Probing The Early Evolution of High-Mass Stars: Formation and Evolution of Massive Stars (FEMS) Project

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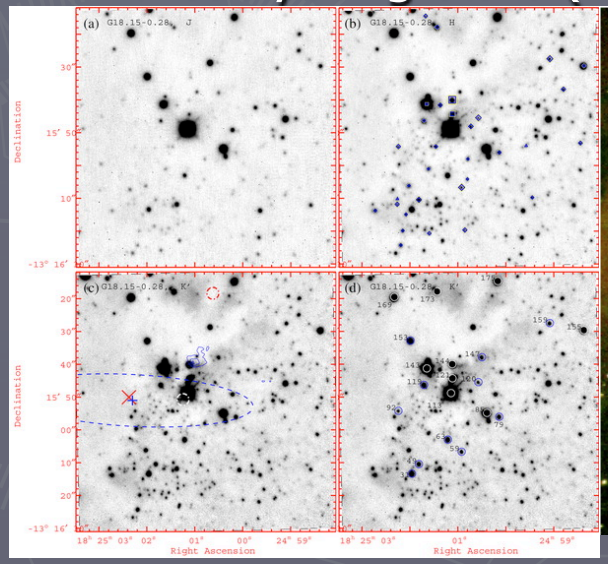
Hendrik Linz (MPIA)

Outline

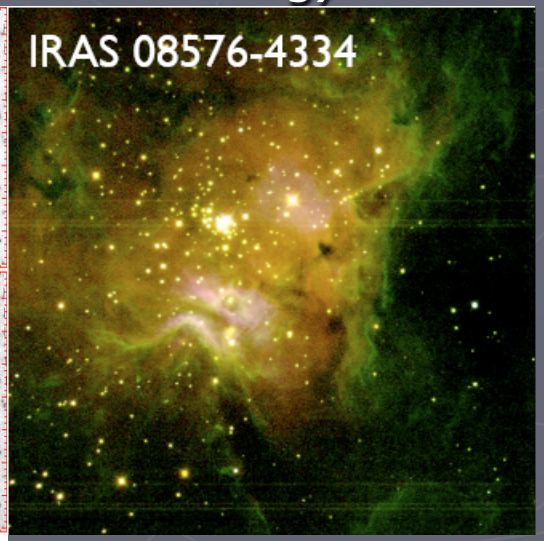
- Motivation
- The NIR window: past and present
- FEMS: Multi-wavelength Approach
- On-going NIR VLT Pilot Study
- First SINFONI results
  - IRAS 08563-4711
  - IRAS 06084-0611 (G12-14)
  - IRAS 06058+2138 (AFGL 5180, S247)
- Present and Future for FEMS

Motivation

- High-mass Star Formation is observed in Cluster Mode:
  - NIR surveys of UCHIIs revealed presence of stellar clusters
    - Bik PhD Thesis 2004, Kaper et al. in prep: 75% stellar clusters (50% associated with the UCHII region)
    - Blum et al. 1999-2005
    - Birkmann et al. private communication: 80% stellar clusters close to IRDC
    - Alvarez et al. 2004; Puga et al. 2006
- NIR is the only window to access the photospheric component of these young stars (A~30-40 mag)



Alvarez et al. 2004

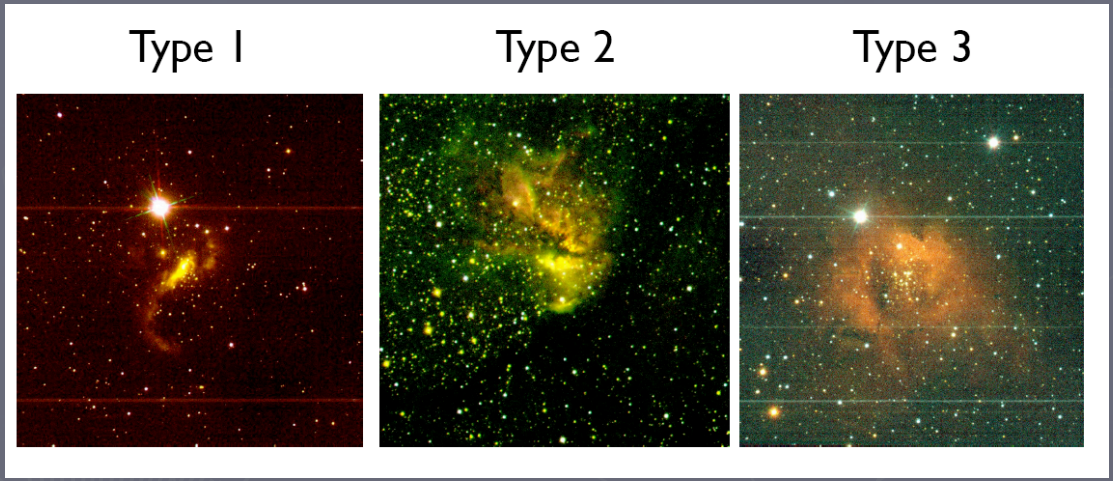


Kaper et al. In preparation

~ 100 stars

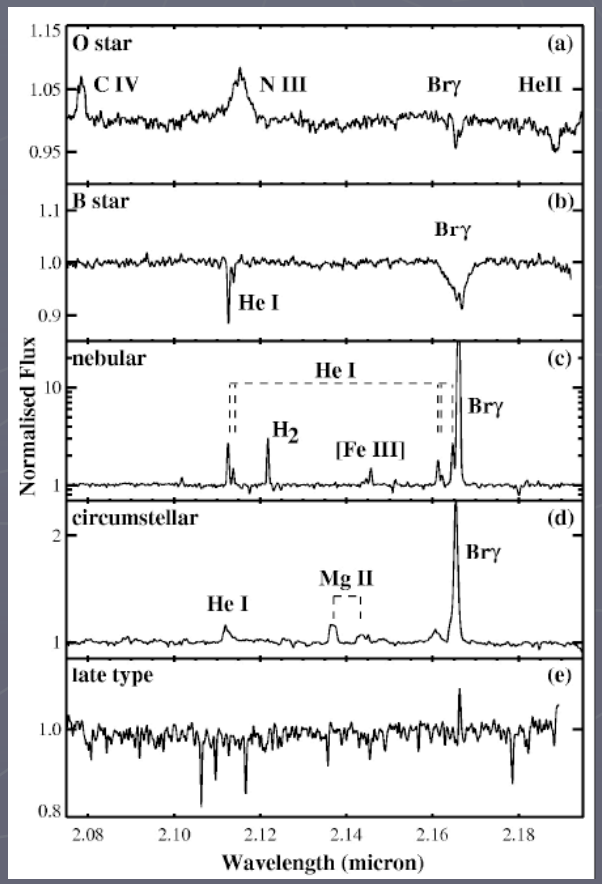
NIR Studies Have Opened a Treasure Box

- Morphologies (Imaging)



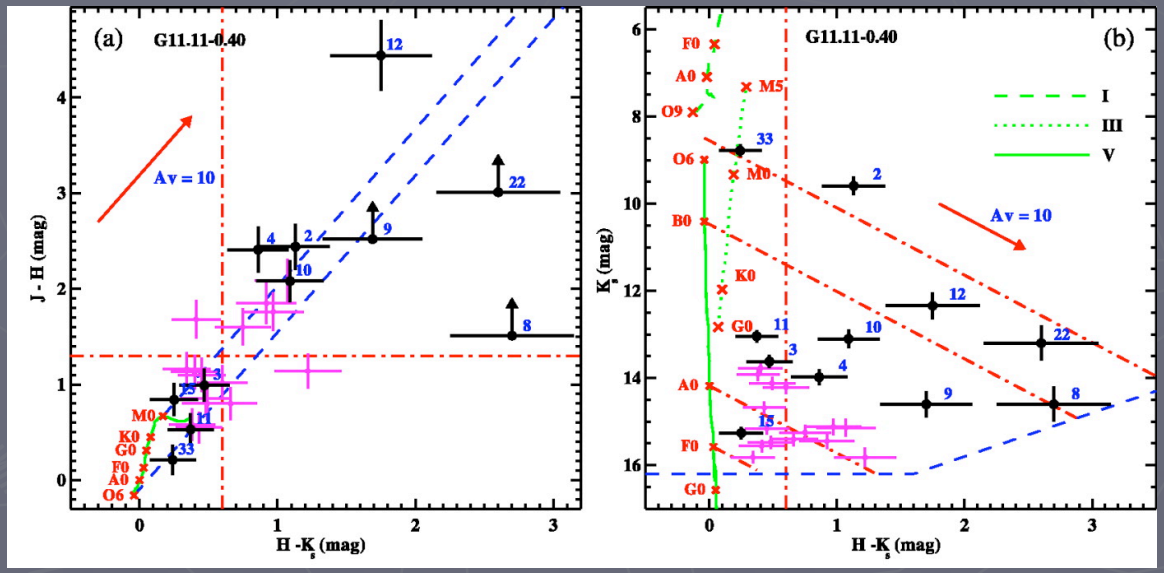
- Classification of stellar content (Spectroscopy)
  - Naked OB stars
  - YSOs
  - Nebula-dominated counterparts to UCHIIs

Bik et al. 2006



Traditional Imaging+Long Slit Spectroscopy

- Selection of the candidates is biased (CMD and CCD)



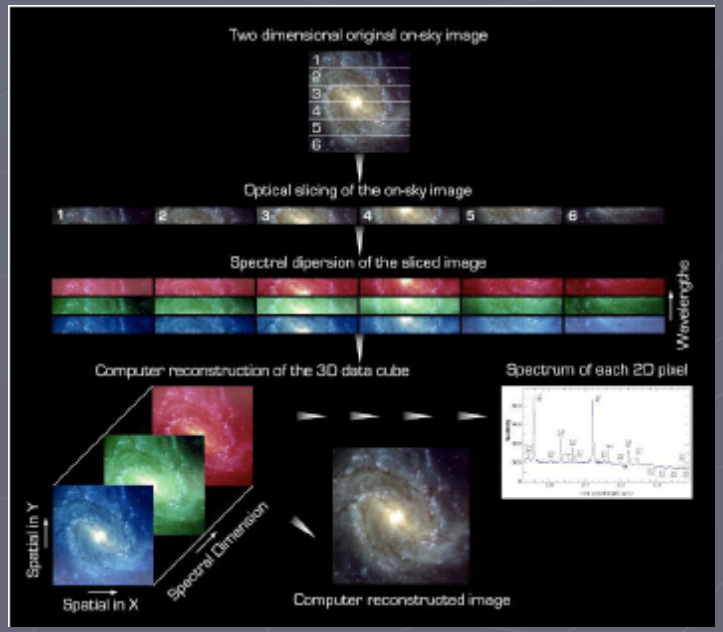
From Alvarez et al. 2004

- Fundamental parameters rely on indirect observations (radio, FIR) with different spatial resolutions and are model dependent.
- Long-slit spectroscopy is not efficient; completeness is seldom

NIR Integral Field Spectroscopy

- Near-IR IF Spectroscopy provides an unbiased picture of the stellar content of young SF regions
- Simultaneous information about the nebular component

SINFONI BRINGS SIMULTANEOUS SPATIAL AND SPECTRAL INFORMATION



Moderate Spectral Resolution H+K ~ 1500

Motivation

FEMS: Multidisciplinary Group in order to obtain a full picture of HMSF regions

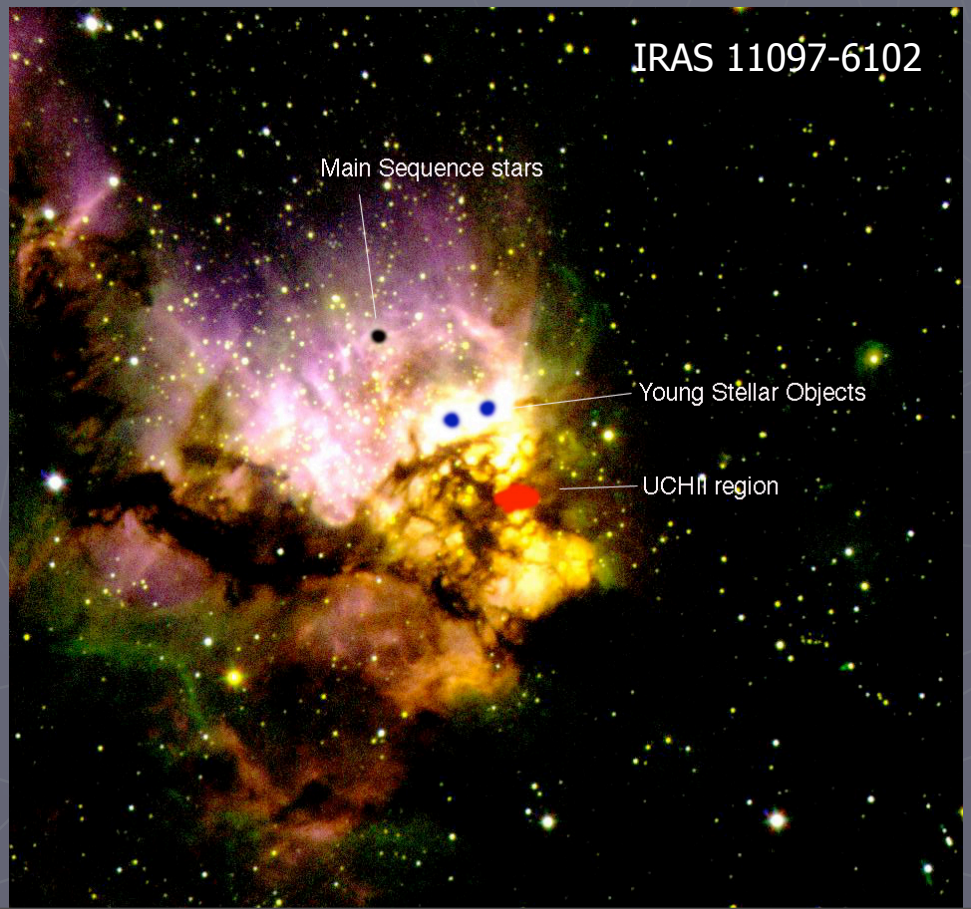
Answers to the questions…..

