Photoevaporating protoplanetary discs from the VLT to the E-ELT era

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1. Introduction and rationale

Proplyds are evaporating protoplanetary 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 clustered near the hot massive stars of the Trapezium. 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 E-ELT should revolutionize their study. 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) 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. Our programme (Tsamis et al. 2011; Tsamis & Walsh 2011; Tsamis et al. 2013) is yielding the first inventory of proplyd He, C, N, O, Ne, S, Cl, Ar, Fe abundances: these are accessible via the analysis of their forbidden and permitted emission lines in far-UV to near-IR spectra. Here studies of Orion proplyds LV 2 and HST 10 are presented, based on VLT FLAMES optical integral field spectroscopy (Fig. 1, 2) and *HST* FOS and STIS data (far-UV to far-red). These observations have yielded the first detections of weak O II and C II optical recombination lines from proplyds, useful as abundance diagnostics (Fig. 3).

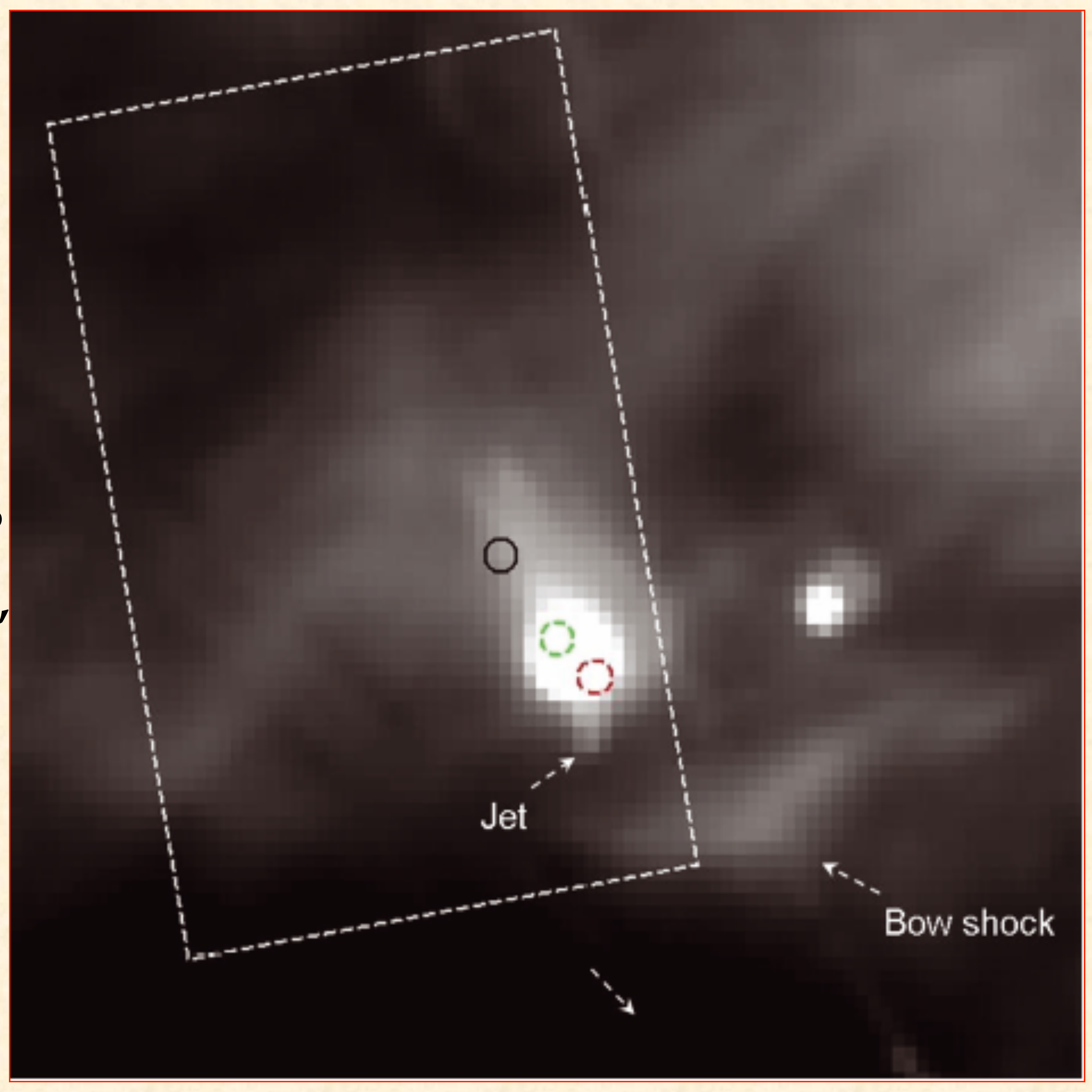
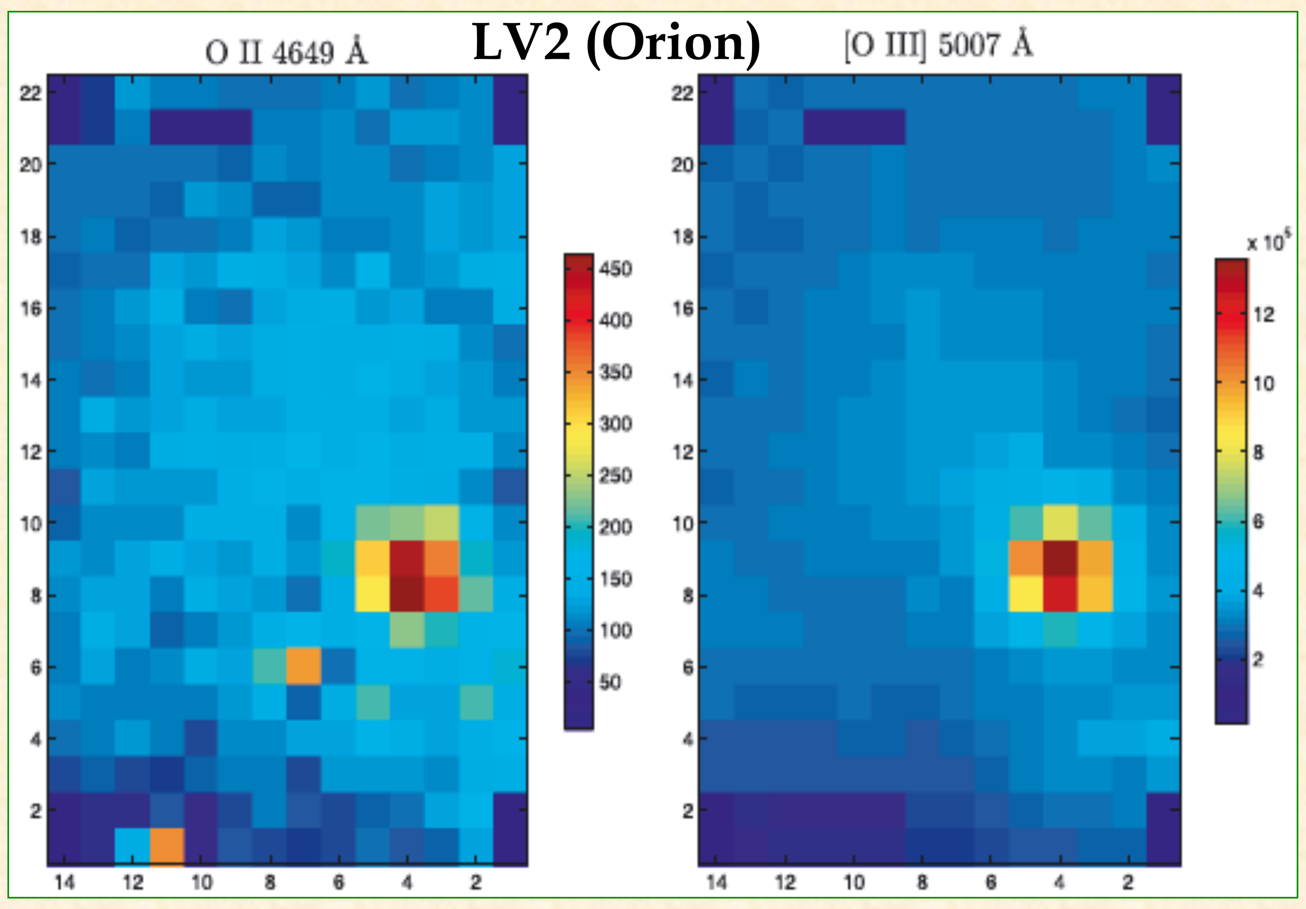


