Mapping the ionized gas of the metal-poor HII galaxy PHL 293B with MEGARA IFU

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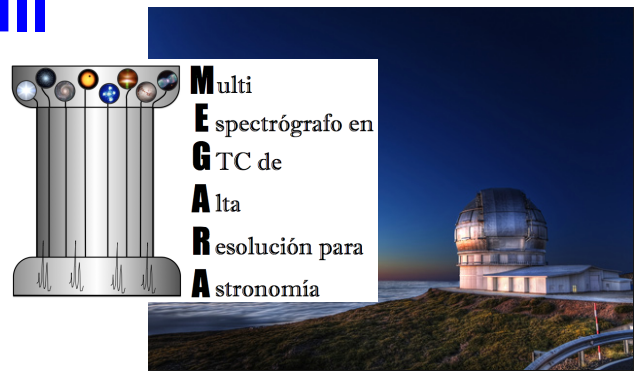

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Here we report the first spatially resolved spectroscopic study for the galaxy PHL293B using the GTC/MEGARA IFU. PHL293B is a local, extremely metal-poor, high ionization galaxy. This makes PHL293B an excellent analogue for galaxies in the early Universe. The MEGARA FOV (~12.5”×11.3”) covers the entire PHL293B main body and its far-reaching ionized gas. We created maps of all relevant emission lines, line ratios and physical-chemical properties of the ionized gas. The narrow emission gas appears to be ionized mainly by massive stars according to the observed diagnostic line ratios. We detected low intensity broad emission components and blueshifted absorptions in the Hα,Hβ lines which are located in the brightest zone of the galaxy ISM. A chemically homogeneity is observed in O/H. The representative very low metallicity derived for the galaxy is 12+log (O/H)=7.64±0.06. Our IFU data reveal for the first time that the nebular HeIIλ4686 emission from PHL 293B is spatially extended and coincident with the ionizing stellar cluster, and allow us to compute its total HeII ionizing photon flux. Wolf-Rayet bumps are not detected excluding therefore Wolf-Rayet stars as the main HeII excitation source.

Context of the research

The PHL293B galaxy shows features that are more commonly observed and predicted in distant star-forming galaxies in comparison with local starbursts:

✔ Very compact HII galaxy: effective radius of its star-forming component ~ 0.7" (e.g., Papaderos+2008)

✔ Extremely low oxygen abundance: 12+log(O/H) ≈ 7.6-7.7 (~ 1/10 solar metallicity; e.g., French 1980;Fernandez+2018).

✔ High specific star formation rate (~ 6Gyr^{-1} ; Filho+2013) and high-excited gas indicated by the presence of the high-ionizing nebular HeIIλ4686 emission (e.g., French 1980; Izotov+2007)

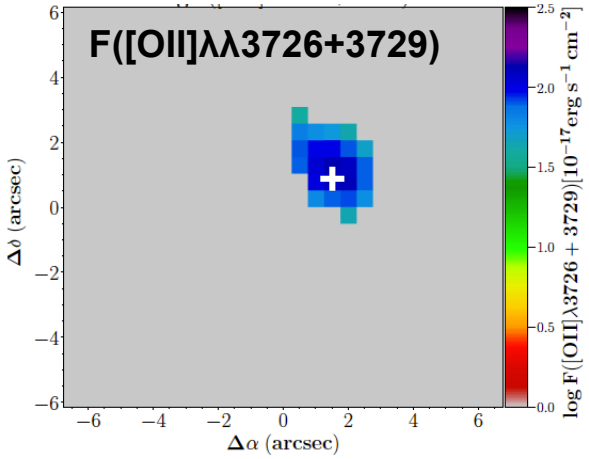
PHL 293B is a remarkable place nearby that allows us to study in detail physical conditions which may be predominant in primeval starbursts

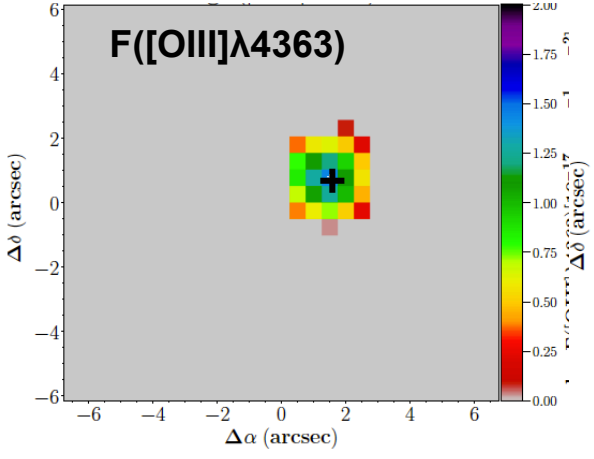
Our team is working on spatially resolved spectroscopy of local, metal-poor, high-ionizing galaxies using worldwide IFUs (e.g. Kehrig+2013,2015,2016,2018)