What is there?
What is where?
What affects what?

- Full census of the stellar and YSO content and how it is spatially distributed
- Detection of deeply embedded objects (earliest phases of SF)
- Determination of stellar parameters (Teff, log g, v sin i?)
- Interplay (Outflows, disk fraction)
- Characterisation of the nebula (Extinction, HII region, PDR)
- Clusters IMF
- Relics of the SF process
- Impact on the environment

But a Complete Picture Needs a Multi-wavelength Approach….

- Near-IR SINFONI
- Mid-IR Spitzer(GLIMPSE+MIPSGAL)+VISIR
- Radio (VLA, mm)



VLT Pilot Study

VLT proposal P78 got 50 hours of SINFONI AS PROOF OF CONCEPT

Cluster Sample: 8 regions from Bik PhD Thesis, 2004 (NTT+ISAAC)

- IRAS colours of UCHII region
- UC radio source detected in Wood & Churchwell 1989, Kurtz et al. 1994, Walsh et al. 1998
- Detected in CS (2-1) by Bronfman et al. 1996

Covers a wide parameter space in

- Luminosities
- Distances
- Morphologies

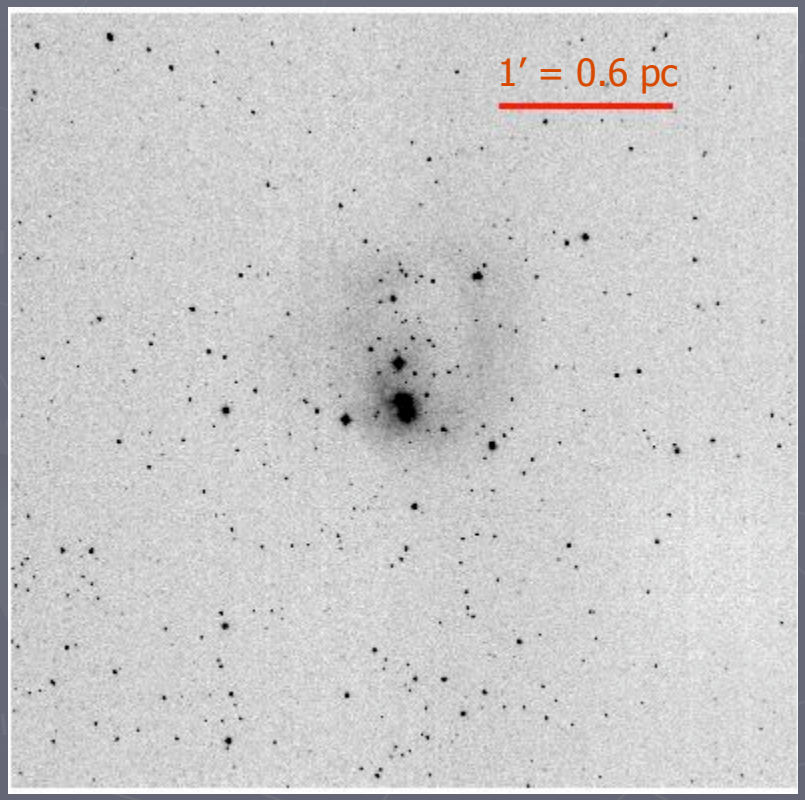
First Results of VLT(SINFONI) Pilot Study: I

IRAS 08563-4711

Located d~2 kpc in the Vela Molecular Ridge

No UCHII detected, no methanol maser emission

Log(L_{IRAS})=4.5 Spectral Type B0.5V



SOFI@NTT NB_2.090 $\Delta\lambda$=0.020 μm

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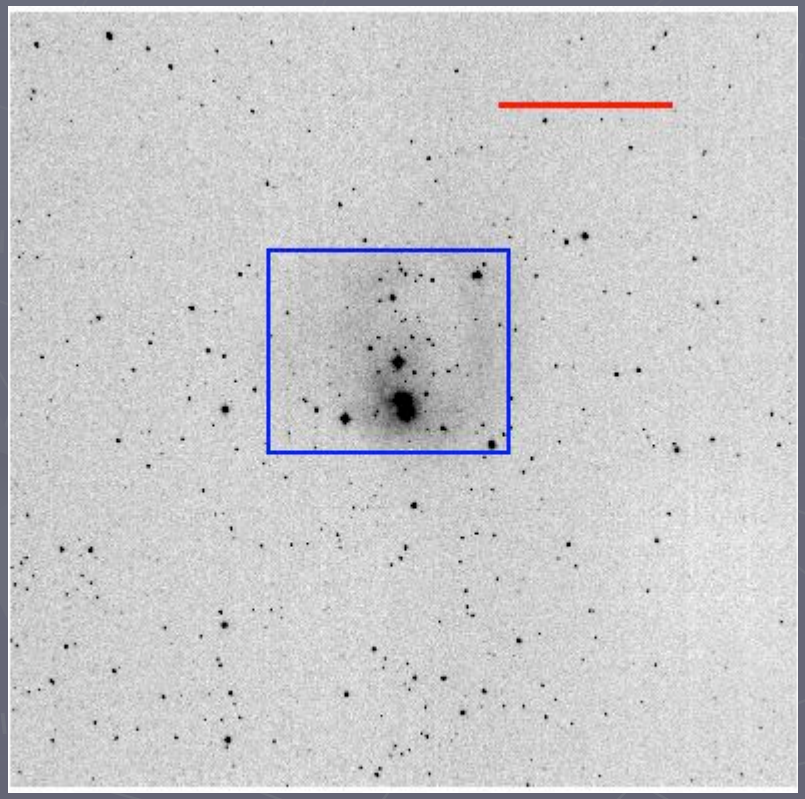

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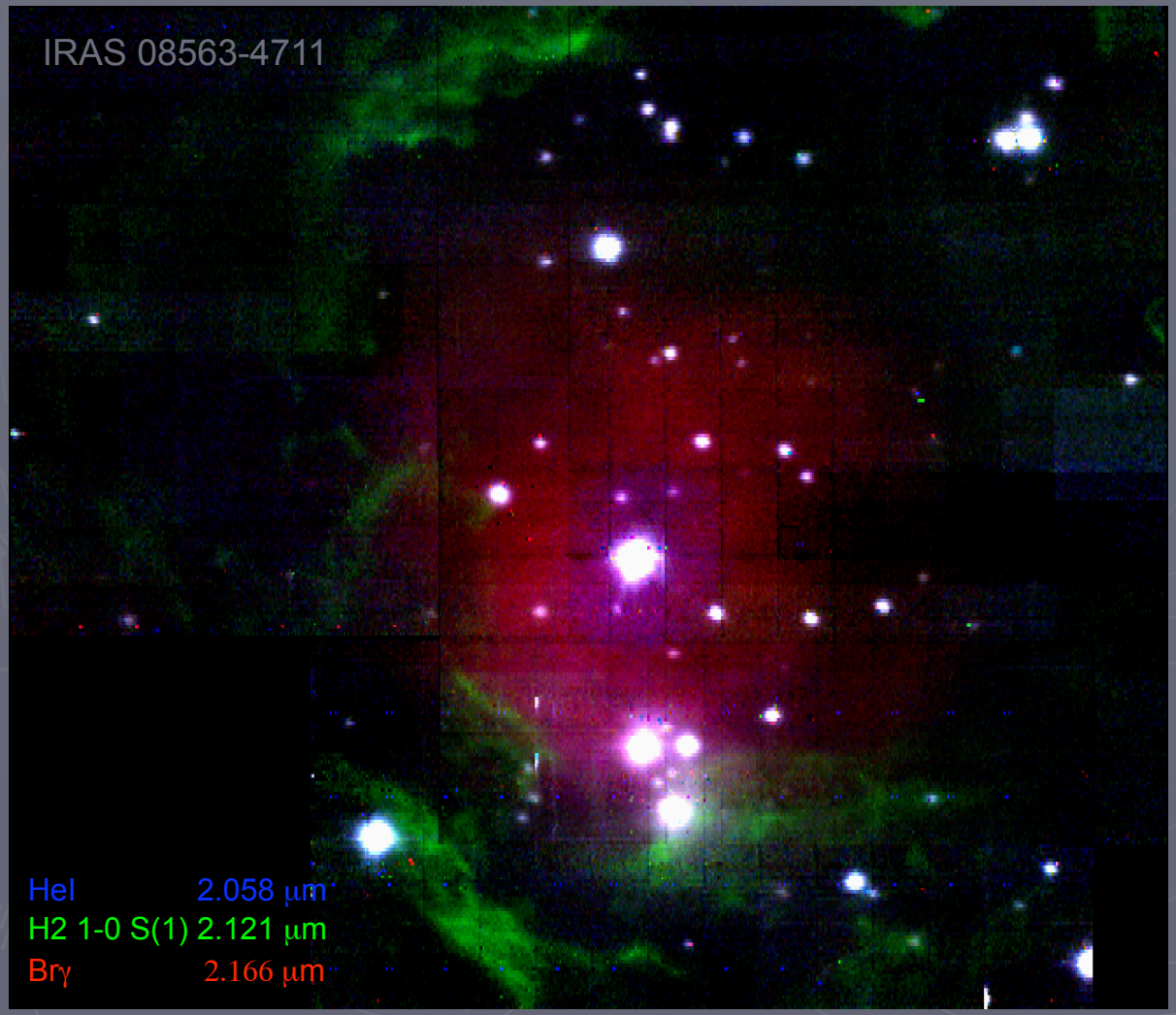
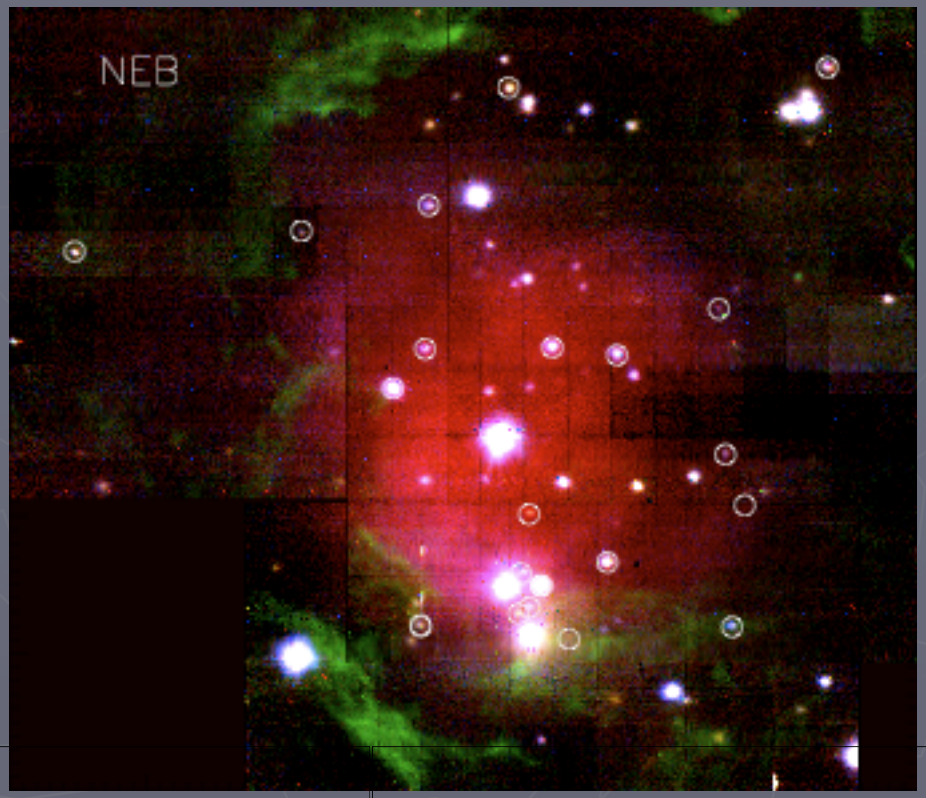
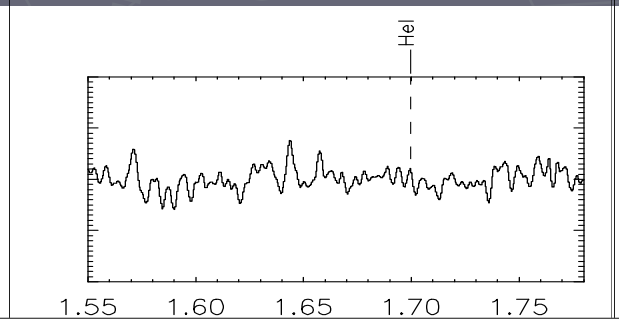


