Integral Field Spectroscopy of HII galaxies with Wolf-Rayet signatures

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2D view on the interplay between massive stars and ionized gas in HII galaxies with Wolf-Rayet features using IFS

**AIMS:**

- Locate and characterize the Wolf-Rayet (WR) stars
- Chemical abundance of the ISM
- Gas excitation (origin of nebular HeII)
HII galaxies: general properties

- local, gas-rich star-forming systems
- low metallicity \[7.2 < 12 + \log(O/H) < 8.3\]: the most metal poor galaxies known in the local Universe belong to this class of objects
**HII galaxies with WR features**

- **Wolf-Rayet (WR) signatures** (broad bump at ~ 4680 Å) → the presence of WR stars (a late evolutionary phase of massive O stars; e.g. Crowther 2007), have been found in the spectra of some HII galaxies (e.g. Legrand+ 1997; Guseva+2000).

- Single star, non-rotating stellar evolution models fail in reproducing the WR content in low-metallicity environments (e.g. Papaderos+06; Brinchmann+08)

- The investigation of the WR content in metal-poor galaxies → to test stellar evolutionary models at low metallicities where more data are needed to constrain these models
HII galaxies with WR signature: IFS as a suitable tool

- long-slit may fail in detecting the WR bumps (faintness and spatial distribution of WR stars across the galaxy)
- Locate the WR stars and find them where they were not detected before! (e.g. Kehrig, Vilchez et al. 2008; Kehrig+2013)

**Power of IFS in finding WR stars**

- Lowers the difficulty when doing the spatial correlation between WR stars and nebular properties (e.g. De mello 1998)
- Formation and thereabouts of GRBs/SN progenitors may benefit from 2D study of metal-poor WR galaxies
IFU data of 15 metal-poor WR galaxies (PMAS at 3.5m CAHA)

- Arp 2
- CG1057
- WR404
- Mrk 178
- Mrk 475
The first 2D spectroscopic study of Mrk 178

The study of the WR content has been extended beyond its brightest star-forming knot uncovering new WR star clusters

Locate the WR stars → study more precisely the effects on their environments
Mrk178: an intriguing object

- The strength of the broad WR features and its low metalliclicity ($\sim 1/10 \, Z_\odot$)

Mrk178 as a significant outlier among WR galaxies from SDSS

- Mrk178 as the strongest WR feature relative to H$\beta$ of any galaxy in their sample

Brinchmann et al. (2008)
Mrk178: locating and characterizing WR stars
Mrk178: locating and characterizing WR stars

Using Large/Small Magellanic Cloud-template WR stars, we empirically estimate a minimum of ~20 WR stars within our FOV.

The comparison between the observed WR bumps and the WR template spectra [WN stars, WC/WO stars and composite WN+WC/WO stars]

~ 5 x WN5-6 stars
~ 6 x WN5-6 stars + 8 x WO stars
~ 1 x WN5-6 stars + 1 x WC4 star
Mrk 178: Distribution of O/H

- O/H from Te[OIII]4363

- The variations in the derived O/H are not statistically significant

*Chemically homogeneous ISM on spatial scales of hundreds of pc* (e.g. Lee & Skillman 1997; Kehrig+04; Perez-Montero+09; Cairo+09)
Mrk178: N/O and He/H abundance

- WR Knot C appears to present a higher N/O
- WR Knot C also shows a higher He/H
- Localized N and He enrichment, spatially correlated with WR Knot C (size ~ 20 pc)

Chemical enrichment associated with WR stars has been found previously in other dwarf galaxies (e.g. Lopez-Sanchez et al. 2011; Monreal-Ibero et al. 2010; Perez-Montero et al. 2013)
Mrk178: aperture effects on the detection of WR features

- WR galaxies from SDSS DR7: the most deviant point belongs to Mrk178

- From our IFU data: 1D spectra by combining fibers within circular apertures of increasing diameters

- Mrk178 gets closer to the bulk of metal-poor systems as the aperture size increases

  The offset is not real and is caused by aperture effects

- For apertures with $D > 10''$, we no longer detect the WR bump

  The power of IFS for investigating issues related to aperture effects!
excitation sources → the origin of nebular HeII emission

- HeII tend to be brighter in low metallicity systems and it is seen in high-z galaxies (e.g. Schaerer 2008) → offers a probe to infer properties of distant star-forming regions and search for PopIII stars.

- Usually nebular HeII is associated with WR stars but several studies have demonstrated that it is not always the case (e.g. Pakull et al. 2010; M.Pakull’s talk). From GMOS spectroscopy of HeII nebulae in M33:

  Kehrig, Oey, Crowther et al. (2011)

  New HeII nebula in M33: HBW673
The origin of nebular HeII emission

- Shirazi & Brinchmann (2012) → a large fraction of HeII-emitting galaxies do not show WR features and this fraction increases systematically with decreasing Z

- Different mechanisms (e.g., shocks) responsible for producing HeII line apart from WR stars (e.g., Pakull & Motch 1989; Garnett+91) & spatial separation between WR stars and the HeII-emitting zone can be a possible explanation for non-detection of WR features

- Mrk 178: HeII emission is extended and not always coincident with the location of WR stars: an effect of the mechanical energy input by the WR star winds

Shirazi & Brinchmann (2012) → a large fraction of HeII-emitting galaxies do not show WR features and this fraction increases systematically with decreasing Z. Different mechanisms (e.g., shocks) responsible for producing HeII line apart from WR stars (e.g., Pakull & Motch 1989; Garnett+91) & spatial separation between WR stars and the HeII-emitting zone can be a possible explanation for non-detection of WR features. Mrk 178: HeII emission is extended and not always coincident with the location of WR stars: an effect of the mechanical energy input by the WR star winds.
Summary & Conclusions

- We have initiated a programme to investigate metal-poor WR galaxies using IFS.

On Mrk 178, the closest metal-poor WR HII galaxy, our main results are:

- We defined 3 WR knots from which 2 were identified for the first time here.

- By using SMC/LMC template WR stars, we estimate a minimum of ~ 20 WR stars, already higher than that found in the literature.

- Localized N and He enrichment, spatially correlated with WR stars, is suggested by our analysis.

- Spatial offset between nebular HeII emission and WR stars can be explained based on mechanical energy arguments and does not rule out WR stars as the HeII ionization source.

- We study aperture effects on the detection and measurements of WR features → WR galaxy samples constructed on single fibre/long-slit spectrum basis may be biased in the sense that WR features can scape detection depending on the distance of the object and on the aperture size.