Chemical Abundances in Orion Protoplanetary Disks and Jets

Yiannis G. Tsamis

European Southern Observatory

ytsamis@eso.org

(with J. R. Walsh, J. M. Vilchez, D. Pequignot, R. H. Rubin)

1. Introduction and rationale

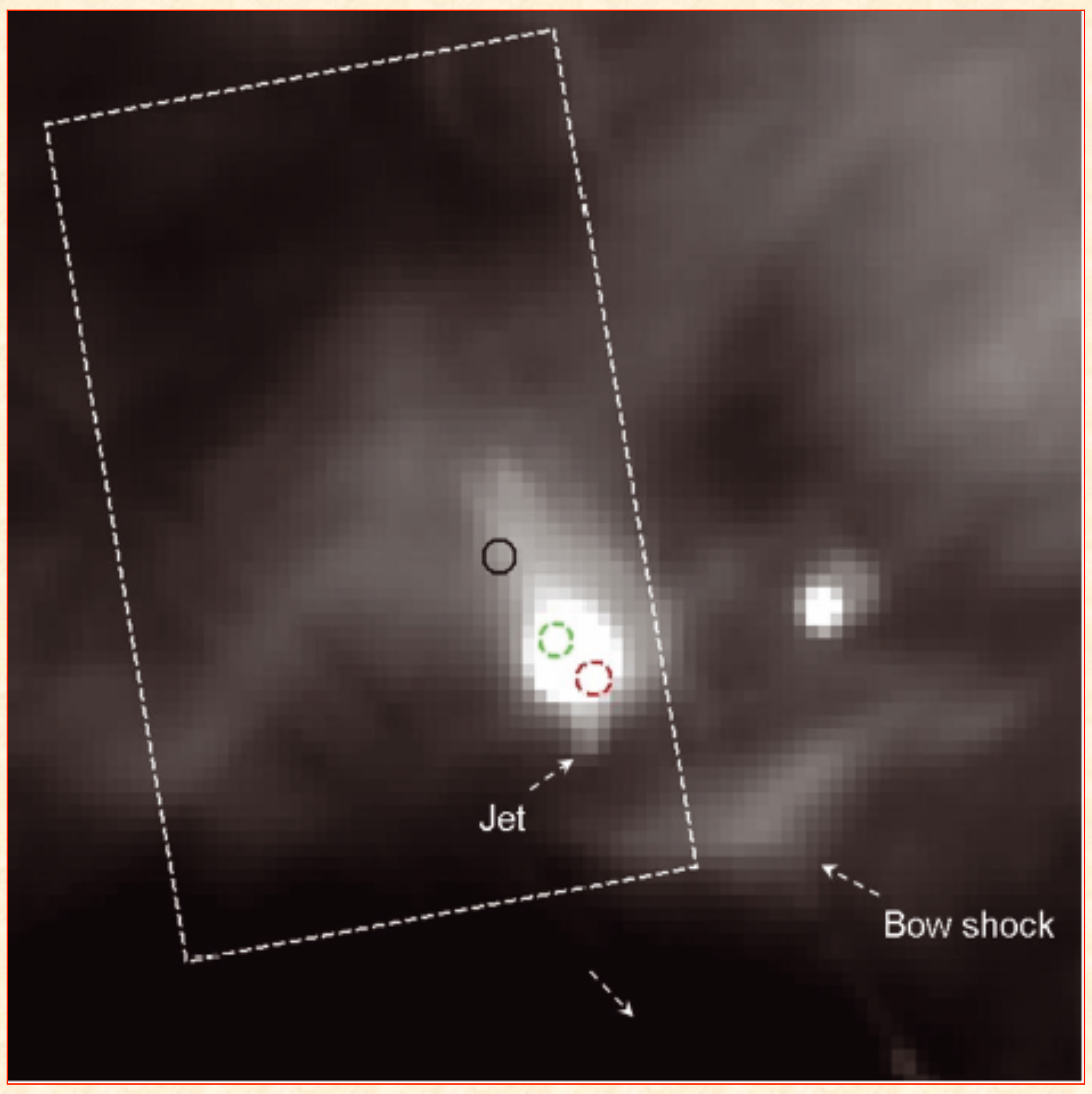
Proplyds are photoevaporating accretion disks around young stars in H II regions (e.g. McCaughrean & O'Dell 1996; Mann & Williams 2010). The archetypal proplyds were identified within Orion, associated with low-mass star formation reminiscent of the protosolar nebula. They are present in the vicinity of the hot massive stars of the Trapezium cluster. Massive stellar associations, such as Orion, are thought to represent the closest analogues to the birth environment of our solar system (Adams 2010). Proplyds are thus important to both planetary science and astrophysics.