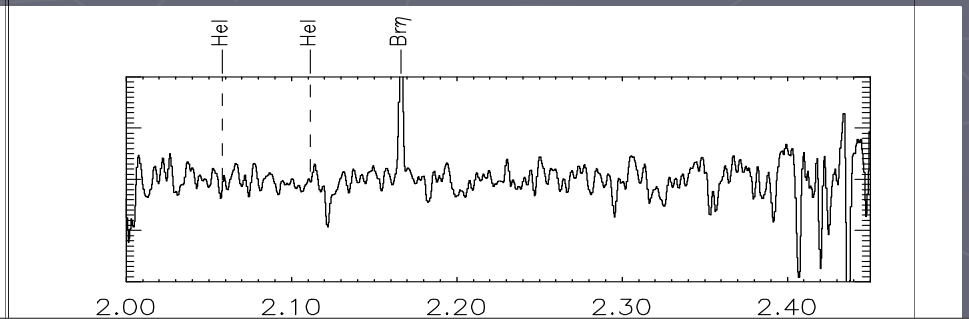
4 nights of ISAAC
=
6hr SINFONI

73 stellar spectra extracted!!!

Spatial Distribution of Stellar Content







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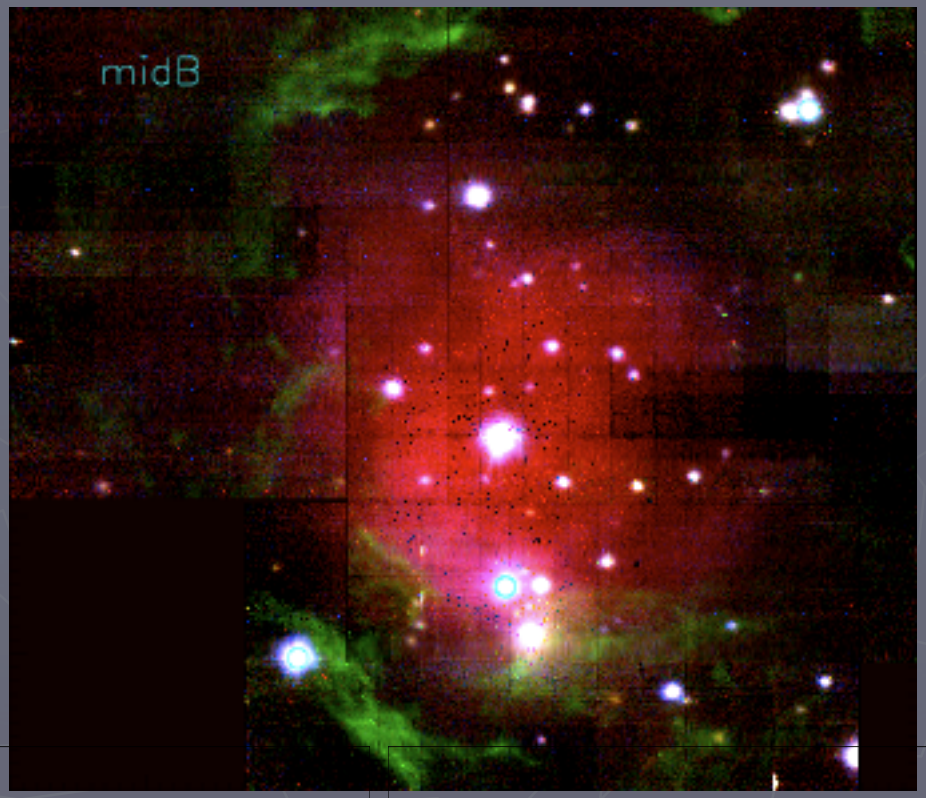

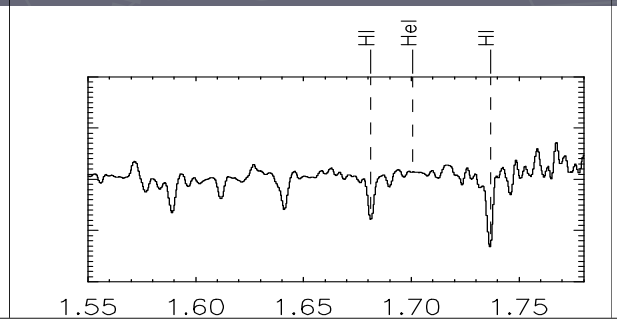

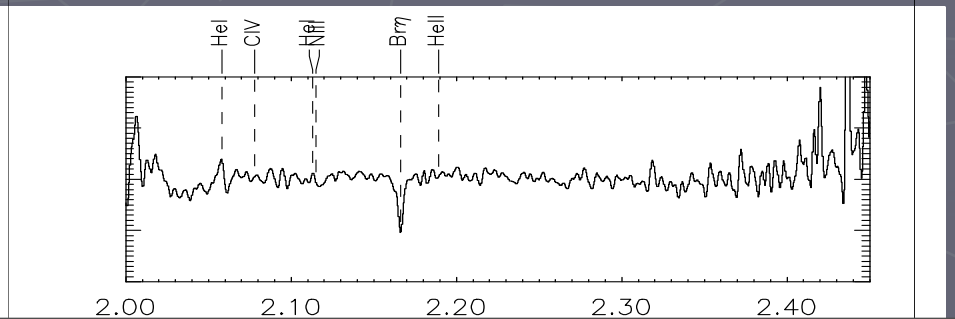

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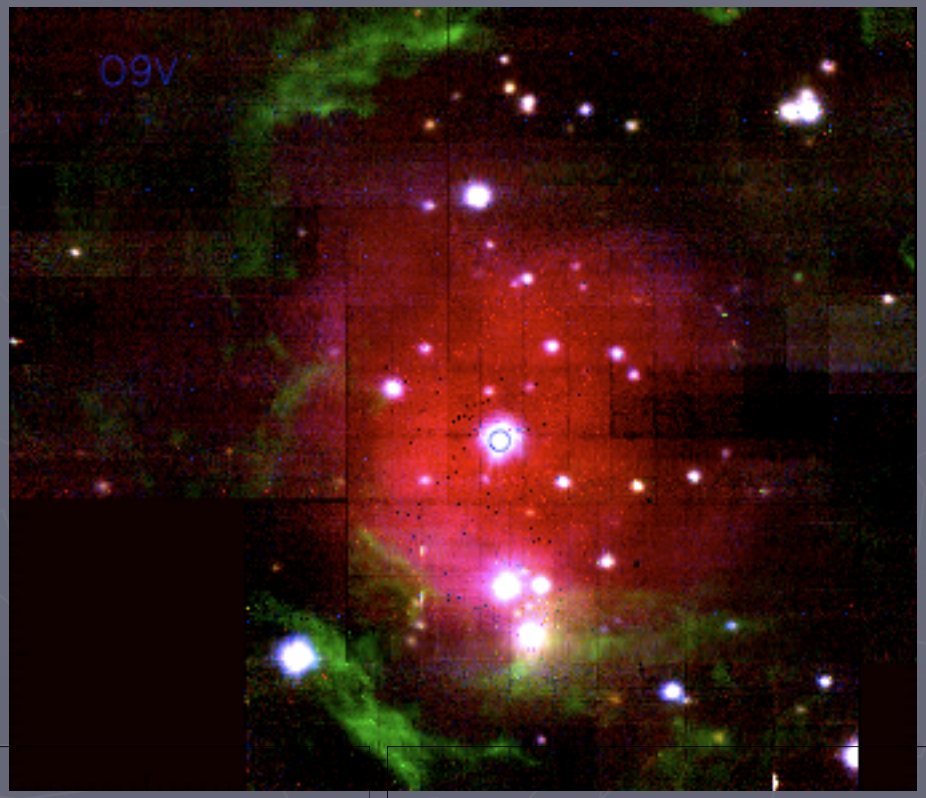

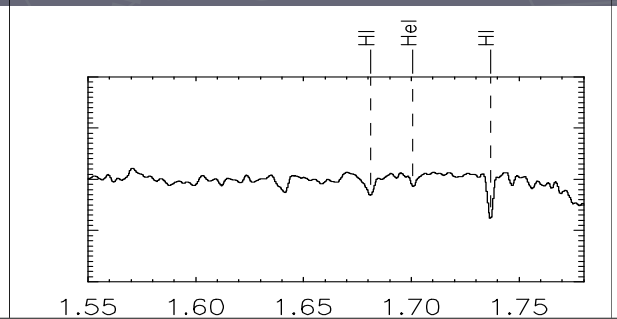

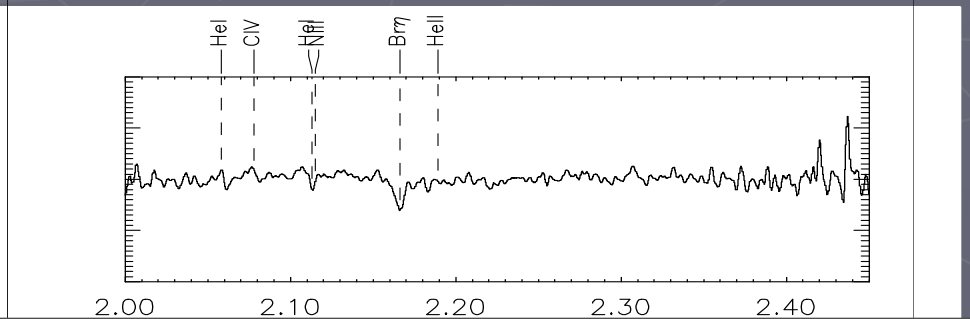

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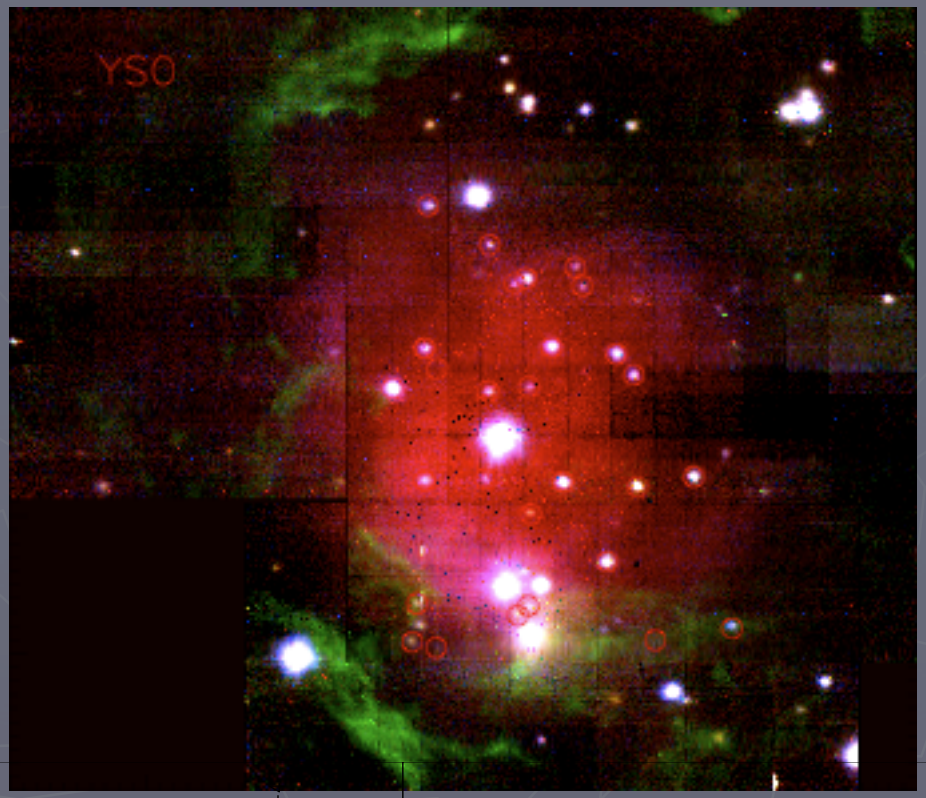

