Powerful jets in the Carina nebula

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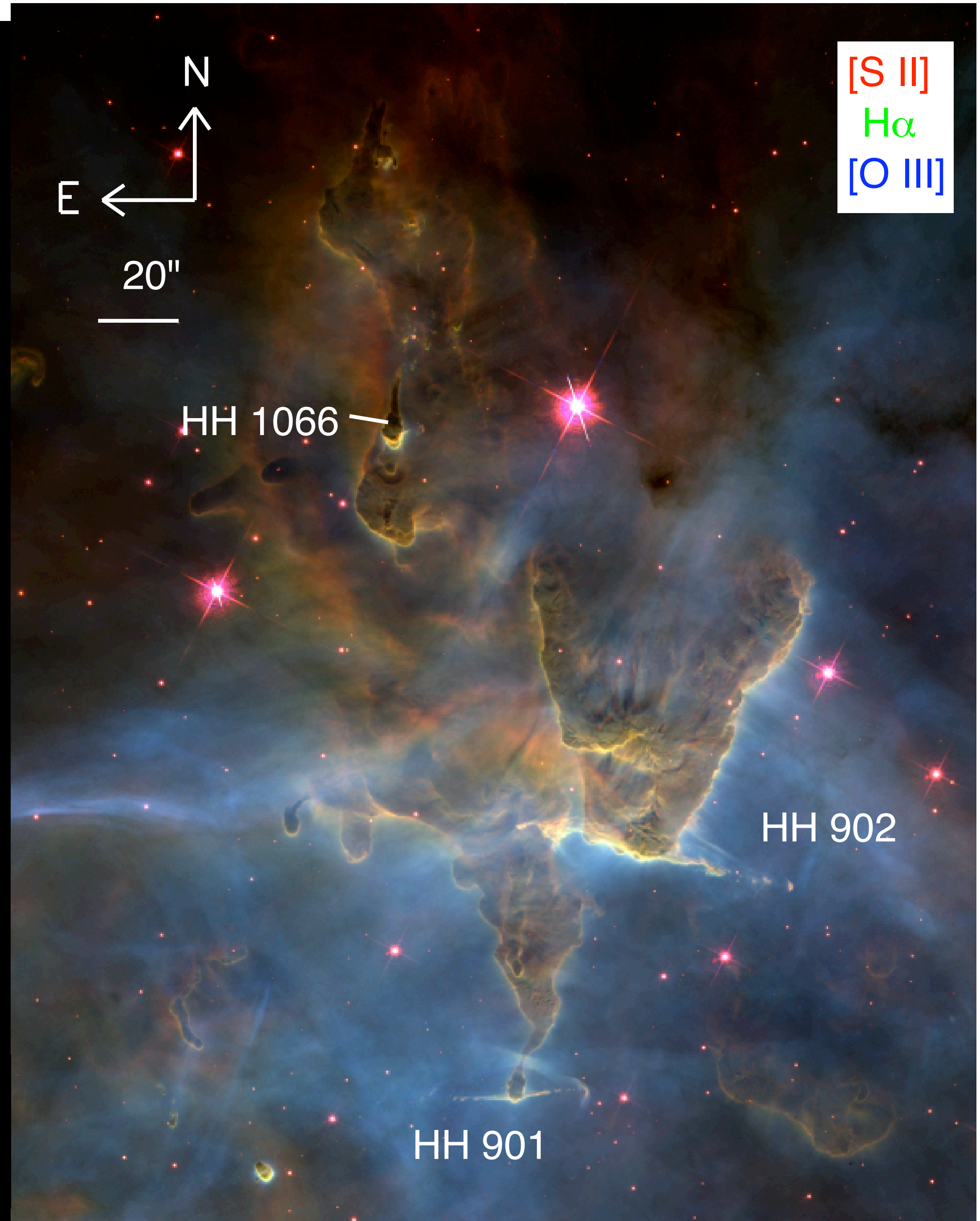
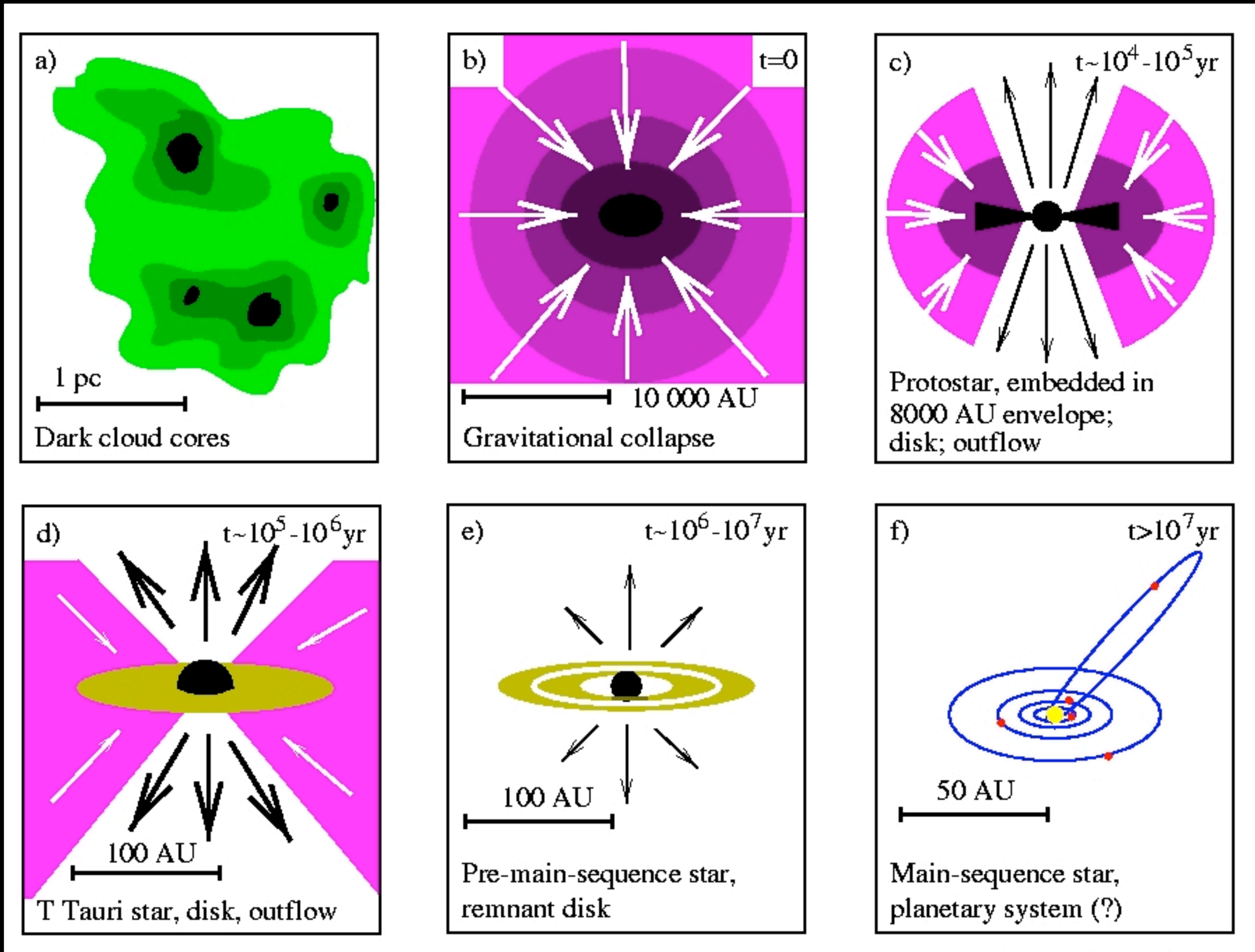
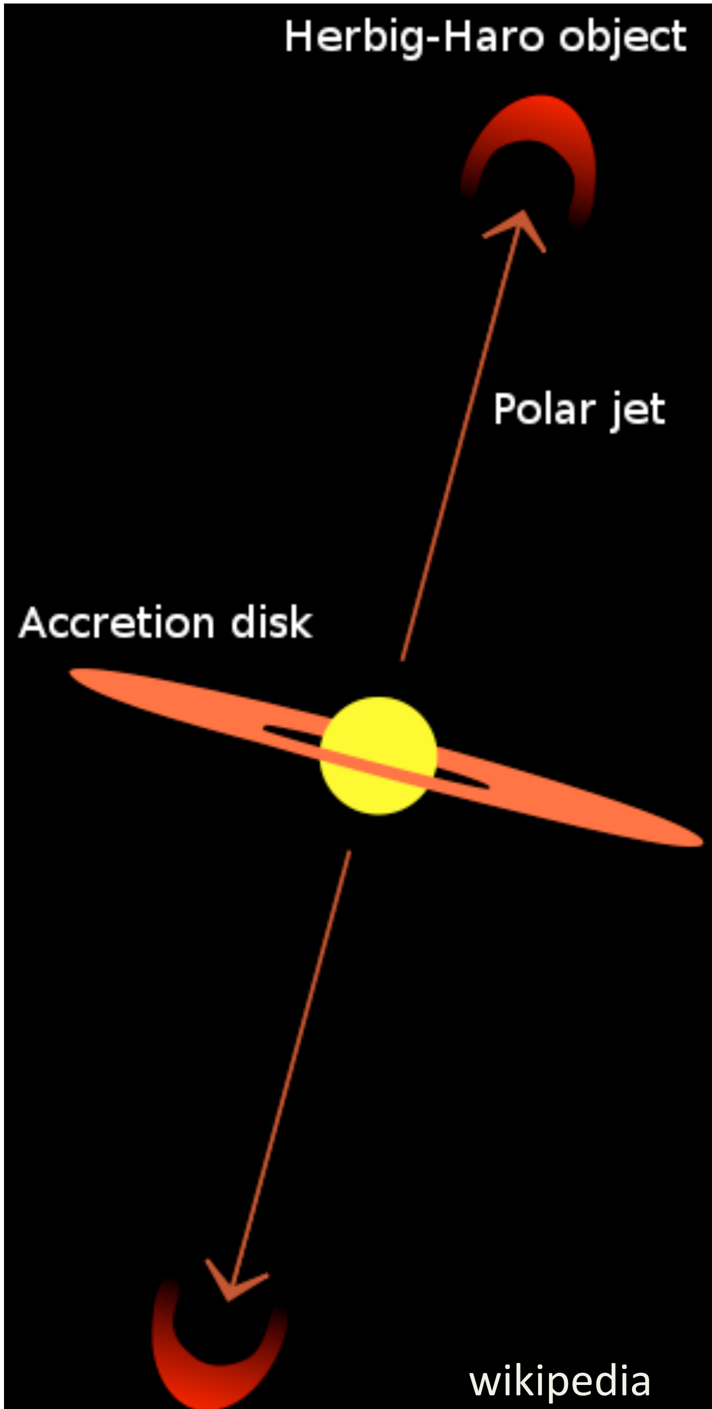