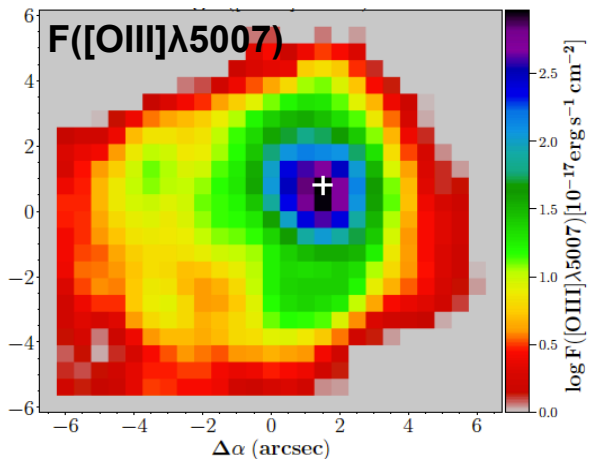
Observations

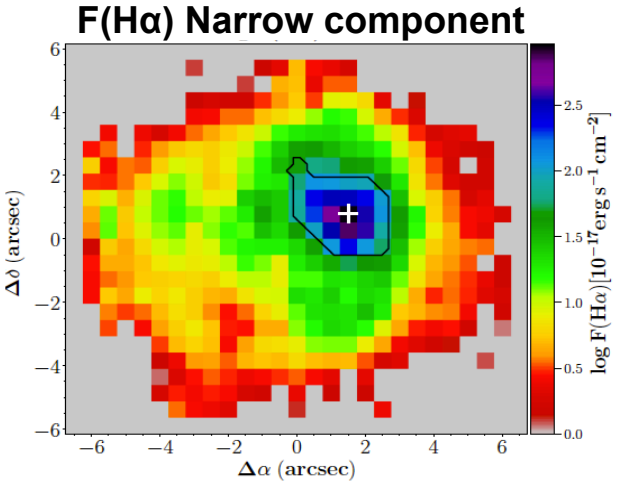
✔ We present the first integral field spectroscopic study of PHL 293B based on MEGARA commissioning observations (Kehrig+2020 submitted).

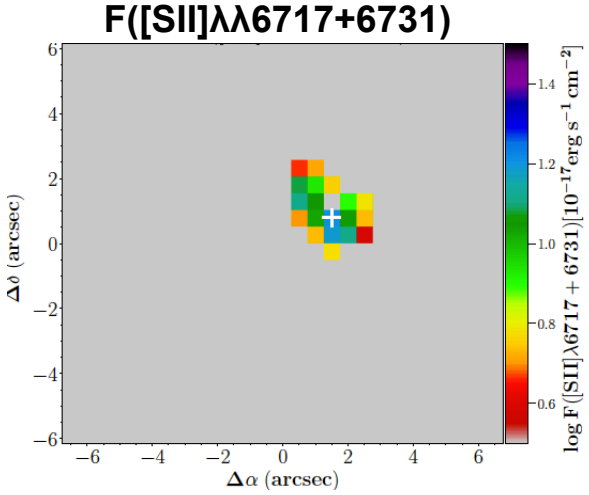
✔ We used the following gratings: “blue” VPH405-LR (~ 3653-4386 Å), “green” VPH480-LB (~ 4332-5196 Å) and “red” VPH665-HR (~ 6445-6837 Å)