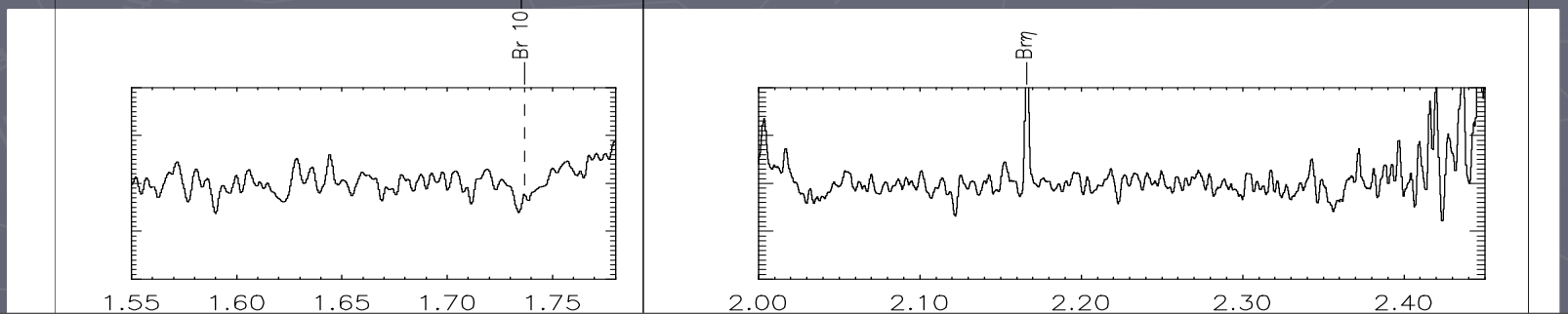

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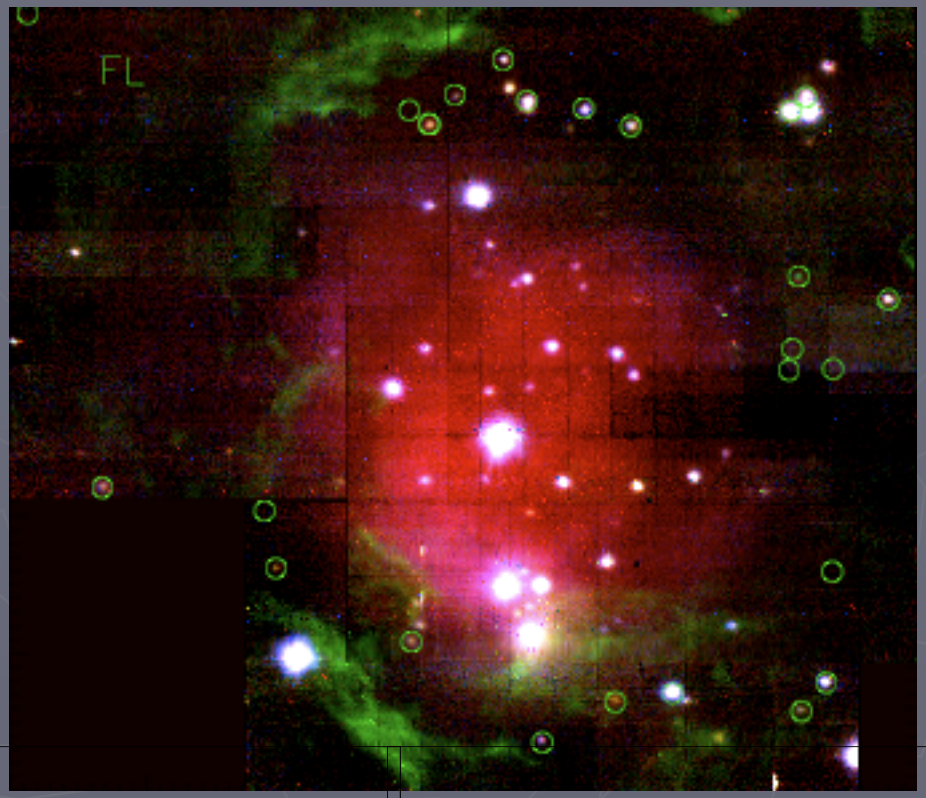

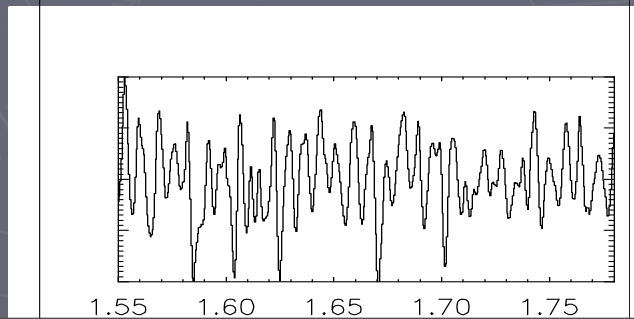

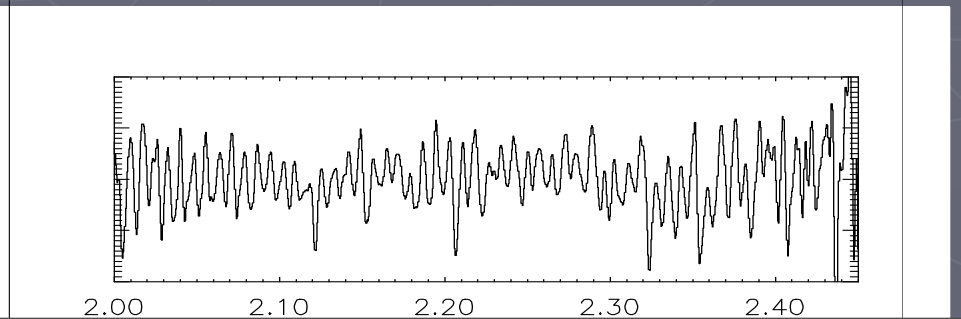

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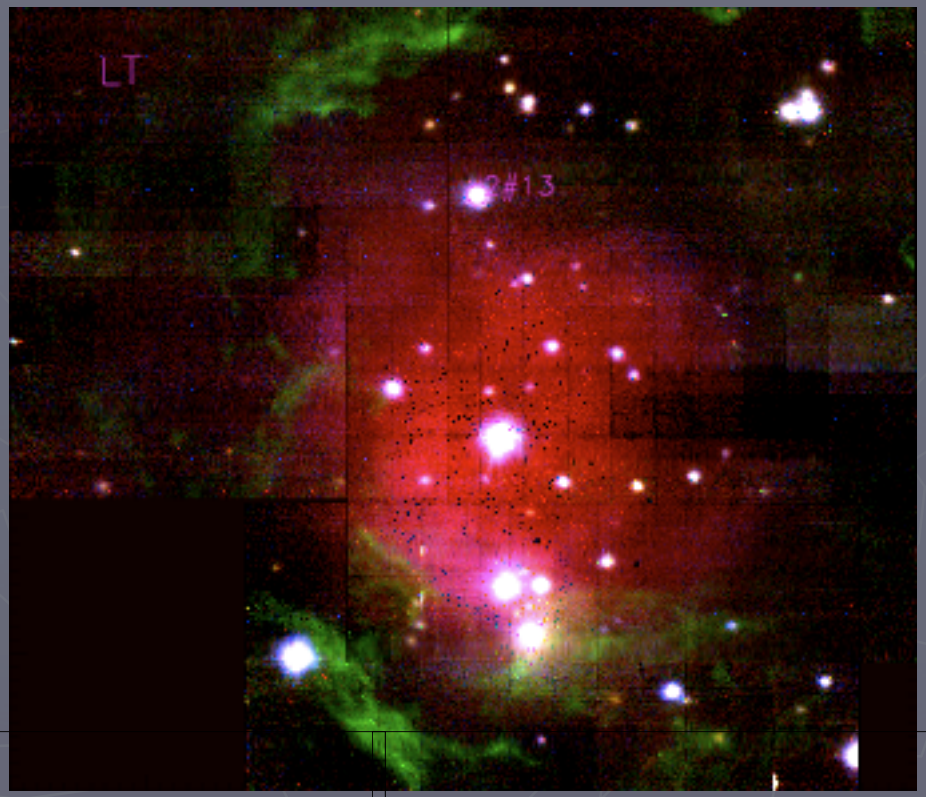
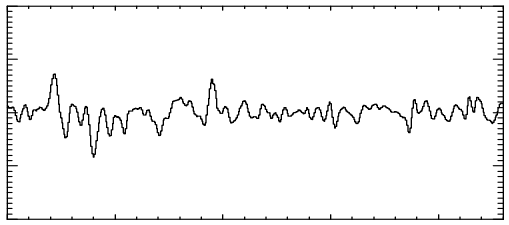
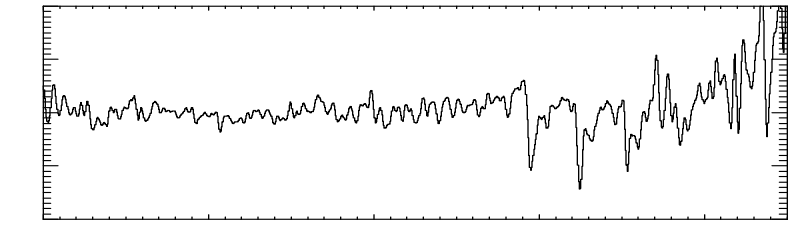
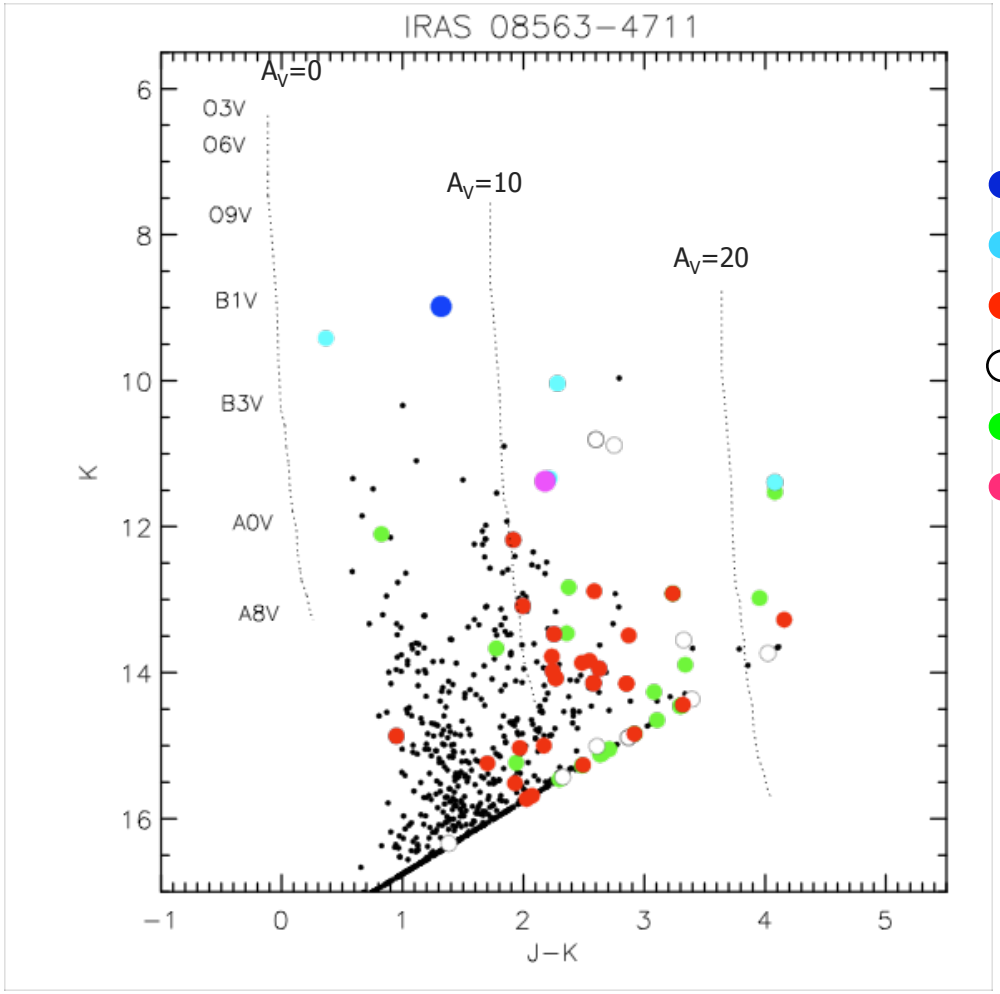






