A Massive Star Odyssey, from Main Sequence to Supernova
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On the ionizing source of the Flame Nebula (NGC 2024)

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Abstract. We have identified IRS 2b as the ionizing source of the Flame Nebula (NGC 2024). For several decades it has been clear that such a hot, massive star must be present in this heavily obscured region, and now it has been found. New J- and K-band photometry and a VLT-ISAAC K-band spectrum show that IRS 2b is an O8 - O9.7 V star, consistent with published radio continuum and recombination line observations. IRS 2b seems to be slightly evolved from the zero-age main sequence.

1. Introduction

The Orion complex hosts several well-known H II regions, such as the famous Orion Nebula and the compact H II region NGC 2024. In the optical, NGC 2024 appears as a bright nebula straddled by a north-south oriented dust lane, which obscures the central part of the nebula. This has made it very difficult to identify the main ionizing source of this H II region. Obviously, infrared imaging and spectroscopy are needed to obtain a full inventory of the stars in the central region of NGC 2024. Such studies have provided several candidates for the ionizing source of NGC 2024 (*e.g.*, NGC 2024-IRS2, Grasdalen 1974), but none of these candidates are very convincing.

2. The nature of the ionizing source

We present three independent diagnostics that help to constrain the position of IRS 2b in the Hertzsprung-Russell diagram (*cf.* Bik *et al.* 2002). The derived temperature and luminosity of IRS 2b indicate that it is the likely ionizing source of NGC 2024. The three arguments we can offer are: (*i*) the J- and K-magnitude; (*ii*) the K-band spectrum; and (*iii*) the radio continuum flux of NGC 2024.

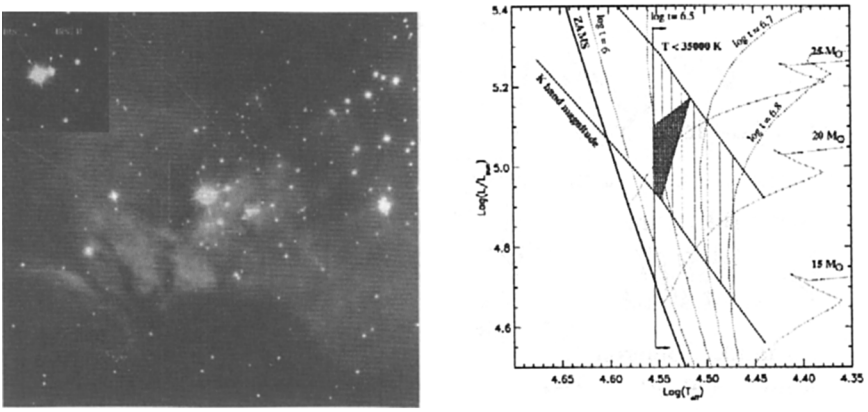

Figure 1. *Left:* Near-infrared image of NGC 2024 (Paβ, H_2, Brγ). The insert shows IRS 2b, the ionizing source of the Flame Nebula. *Right:* H-R diagram, including the derived constraints on L and $T_{\rm eff}$ of IRS 2b.

Adopting a distance $d = 363$ pc (Brown *et al.* 1994) and a reddening of $V = 24$ mag (using an anomalous extinction law with $R_V = 5.5$, Lee 1968), the K-band magnitude can be converted into luminosity for a given temperature, thus constraining its location in the H-R diagram (Figure 1). The K-band spectrum of IRS 2b includes photospheric absorption lines of He I (2.1128, 2.1137 μm) and Brγ (2.1661 μm), indicating that its spectral type is cooler than O7.5 V, corresponding to $T_{\rm eff} < 35\,000$ K (Hanson *et al.* 1996).

The number of ionizing continuum photons derived from radio continuum maps (*e.g.*, Barnes *et al.* 1989) compared with stellar models of Smith *et al.* (2002) provides a further constraint in the H-R diagram (Figure 1). The resulting range in $T_{\rm eff}$ (32 500 to 35 000 K) and in $\log(L/L_\odot)$ (4.8 to 5.2) is consistent with a spectral type O8 - O9.7 V (Martins *et al.* 2002). Its location in the H-R diagram suggests that IRS 2b is slightly evolved from the ZAMS, close to the isochrone of 3×10^6 yr.

References

Barnes, P.J., Crutcher, R.M., Bieging, J.H., *et al.* 1989, ApJ 342, 883
Bik, A., Lenorzer, A., Kaper, L., *et al.* 2002, A&A submitted
Brown, A.G.A., de Geus, E.J., de Zeeuw, P.T. 1994, A&A 289, 101
Grasdalen, G.L. 1974, ApJ 193, 373
Hanson, M.M., Conti, P.S., Rieke, M.J. 1996, ApJS 107, 281
Lee, T.A. 1968, ApJ 152, 913
Martins, F., Schaerer, D., Hillier, D.J. 2002, A&A 382, 999
Smith, L.J., Norris, R.P.F., Crowther, P. 2002, MNRAS 337, 1309

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