Fig 1:

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



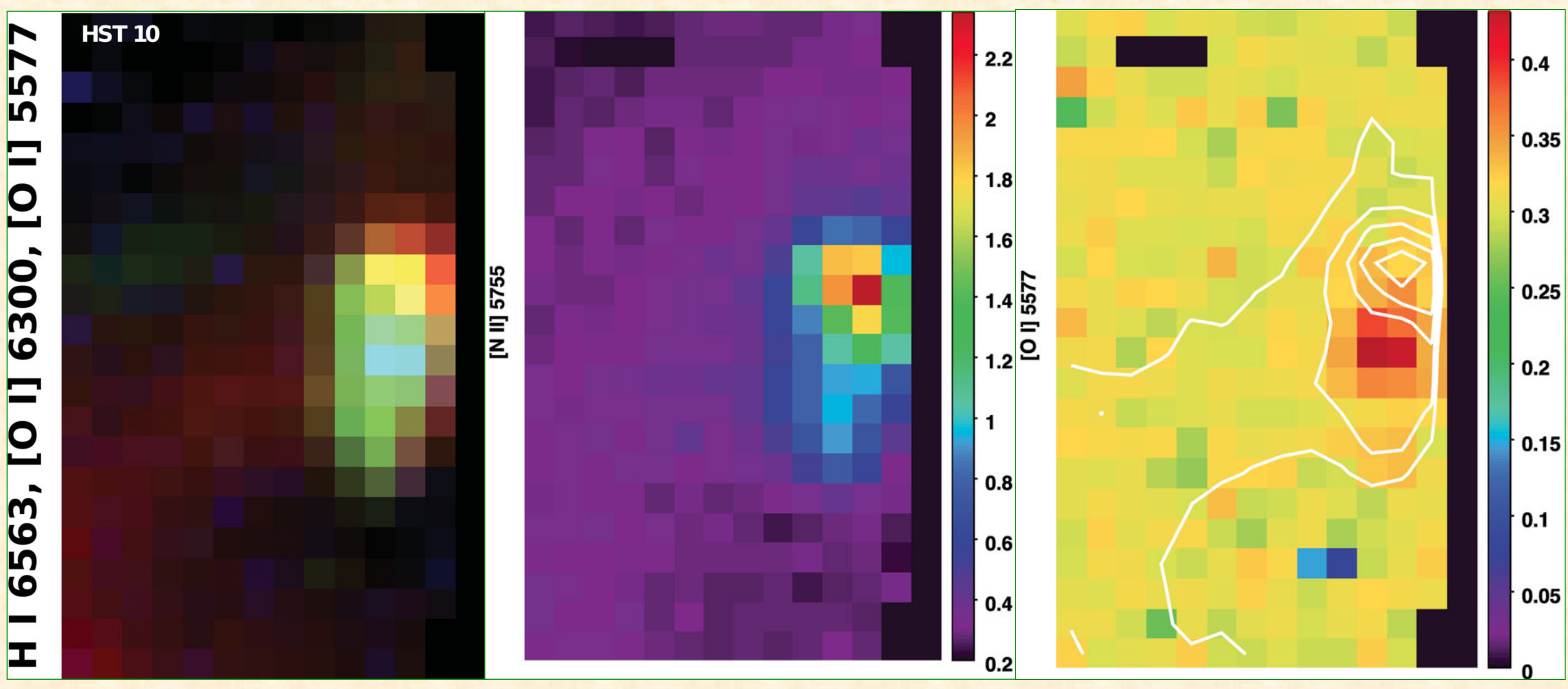
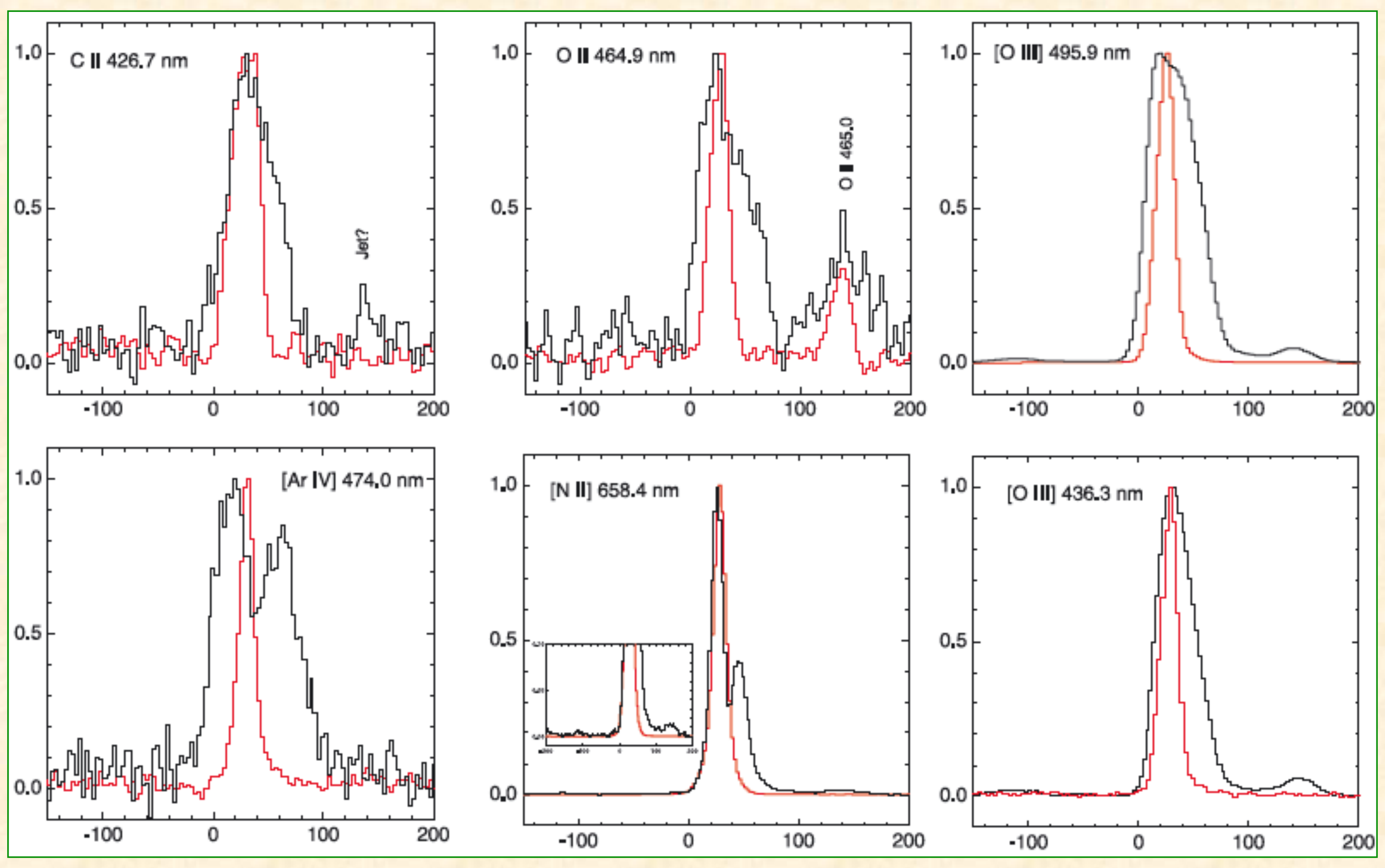


Fig 2: Maps of LV 2 (top) and HST 10 (below) in recombination and forbidden lines with 0.31″ x 0.31″ FLAMES/Argus spaxels