SOFI CMD with classified objects



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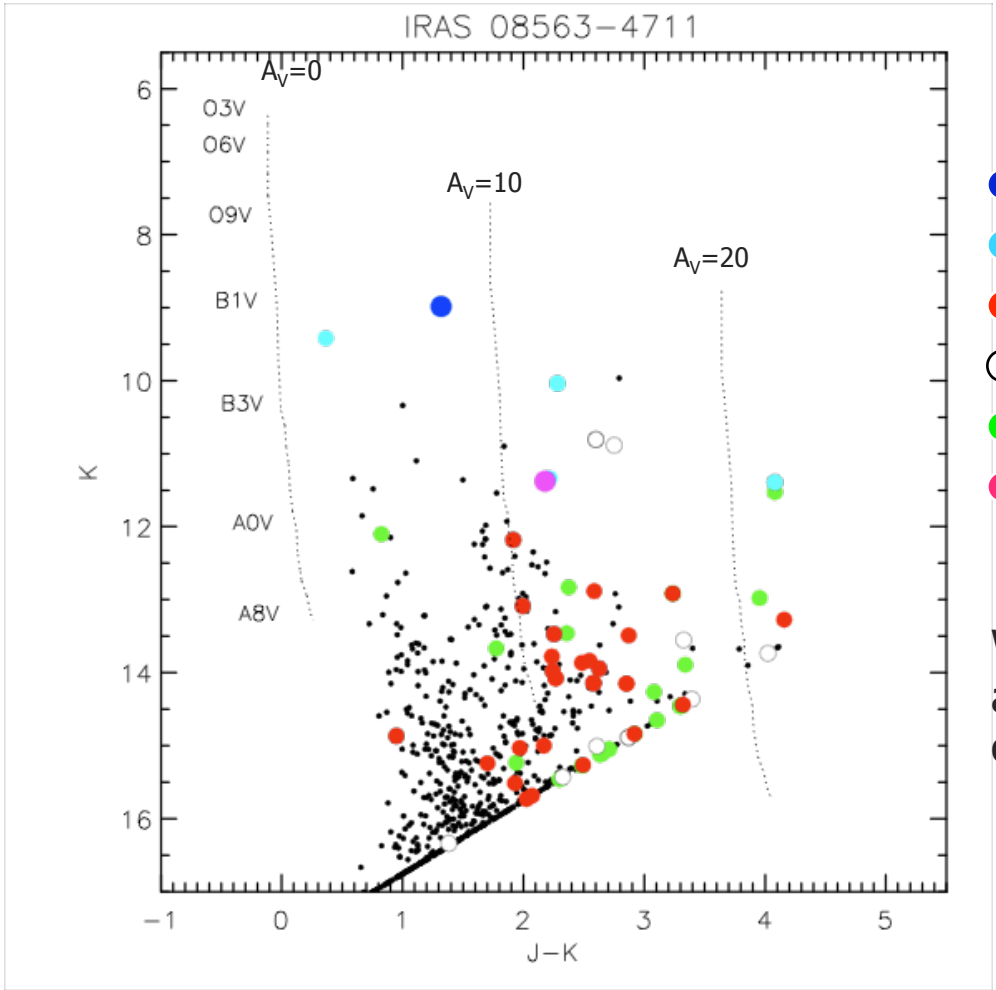


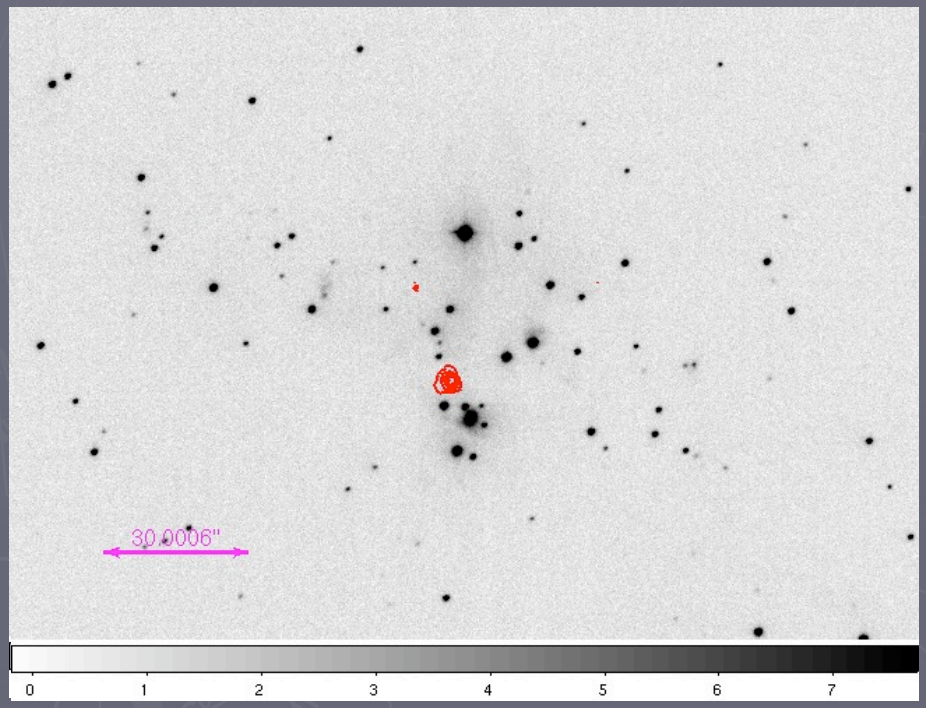
- O9V
- midB
- YSO
- nebular
- featureless
- Late Type

We go as deep as previous SOFI observations!!!

First Results of VLT(SINFONI) Pilot Study: II

IRAS 06084-0611

SOFI@NTT NB_2.090 $\Delta\lambda$=0.020 μm



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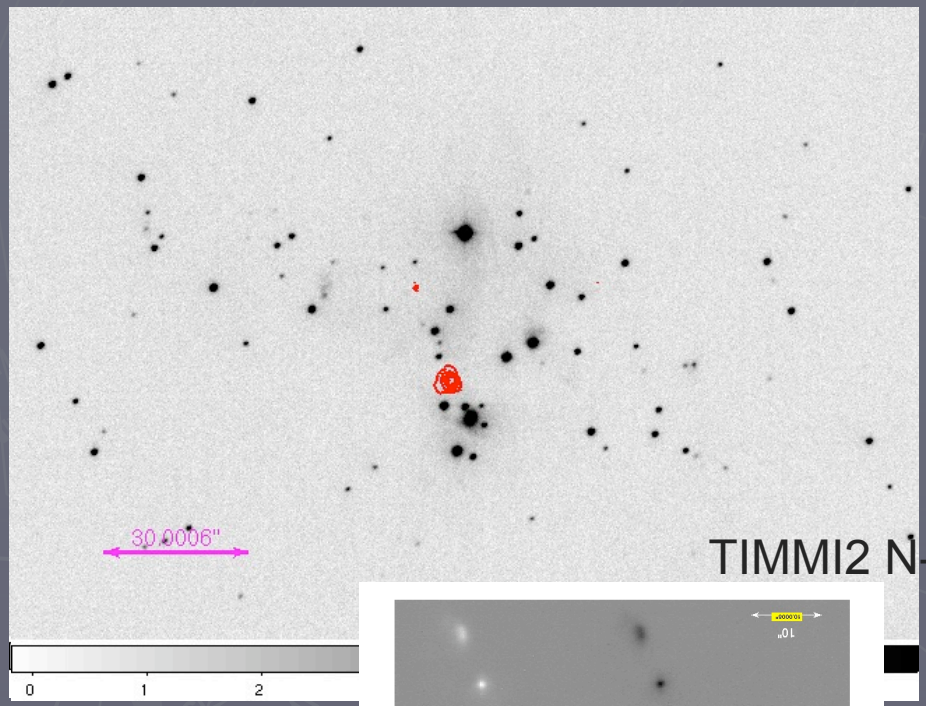
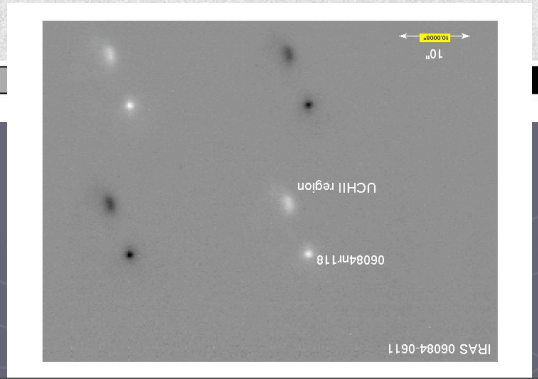


TIMMI2 N-band



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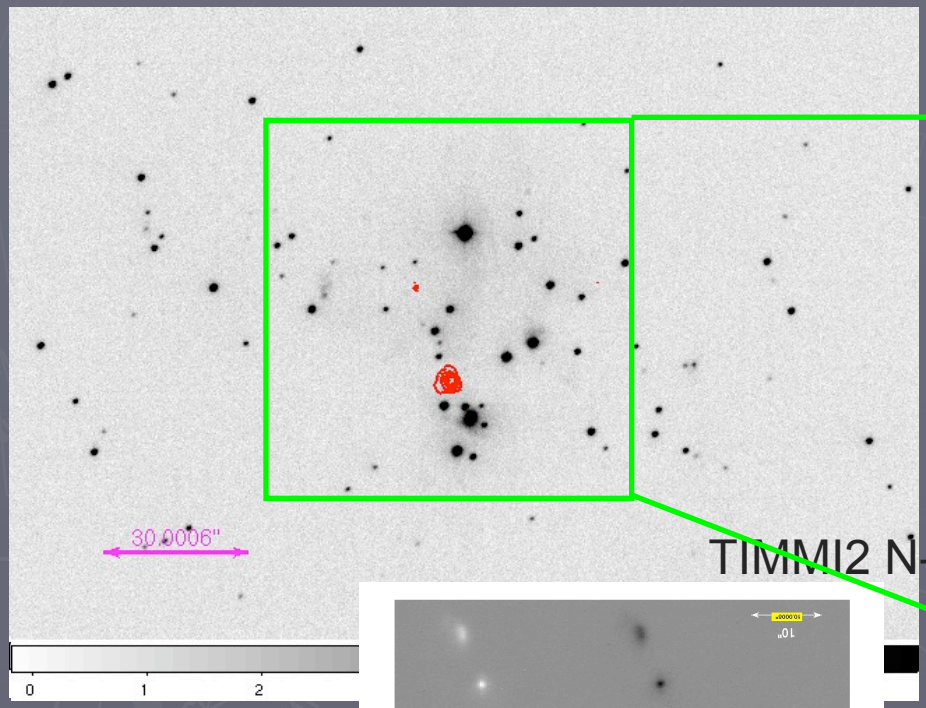

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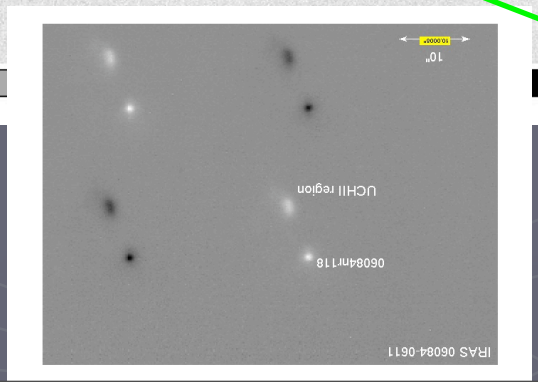

