Photoionized Herbig-Haro objects in the Orion Nebula through VLT´s deep spectroscopy I: HH529 II-III

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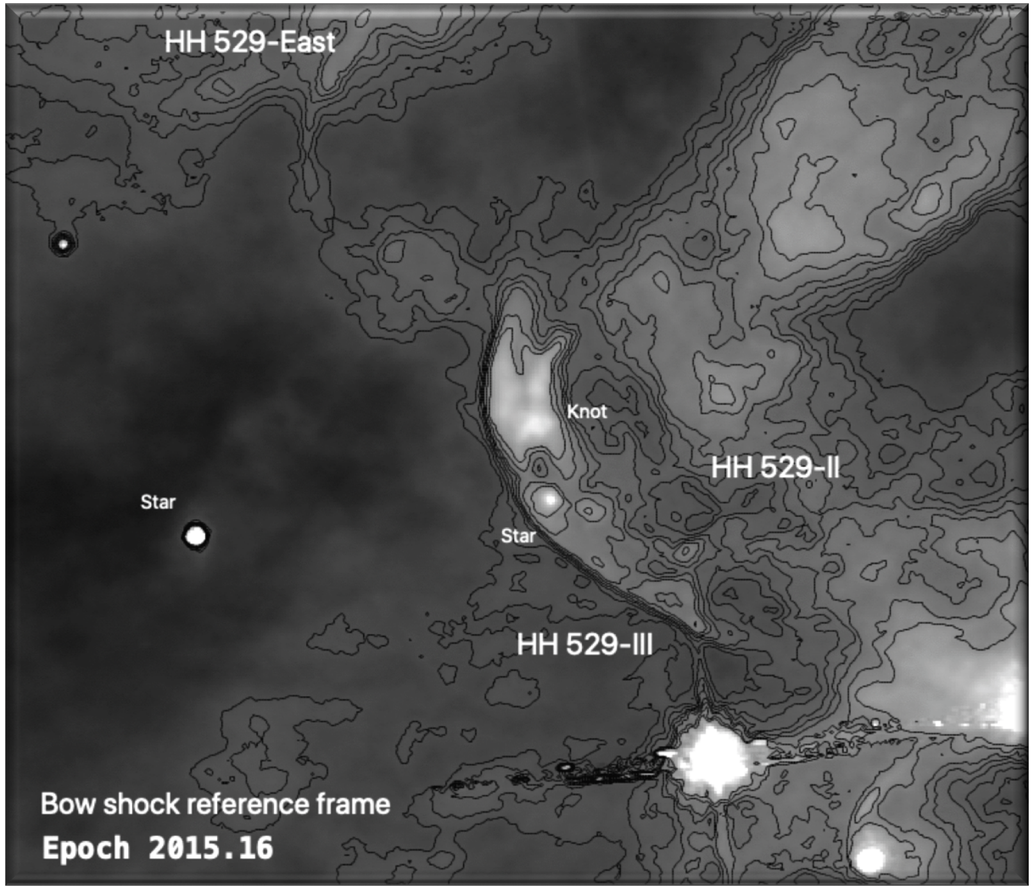
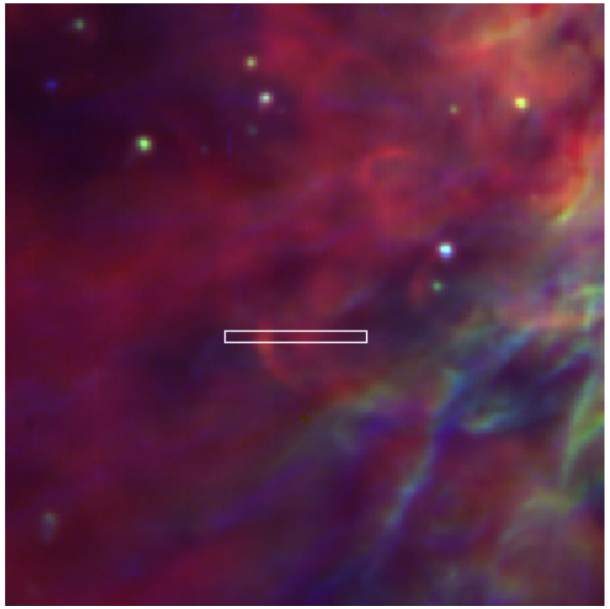
Using the Ultraviolet Visual Echelle Spectrograph (UVES) at the Very Large Telescope (VLT), we study the photoionized Herbig-Haro object HH529 in two associated bowshocks: HH529II and HH529III and its nebular background emission. We spatially isolate each bowshock and separate its blueshifted emission from the nebular background thanks to the very high spectral resolution (6.5 km s^{-1}) of our data. We measure hundreds of emission lines both from collisional excitation (CELs) and recombination (RLs) in each velocity component in our wide spectral range (3100-10400 Å). In each case, we derive physical conditions (electron density and temperature) using multiple methods and chemical abundances both based on CELs and RLs in the cases of He^{+}, O^{+}, O^{++}, C^{++} and Ne^{++}. Dust destruction processes and the reincorporation of heavy elements to the gaseous state are detected in the shock heads of HH529. We also study the velocity structure and thermal width of the detected lines in the spectra for the different velocity components, including the nebular one. Comparatively, there are noticeable differences between the physical conditions and chemical composition of the nebular gas and the shock components. These objects are excellent laboratories to analyze the well-known Abundance Discrepancy problem (AD) and its possible origin.