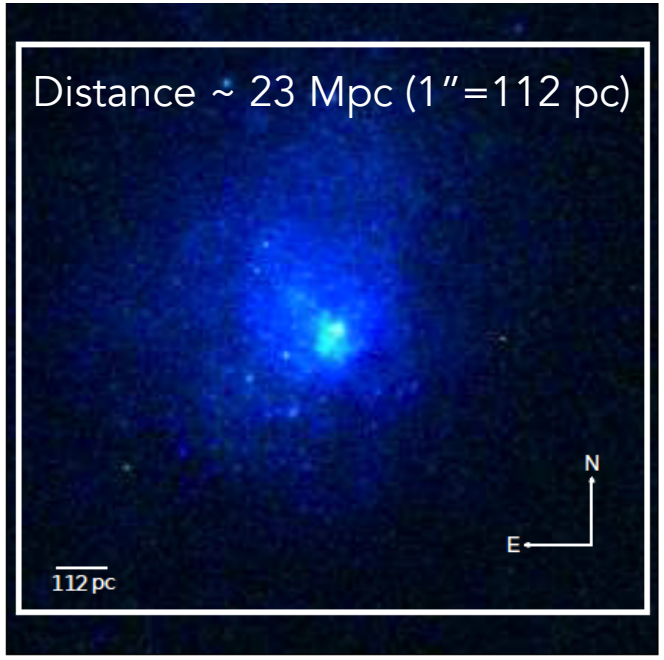








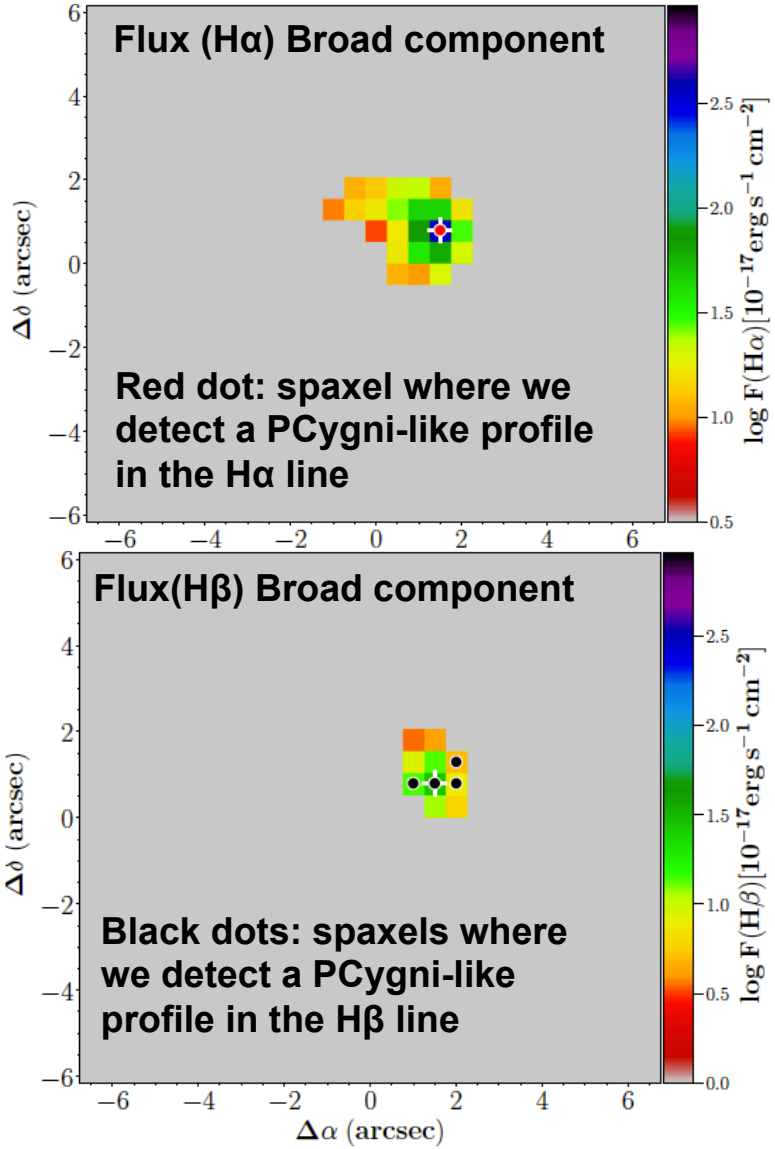
Examples of flux maps of nebular lines in logarithmic scale created from our MEGARA data. Only fluxes with S/N > 3 are shown. The plus (+) sign in the maps marks the Hα emission peak. Each spaxel diameter ~ 0.62 arcsec.