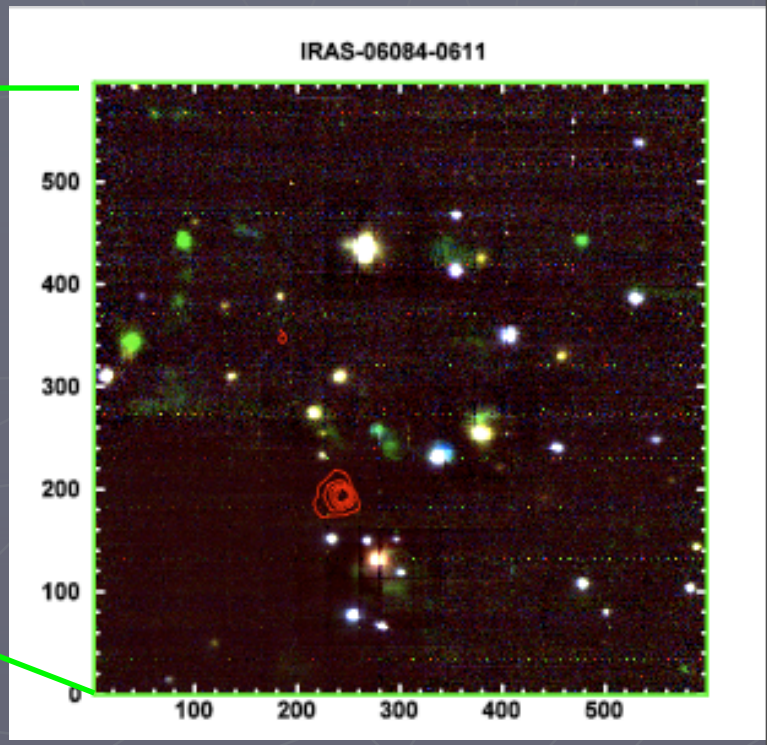

[FeII] 1.644 μm
H2 1-0 S(1) 2.121 μm
Brγ 2.166 μm

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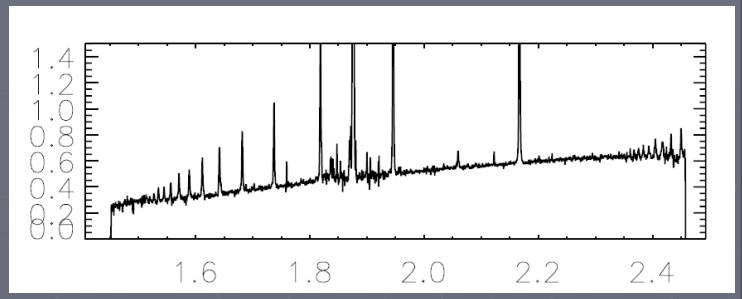

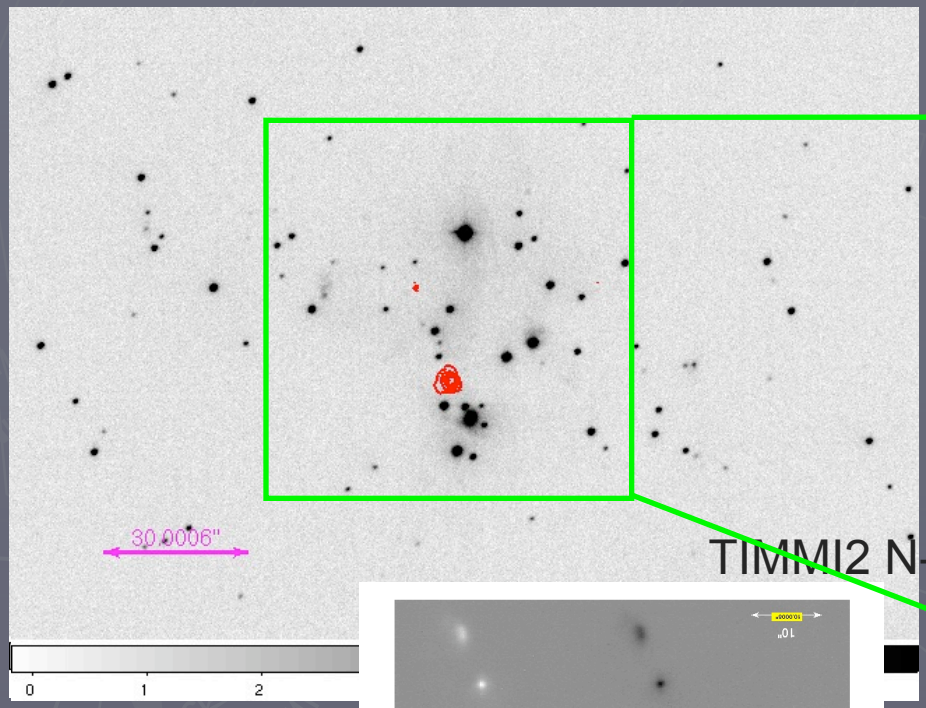

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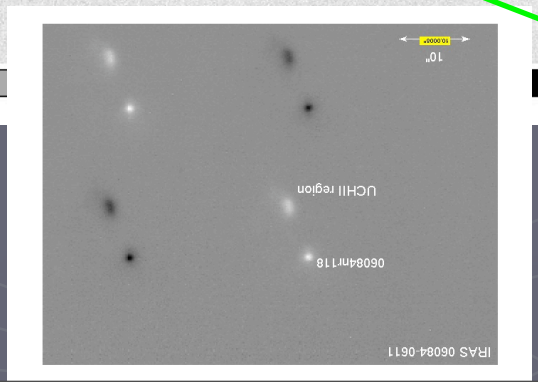

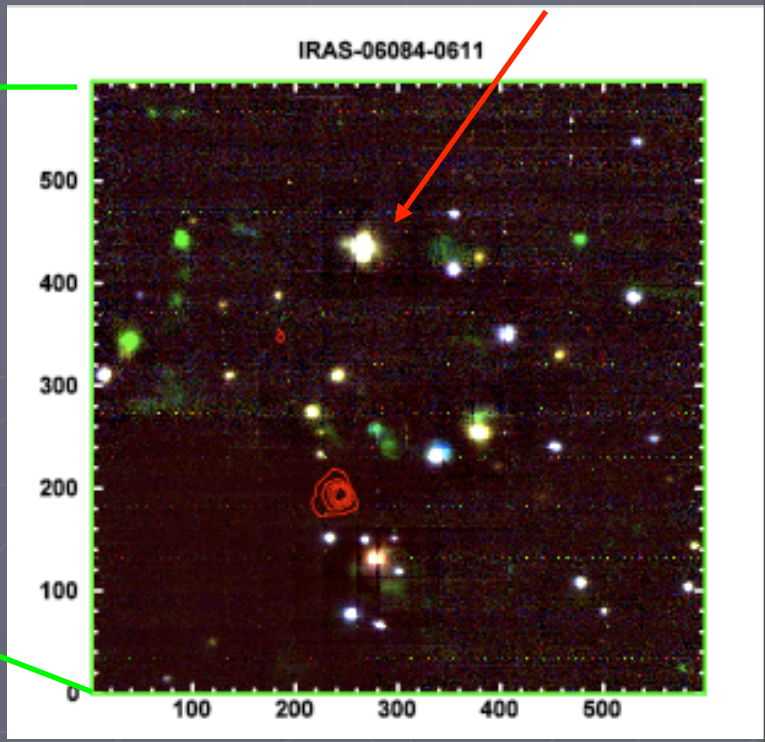

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Outflows

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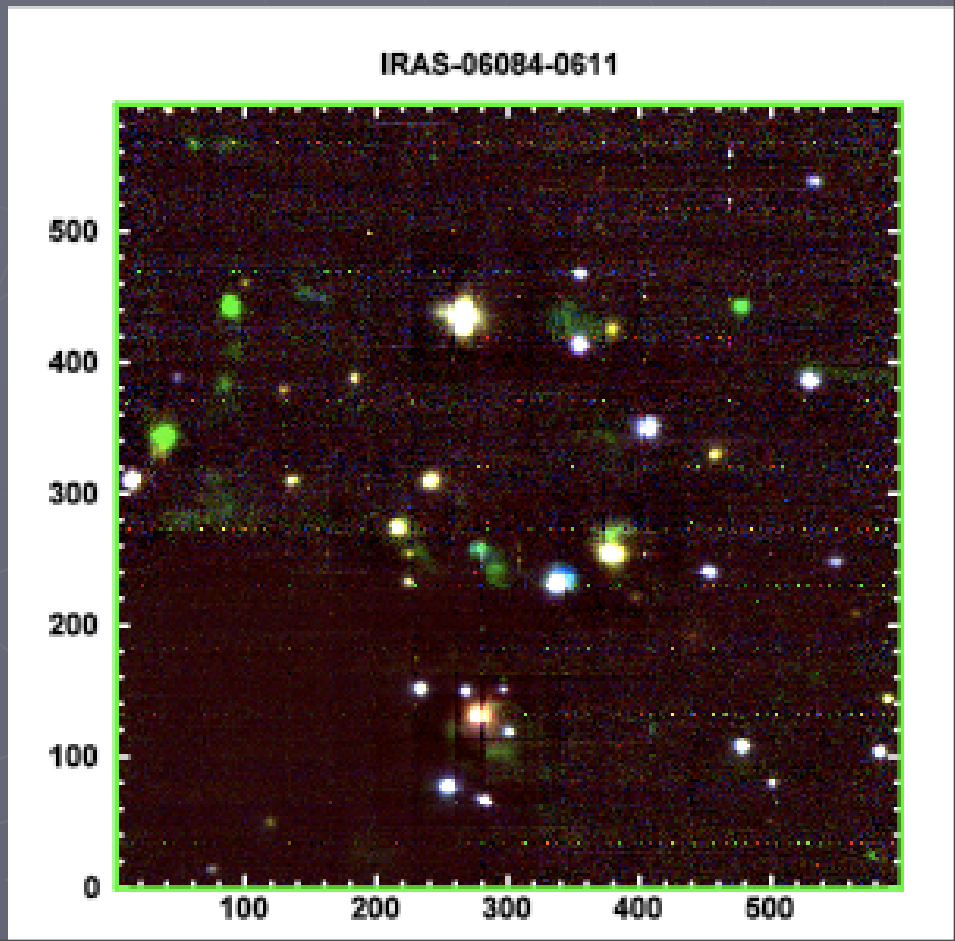

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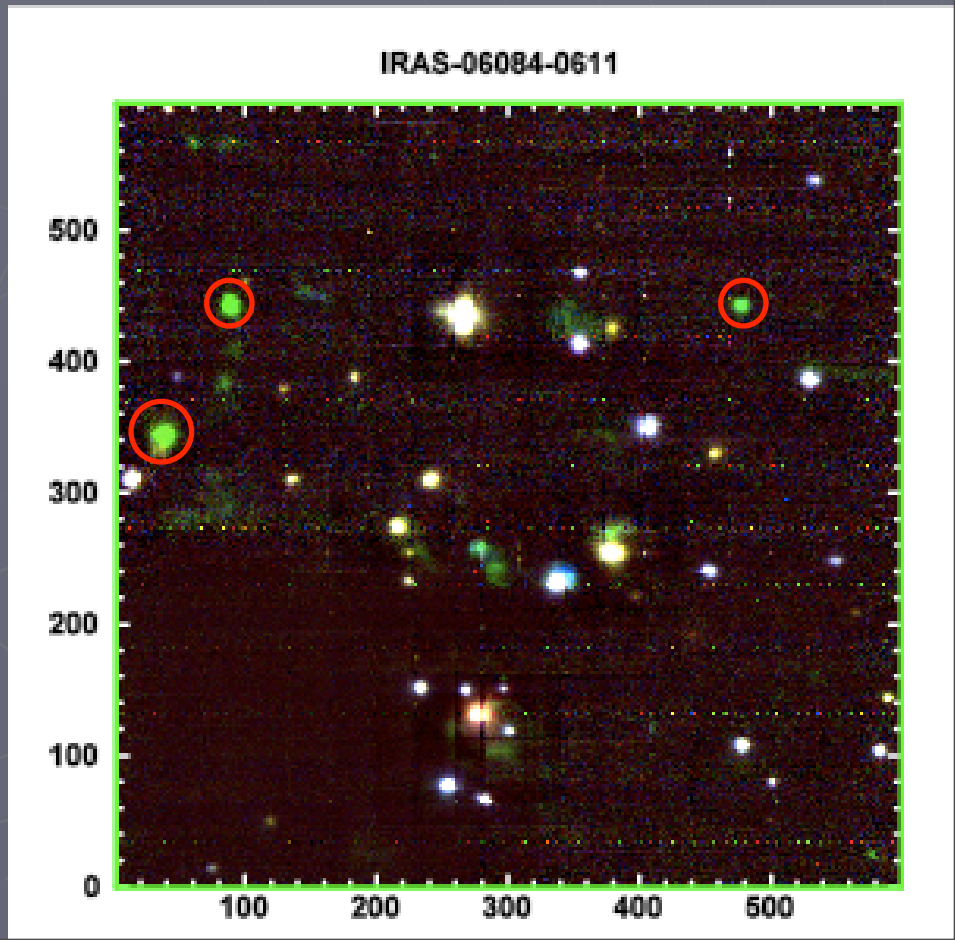