The elemental content and chemistry of proplyds are *virtually unknown*, but studies of their composition may help to elucidate (a) The origin of the Metallicity – Giant Planet Frequency correlation (Petigura & Marcy 2011), (ii) The mechanisms of disk dispersal, (iii) Grain-growth and planetesimal formation in externally irradiated disks. Until very recently there have been no observational studies devoted to the elemental composition of Orion-like disks to provide constraints on planet formation theory.

We have pioneered a programme (Tsamis et al. 2011; Tsamis & Walsh 2011) which is yielding the first inventory of proplyd C, N, O, Ne, S, Cl, Ar, Fe and heavier element abundances (relative to H or He): these are accessible via the analysis of their forbidden and permitted emission lines in far-UV to near-IR spectra.

Here a study of LV 2 (Orion) is presented (Fig. 1), based on our VLT FLAMES optical integral field spectroscopy (Fig. 2, 3) and *HST* FOS and STIS data (far-UV to far-red). This provided the first detections of O II and C II optical recombination lines from proplyds, used here as abundance diagnostics.

Fig 1: LV2 (Orion) in Hα (*HST*). Box is FLAMES 6.6″ x 4.2″ fov. Circles are 0.26″ *HST* FOS apertures.



2. Physical conditions from velocity-resolved line mapping

Using background-subtracted spectra (Fig 3) it has been possible to compute the density and temperature (Fig 4) of the gas evaporated from the embedded disk and the outflowing bipolar jet. The proplyd highly-ionized zone in the 'cusp' and the supersonic redshifted jet lobe has 9200 +/- 800 K and is very dense Ne ~ 10^6 – 10^7 cm^{-3}. The jet contains quasineutral clumps emitting neutral oxygen [O I] 630 nm lines.

