A Detailed Study of the Structure of the Planetary Nebula, Hb 12

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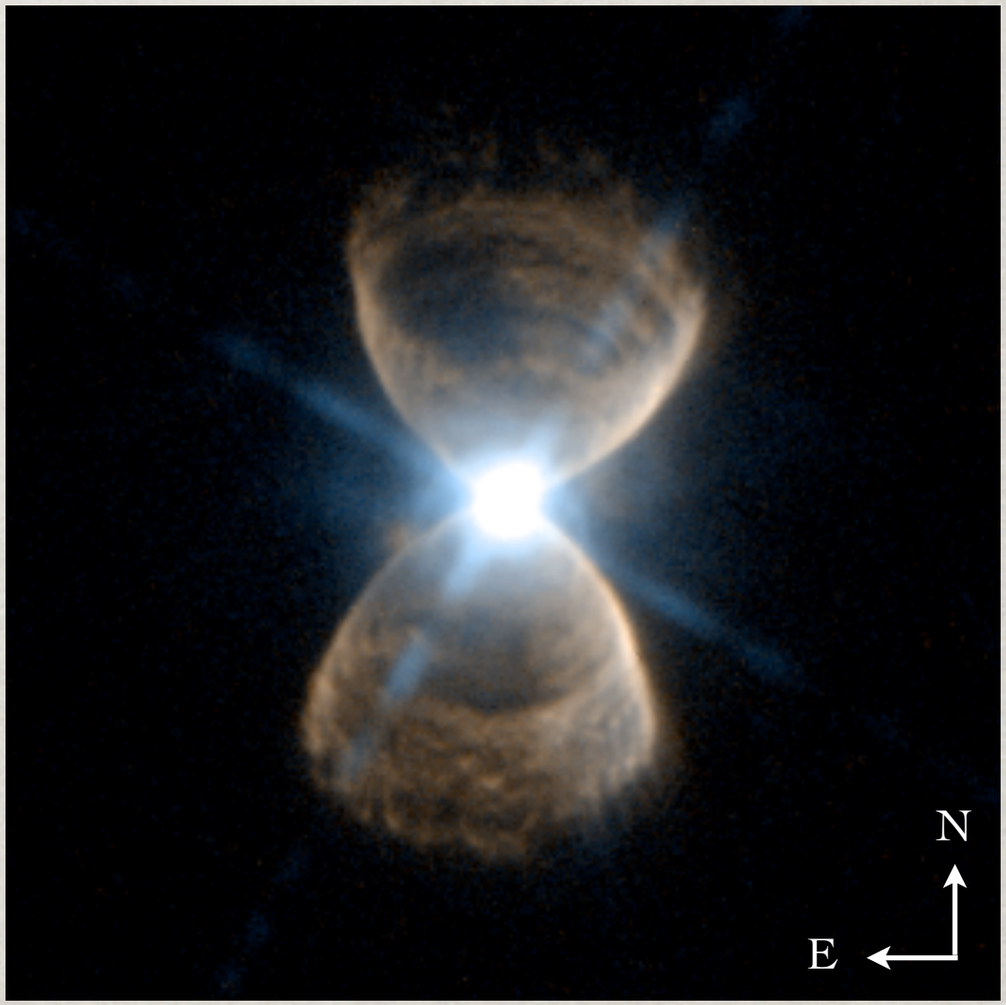
Introduction

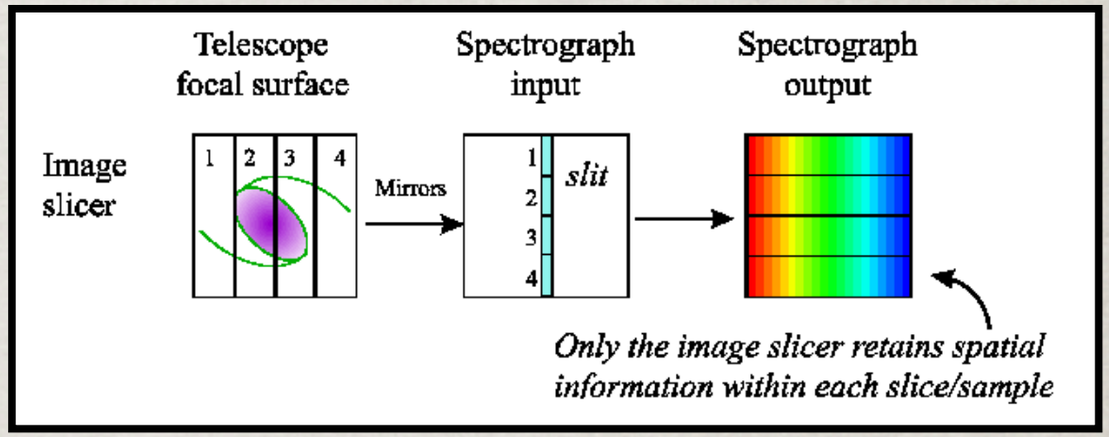
- Background on Hb 12 and observations
- Results
- Conclusions



Hubble Legacy Archive

NIFS

- Image-slicing integral field unit
- Field-of-view: 3”x 3”
- Pixel scale: 0.103” across slit, 0.04” along slit
- Spatial resolution (FWHM): 0.1” with full AO, otherwise seeing limited



- Gratings
  - Z (0.94 - 1.15 µm), R = 4990
  - J (1.15 - 1.33 µm), R = 6040
  - H (1.49 - 1.80 µm), R = 5290
  - K (1.99 - 2.40 µm), R = 5290