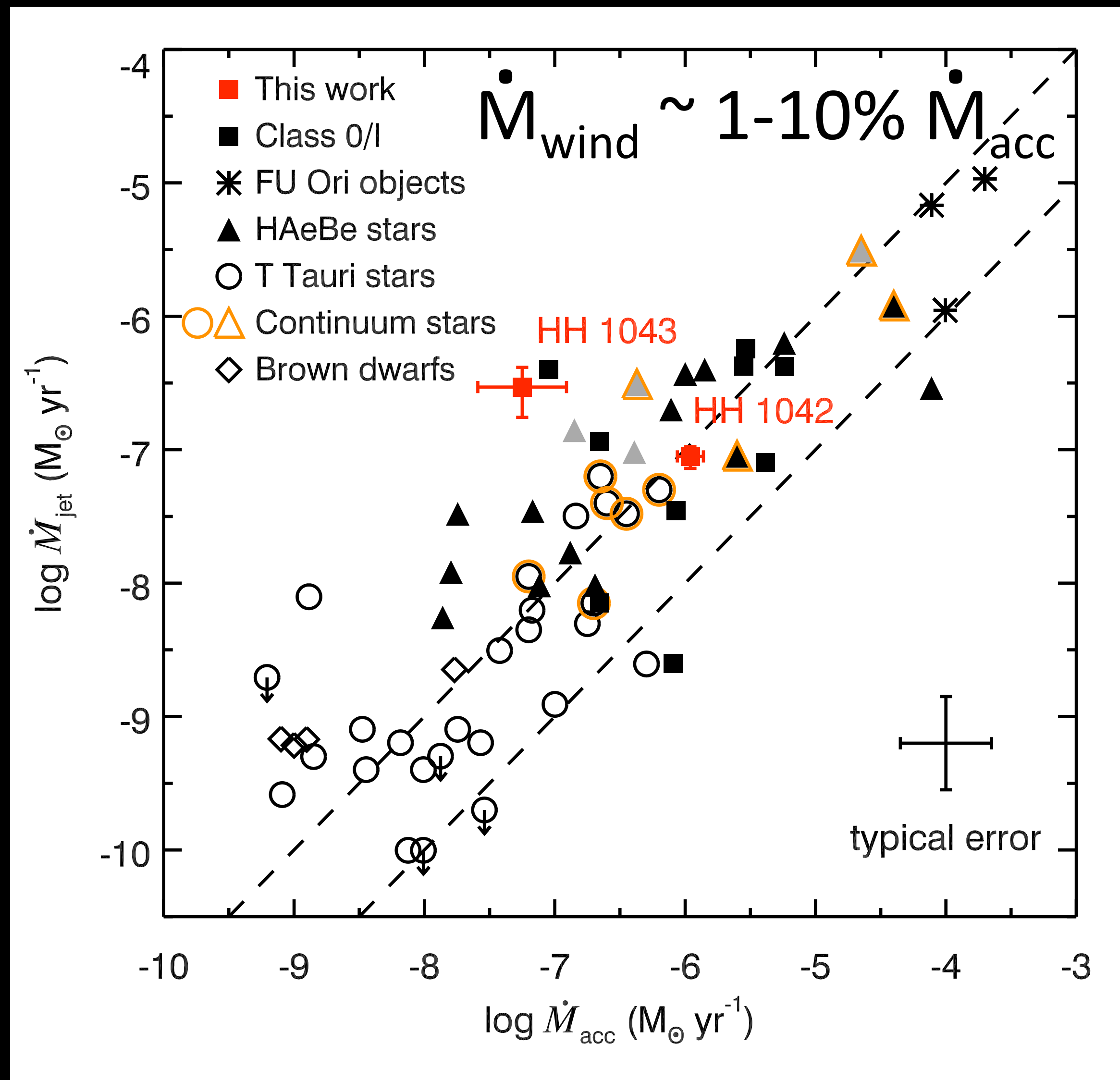


Hogerheijde 1998, after Shu et al. 1987

Accretion-Outflow

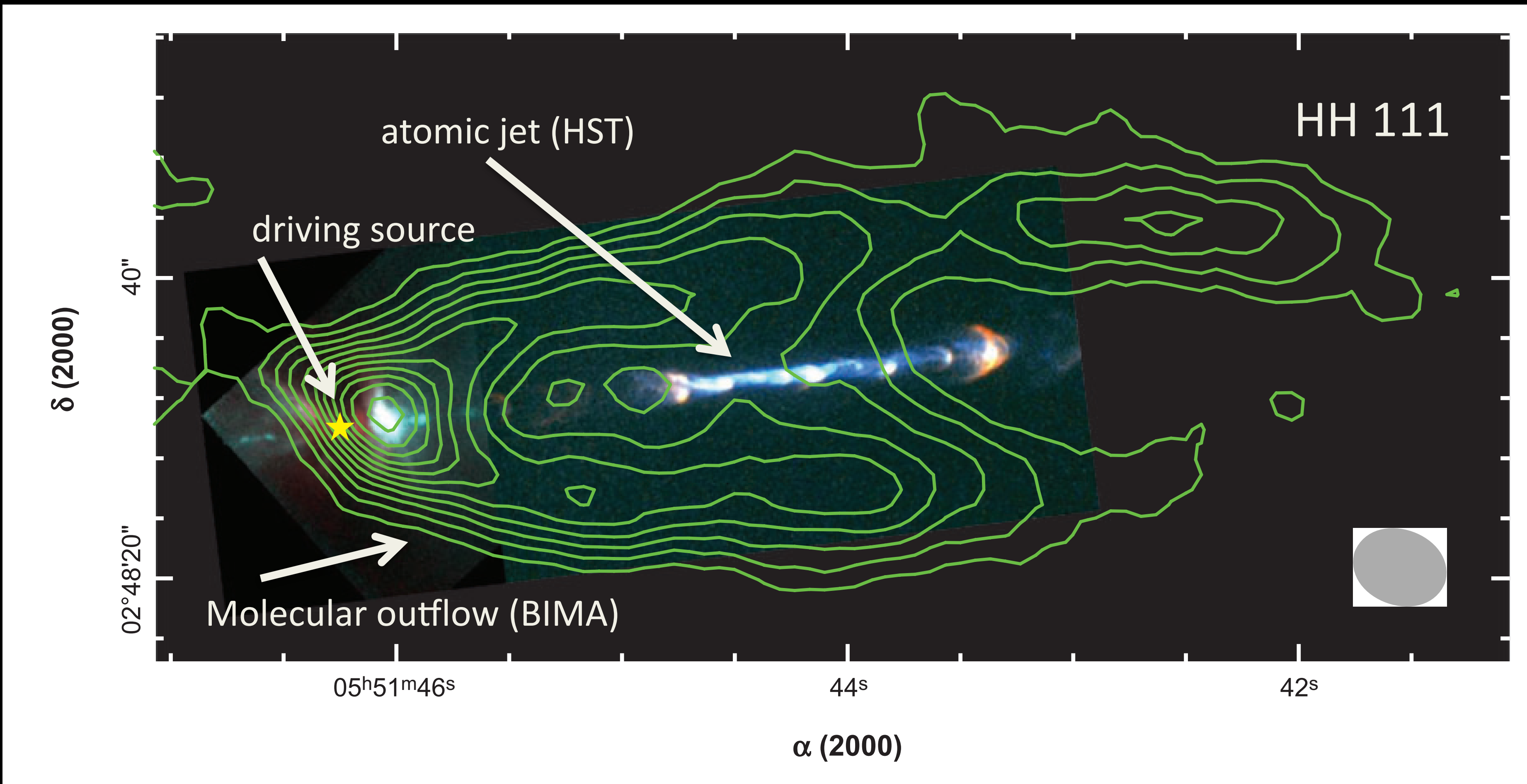


wikipedia

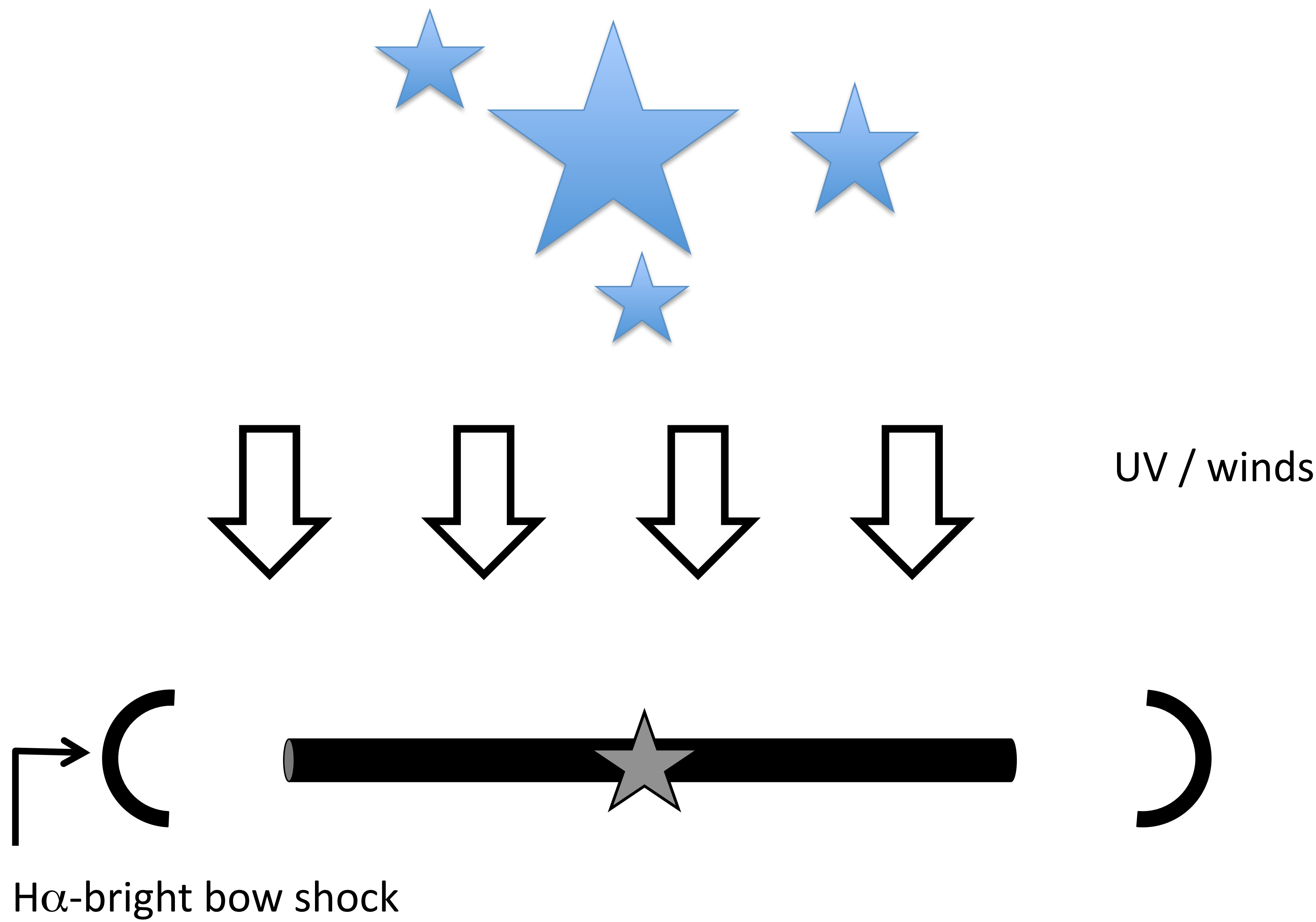


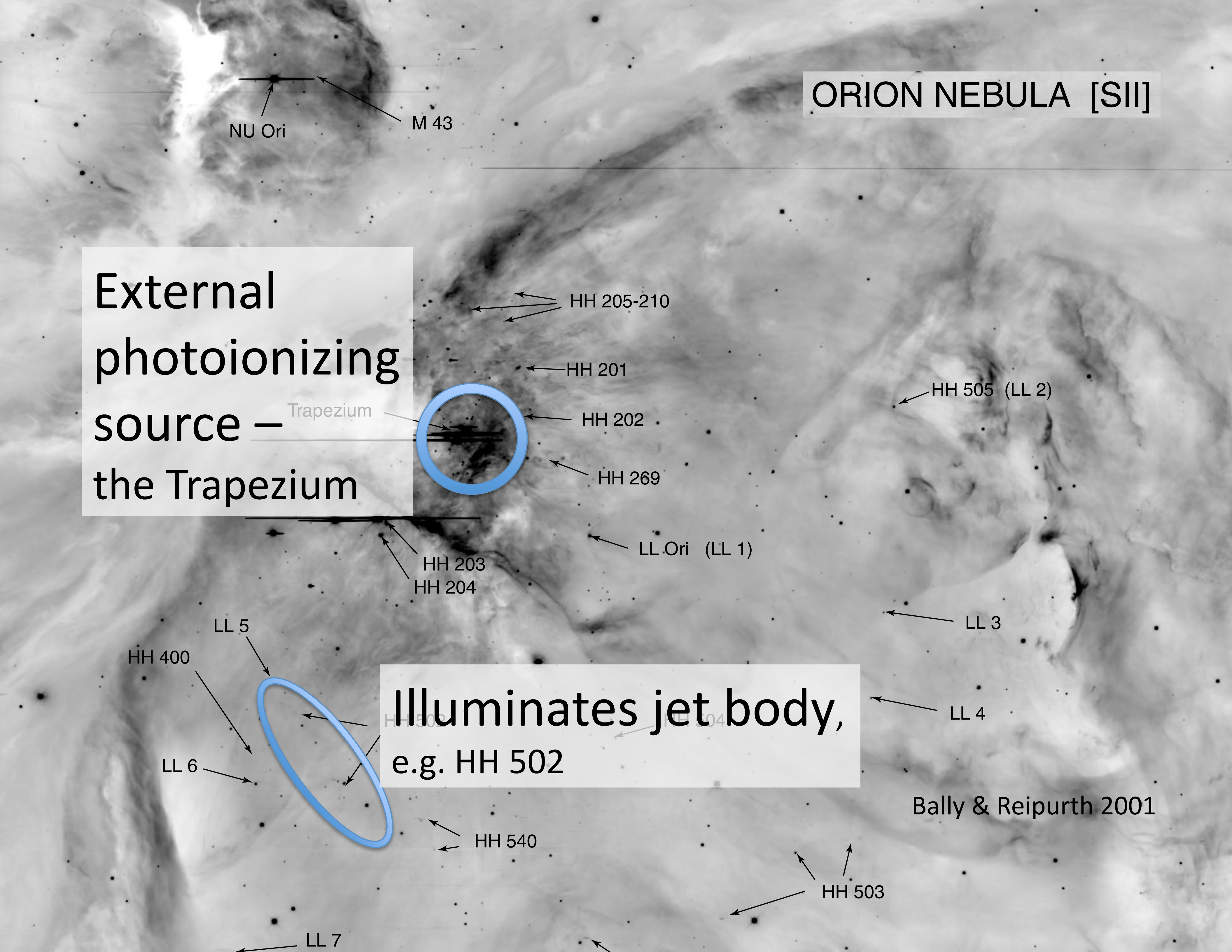
Ellerbroek et al 2013

Best outflow tracers?



Reipurth et al. 1999, Lee et al. 2000, McKee & Ostriker 2007


UV / winds
Hα-bright bow shock



ORION NEBULA [SII]
NU Ori
M 43
External photoionizing source – the Trapezium
Trapezium
HH 205-210
HH 201
HH 202
HH 269
HH 505 (LL 2)
LL Ori (LL 1)
HH 203
HH 204
LL 3
LL 5
HH 400
LL 4
Illuminates jet body, e.g. HH 502
LL 6
Bally & Reipurth 2001
HH 540
HH 503
LL 7