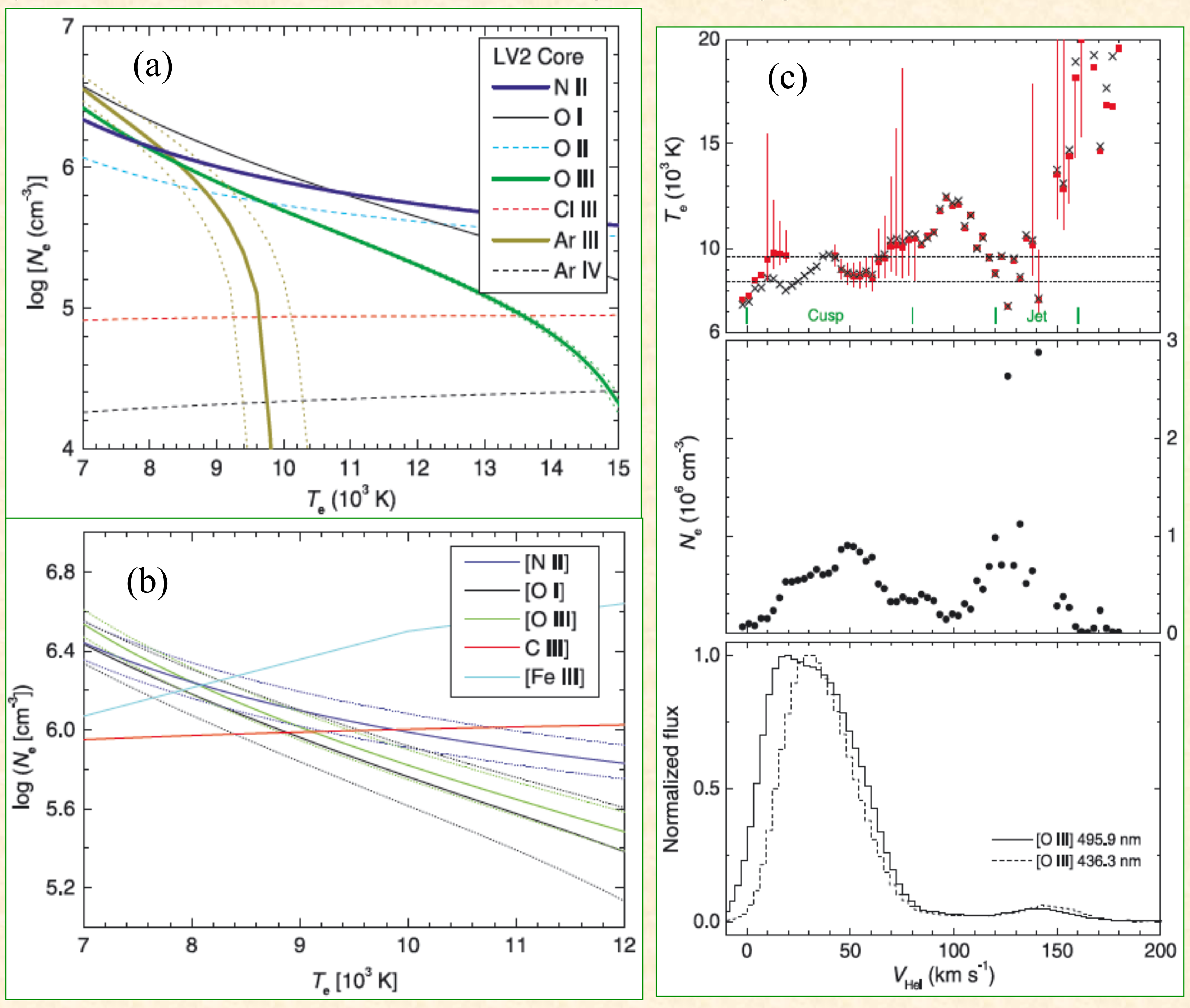


Fig 4: Electron temperature and density diagnostic diagrams for (a) the cusp (rest velocity of LV 2), and (b) the redshifted jet lobe. (c) Velocity-resolved gas conditions.