NIFS Optical layout

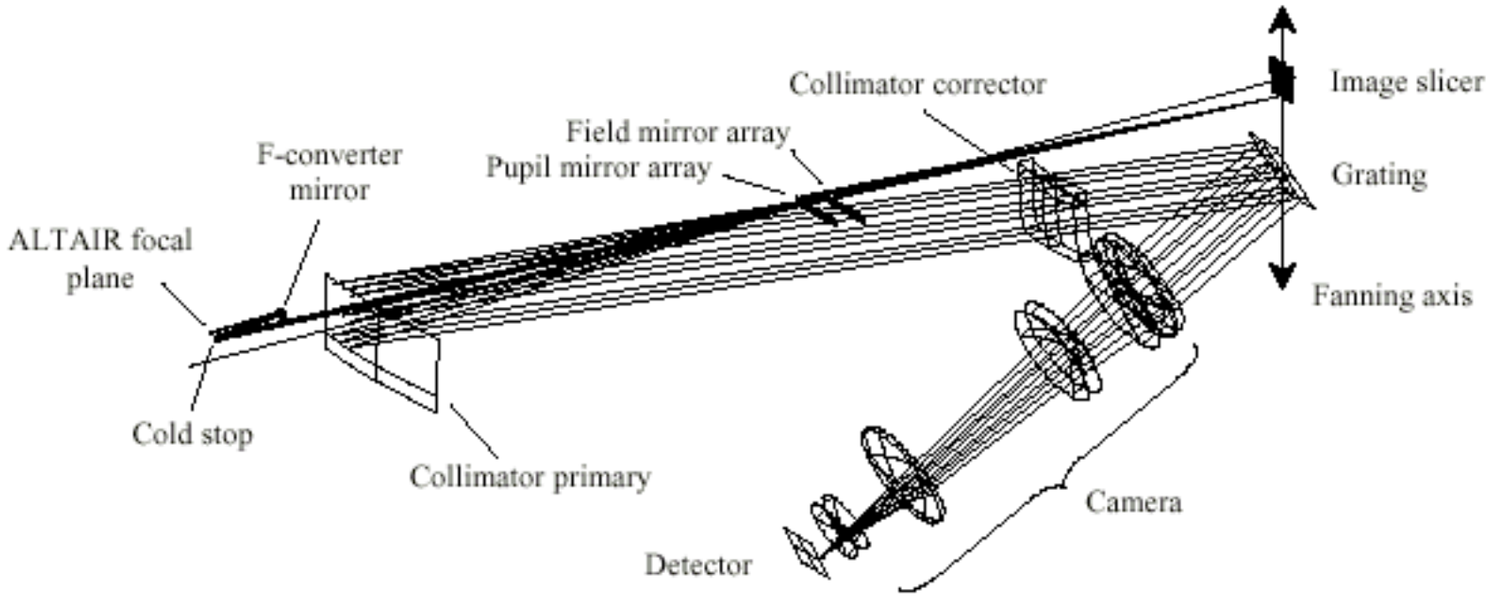


Figure NIFS optical layout showing the concentric IFU at top with fold mirrors omitted. Rays are shown for the far channel of the IFU. Optical components are labeled.

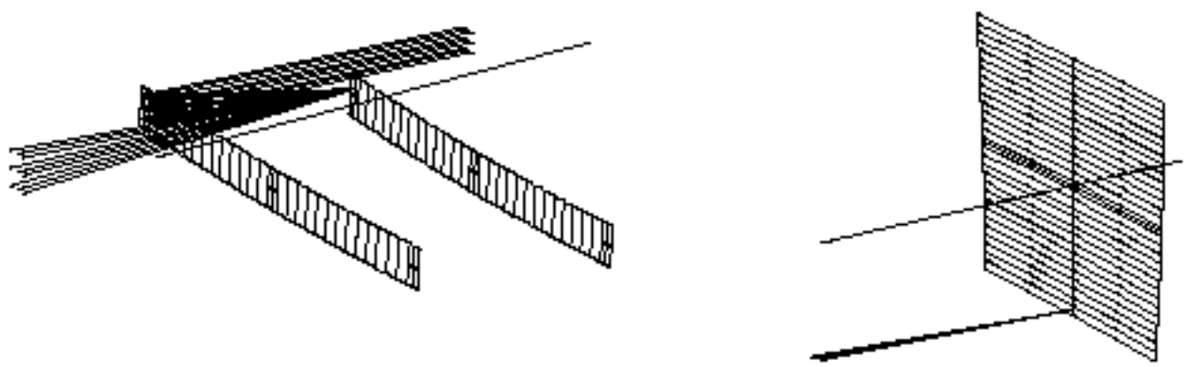
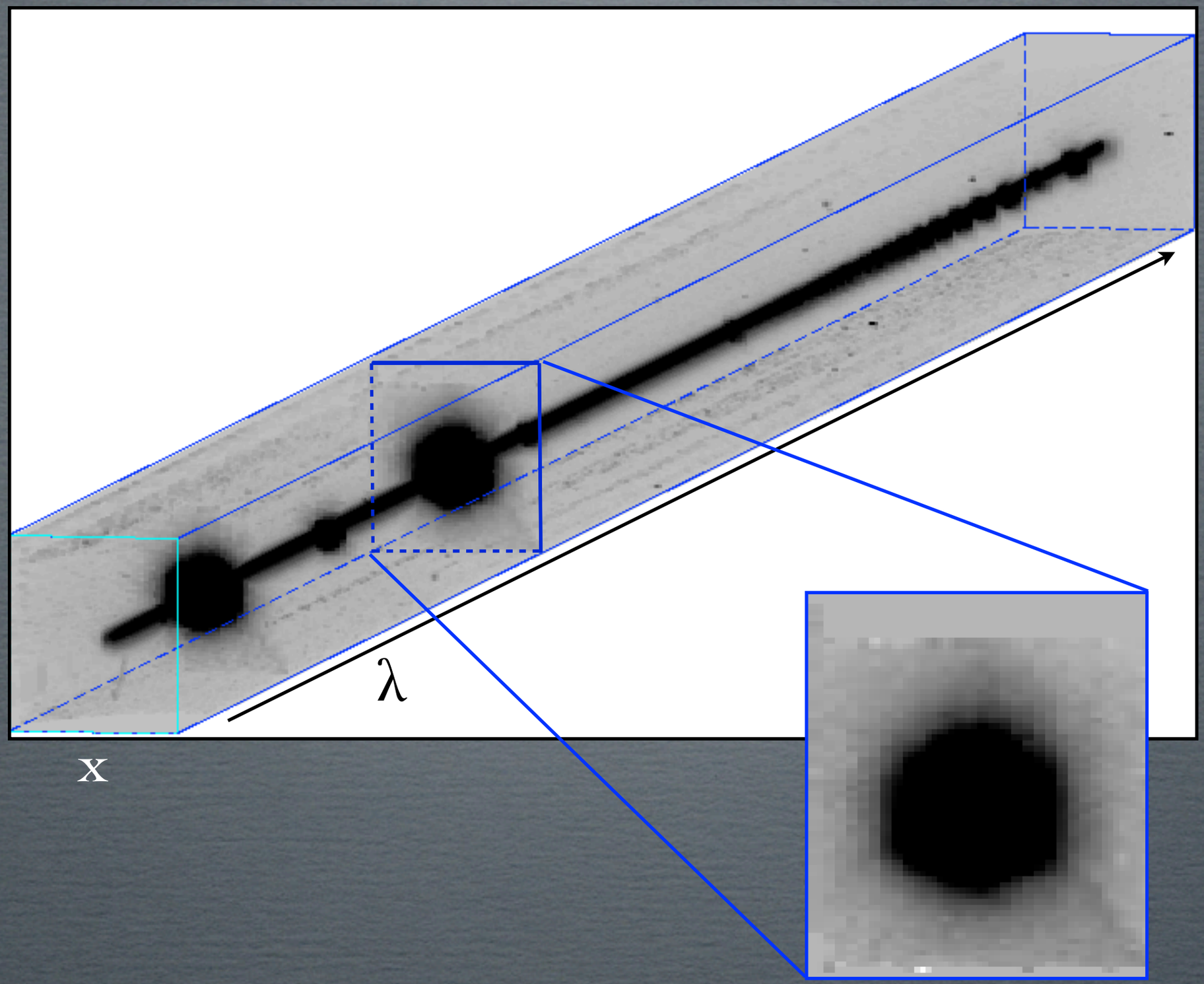


Figure Image slicer (*right*) showing 29 slitlet mirrors each fanned by 0.127°, and pupil and field mirror arrays (*left*) showing rays for the far IFU channel.