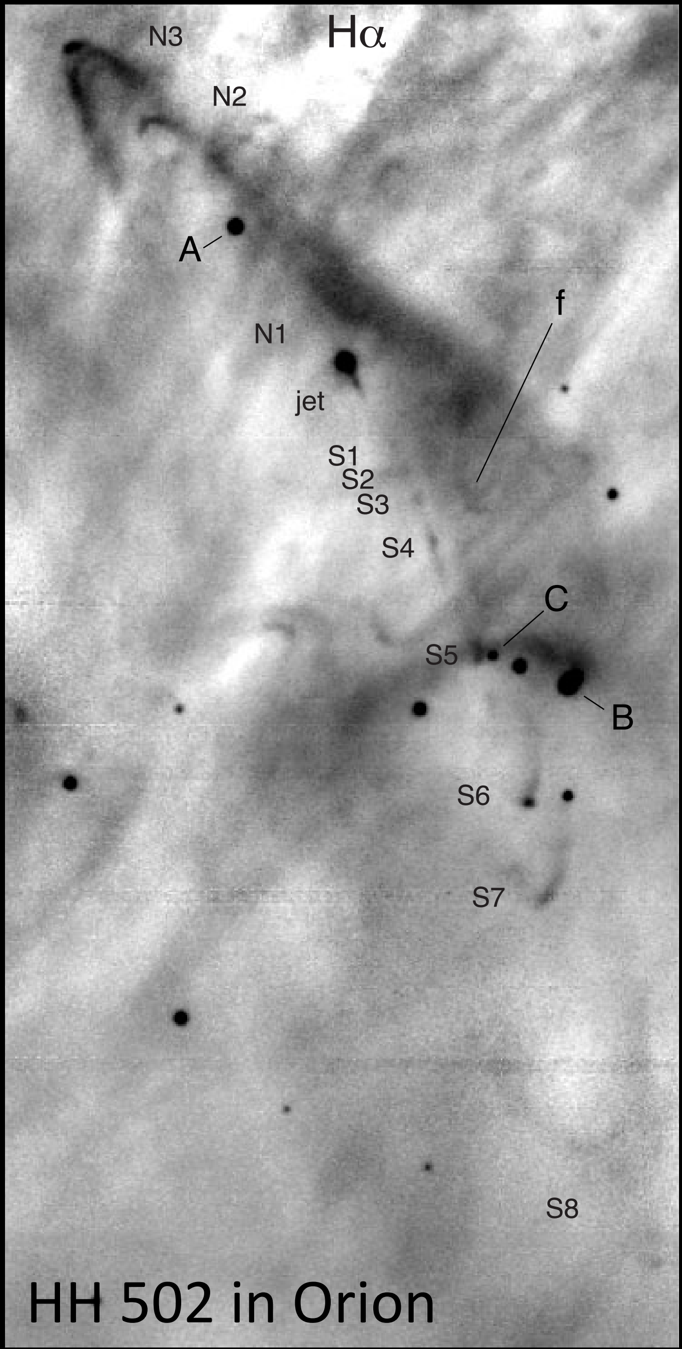
$\dot{M}$ from irradiated jets

- Measure $I_{h\alpha}$
- $I_{H\alpha} \sim n_e^2$

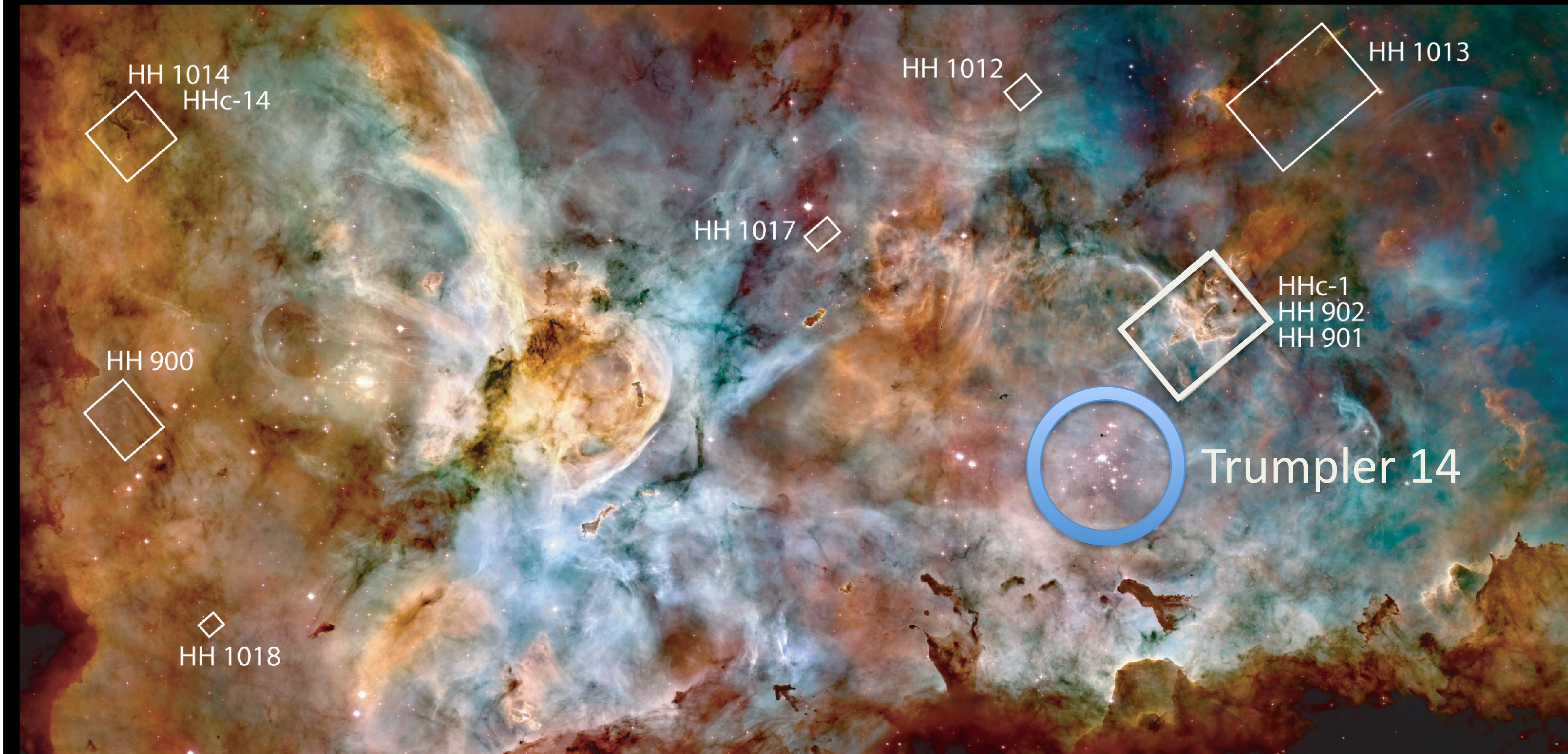
$\rightarrow \dot{M} = \mu m_H n_e V \pi r^2 f$