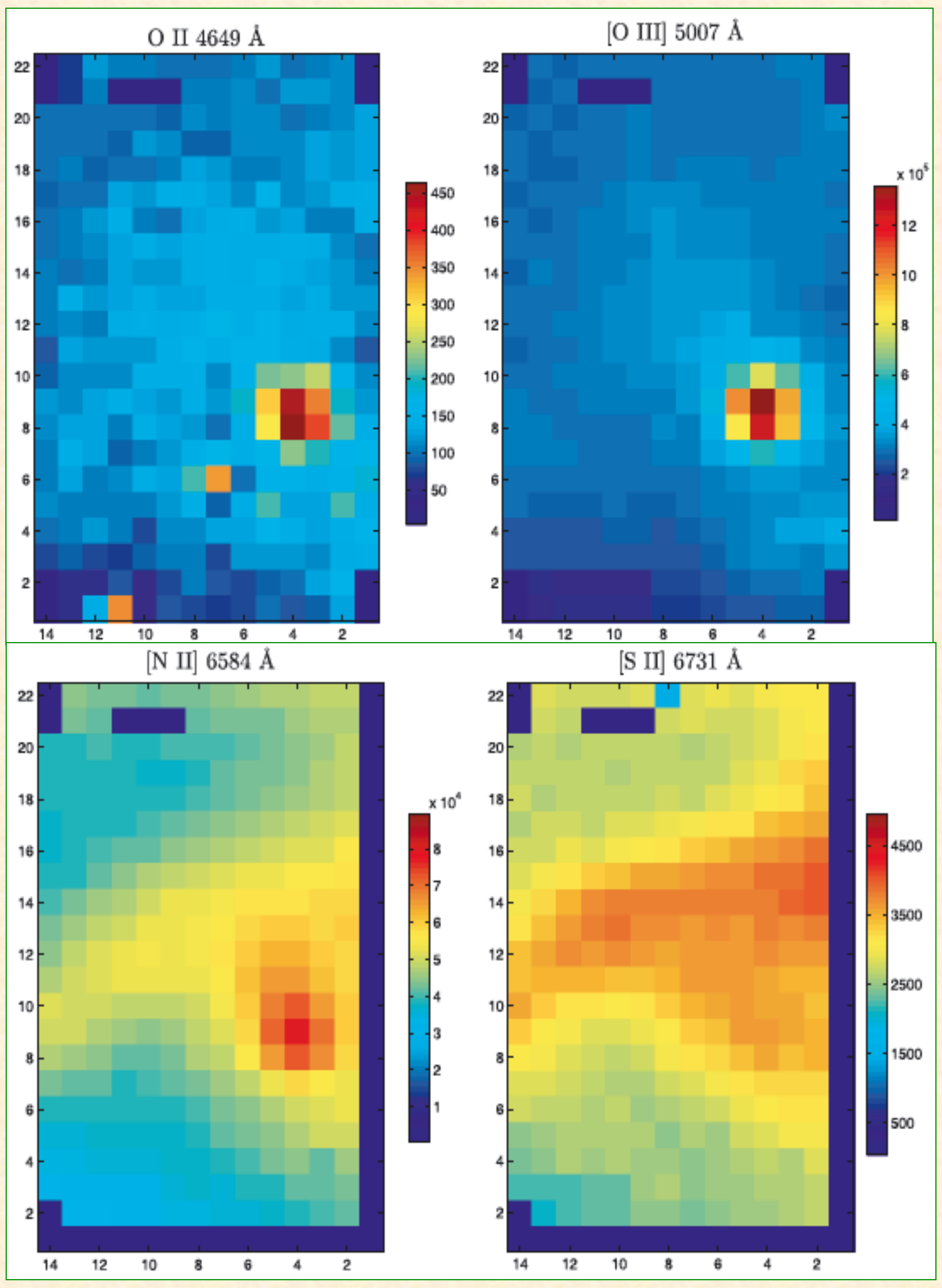
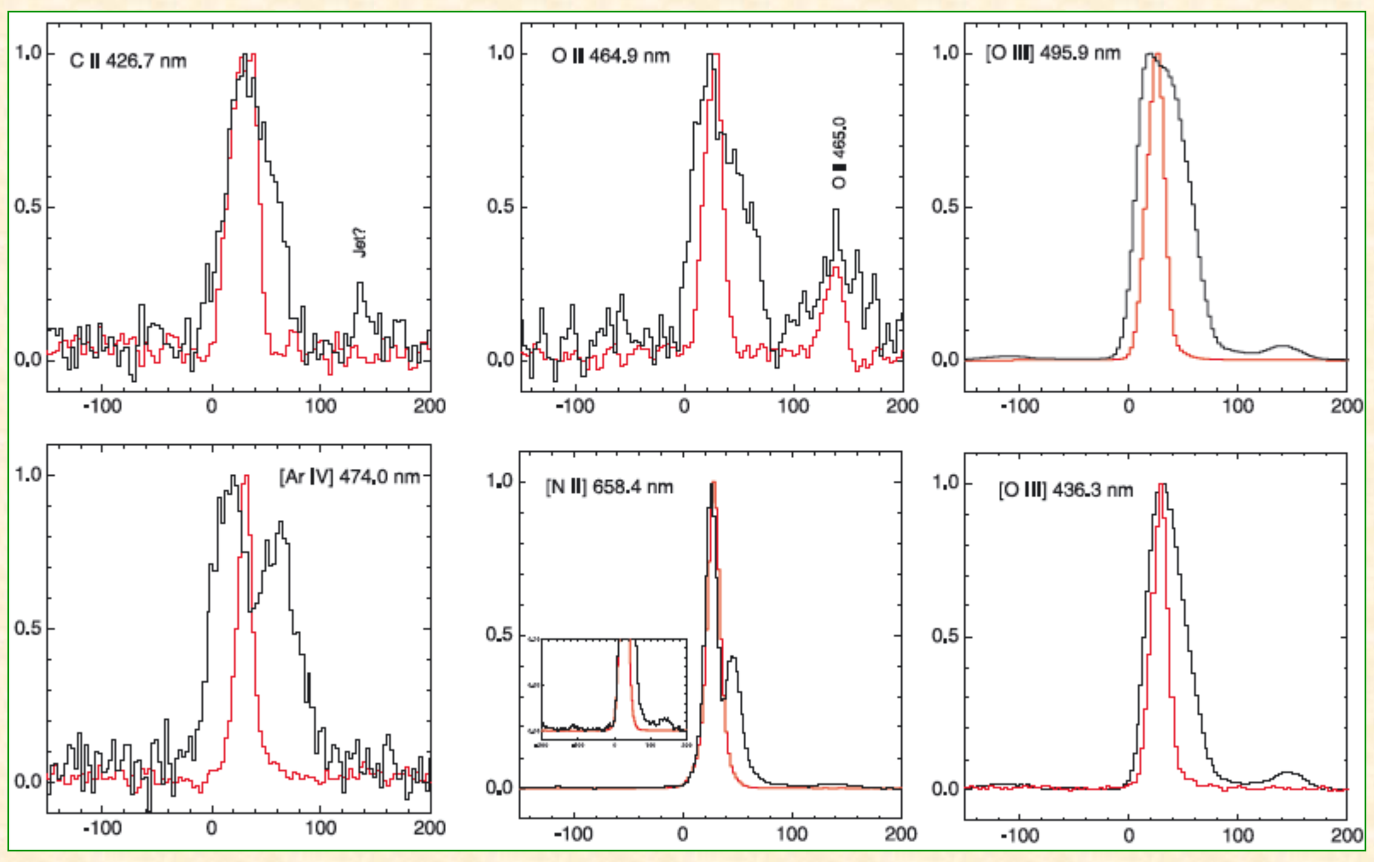