NIFS Datacube



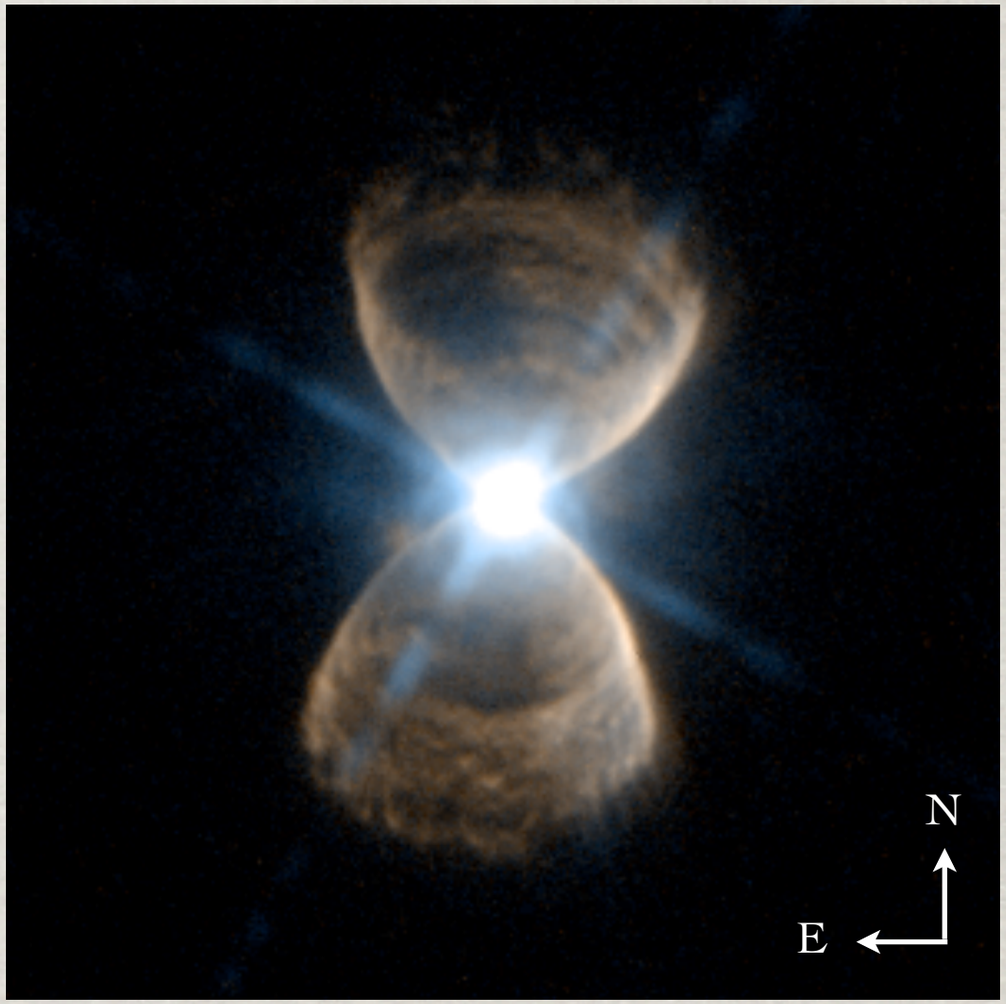
Planetary Nebula Hb 12

- Young PN, hourglass shaped with tight waist

- Axis PA = 171.5°, tilt ≈ 38° with-respect-to the plane of sky (Kwok & Hsia, 2007)

- High velocity outflows, from ~70 - 170 km s^{-1}, extending to 60″ (Vayet et al. 2009)

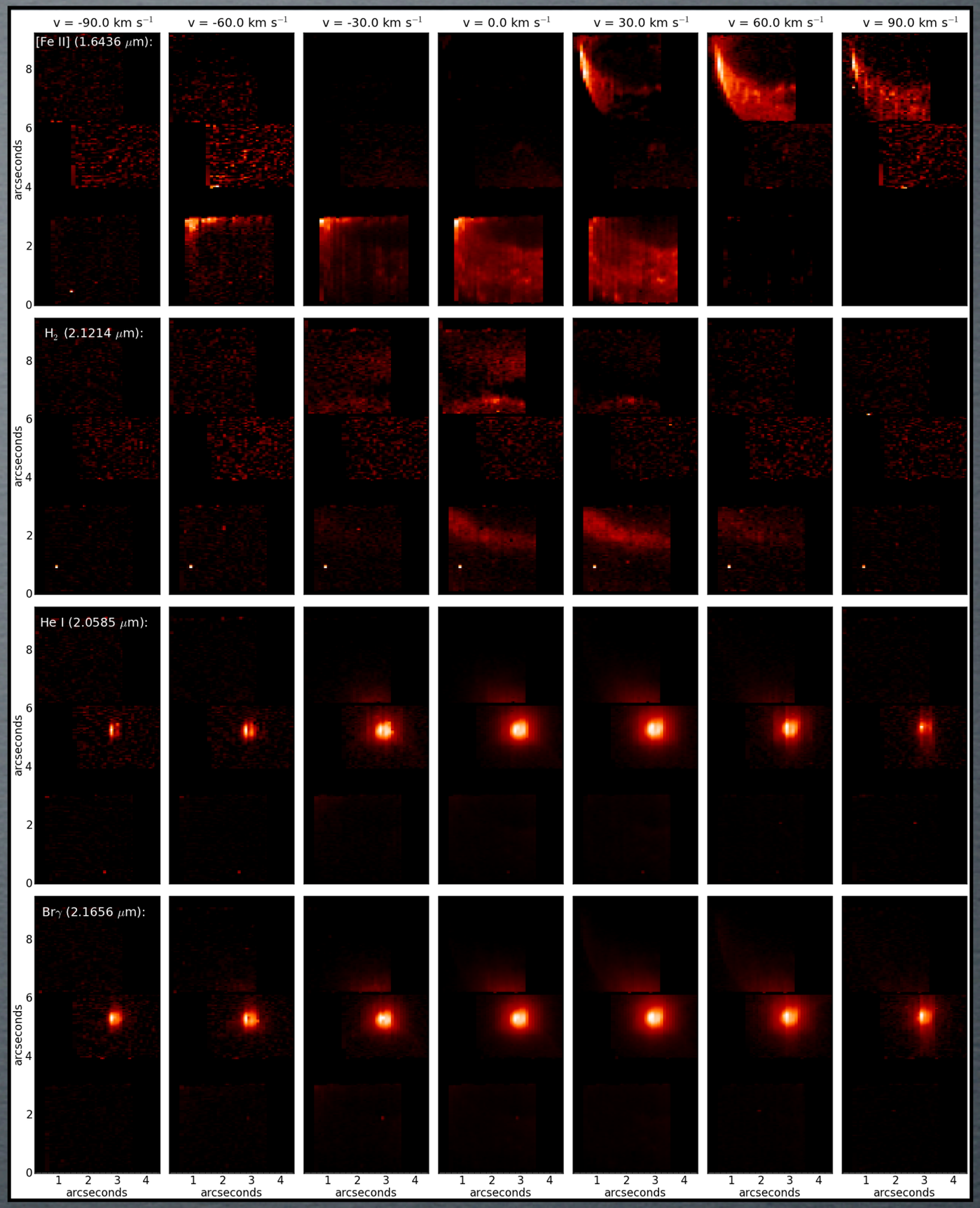
- Complex, nuclear region with rich, emission lines (Hora & Latter 1996)