*assuming that the jet is fully ionized

Bally & Reipurth 2001



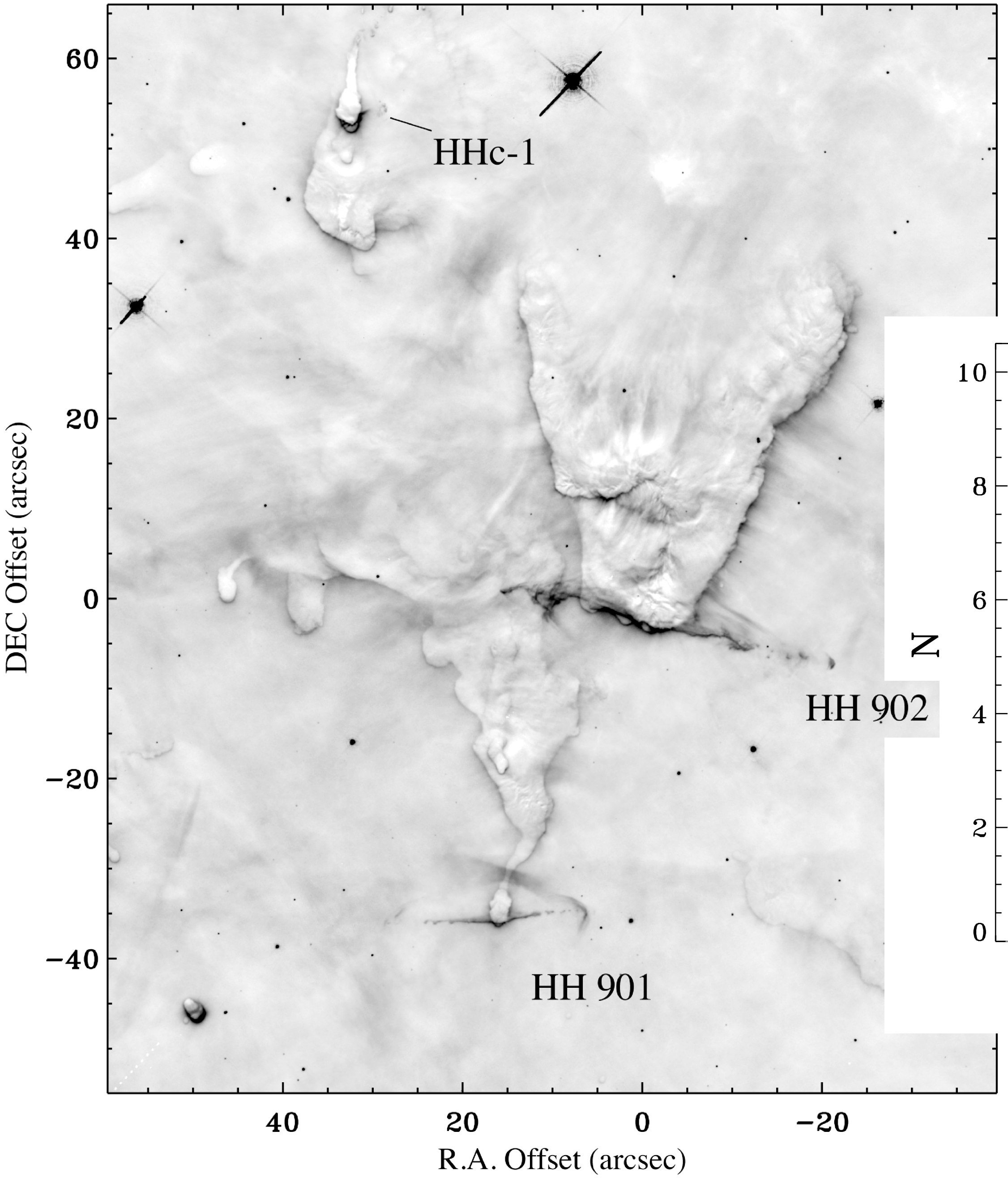
Carina Nebula

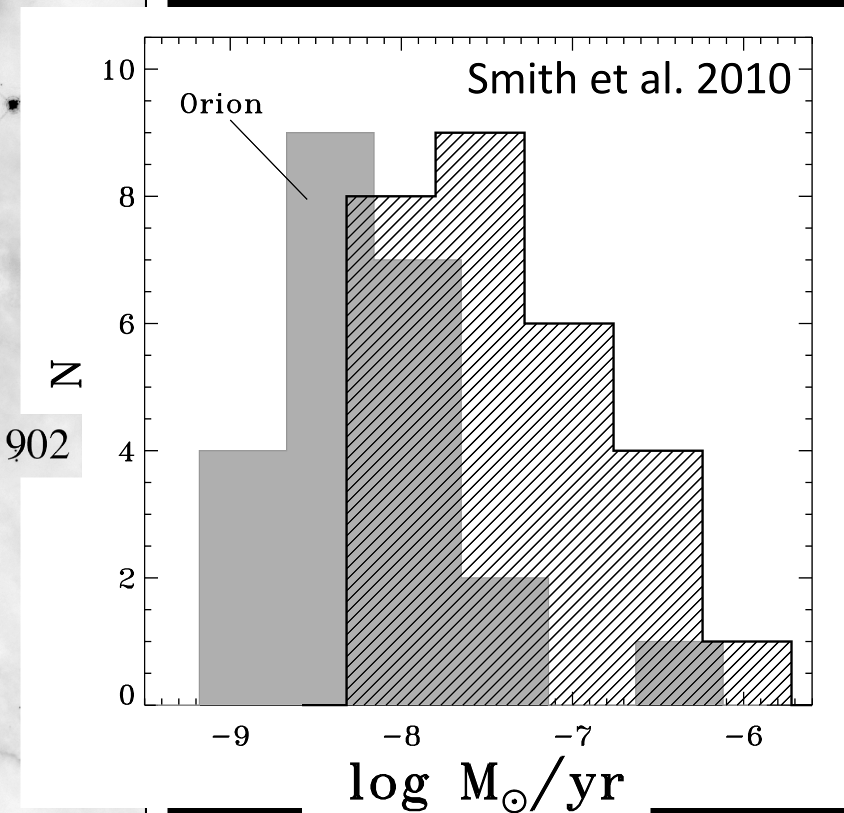


- 40 HH jets discovered with targeted ACS Hα imaging

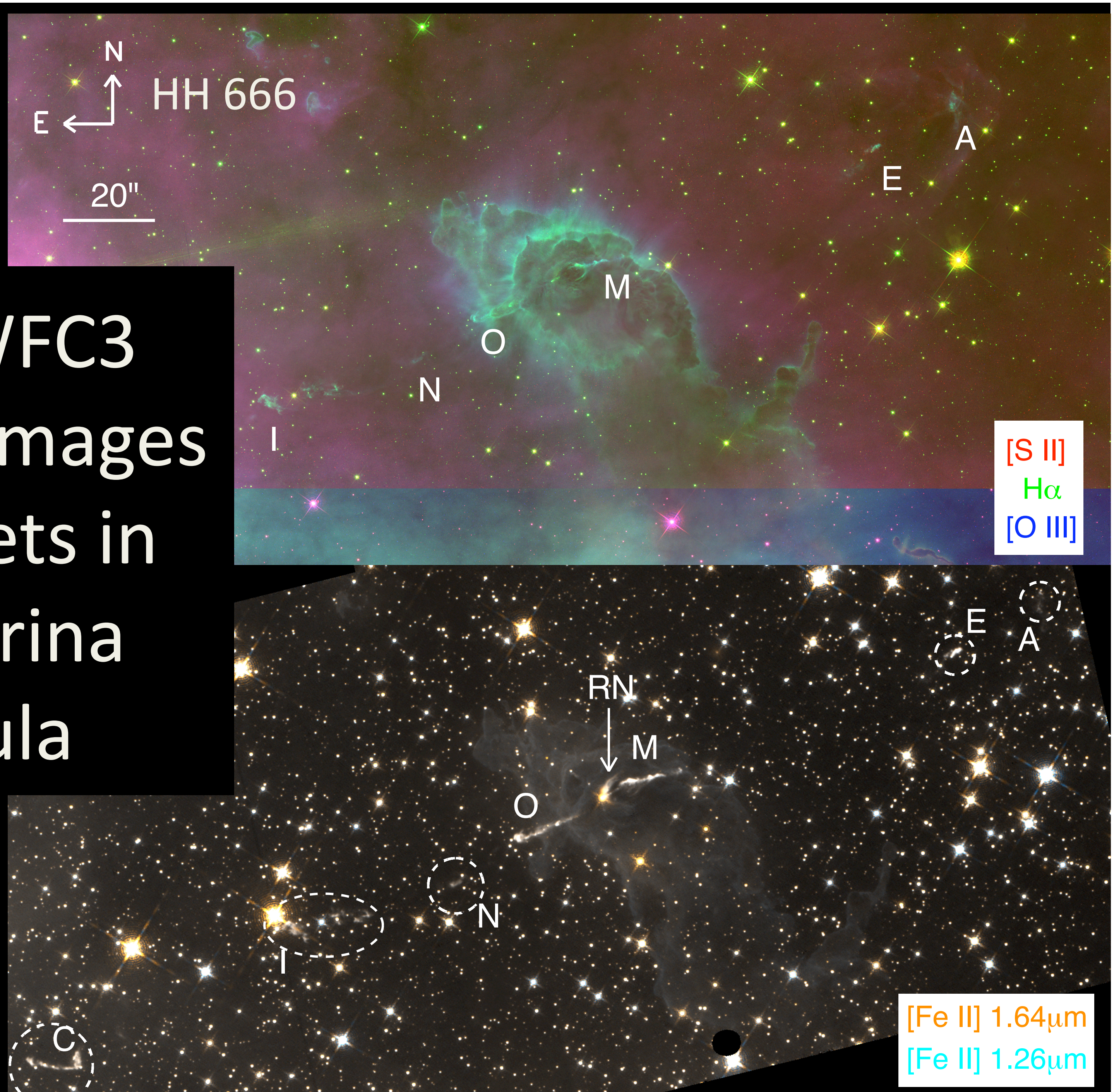
Smith et al. 2010

Carina Nebula



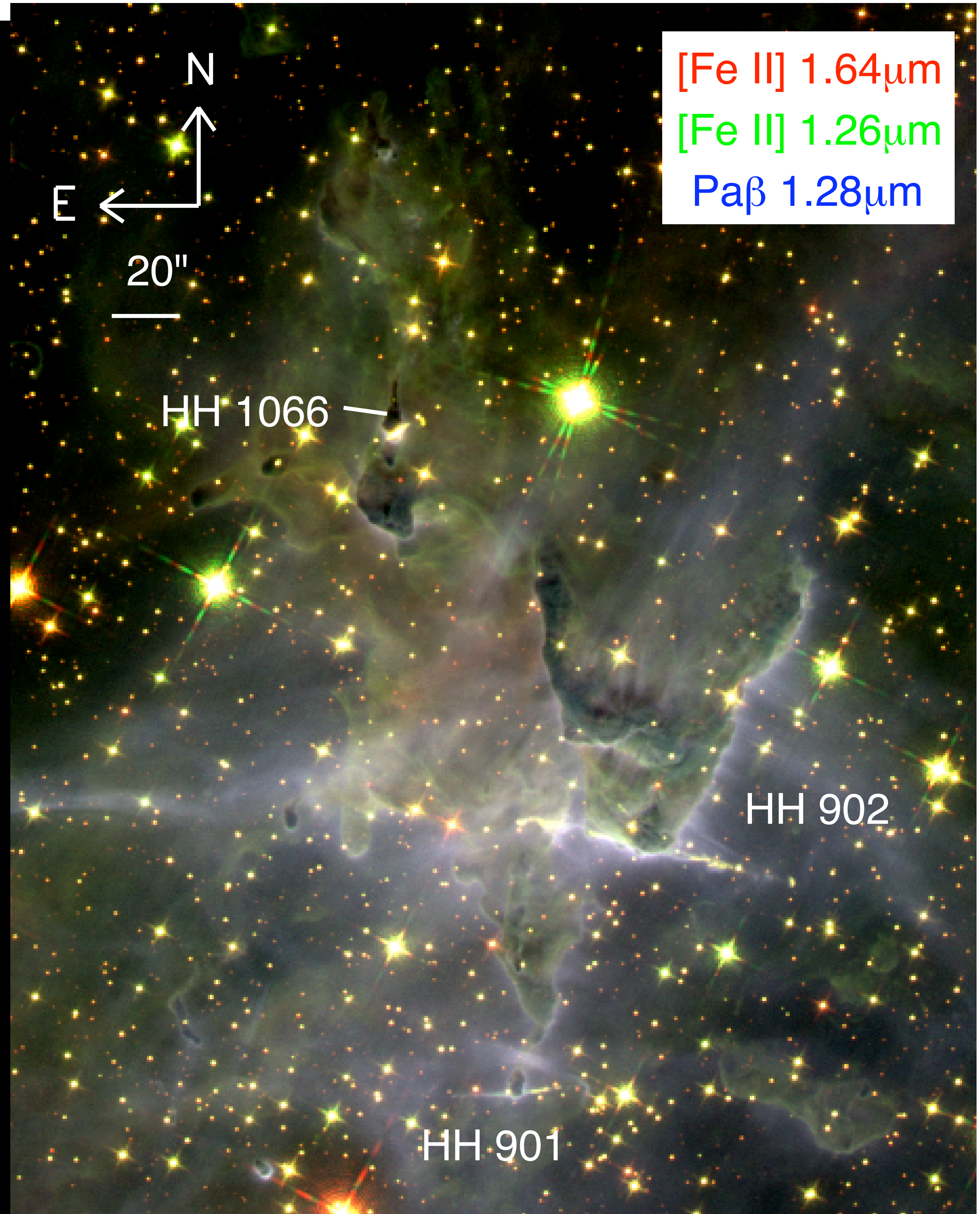


New WFC3 UVIS/IR images of HH jets in the Carina Nebula

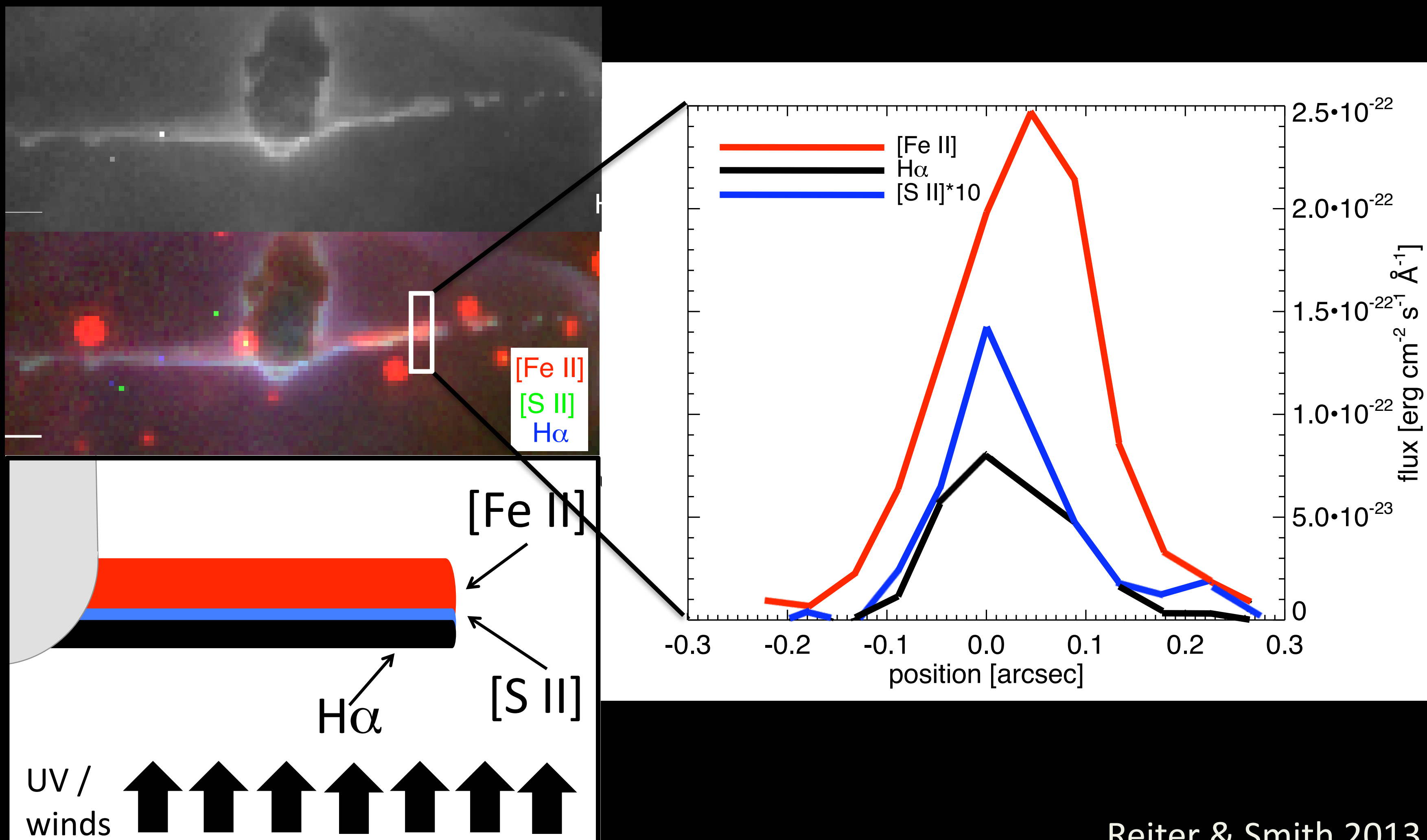


Narrowband [Fe II] 1.26 μm and 1.64 μm