Herbig-Haro Objects

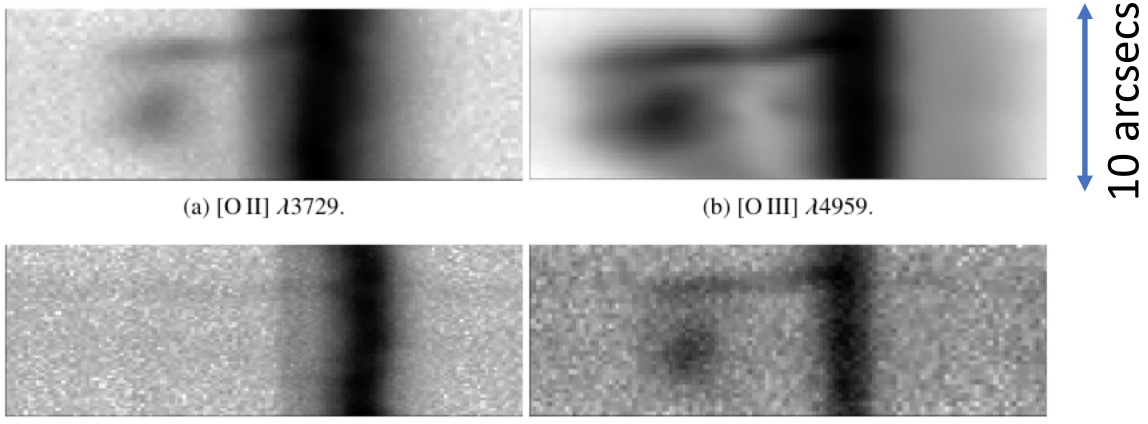


- **Herbig-Haro objects** (HHs): shocks associated to **outflows from young stars interacting with the surrounding environment.**
- In the presence of an ionizing source, the gas outflow becomes photoionized as a small-scale nebula.
- In the case of the Orion Nebula, several HHs are observed within the photoionized gas surrounding θ^1 Ori C, which allow studying the chemical composition of the nebula's gas under atypical physical conditions.

