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

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#### Introduction

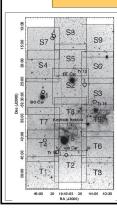


- · Carina Nebula
- $(l, b) = (287.6^{\circ}, +0.9^{\circ})$
- Distance ~ 2.2-2.9 kpc
- Size ~ 180' × 180'
- Star Forming Region with Massive Stars
- Tens of Herbig-Haro (HH) Objects
- Star formations near massive stars ( $\geq 8 M_s$ ) are peculiar in many aspects: for example, strong UV radiation and stellar winds
- Difficulty in finding shock-excited Ha features; instead, [Fe II] 1.64 um is useful under strong UV radiation environments

### Conclusion

- [Fe II] 1.64  $\mu$ m imaging observation over the northern part (~ 24'  $\times$ 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
- $\cdot \dot{M}_{out}$  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<sup>-2</sup> 10<sup>+1</sup>, 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  $\sim 8' \times 8'$ , 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 "  $\pm$  0.5 "

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

#### **AAT-IRIS2**

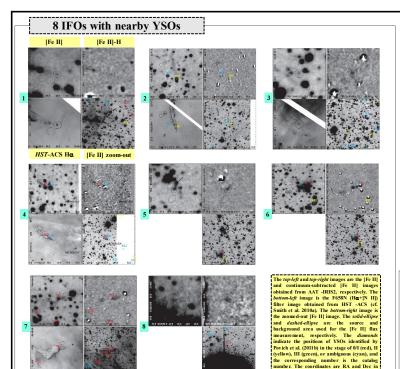


Filter Harry	Cut-on (um)	Cathol
0	ordere)	_
4	3.9%	1.06
)	5.161	5.724
	1.480	5,780
K.	1.967	2,206
к.	4.900	4.394
	3.995	1,000
Minispetiscope	3.95	1.25
Mone specimização	1.53	1.93
Lagathyacock	1/4	5.62
No.	trenhad	
le:	1.075	5.691
Josef num *	1.191	2.210
(Pe Sela) **	1.272	5.290
H portinum	1,000	5.589
(Fa T	1.630	1288
Hothers Offserd (CHS II)	1,52	2.52
HARRIST CONTACT (CLV_I)	1.84	1.70
H <sub>2</sub> (971 0 5(2)	2.105	1339
R: flames	2.130	2.182
To re#2-19(1)	2.201	2,263
KERENJAR	2.234	4.487
COCNE) hand head	2.278	2,317

## 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**



Targets	RA, Dec (J2000)	HH	FRe III flox		
		Object 1		Dereddened <sup>2</sup> g s <sup>-1</sup> cm <sup>-3</sup> )	
IFU-1	10.43:59.090, -59:30:35.77	HH902	8.8±1.5	15.1±2.6	
IFO-23	10:44:20.566, -59:25:57.00	HH1013 NE2	13.8±1.3	23.6±2.3	
IFC-3	10:44:59.910, -59:45:06.55	***	15.4±1.5	25.4±2.5	
IFO-4"	10:45:19.854, -58:44:19.98	HEECO	37.2±1.8	53.8±3.2	
IPO-5	10:45:26 143, -59:12:44.38		23.6±1.1	49.4+2.0	
IFO-6s.	10:45:29 555, -58:13:21.05		93.6+4.0	163.0+5.8	
IFO-6b	10:45:30 849, -59:13:26:27	***	17.111.0	29.3   1.7	
IFO-6c	10:45:31.373, -59:13:26:27	44.5	12.610.9	21.6±1.5	
IFO-7s	10:45:46.098, -59:41:06:43	11111014	32.612.3	55.8±4.0	
IFO-7b	10:45:47.306, -59:41:07.87	100	8.7±2.0	14.9±3.5	
IFO 8	10:45:49.292, -56:27:56.72		38.7±4.9	66.2±8.4	

<sup>17</sup>The extinctions were corrected, using a typical  $A_V$  of 3.5 (Preitisch et al. 2011b) and the extinction curve of "Milky Way,  $R_V = 4.0$ " (Weingsttarr & Desine 2001; value 2003).

Tergets	Shape <sup>†1</sup>	Solid	Outflow	Gutflow Mass Loss	Ontflow Mass Loss
		Argle ( $\Omega$ ) Length ( $L_{out}$ ) ( $\Pi^{-10}$ sr) ( $^{9}$ )		Rate $^{2}(M_{\text{out}};  \text{Fe II} )$ $(10^{-7} M_{\odot} \text{yr}^{-1})$	Rate <sup>B</sup> ( $M_{cat}$ ; Ho) ( $10^{-7} M_{\odot} \text{ yr}^{-1}$ )
IFO-1	K			11.5+2.0	1.76
IFO-254	K	430	100	18.011.7	0.21
IFO-3	K	446	100	20.1±1.9	
IFO-IB	L	2.8	2.0	6.7±0.8	5.68
IFO-5	L	2.8	2.3	4.5±0.2	***
IFO-6a	L	3.8	2.7	15.6±0.7	***
IFO-6b	K	444	1.44	22.3±1.3	100
IFO-6c	K			16.5±1.1	
IFO-7a	T.	1.8	2.0	7.2+0.5	0.44
IFO-7b	K			11.4+2.7	

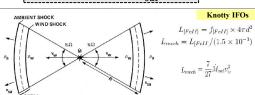
Toble 3 - Patimated Certifox Rate

PThe outflow rate is from Smith et al. (2010s), who estimated the rate from II a internal in internal internal

#### Table 4. Physical Parameters of the Relevant YSOs

Carslog $log L_{bol}^{\dagger 2} = log L_{acc}^{\dagger 2}$ Number <sup>††</sup> $(L_{\odot})$ $(L_{\odot})$	$log L_{rol}^{\dagger 2}$	$log L_{acc}$ 12	log M <sub>*</sub> -2	log M <sub>dtah</sub> 2	log M <sub>cav+amb</sub> †2	log1, 12	log Mass, eno 12	log Macc, sink 12	YSO Stage <sup>†2</sup>	Targets <sup>12</sup>
	(M <sub>50</sub> )	$(M_{\odot})$ $(M_{\odot})$	$(M_{\odot})$	$(yr)$ $(M_0/yr^{-1})$	$(M_{\odot} \ yr^{-1})$					
490	1.58±0.07	$-1.35\pm0.24$	0.40±0.02	-3.22±0.29	$-5.87 \pm 0.43$	6.77±0.10	$-9.9 \pm 0.29$	$-8.93 \pm 0.26$	II	IFO-2
842	1.48±0.31	0.32L0.50	-0.01±0.22	$-2.64\pm0.64$	-0.44±0.31	3.67±0.44	$-4.25\pm0.42$	-6.111.0.52	0/1	IFO-4
984	1.221.0.14	-0.27_0.47	0.01±0.15	$-2.21\pm0.32$	0.26±1.55	4.33L0.49	-3.75±1.70	$-6.86\pm0.59$	0/1	IFO-7

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



 $\frac{f_{[FeII]}}{\Omega} = \frac{h\nu_{ul} N_{Fe^+,u} A_{ul}}{N_{Fe^+,u} N_{ul}}$  $N_{Fe^+,u}$  $N_H = \frac{A_{Fe/H} f_{Fe^+} f_{Fe^+,u}}{A_{Fe/H} f_{Fe^+} f_{Fe^+,u}}$  $M_H = N_H \mu \Omega d^2$  $\dot{M}_{out} = \frac{M_H}{\tau} = \frac{M_H}{l_{out}/v_{ou}}$