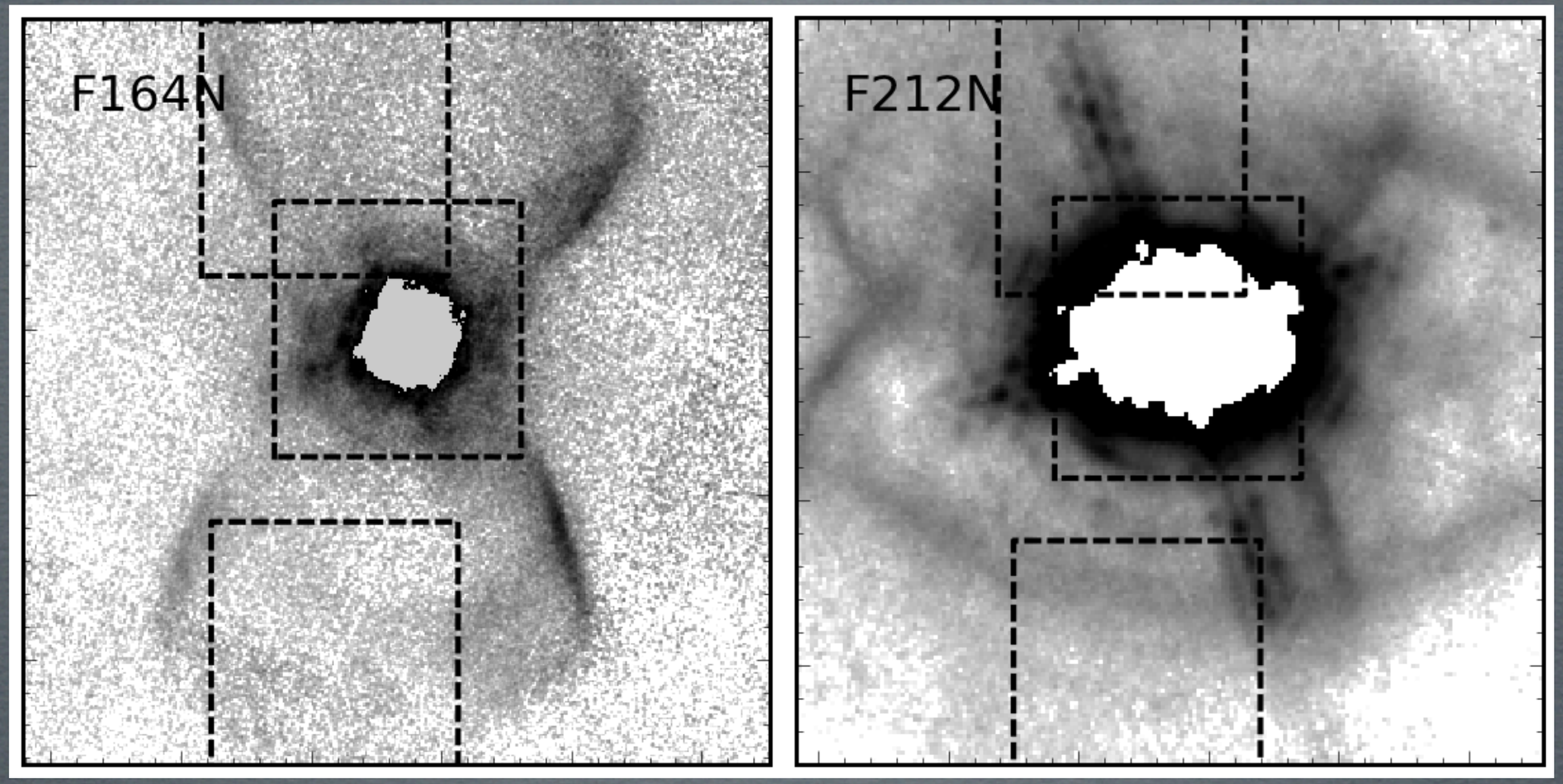
Hubble Legacy Archive

Lobes

- Lobes most prominent in [Fe II]
  - N lobe red shifted, S lobe blue shifted
- Nucleus
  - Very little [Fe II]
  - Bright in Brγ and the He I lines
- H_2 emission
  - Neither in center, nor lobes
  - Appears as arcs of emission, also seen in *HST* images



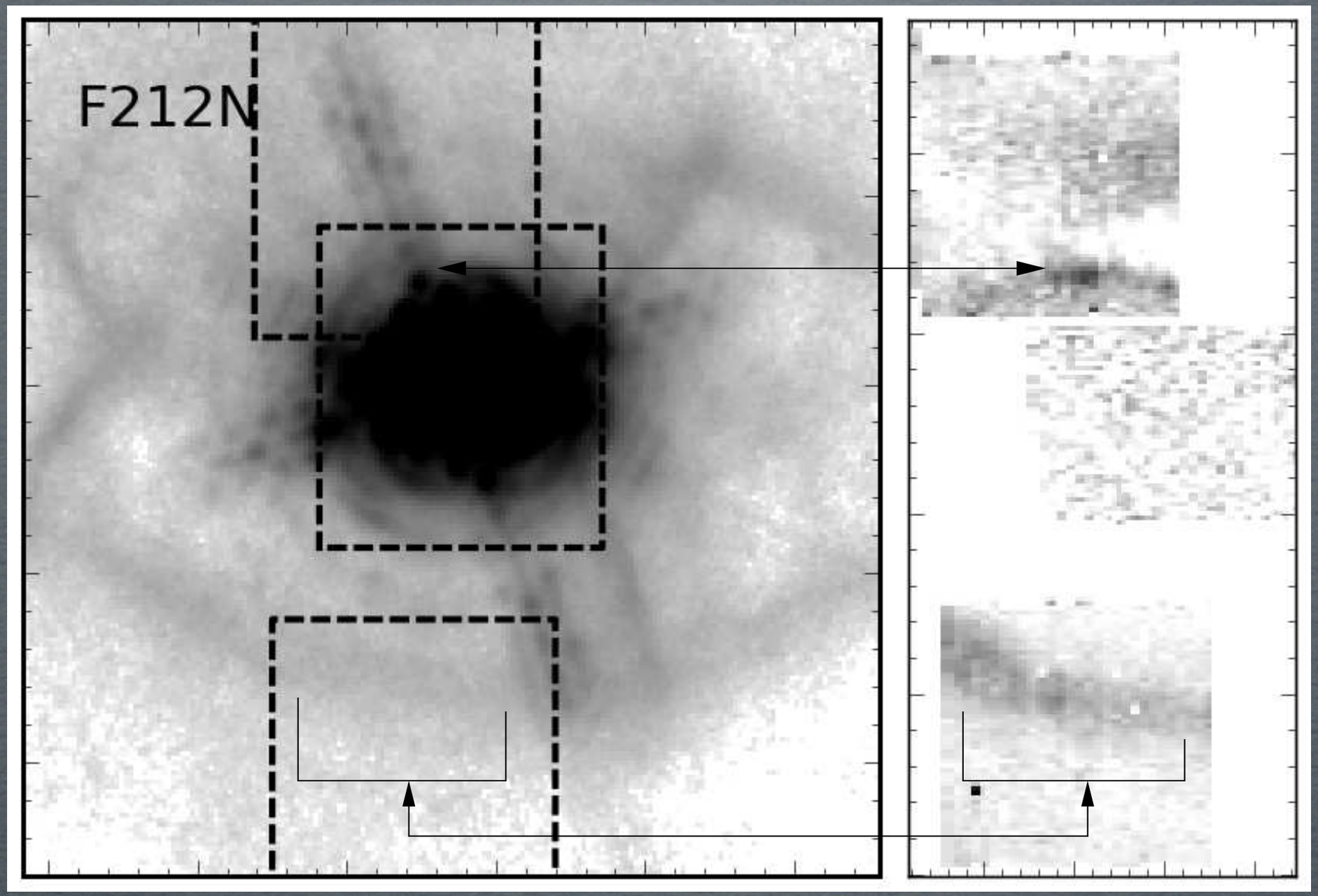
HST Images of Lobes



- Dashed squares represent NIFS pointings
- Notice arcs of emission in F212N image
- Width ~10000 AU (d = 2000 pc)
- Each image 9” × 9”