The data



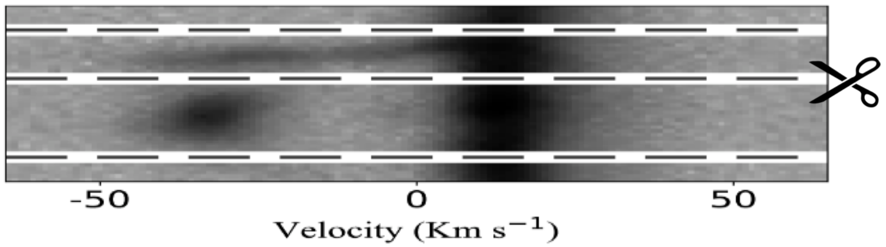
2D spectra



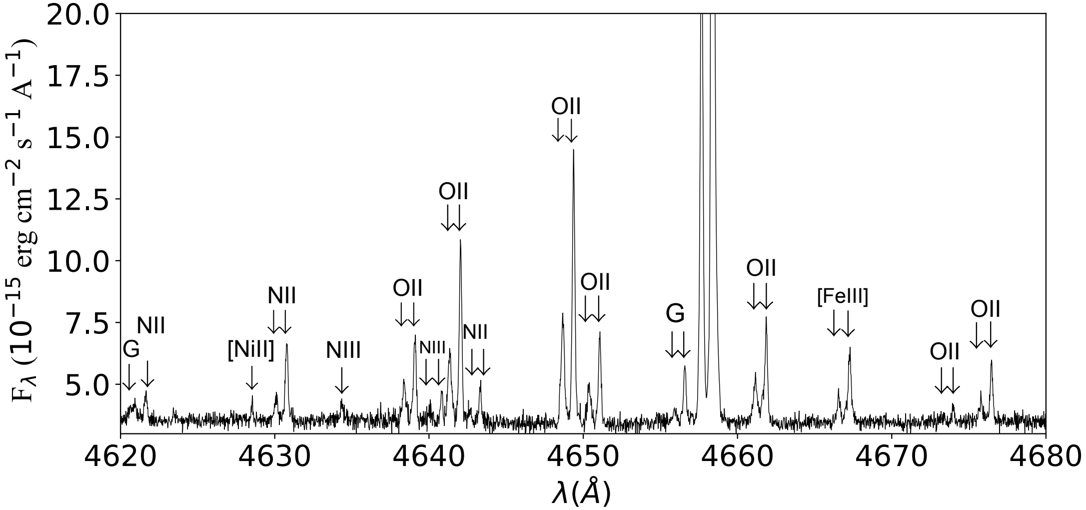
(a) [O II] λ3729. (b) [O III] λ4959.

(c) [O I] λ6300. (d) O II λ4649.