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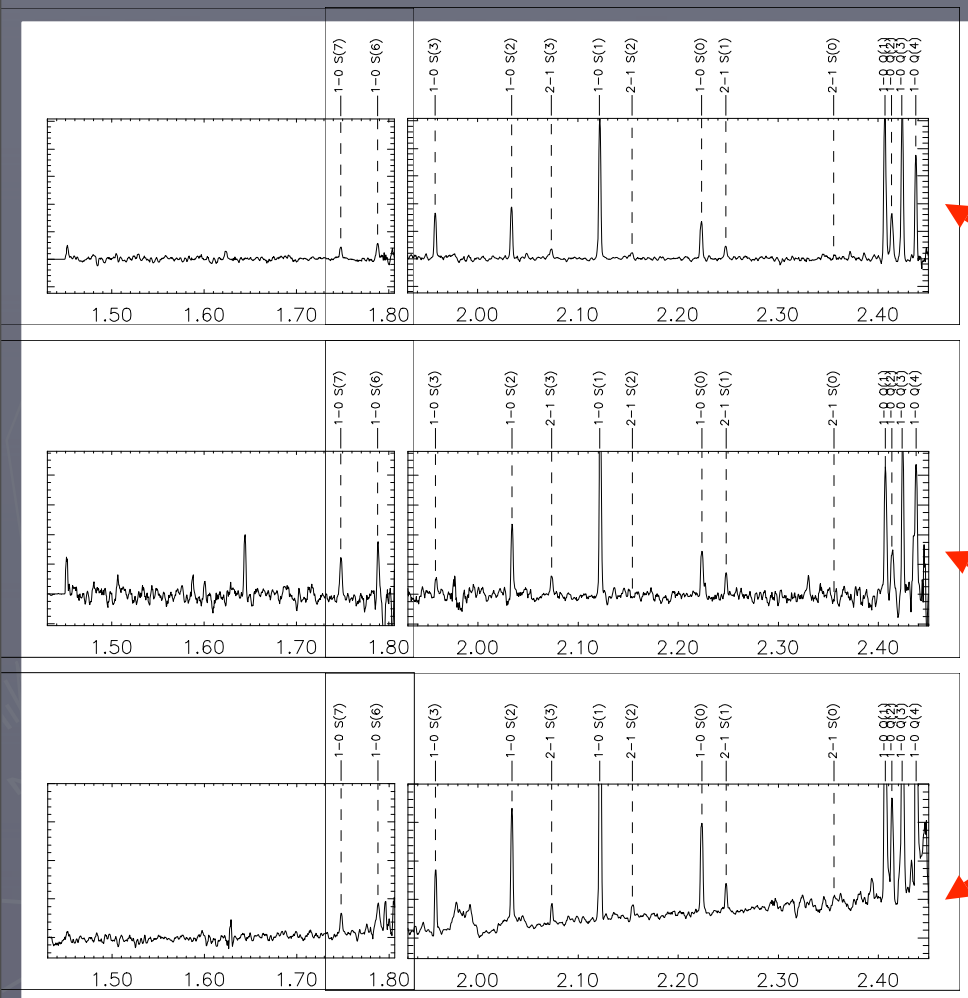

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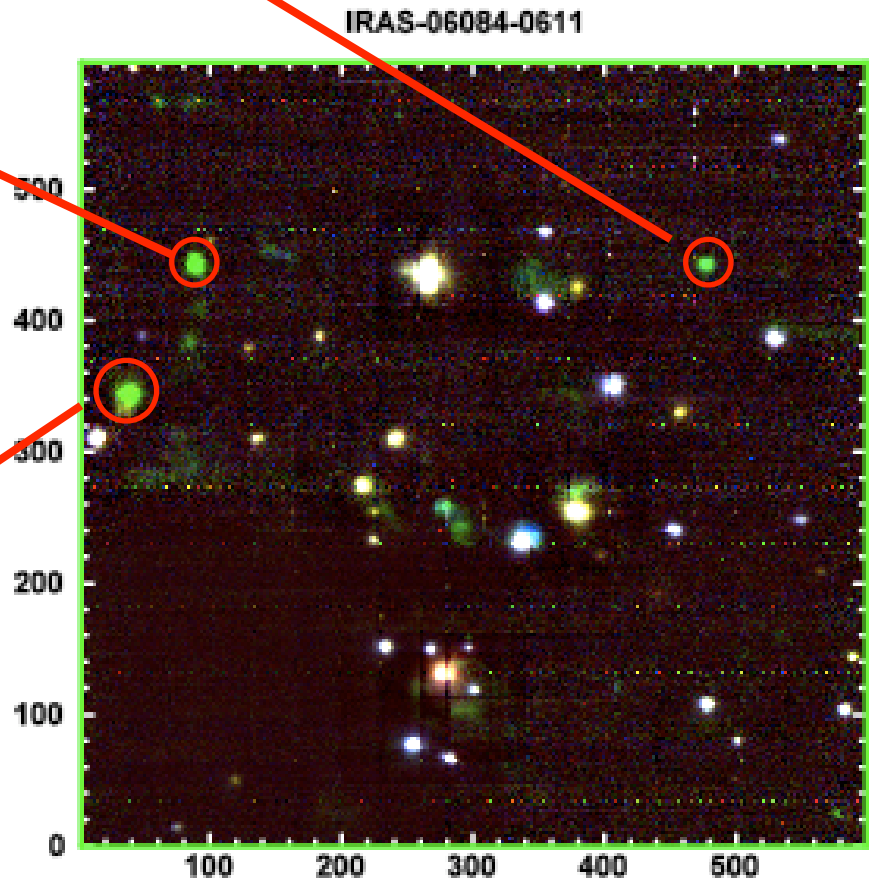
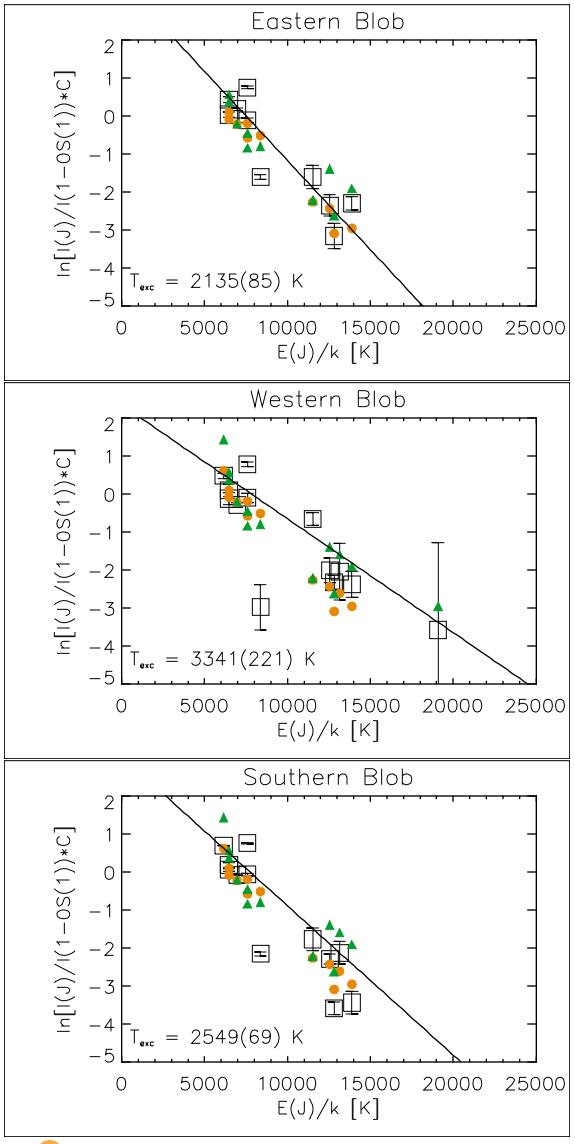


Line Ratios v= 1 – 0 {S(1), Q(3)}
{S(0), Q(2)}

Av~7 mag

Outflows



Shocks (LTE)

Fluorescence (n~10^6 cm^{-3})

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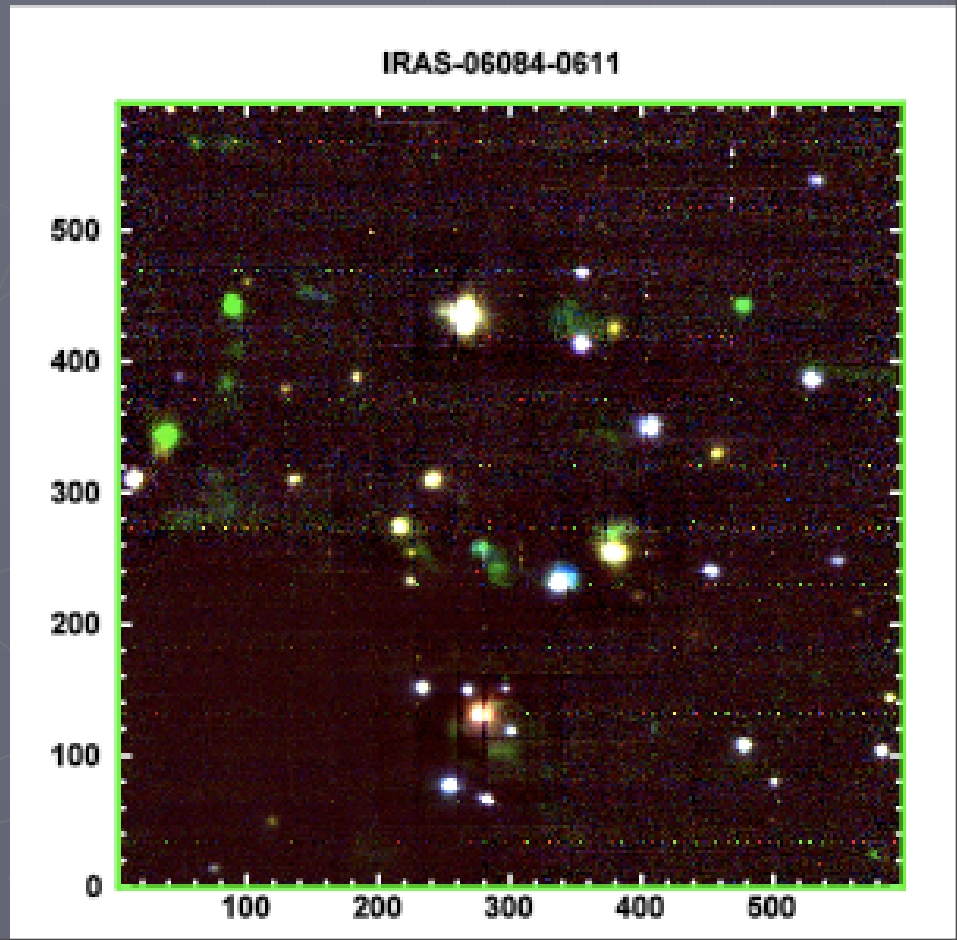
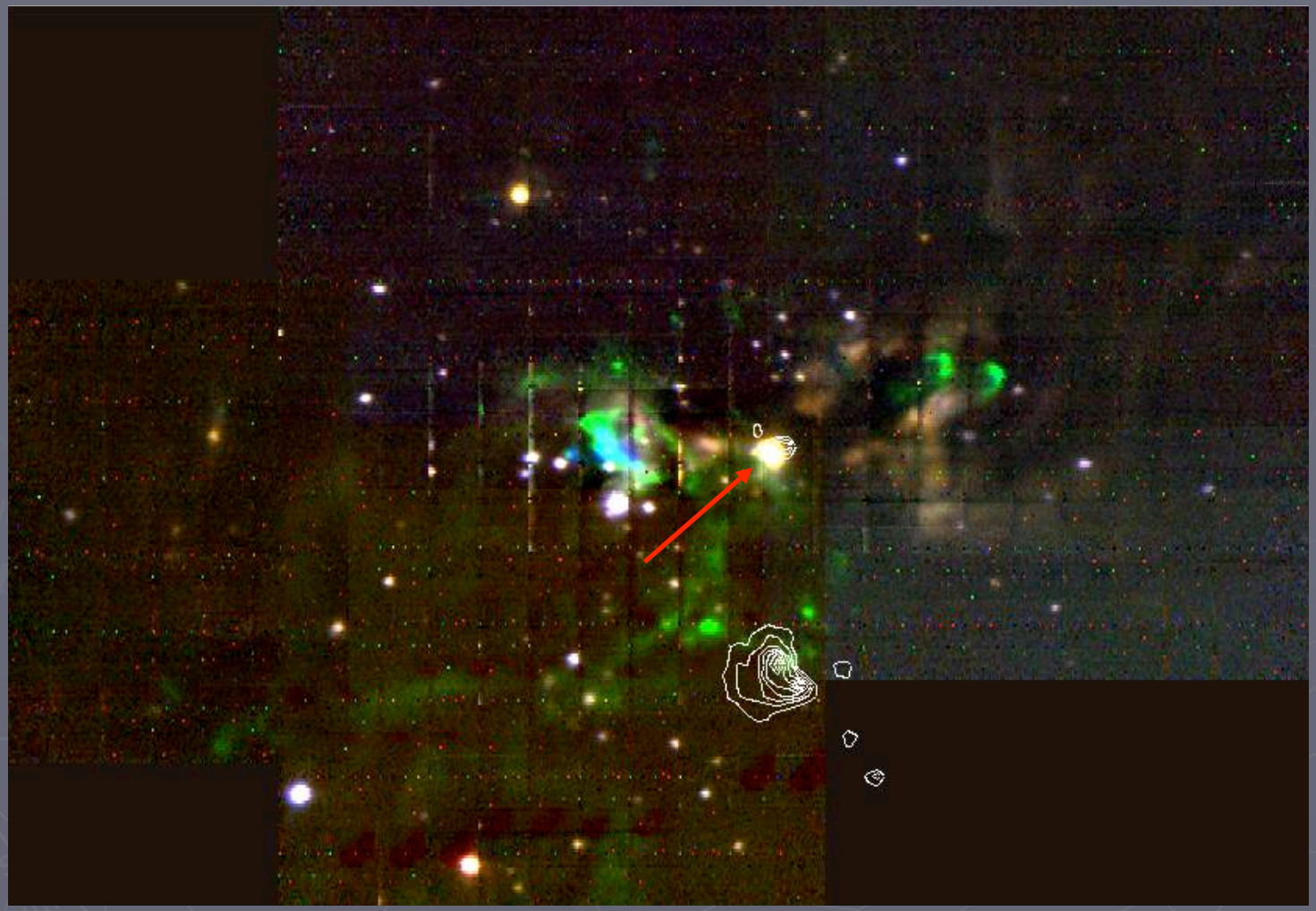