2. Velocity-resolved physical conditions and hydro-ionization models

Using background-subtracted spectra (Fig. 3 top) we have computed the density and temperature (Fig. 4) of the very dense gas (~10^6 – 10^7 cm^{-3}) evaporated from the disk and jet of LV 2. The jet contains quasi-neutral clumps emitting oxygen [O I] 630.0 nm lines. Dynamic Cloudy models show typical mass-loss rates of 2–3 x 10^{-7} $M_{\odot}yr^{-1}$ (Tsamis et al. 2013). Interestingly, the elapsed evaporation times are too short (1–3 x 10^4 yr) compared to the age of Orion (>10^5 yr), but would come into agreement if the disk masses were increased by x 5-10 due to lower than assumed dust opacities. That would make the disks at least as massive as the 'minimum mass solar nebula'.



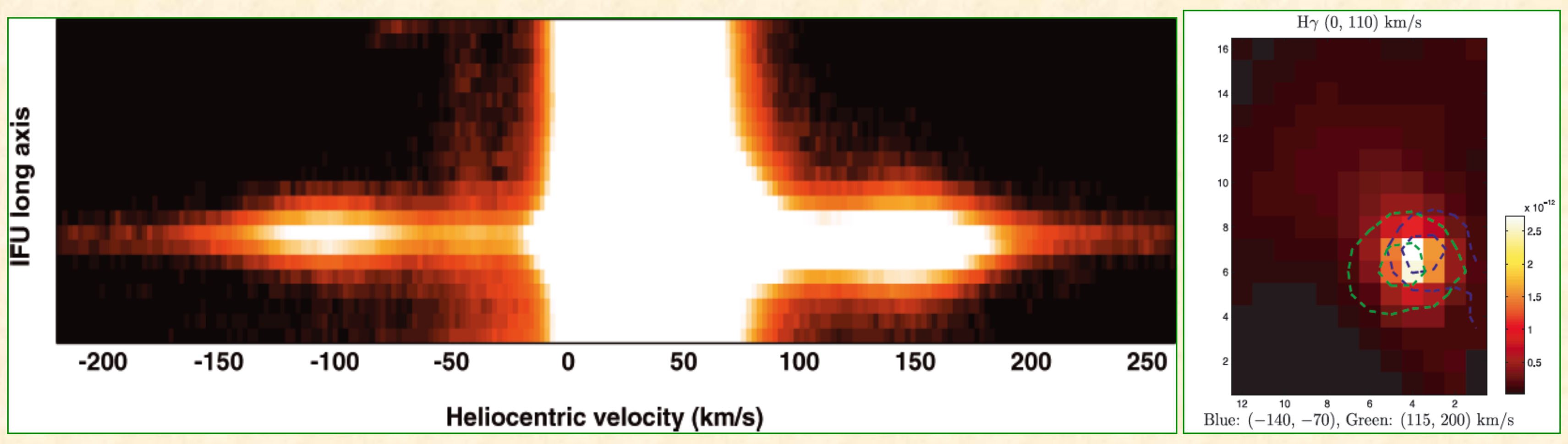
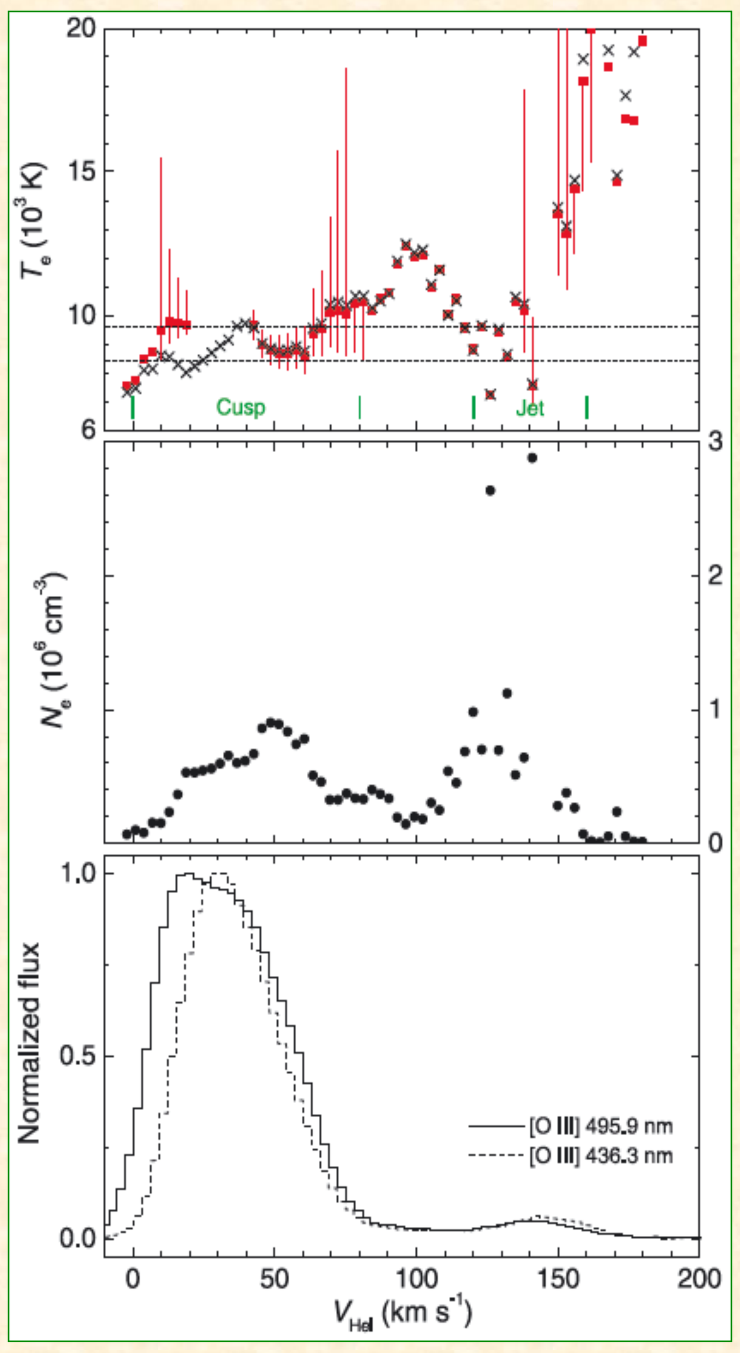


