A spectroscopic census of the stellar content of high-mass star-forming regions

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Detecting the stellar content in the near-infrared

**Open Questions:**

- What is the stellar content and how does it depend on cluster properties?
- What is the interaction between the massive stars and their environment?

**An Integral Field spectroscopic survey of high-mass star-forming regions using SINFONI (VLT) of 10 clusters.**

- Mapping pattern to cover entire cluster area (200 SINFONI pointings)
- 1.5 - 2.4 micron spectra (R=1500) of all stars
- spectral line maps in emission lines (HII region, PDR, outflows)
- \( L_{\text{cluster}} = 10^4 - 8 \times 10^5 \text{ L}_\odot \) (sample expanding to higher luminosity)

**Multi-wavelength dataset: Spitzer, sub(mm), radio**

See also poster CP2 from Yuan Wang on S255IR
RCW 34

- Vela Molecular ridge at 2-3 kpc
- Spitzer/IRAC imaging reveals large bubble.
- HII region at the northern edge
- Molecular cloud north of HII region detected in CS (Bronfman et al. 1996)
- \textbf{Multiple generations of star-formation?}
- Why is the HII region not in the center?

IRAC stellar classification

- Star without IR excess: randomly distributed over the field
- Class II objects: located inside the bubble
- Class 0/I objects: associated with molecular cloud.
- Multiple generations of star formation!
SINFONI observations of RCW 34

Blue: HeI, Green: H2, Red: Bracket gamma, Contours: IRAC 3.6 micron
Stellar Content: Massive stars and PMS stars

• Classification by absorption lines (Hanson et al, 1996, Rayner et al, 2009)

• Ionizing source: O8.5V (Heydari-Malayeri, 1998)

• two early type B star

• Distance: 2.5 ± 0.2 kpc

• No A and F stars!

• G and K stars: low surface gravity derived from CO: PMS stars.

• Spitzer IR excess of most PMS stars
Stellar content: Cluster properties

• Comparison with theoretical PMS evolutionary tracks and isochrones (Siess et al, 2000, Da Rio et al, 2009)

• 2 - 4 Msun, still contracting to the main sequence.
  • A and F stars, now detected as G and K stars.

• Age of the stars in the HII region: 2 +/- 1 Myr
Stellar content: Cluster properties

- Comparison with theoretical PMS evolutionary tracks and isochrones (Siess et al, 2000, Da Rio et al, 2009)
- 2 - 4 Msun, still contracting to the main sequence.
  - A and F stars, now detected as G and K stars.
- Age of the stars in the HII region: 2 +/- 1 Myr
RCW 34 - Three different star-formation sites?

Possible scenarios:

- **I**: Bubble with intermediate-mass class II stars. No O and early B star present!

- **II**: HII region with an O8.5V @ 2 Myr expanding into the bubble

- **III**: Molecular cloud with class 0/I and masers

**Possible scenarios:**

- HII region triggers star formation in bubble and MC.
  - Problem: stars in the bubble older than stars in MC.

- Intermediate-mass stars create bubble and trigger the formation of the HII region. HII region triggers star formation in MC

**We need: Age dating of the class II source in the bubble!**
Conclusions

- Near-infrared spectroscopy is a very powerful way of classifying the stellar content of high-mass star-forming regions.
  - spectral typing of OB stars and PMS stars deliver cluster parameters
- Multi-wavelength observations are essential to understand the cluster in relation to its surroundings.
- Multiple generations of star formation are commonly present in young stellar clusters
  - triggering on parsec scales
  - also present on small scales inside a cluster