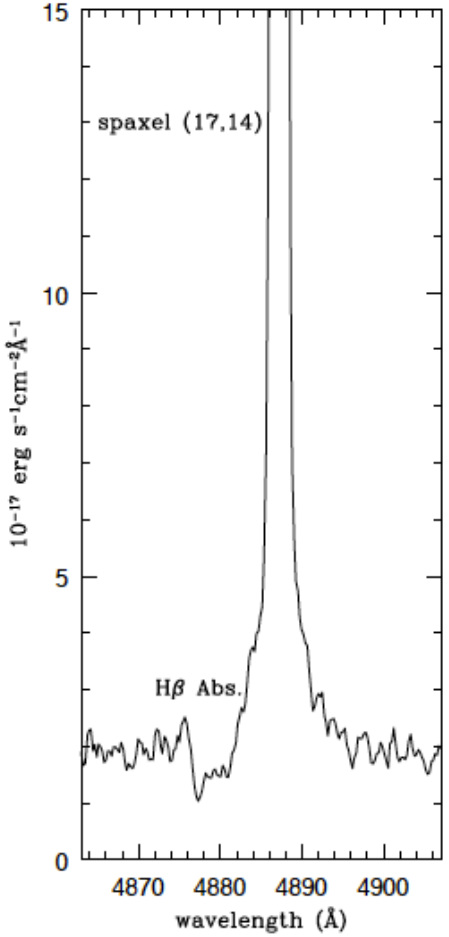


Three-colour composite HST image of PHL 293B (blue = WFC3/F606W, green = WFC3/438W, red = WFC3/F814W (HST Proposal ID 12018; PI: A.Prestwich). The white box shows the FOV of MEGARA

Results

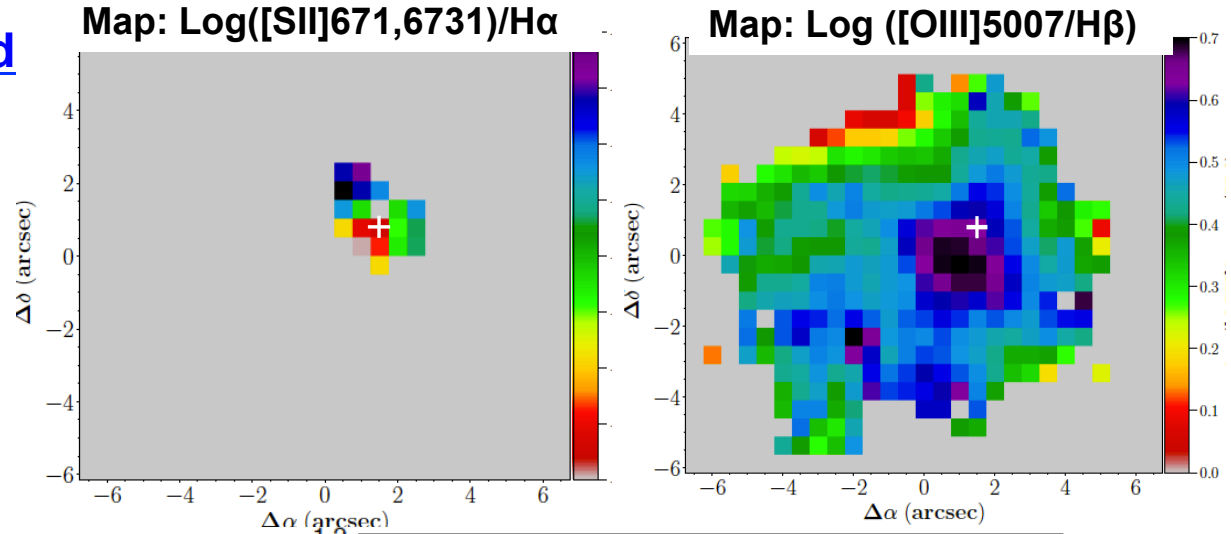
Detection and spatial distribution of low intensity broad components and PCygni profiles in the Balmer lines