Fig 3 (top): Lines from LV 2 (black) and Orion background (red) in the heliocentric velocity frame. (Bottom): Hα and Hγ observation of LV2 (2 km/s). Note the bipolar jet lobes at high velocities.



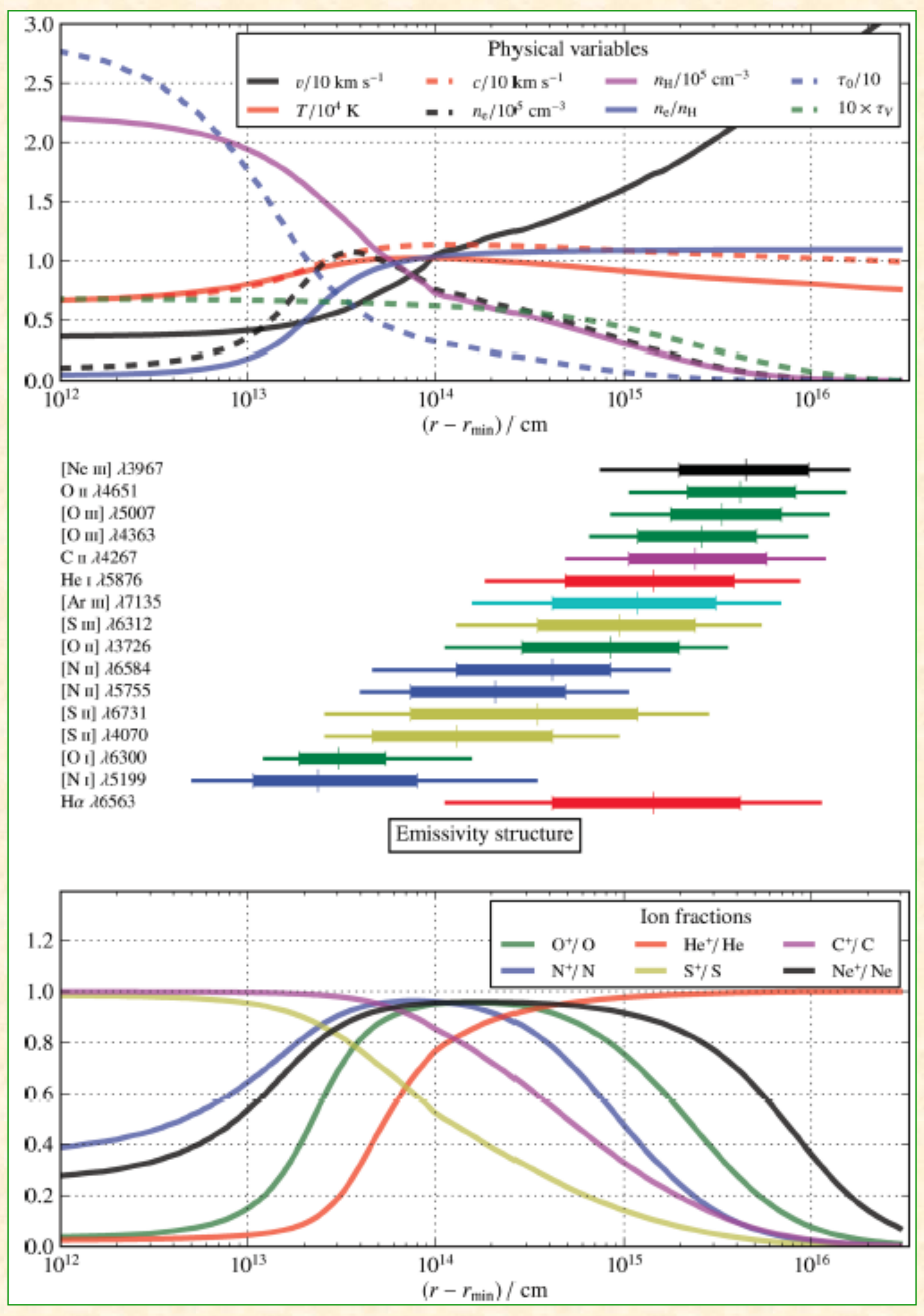
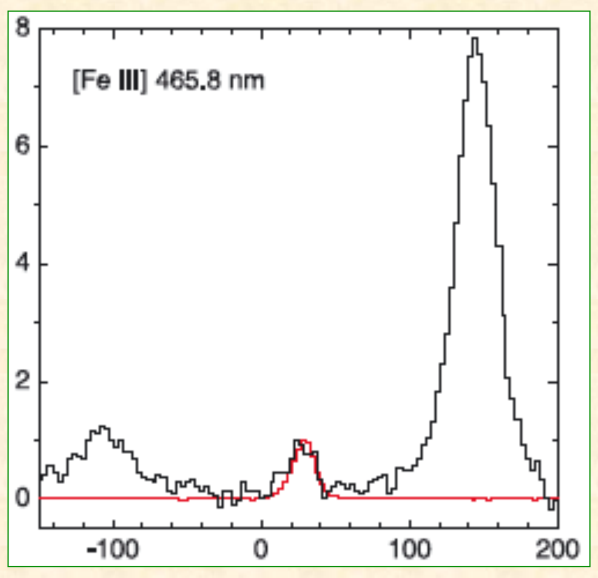


Fig 4: (L) LV2 velocity-resolved conditions across the cusp and red-shifted jet lobe. (R) Structure of HST 10 from hydrodynamic photoionization simulations.

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 jet the iron abundance is half solar providing evidence for grain destruction there (see left Fig; Tsamis & Walsh 2011). The C, O, Ne abundances in HST 10 are equal to those in B-type Orion stars (Tsamis et al. 2013).

References: Tsamis et al. (2011), MNRAS, 412, 1367; Tsamis & Walsh (2011), MNRAS, 417, 2072; Tsamis et al. (2013), MNRAS.tmp..770T; 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