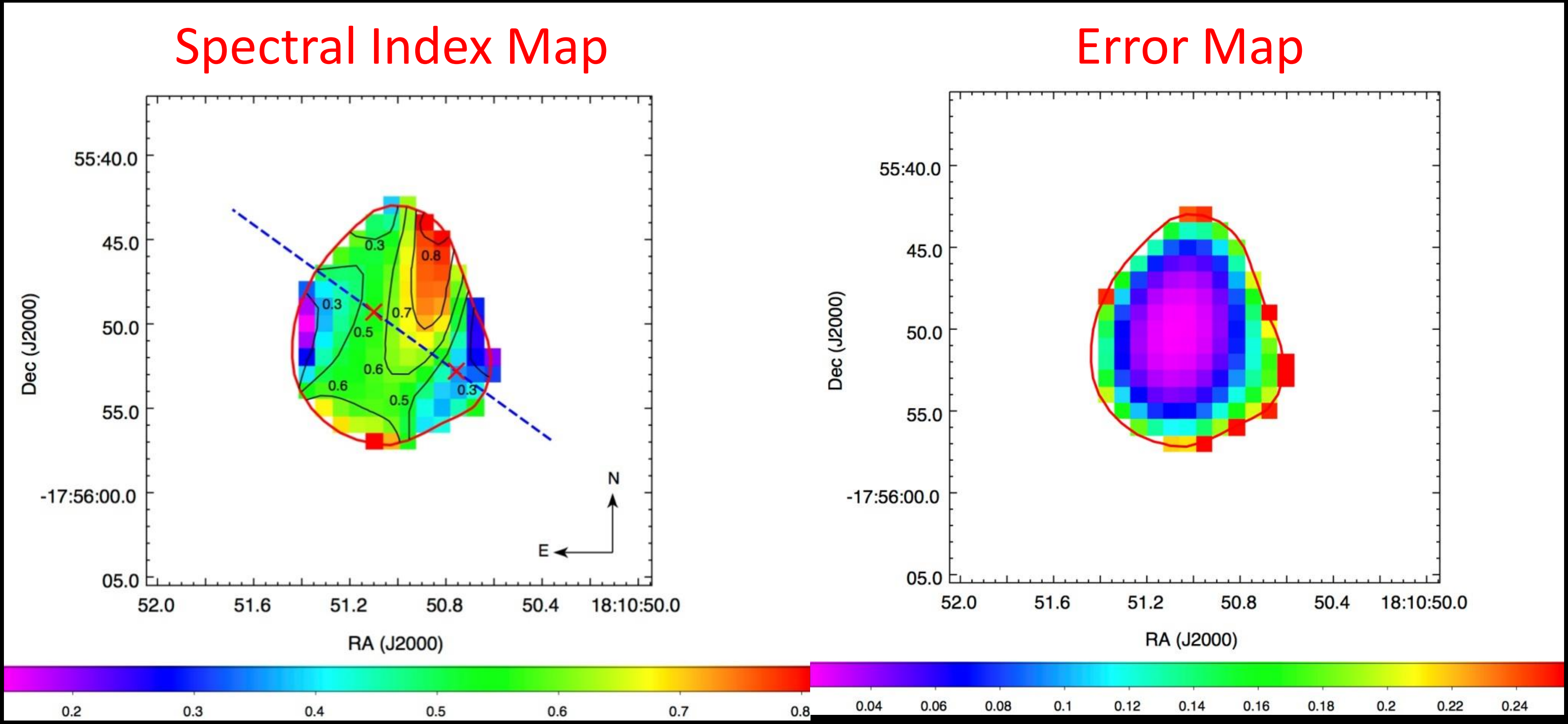


2MASS Class II YSO

J18105109-1755496; J = 13.727, H = 11.011, K = 9.351)