Spatial cuts



Cut 2



HH529II and the nebular emission showing faint RLs of OII

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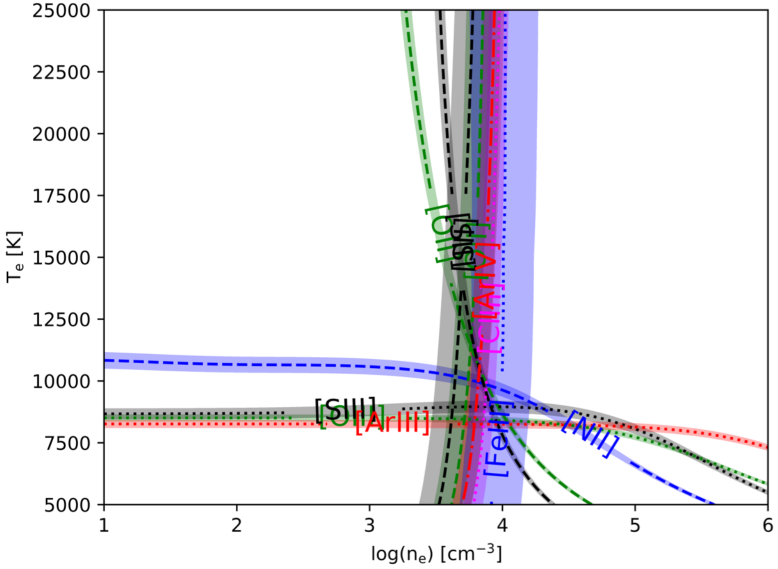
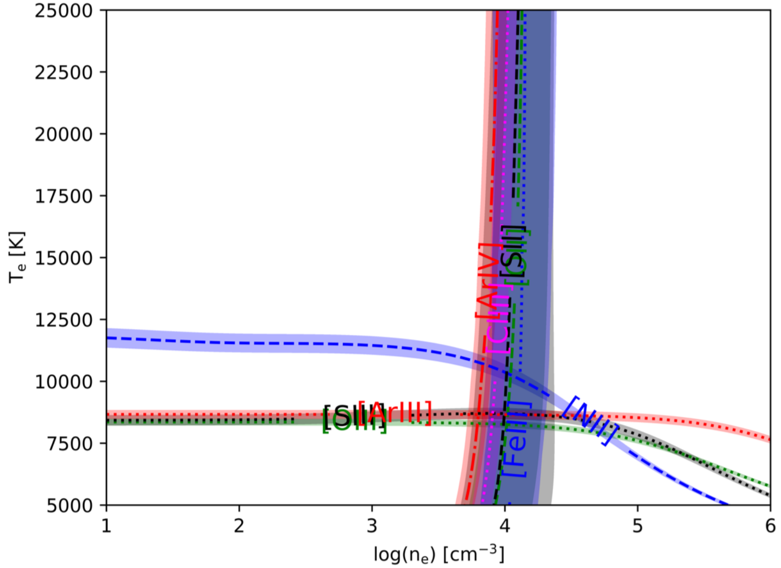
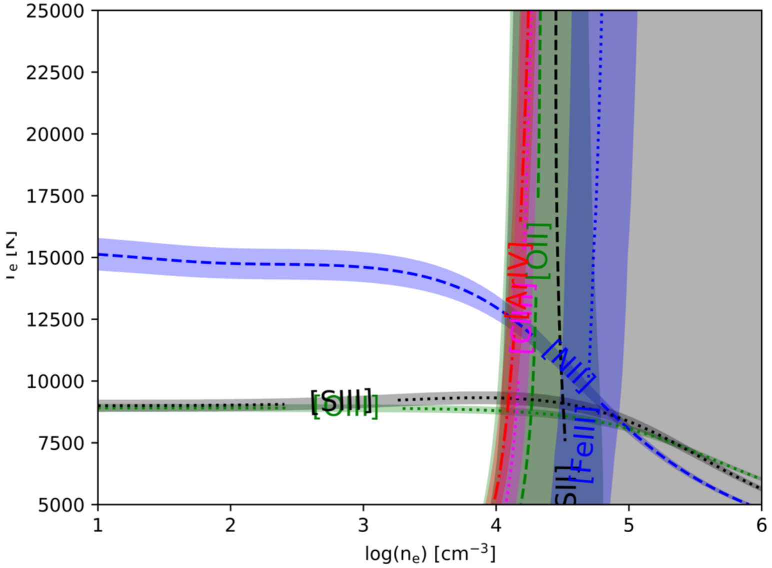
Plasma diagnostics of physical conditions



Orion nebular emission

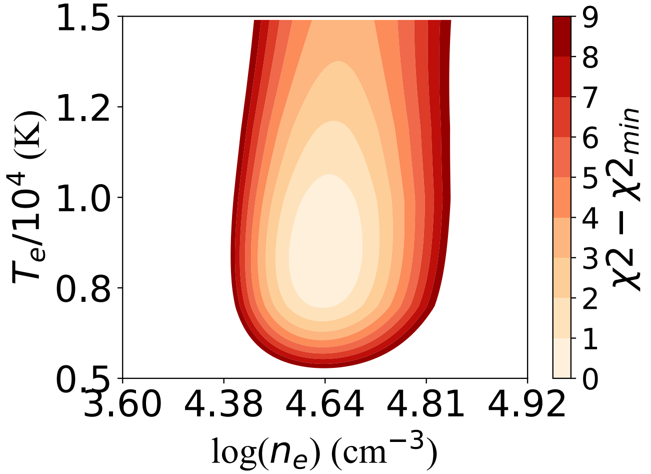


HH529II



HH529III: Beyond the critical density of usual diagnostics!