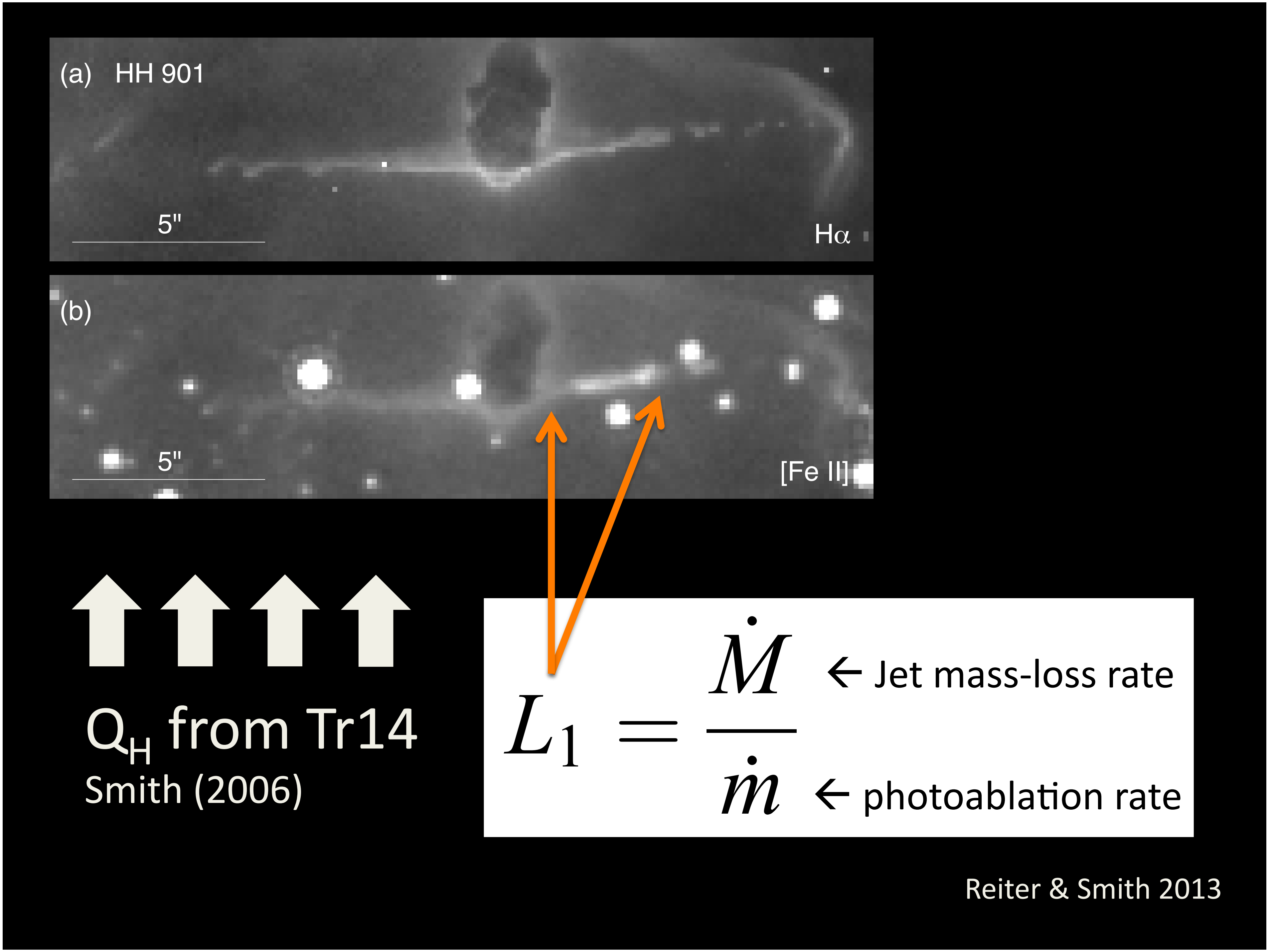
- Must be self-shielded to prevent ionization to Fe^{++}
- traces high density, low-ionization material
- [Fe II] reveals dense, neutral gas in these jets

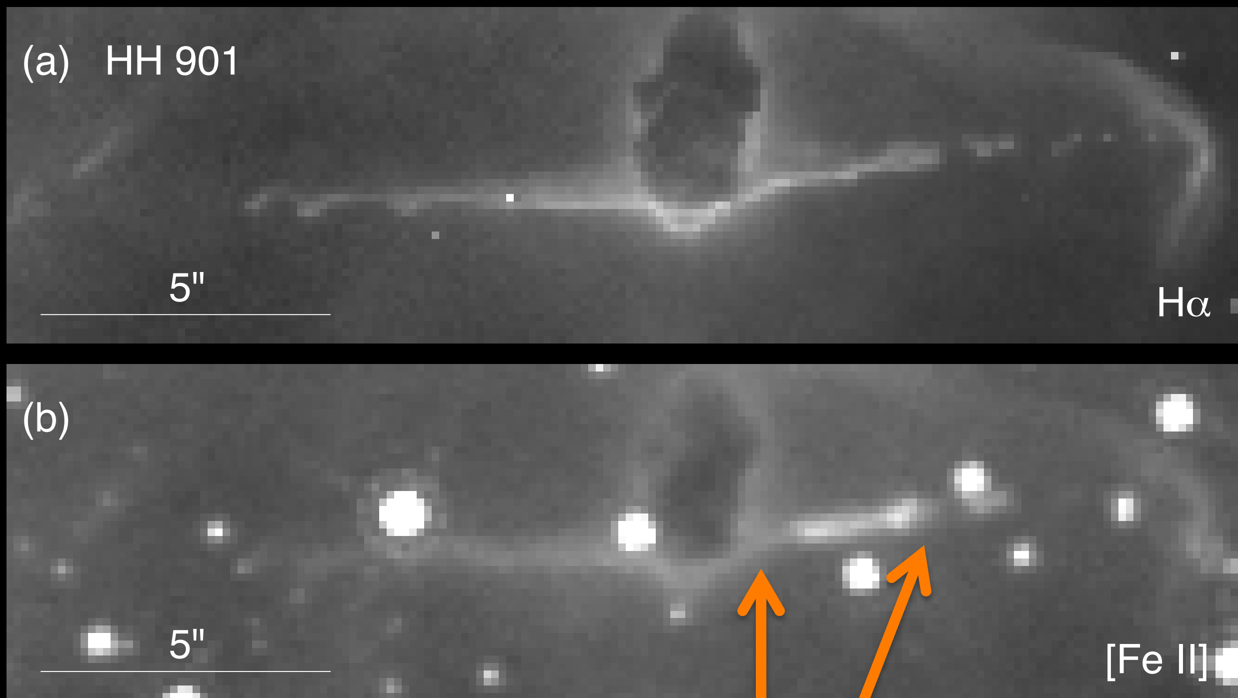


Ionization front in the jet...



Reiter & Smith 2013


(a) HH 901
5"
Hα
(b)
5"
[Fe II]
$L_1 = \frac{\dot{M}}{\dot{m}}$
← Jet mass-loss rate
← photoablation rate
Q_H from Tr14
Smith (2006)
Reiter & Smith 2013



Q_H from Tr14

Smith (2006)