Spectral type from 1390 MHz: B0.5 – B1

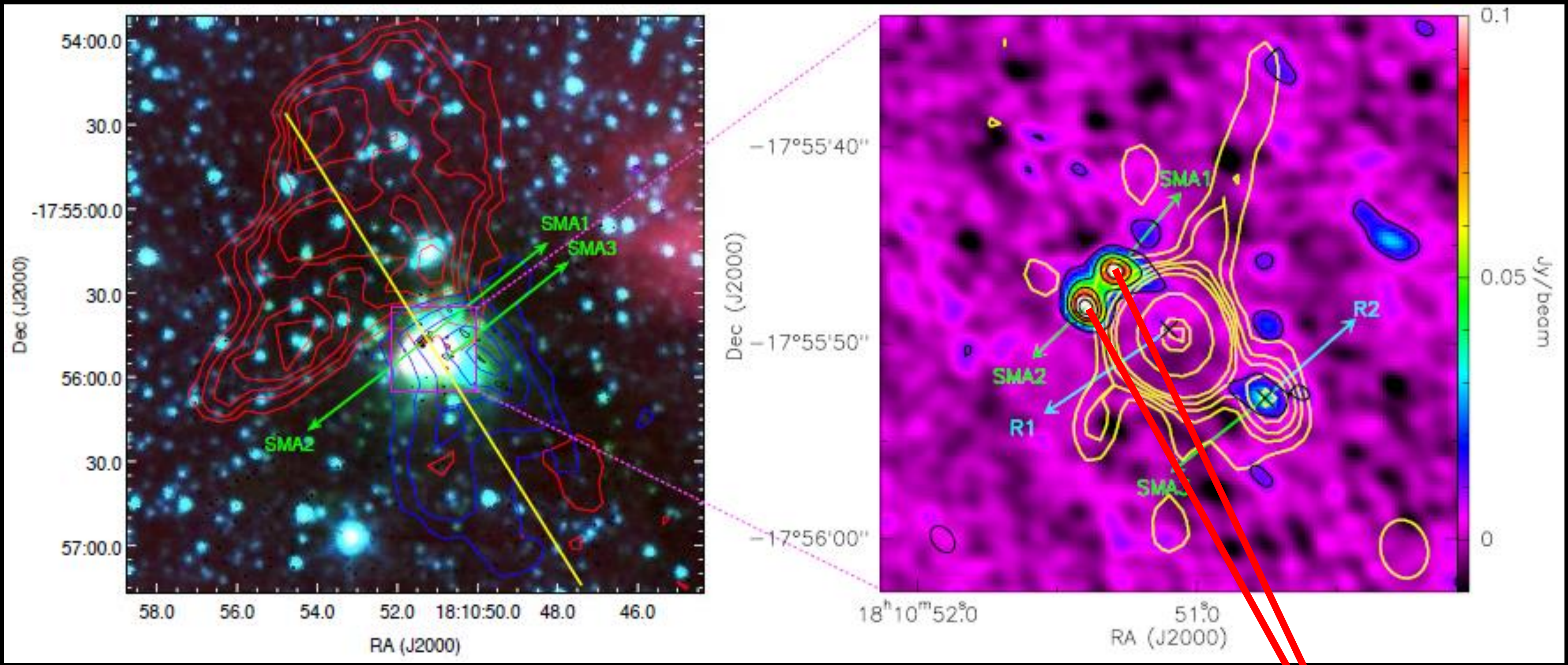
Nature of ionized emission – spectral index map



α varies between 0.3 – 0.7

Characteristic range seen in thermal jets

UC HII region or a possible jet?



High-mass cores ~20$_\odot$

In a nutshell ……

- G12.42+0.50 is associated with the outflow from a massive star possibly at a very early evolutionary stage
- NIR spectral carriers – shocked H_2
- Gas kinematics – Signatures of both outflow and infall
- Network of filaments feeding to the clump
- Possible thermal jet – YSO producing UCHII region as well as driving the thermal jet