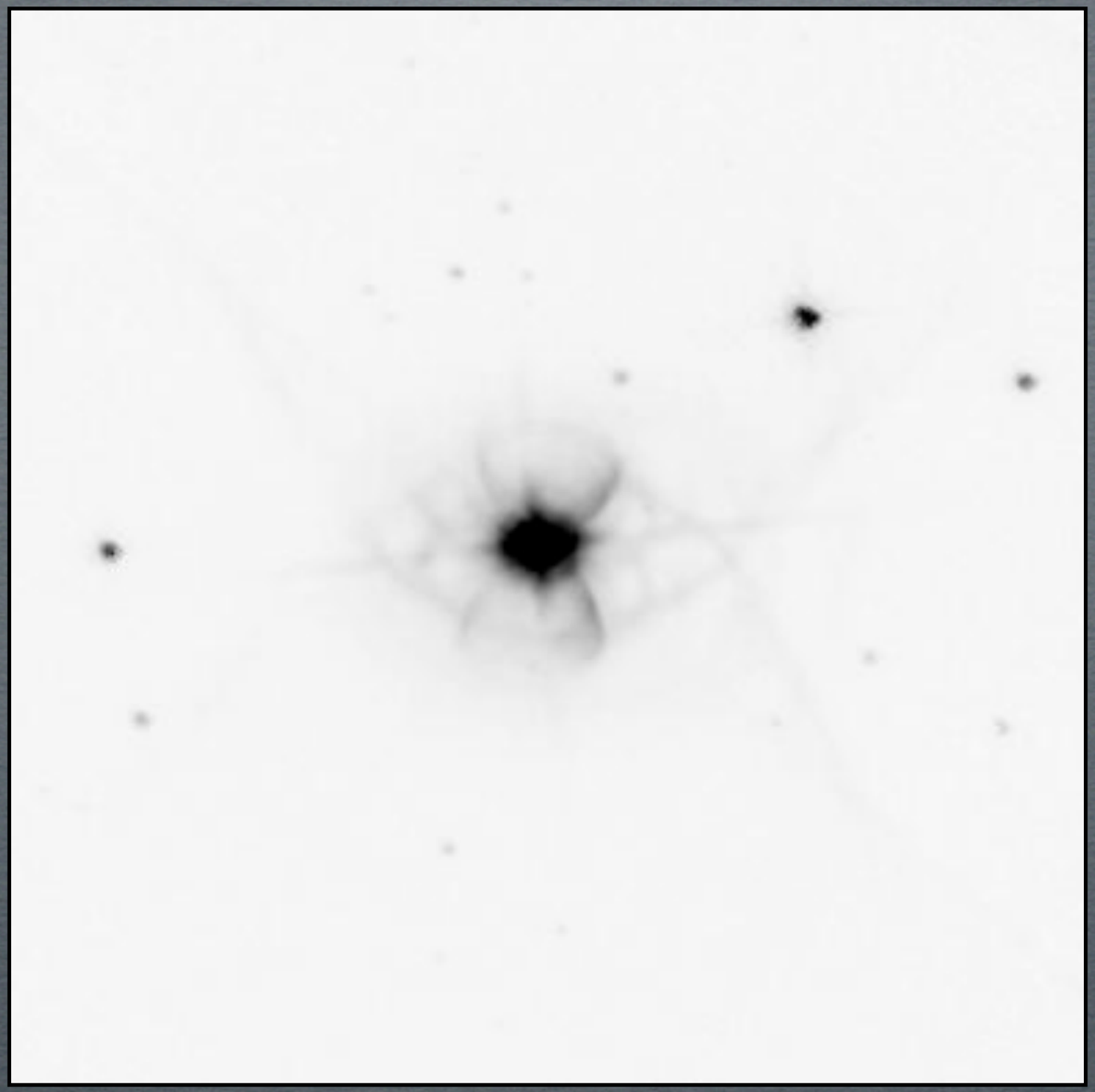
HST Images of Lobes

H_2 (2.1214 μm), v = 0 km s^{-1}



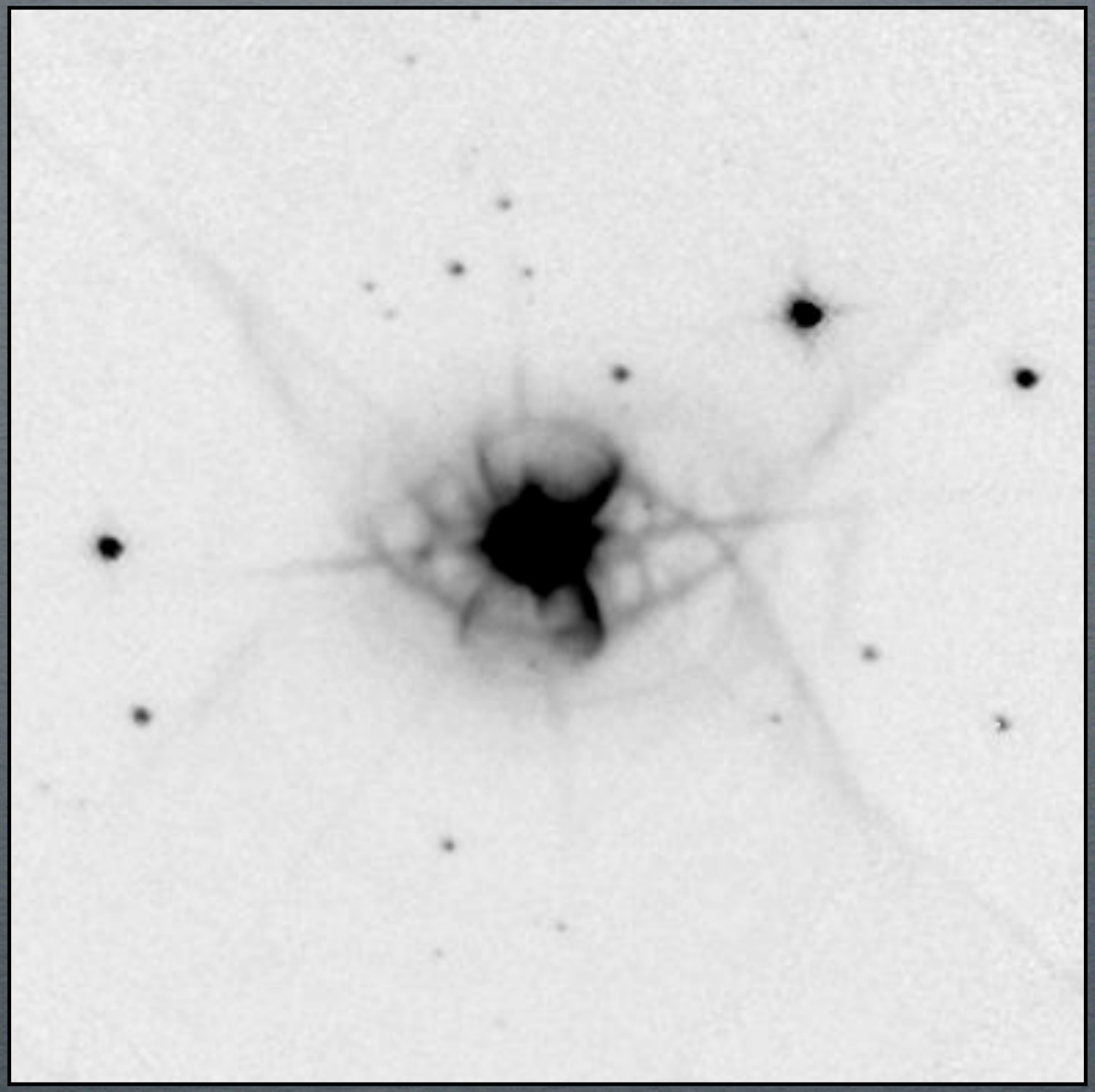
- Comparison between *HST* and NIFS H_2 images
- Notice arcs seen in both images