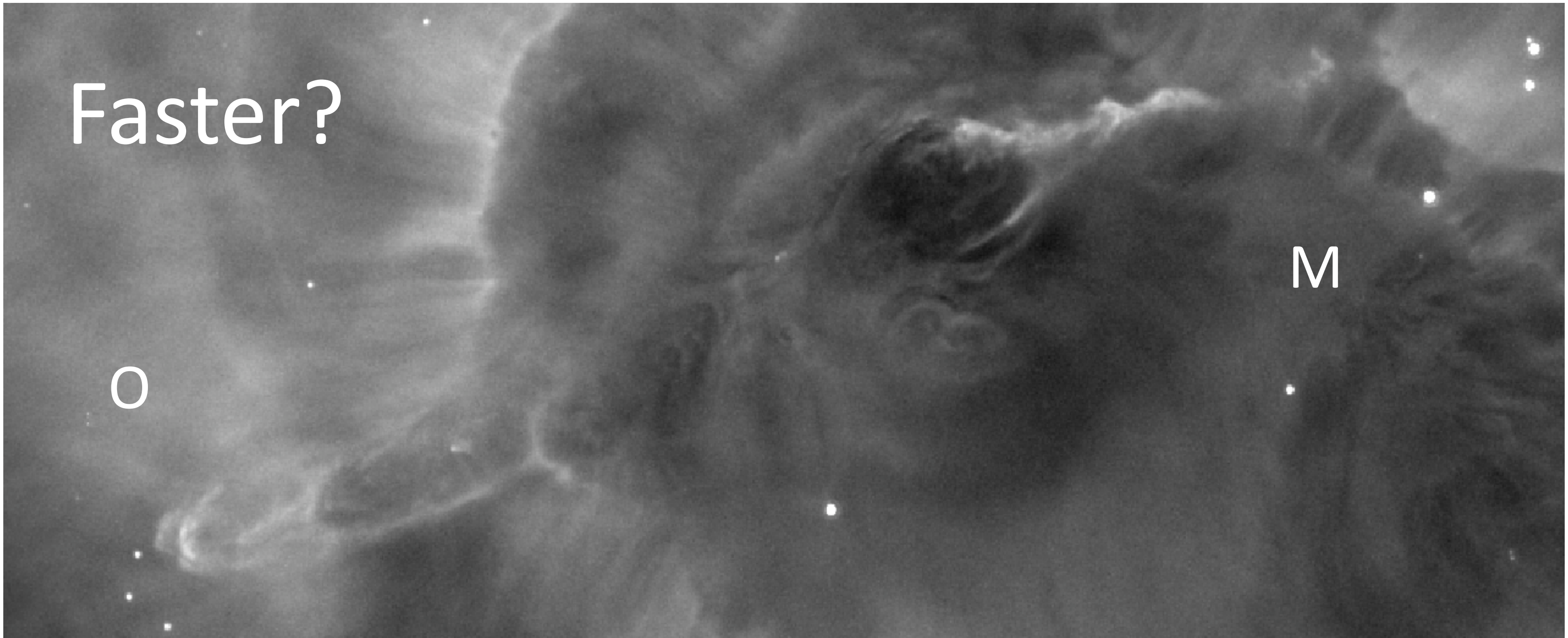
→ ~10x $\dot{M}$ from Hα EM

$$L_1 = \frac{\dot{M}}{\dot{m}}$$

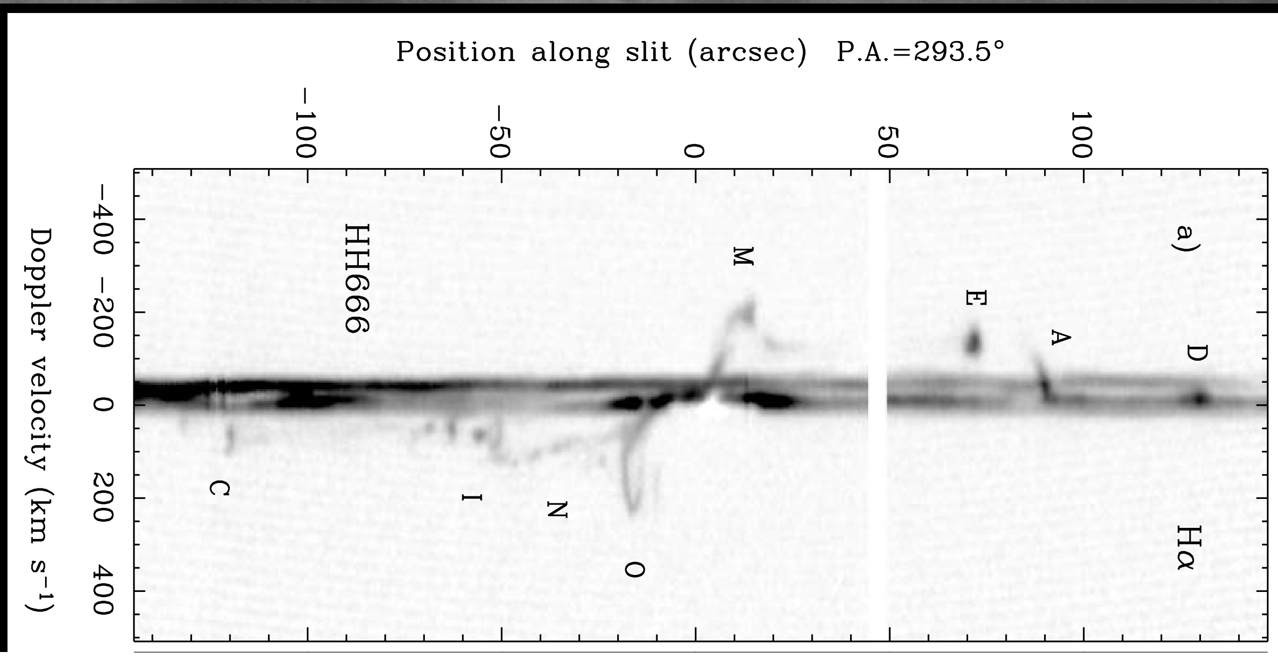
← Jet mass loss rate

← photoablation rate

Reiter & Smith 2013

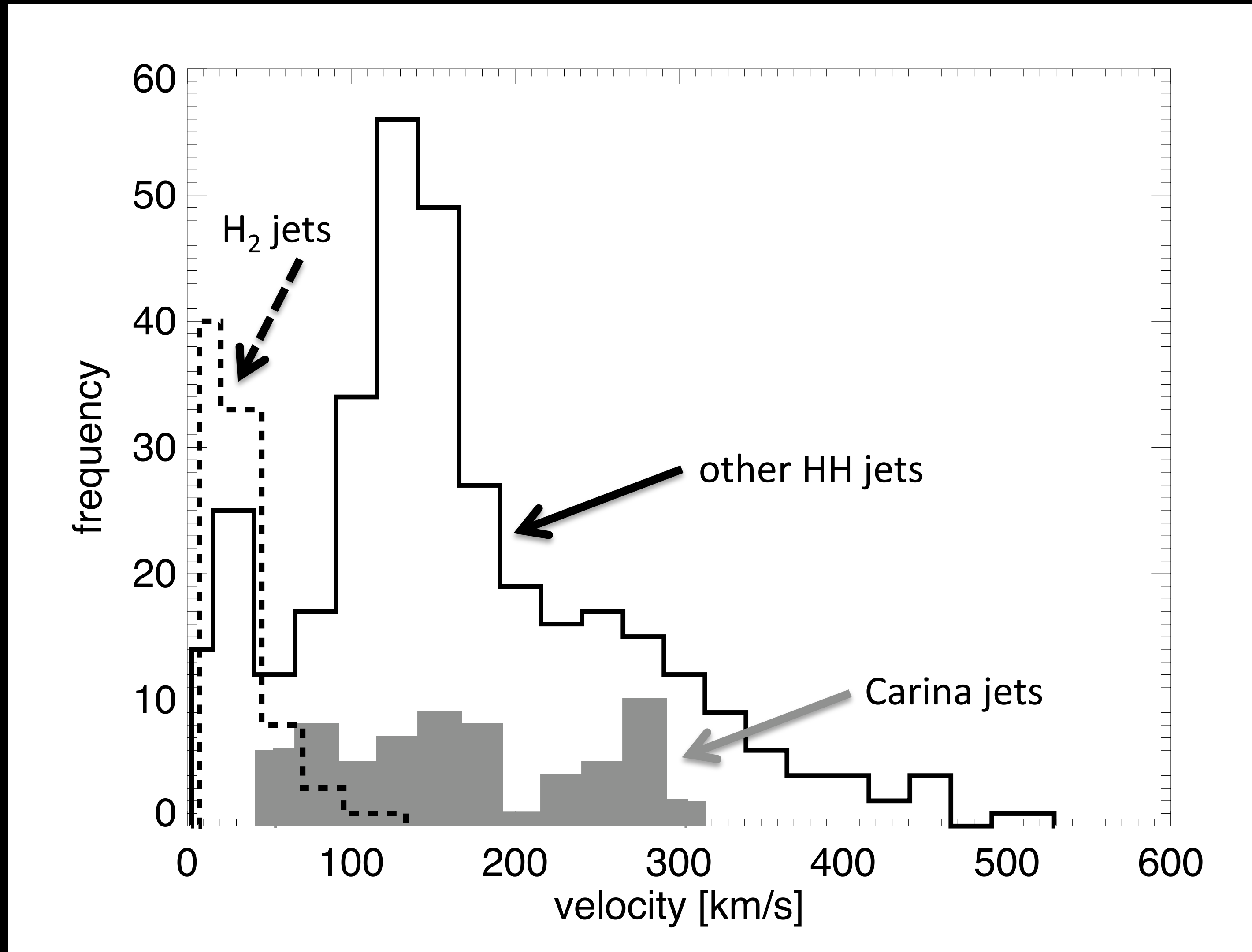


Faster?
O
M



Position along slit (arcsec) P.A.=293.5°
Doppler velocity (km s-1)
HH666
a)
Hα
M
E
A
D
C
I
N
O

Faster?