First Results of VLT(SINFONI) Pilot Study: III

IRAS 06058+2138



Created by Tatiana Vasyunina,
Javier Rodon ,Henrik Beuther

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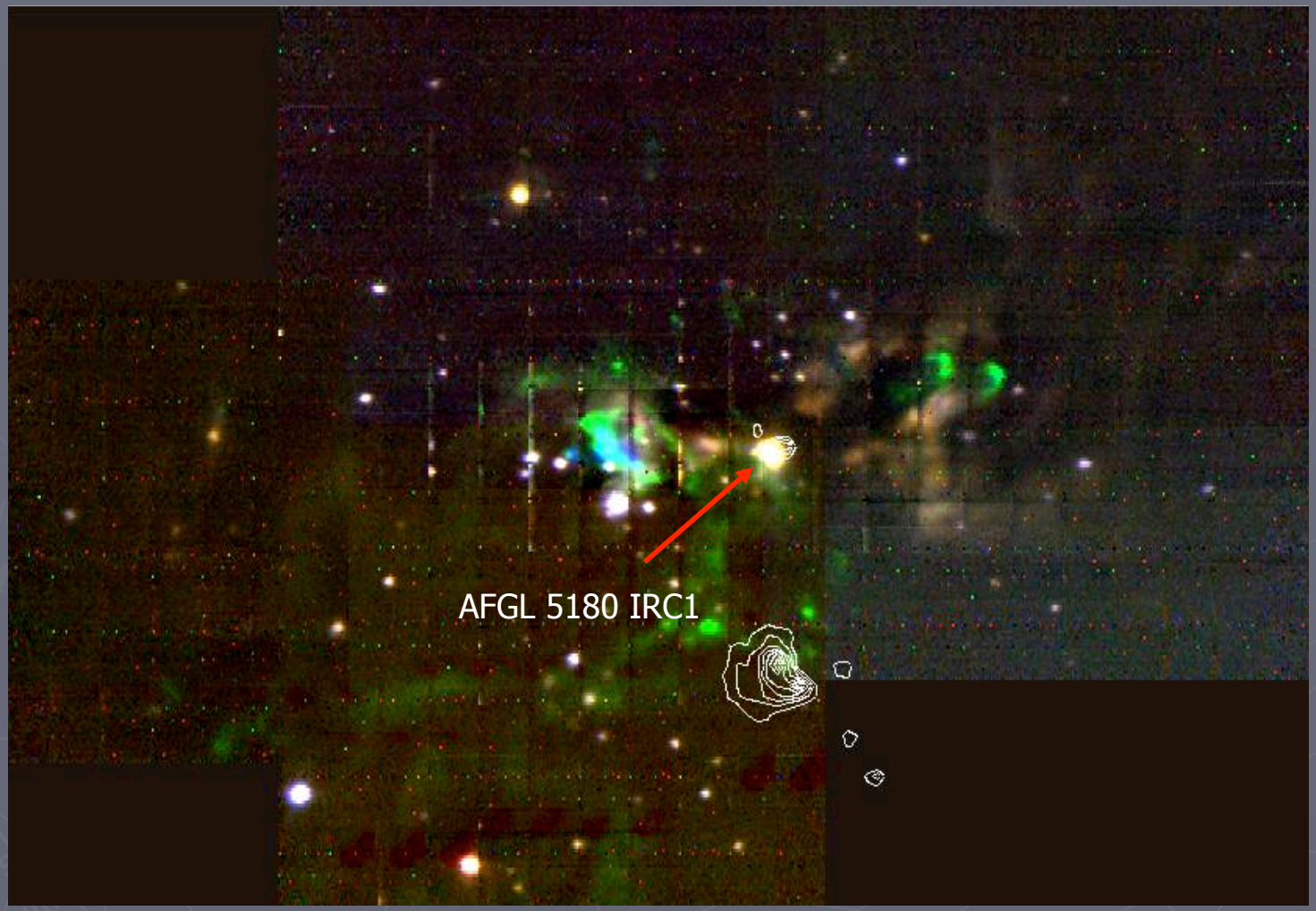
Contours: SMA/1mm continuum
SiO, H2CO

IRAS 06058+2138



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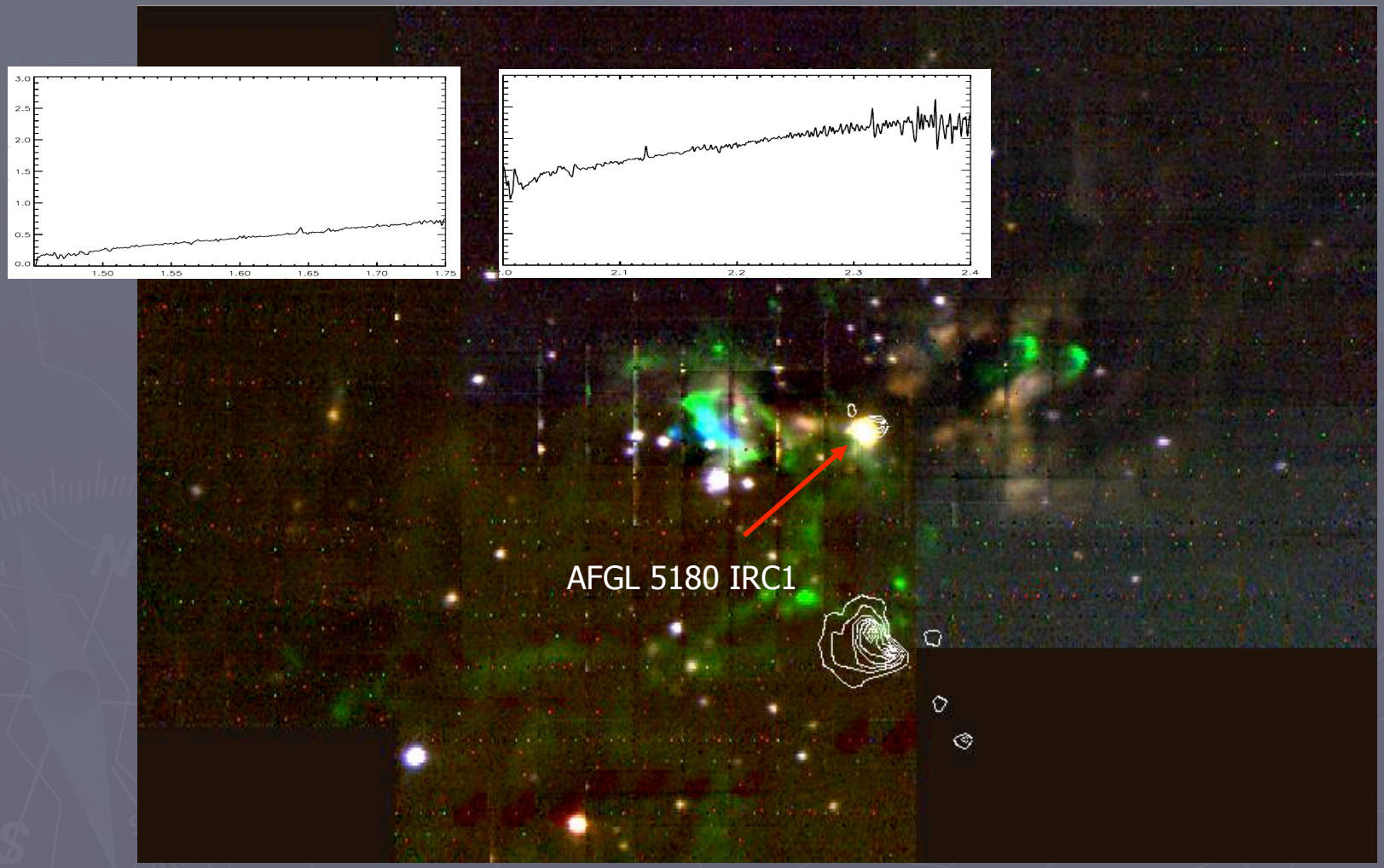
IRAS 06058+2138



Created by Tatiana Vasyunina,
Javier Rodon ,Henrik Beuther

[FeII] 1.644 μm
H2 1-0 S(1) 2.121 μm
Brγ 2.166 μm

Contours: SMA/1mm continuum
SiO, H2CO

Conclusions

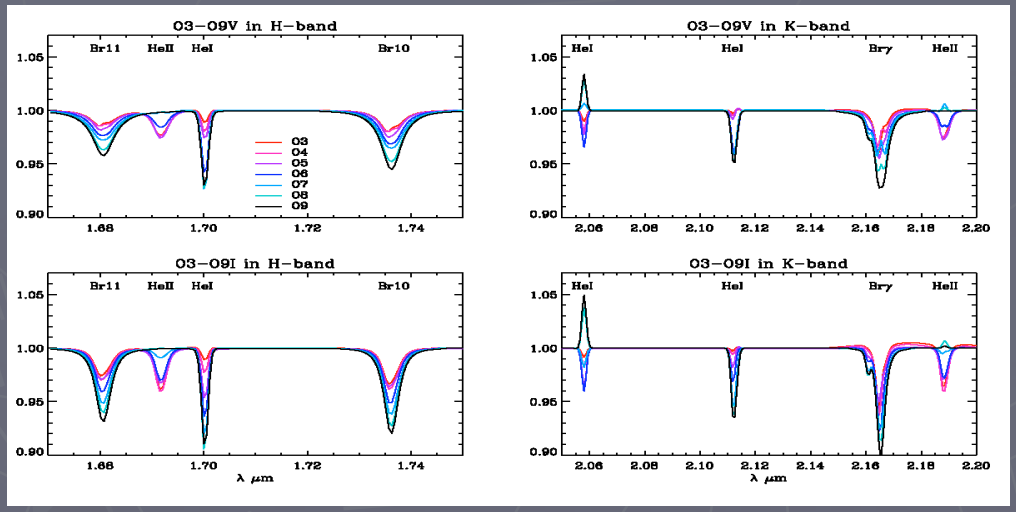
- NIR SINFONI observations are very efficient and provide an overwhelming amount of data
- Stellar content can be characterised down to ST of the order of B0 stars
- The nebular component can be successfully traced.

- YES, the concept works and can bring out the science, reason for a VLT Large Programme.
- The example of IRAS06058+2138 shows the importance of mm observations. Extension to the mm with SMA/PdB

- Upcoming results: http://www.eso.org/~abik/FEMS

Stellar Fundamental Parameters

Classification based on the HeI and HeII lines with state-of-the-art models and Genetic code algorithms



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