H_2 Arcs



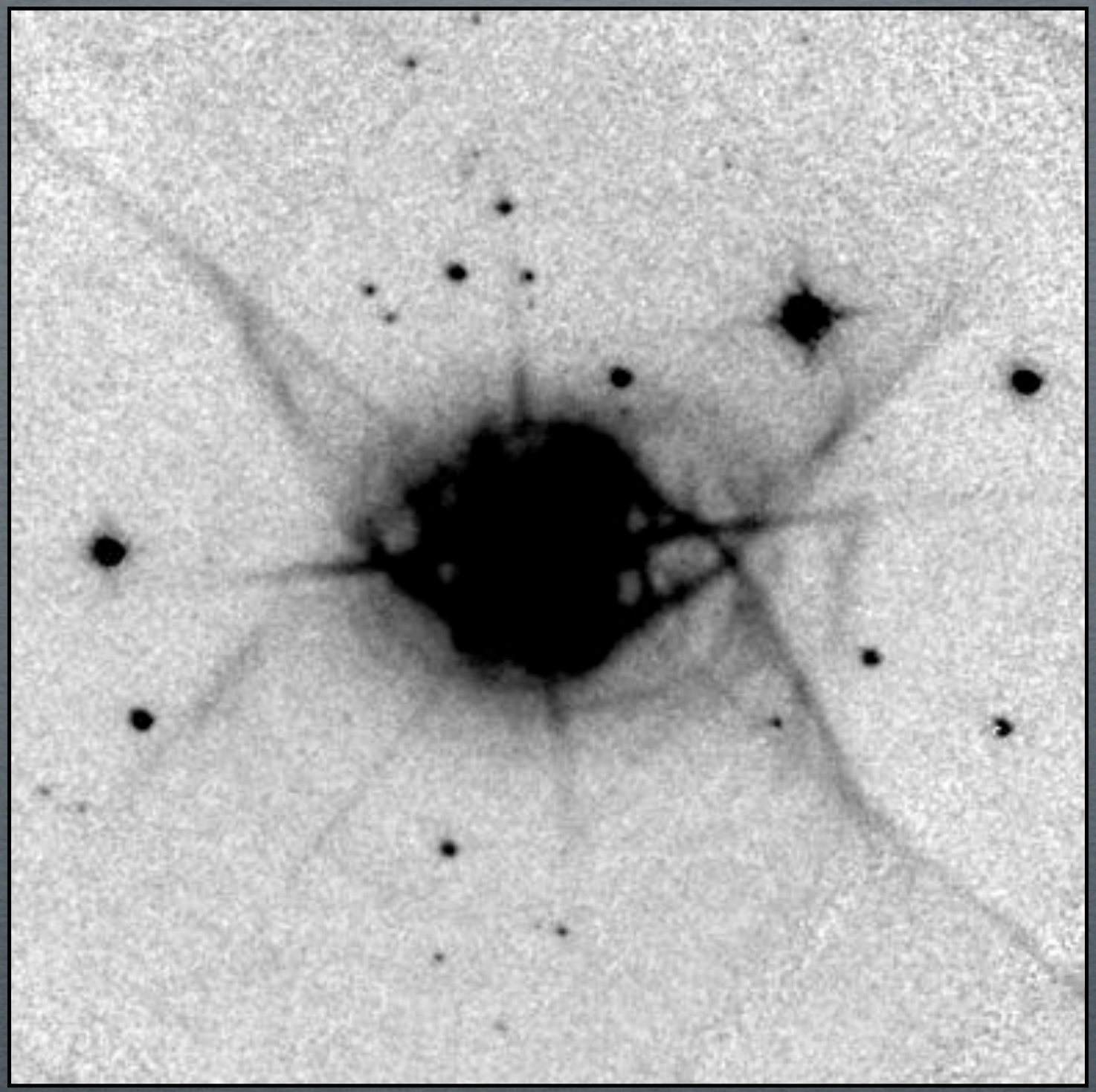
NIC3 F160W

H_2 Arcs



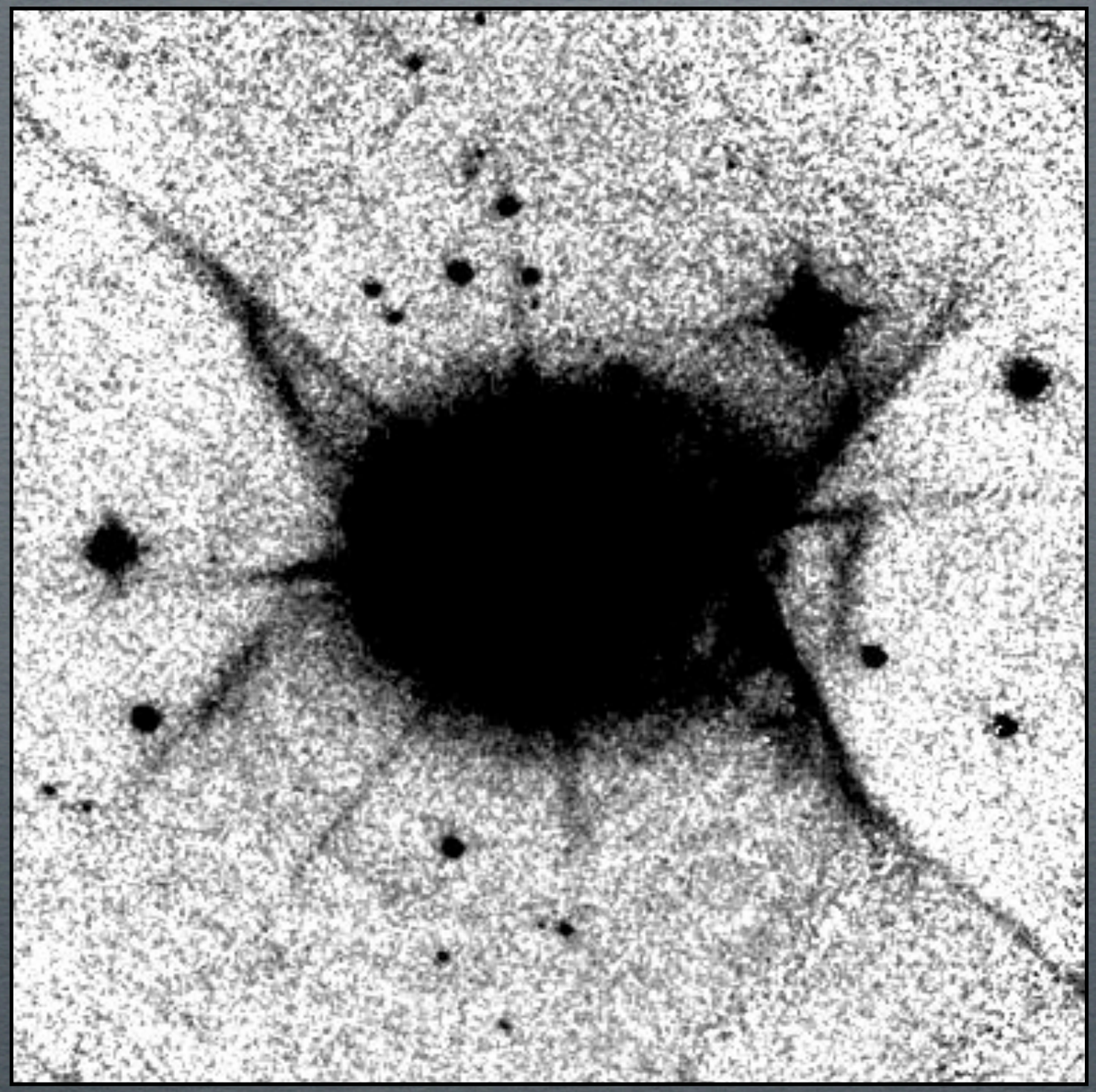
NIC3 F160W

H_2 Arcs



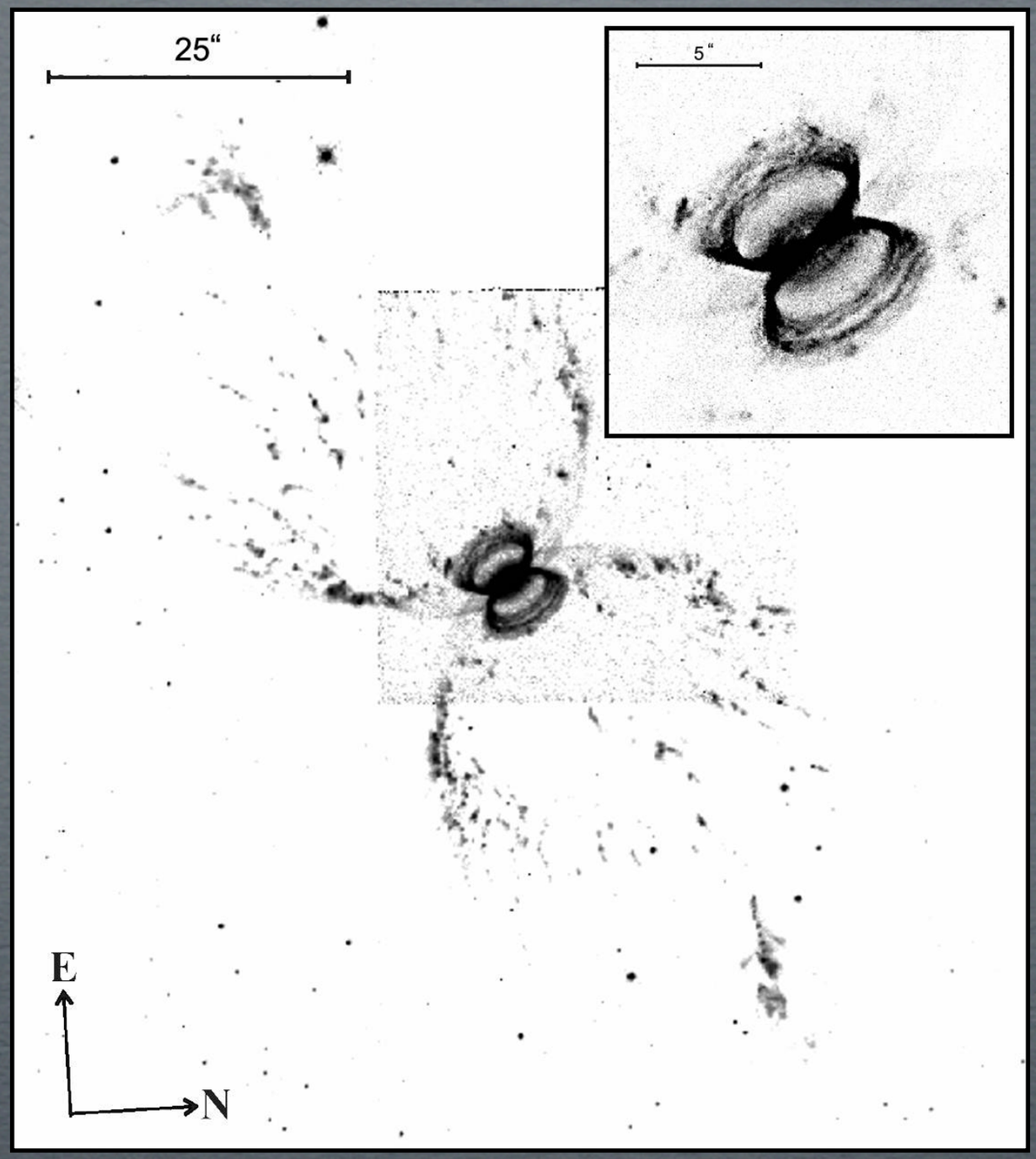