Fig 2: Spectral maps of LV 2 in recombination and forbidden lines



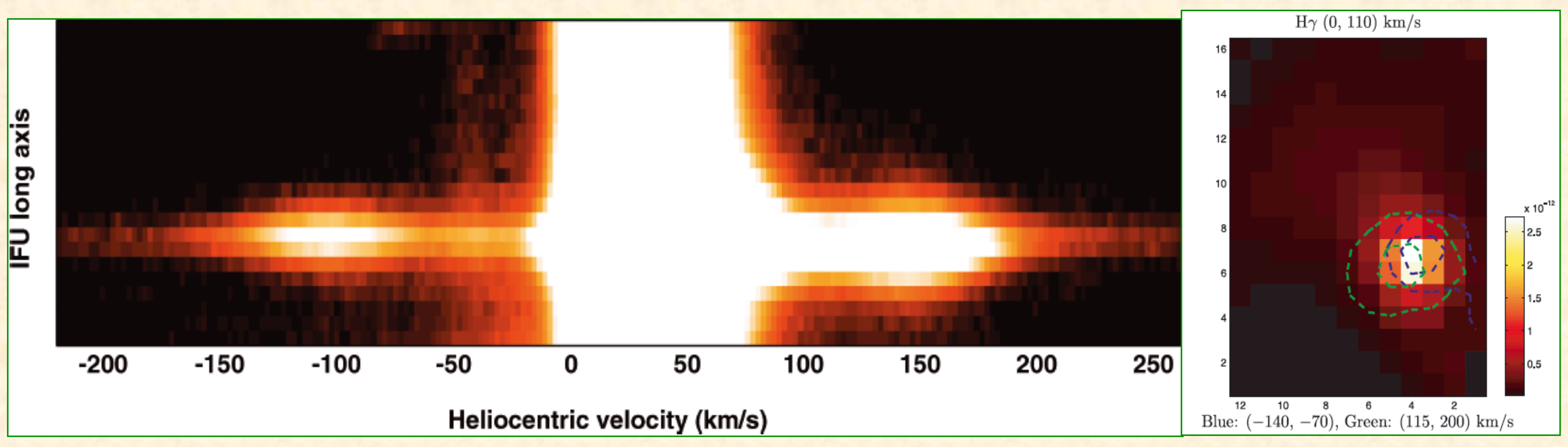
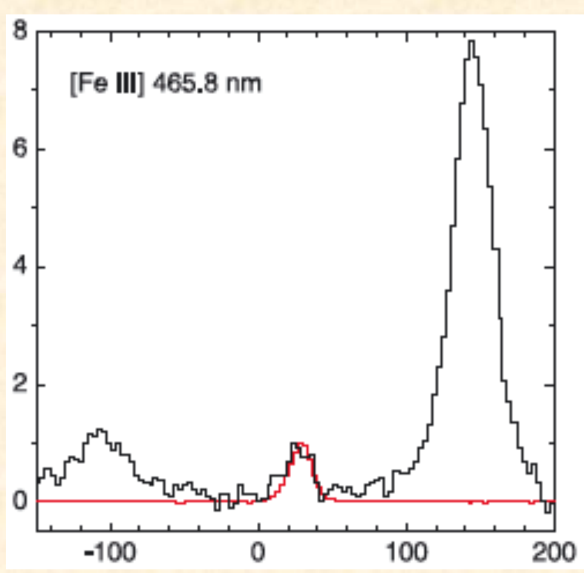


Fig 3 (top): Lines from LV 2 (black) and Orion background (red) in the heliocentric velocity frame. (Bottom): Hα and Hγ observation of LV2 (2 km/s/pix). Note the bipolar jet lobes at high velocities.



3. Chemical abundances

The gas-phase abundances in LV2 for carbon, oxygen and neon are 0.2 – 0.3 dex higher than solar, the local Orion nebula, and the OB-type ionizing stars (Tsamis et al. 2011). On the other hand, in the kinematic core of LV 2 iron is highly depleted relative to solar (2.5 dex). This shows that dust grains are precipitating towards the embedded disk where grain-growth is underway. In the red-shifted jet lobe the iron abundance is half solar providing evidence for grain destruction there (see [Fe III] observation left). Finally, the Ne/S abundance ratio in LV 2 is at least twice solar (Tsamis & Walsh 2011).

References: Tsamis et al. (2011), MNRAS, 412, 1367; Tsamis & Walsh (2011), MNRAS, in press (arXiv: 1107.1531); Adams (2010), ARA&A, 48, 47; Mann & Williams (2010), ApJ, 725, 430; McCaughrean & O'Dell (1996), AJ, 111, 1977; Petigura & Marcy (2011), ApJ, 735, 41