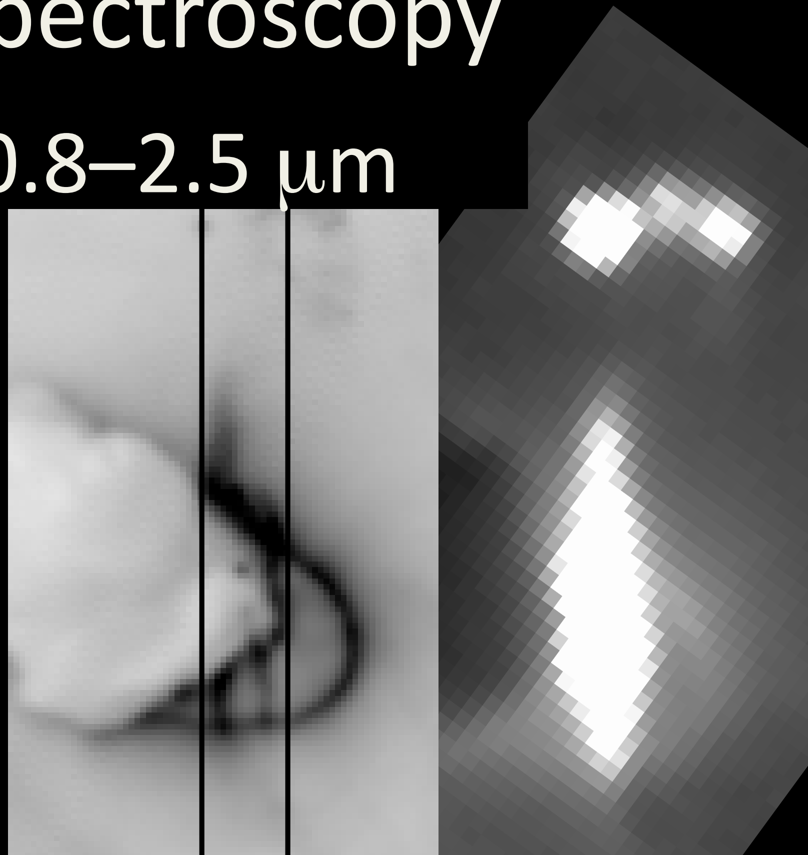


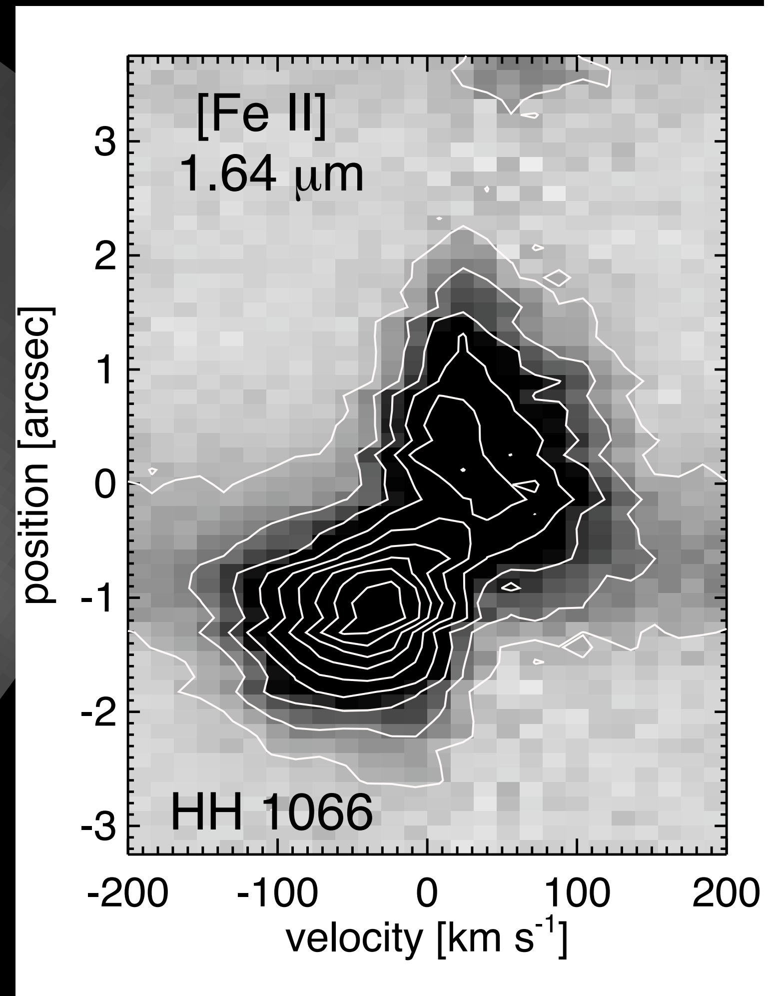
Bally et al. (2002), Bally et al. (2012), Devine et al. (1997), Devine et al. (2009), Hartigan et al. (2001), Hartigan et al. (2005), Hartigan & Morse (2007), Kadjiˇc et al. (2012), McGroarty et al. (2007), Noriega-Crespo & Garnavich (2001), Reipurth et al. (2002), Smith et al. (2005), and Yusef-Zadeh et al. (2005). H2 jet velocities from Zhang et al. (2013)

Reiter & Smith in prep

FIRE spectroscopy

$\lambda = 0.8–2.5\ \mu m$

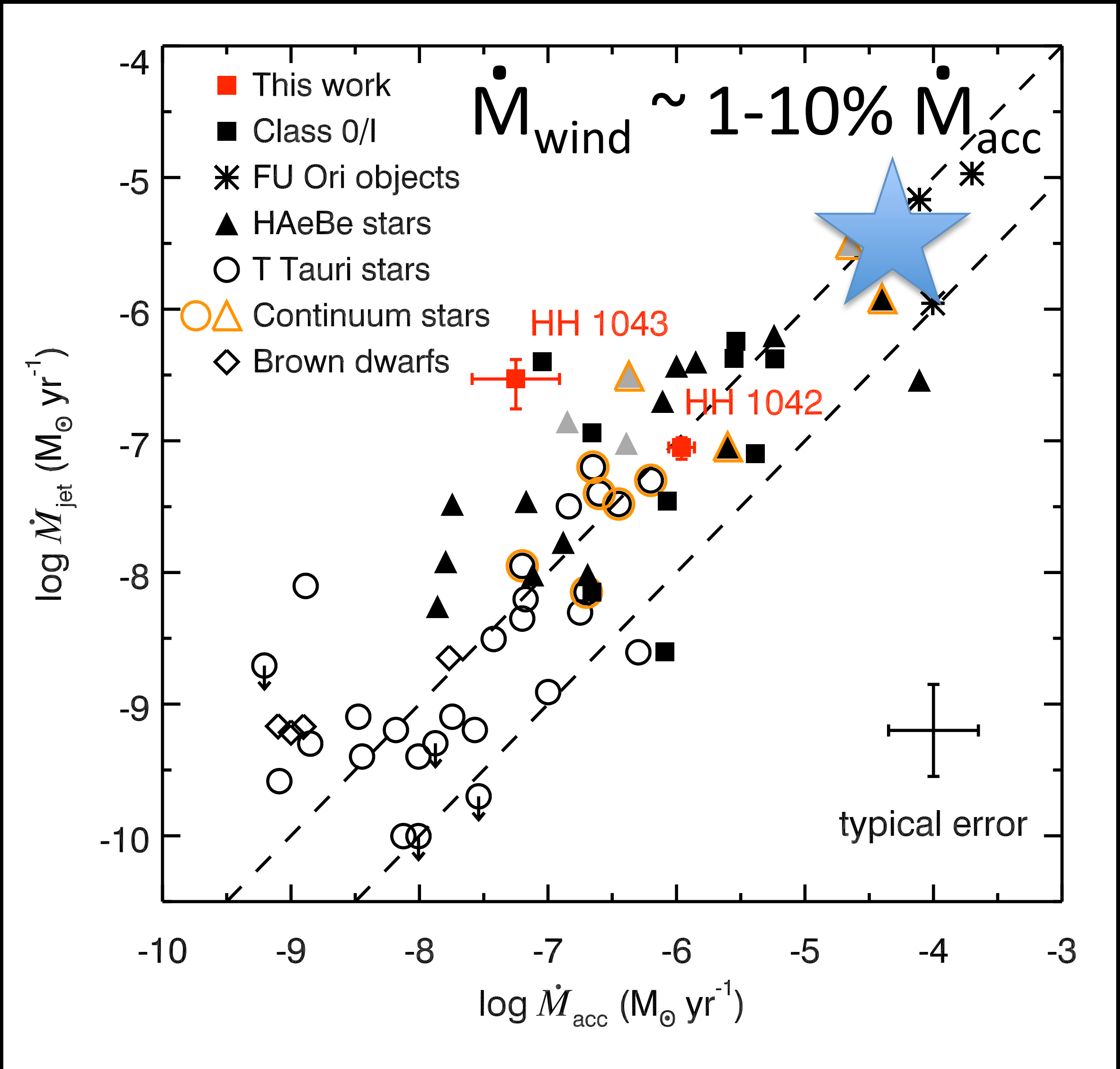




1. [Fe II] line ratios → jet density
2. Doppler velocity
3. Brγ → accretion rate

Reiter & Smith in prep

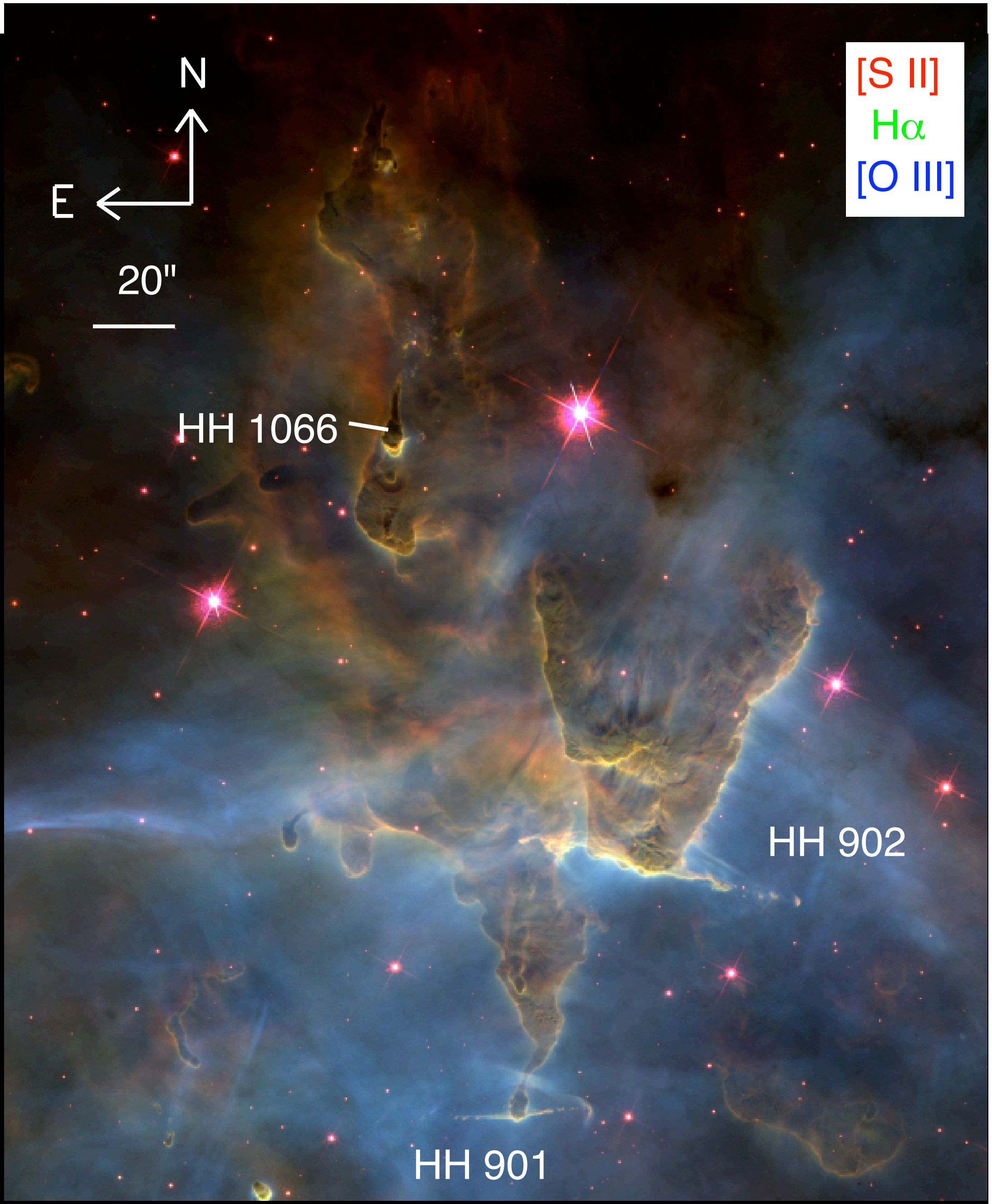
Accretion-Outflow of intermediate-mass stars



Ellerbroek et al 2013

HH jets from intermediate-mass stars

- Highly collimated
- [Fe II] traces high density, neutral material
- Proper motions and spectroscopy reveal 3D velocities similar to low-mass stars
- High-mass loss rates



→ stars up to at least 8 M_{sun} form by same accretion mechanism as low-mass stars

[redacted]