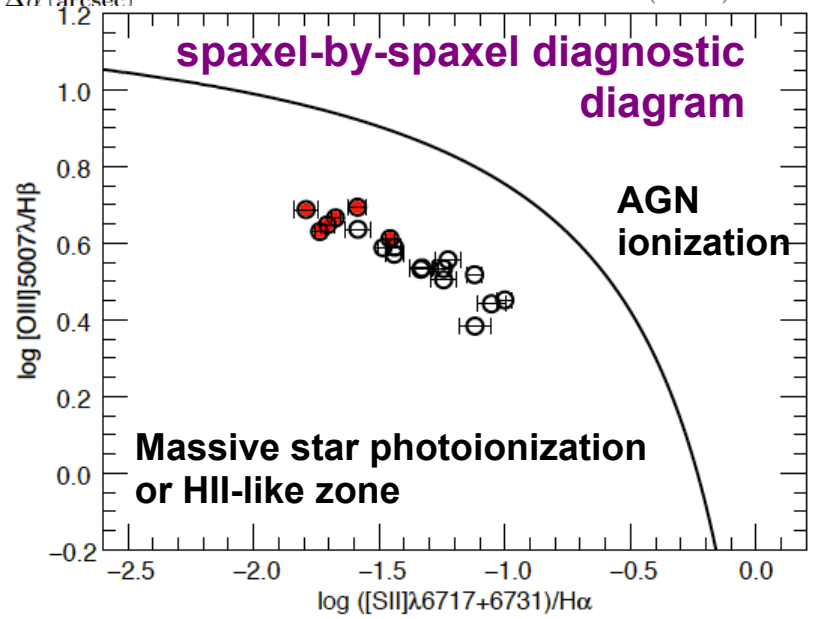




Spectral region around Hβ of one of the spaxels where we detect Pcygni-like profile

Spatially resolved ionization structure

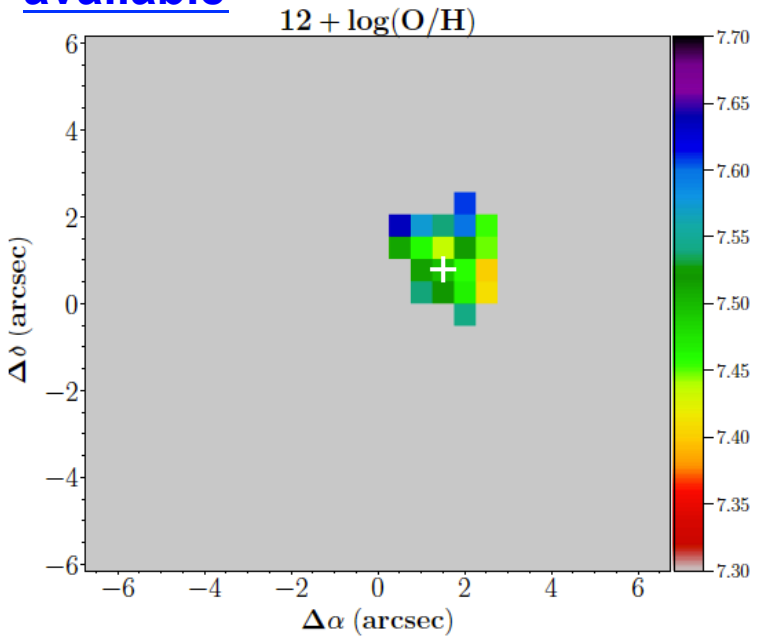




open circles: individual spaxels from the data cube; red circles: individual HeII-emitting spaxels. All points lie at the HII-like zone of the diagram regardless of the locus in the galaxy

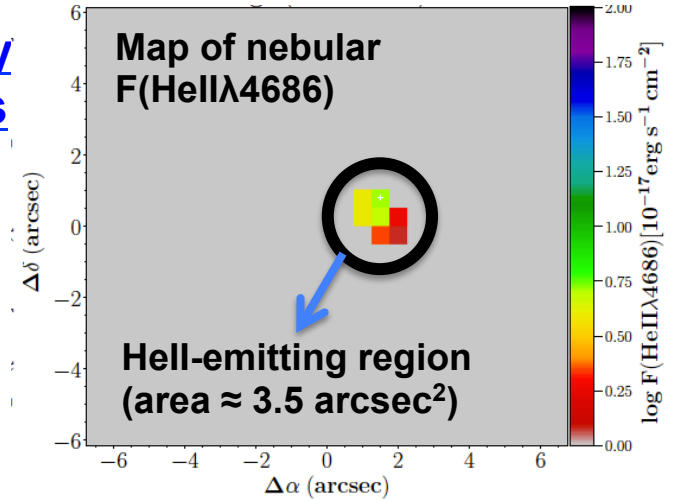
Results

Map of oxygen abundance derived only for spaxels with Te[OIII] measurements available



~ 80% of the spaxels show oxygen abundance in the range of ≈ 7.5–7.6. This indicates that the ionized gas-phase O/H in PHL 293B stands largely constant beyond hundreds of parsecs.

