HII REGION - PHOTODISSOCIATION REGION INTERFACE CHARACTERISATION WITH MISTRAL

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Abstract.
Feedback from high-mass stars plays a crucial role in galactic star formation, yet its physical mechanisms remain poorly understood due to a lack of spatially resolved observations. To advance our knowledge of massive star feedback, we propose using optical emission lines as diagnostics of the physical conditions in the transition zones between ionized gas and molecular clouds. This study focuses on a well-selected sample of ten Galactic H II regions.

Keywords: ISM: H II regions, ISM: individual objects: NGC 7538, ISM: lines and bands

1 Introduction

Massive stars profoundly influence their surroundings through radiative and mechanical feedback. Their ultraviolet (UV) radiation and stellar winds affect the star-forming potential of the parent molecular cloud, either by dispersing it (negative feedback) or by sweeping up and compressing material into dense, localized structures (positive feedback).

The morphologies of photodissociation regions (PDRs)—the boundaries between H II regions and the molecular medium—are strongly shaped by these feedback processes. Observed in the infrared (e.g., with *Spitzer* or *WISE*), PDRs exhibit a variety of structures (pillars, globules, dense clumps, bright rims, bow shocks, etc.), each reflecting the complex interaction between ionized gas and the molecular cloud or layer.

Optical emission lines are crucial for characterizing the physical conditions (extinction, density, temperature) within H II regions, particularly near PDRs where photo-evaporative flows originate. We selected a sample of ten H II regions that differ in distance, exciting source, and PDR morphology. Here, we present our methodology and first results for the well-studied H II region NGC 7538 (Barriault & Joncas 2007 and references therein) whose distance is 2.7 kpc and the main ionizing source is an O3.5V((f*))+O9.5V binary system (IRS6).

2 Observations and data reduction

The H II regions were observed using the MISTRAL* spectro-imager , mounted on the T193 telescope at the Haute-Provence Observatory. All observations were carried out with the blue objective, employing a slit of 5.1′ in length and 2″ in width, yielding a spectral resolution of $R = 709$ at 6000 Å. Data reduction was performed using a dedicated pipeline.

In NGC 7538, key features, as shown in Fig. 1, are: a compact H II region (IRS1), known to drive a bipolar outflow (Sandell et al. 2020), an edge-on PDR (the Ridge), and an arc-shaped structure (the Ark). Four slits, each with distinct orientations and positions relative to the H II region and its associated PDR, were observed (Fig. 1). This configuration enabled both the targeted study of these features and the inclusion of a sky background region for accurate spectrum calibration. Each slit was segmented into 21 sub-sections, each approximately 15″ (0.2 pc) long, from which individual spectra were extracted (Fig. 1). Gaussian line fitting was subsequently applied to each extracted spectrum.

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*see `https://ohp.osupytheas.fr/mistral-spectro-imager/`

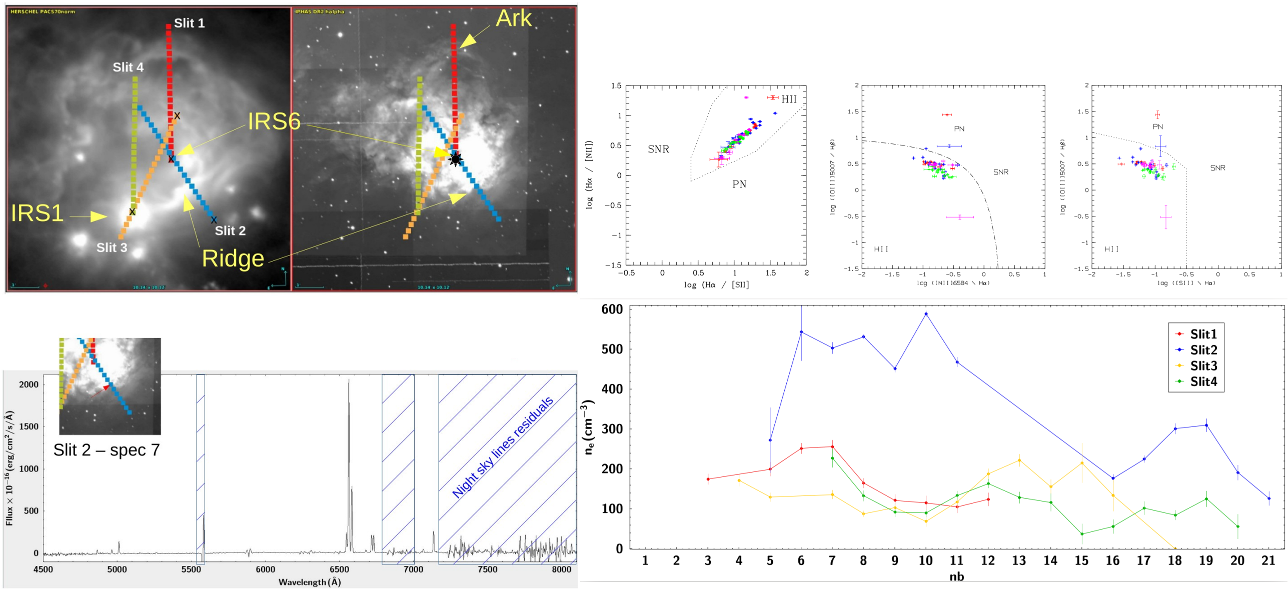

Fig. 1. Top-left: PACS 70 μm (left) and IPHAS Hα (right) images of NGC 7538 (field of view: 10′). Overplotted slits are shown, with the black arrow marking the position of the first spectrum; key features are labeled. **Bottom-left:** Example of an extracted spectrum (spectrum 7 of slit 2, as indicated in the inset), showing optical emission lines from Hβ (4861 Å) to [Ar III] (7136 Å). **Top-right:** Line ratio diagnostic diagrams. The boundaries of the H II region are defined following Sabin et al. (2013). **Bottom-right:** Electron density (derived from the [S II] lines ratios) as a function of spectrum number along the different slits.

3 Results and Conclusion

Figure 1-right presents our main results. The line ratio diagnostic diagrams indicate that the majority of our data points are consistent with H II region physical conditions, suggesting that shock excitation—as typically observed in supernova remnants—is not dominant in this region. As Sandell et al. 2020 and Royer et al. 2025, we observe a clear increase in electron density in the region directly in front of the Ridge, relative to the position of the ionizing star.

To further refine these preliminary findings, we plan to:

- investigate the dependence of physical parameters on the distance to the ionizing star;
- enhance the signal-to-noise ratio in faint regions by integrating over a larger spatial window;
- employ different photoionization models (e.g., Cloudy, PyNeb) to better constrain the physical conditions;
- compare with near infrared spectral line observations of the PDR itself

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