Jets & Outflows from YSOs
in the Carina Nebula Observed in [Fe II] 1.64 μm

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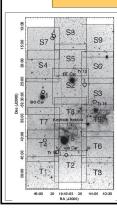
Introduction

- Carina Nebula
- $(l, b) = (287.6°, +0.9°)$
- Distance ~ 2.2-2.9 kpc
- Size ~ 180' × 180'
- Star Forming Region with Massive Stars
- Tens of Herbig-Haro (HH) Objects

- Star formations near massive stars (≥ 8 M_s) are peculiar in many aspects: for example, strong UV radiation and stellar winds

- Difficulty in finding shock-excited Hα features; instead, [Fe II] 1.64 μm is useful under strong UV radiation environments

Conclusion

- [Fe II] 1.64 μm imaging observation over the northern part (~ 24' × 45') of the Carina Nebula

- 11 jet and outflow [Fe II] features are detected, and named as Ionized Fe Objects (IFOs); IFO-2, -4, -7 can be linked to jet-driving objects

- Detection Rate: 40 % against HH objects, 0% against Molecular Hydrogen Emission Line Objects (MHOs): J-shock vs. C-shock

- Morphology of IFOs: knotty or longish

- $\dot{M}_{out}$ is estimated with two different methods along with IFO morphologies

- $\dot{M}_{out}/\dot{M}_{acc}$ of IFO-4 and -7 fall into the observed range ($10^{-2} - 10^{+1}$, Ellerbroek et al. 2013); IFO-2 of excessive ratio---underestimated $\dot{M}_{acc}$

- Reasonable relation or trend between $\dot{M}_{out}$ and other YSO physical parameters

Observation & Data Reduction

- IRIS2 of Anglo-Australia Telescope
- FoV of ~8' × 8', 0.4486" per pixel,
- observed 2011-Feb & Mar
- 3 × 3 dithering
- H = 10s, [Fe II] = 200s
- 18 tile, target-sky pairs
- seeing of 1.5 " ± 0.5 "

[Fe II] 1.64 μm image of observed area
8 black circles = IFO; 5 black 'X' = MHO

AAT-IRIS2

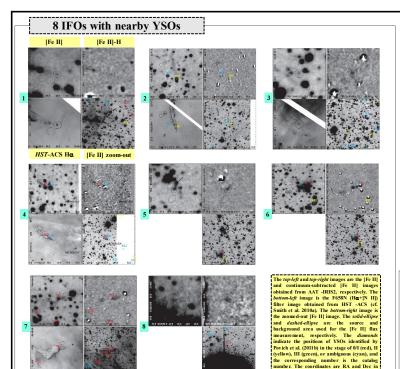### Data Reduction

- Used the standard pipeline, ORAC-DR packaged in STARLINK

- Flux calibration using 2MASS catalog: 8-20 % errors dominated by 2MASS photometric error

Analysis & Result

8 IFOs with nearby YSOs

The *top-left* and *top-right* images are the [Fe II] and continuum-subtracted [Fe II] images obtained from AAT -IRIS2, respectively. The *bottom-left* image is the F658N (Hα+[N II]) filter image obtained from HST -ACS (cf. Smith et al. 2010a). The *bottom-right* image is the zoomed-out [Fe II] image. The *solid-ellipse* and *dashed-ellipse* are the source and background area used for the [Fe II] flux measurement, respectively. The *diamonds* indicate the positions of YSOs identified by Povich et al. (2011b) in the stage of 0/I (red), II (yellow), III (green), or ambiguous (cyan), and the corresponding number is the catalog number. The coordinates are RA and Dec in J2000. IFO-1 to -8 from left to right and from top to bottom.

Estimation of $\dot{M}_{out}$

Knotty IFOs

$$L_{[FeII]} = f_{[FeII]} \times 4\pi d^2$$

$$L_{mech} = L_{[FeII]}/(1.5 \times 10^{-3})$$

$$L_{mech} = \frac{7}{27}\dot{M}_{out}v_w^2$$

Longish IFOs

$$\frac{f_{[FeII]}}{\Omega} = \frac{h\nu_{ul}\,N_{Fe^+,u}\,A_{ul}}{4\pi}$$

$$N_H = \frac{N_{Fe^+,u}}{A_{Fe/H}\,f_{Fe^+}\,f_{Fe^+,u}}$$

$$M_H = N_H\mu\Omega d^2$$

$$\dot{M}_{out} = \frac{M_H}{\tau} = \frac{M_H}{l_{out}/v_{out}}$$

Table 2. [Fe II] Flux Measurements

Table 3. Estimated Outflow Rate

Table 4. Physical Parameters of the Relevant YSOs