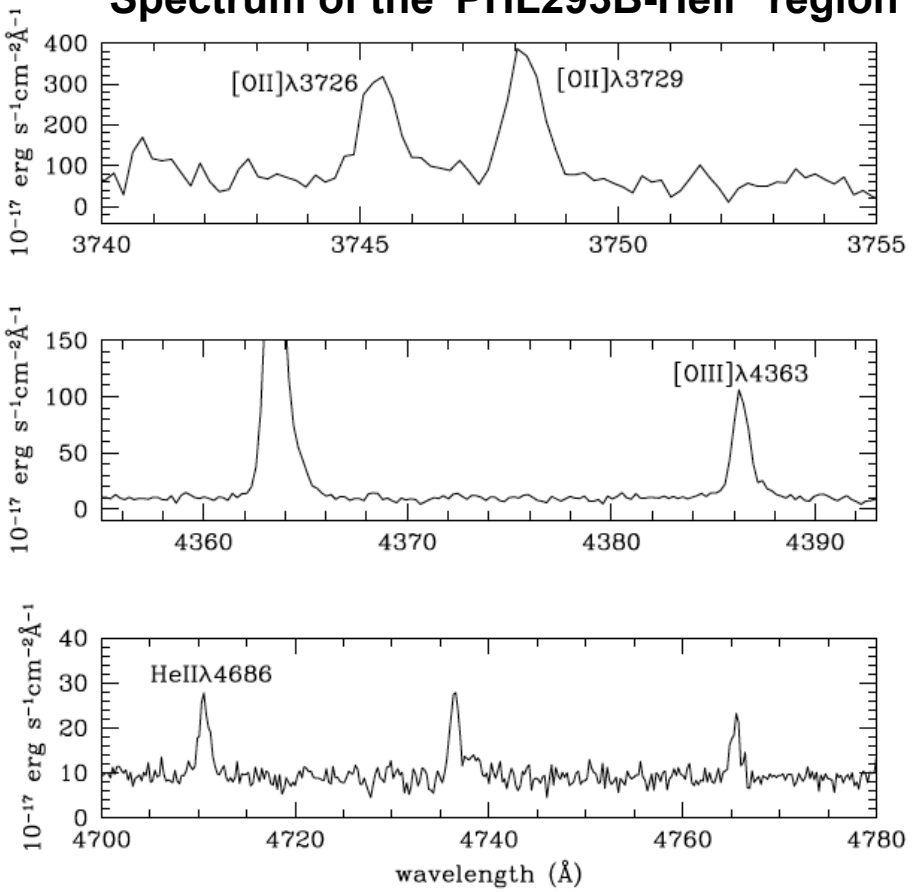
Integrated spectra and the extended nebular HeII4686 in PHL293B



We obtained the spectrum of the region "PHL293B-HeII" by addind all HeII-emitting spaxels (see map above). From this spectrum we measured the total HeII ionization budget $Q(HeII)=3.7\times10^{49}$ photon/s.

We also created the integrated spectrum of PHL293B by adding basically all the nebular emission across our FOV (area ≈194 arcsec² ≈ 2.4 kpc²). Such spectrum does not show HeII line!

Spectrum of the"PHL293B-HeII" region



From top to bottom: a zoomed-in view of the [OII] doublet, and of the Δλ ~ 4355-4390Å and Δλ~4700-4780 Å showing the [OIII]λ4363 and nebular HeIIλ4686 lines, respectively.

IMPACT: IFS for the PHL293B galaxy is obtained for the first time

✔ We analysed MEGARA observations of the nearby, metal-deficient galaxy PHL 293B. Such objects constitute unique laboratories for probing the conditions of primordial galaxies.

✔ We show for the first time the spatial distribution for low intensity broad components and PCygni-like profiles in the Balmer lines in PHL 293B: they coincide spatially with the brightest star-forming cluster of the galaxy.

Nebular HeIIλ4686 emission

✔ We derive the first spectral map for the nebular HeIIλ4686 line in PHL293B. Wolf-Rayet stars and X-ray binaries can be ruled out as the main HeII ionization sources in PHL 293B (see also e.g. Kehrig+2015,2018).

✔ Our integrated spectrum of PHL293B does not show the HeIIλ4686 line. This suggests that searches for reionization-era HeII-emitters, for which only the total integrated spectra will be available, might be biased, i.e., a non-detection of the HeII line does not necessarily mean the intrinsic absence of HeII emission in the system.

Prospects for the future

Detailed galaxy-by-galaxy studies of metal-deficient and nebular HeII-emitters are needed to better understand the nature of these objects.

Our team leads a Guarantee Time MEGARA project to spectroscopically follow-up local-intermediate redshift HeII-emitters.