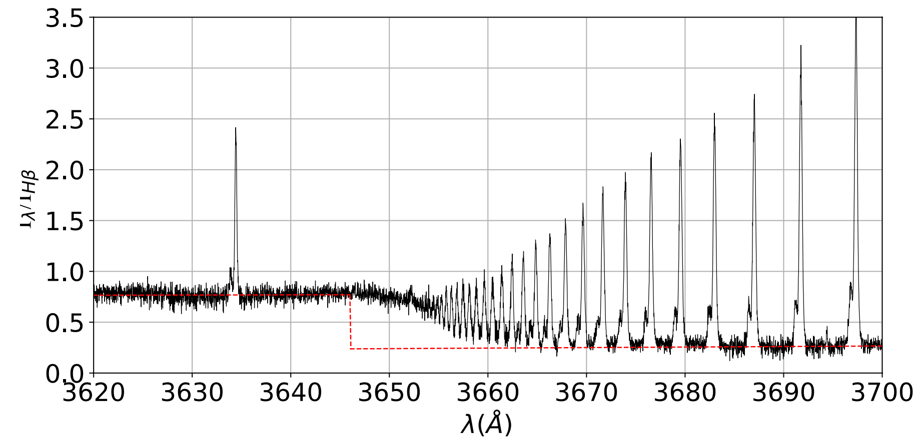
We follow the same procedure to **derive physical conditions with OII RLs.**

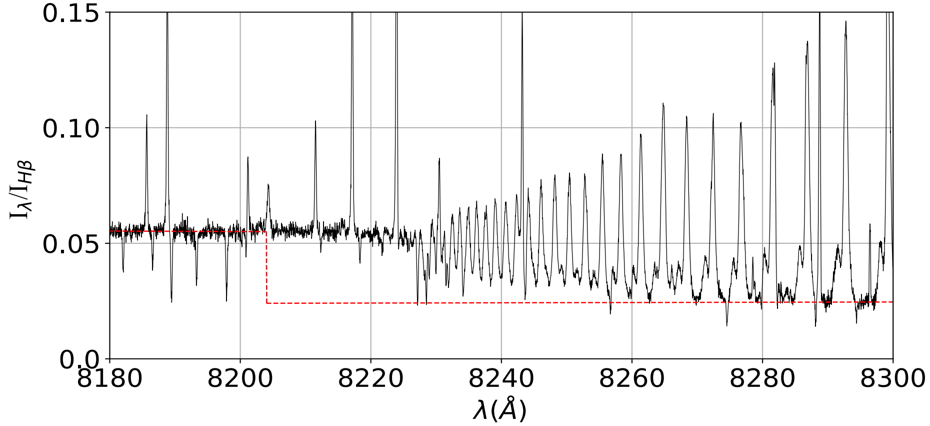


Maximum likelihood method based on [FeIII] lines. Minimization of χ^2 to derive n_e

Results

We have multiple estimates of physical conditions, including **T_e(HI) and T_e(HeI)**, and several determinations of ionic abundances with RLs, covering different degrees of ionization.





- We found a higher content of gaseous Fe/H in HH529II and HH529III in comparison with the Orion Nebula, that evidences the destruction of dust grains.
- The higher O abundances (derived with both RLs and CELs) in the shock fronts indicate some contribution of O from the destruction of dust grains.
- The Abundance Discrepancy Factor is higher in the shock components in comparison with the Orion Nebula. We did not find evidence of higher temperature inhomogeneities in the HHs.

Questions for the future...

- Which factors determine the dust destruction rate? Is there any relationship with physical conditions? with the shock velocity?
- Maintaining the same chemical composition, how does the ADF behave under different physical conditions?

Coming soon ...

- Analysis of **new photoionized Herbig-Haro objects**, covering a wide range of distances from θ^1 Ori C and θ^2 Ori A, the main ionization sources of the Orion Nebula, and different shock velocities.
- Analysis of ionized protoplanetary disks (Proplyds) in the Orion Nebula.

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