NIC3 F160W

H_2 Arcs



NIC3 F160W

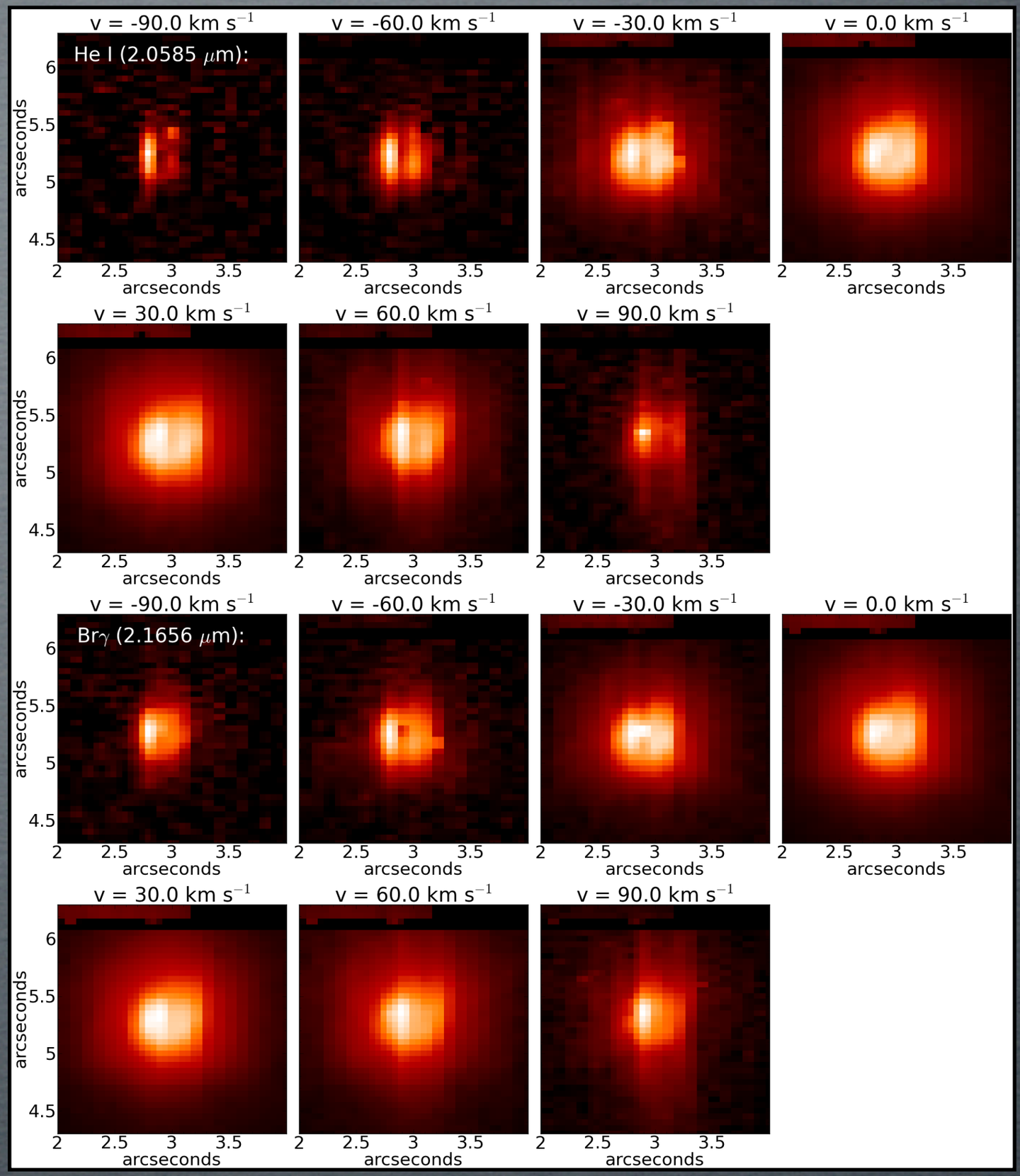
Hen 2-104, The Southern Crab



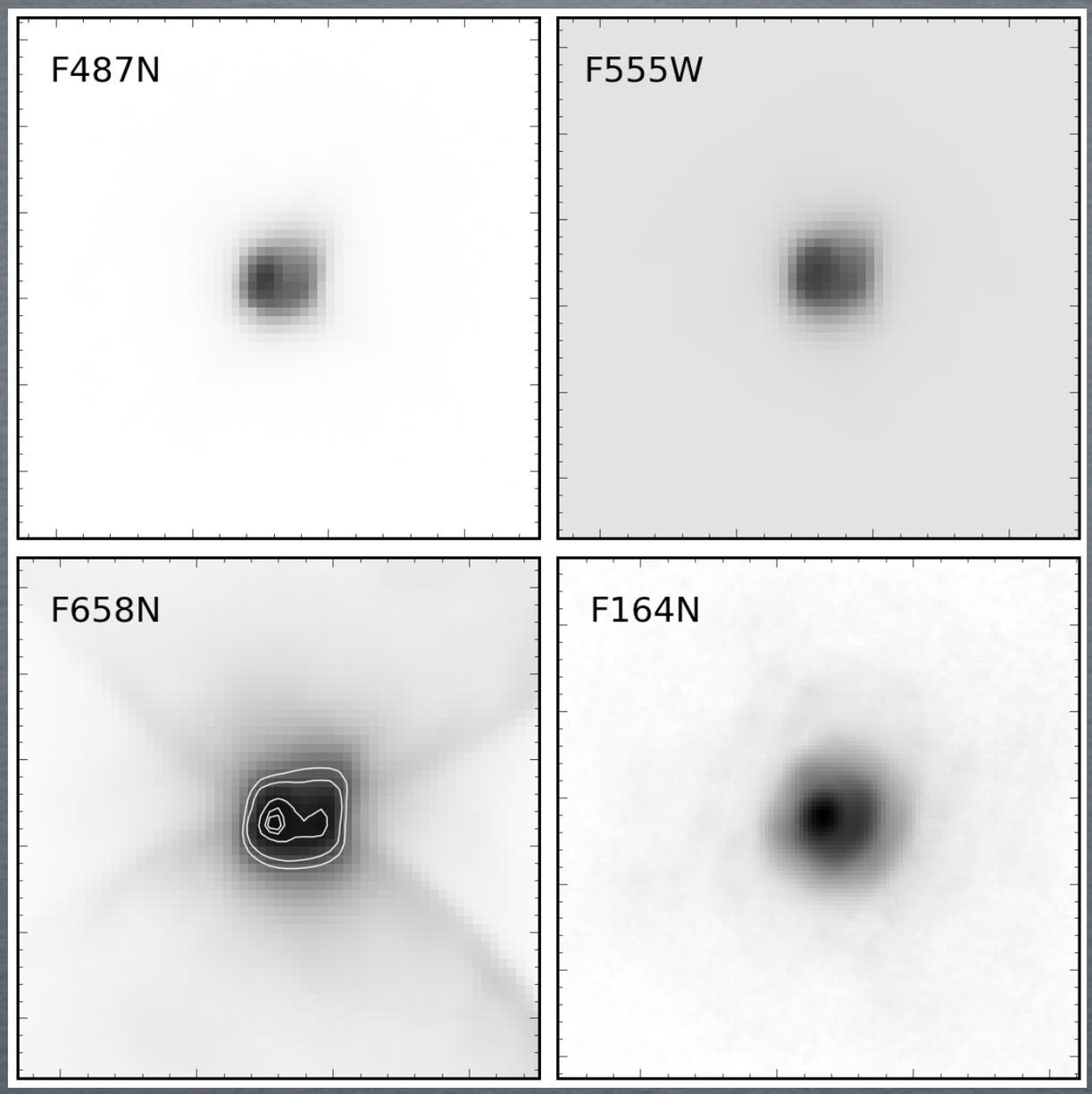
Taken from Kwok and Hsia (2007)

Core

- Core brighter on E side than on W side
- Each image 2” × 2”
- Width = ~320 pc (d = 2000 pc)
- **Torus ~30 times narrower than width of hourglass!**

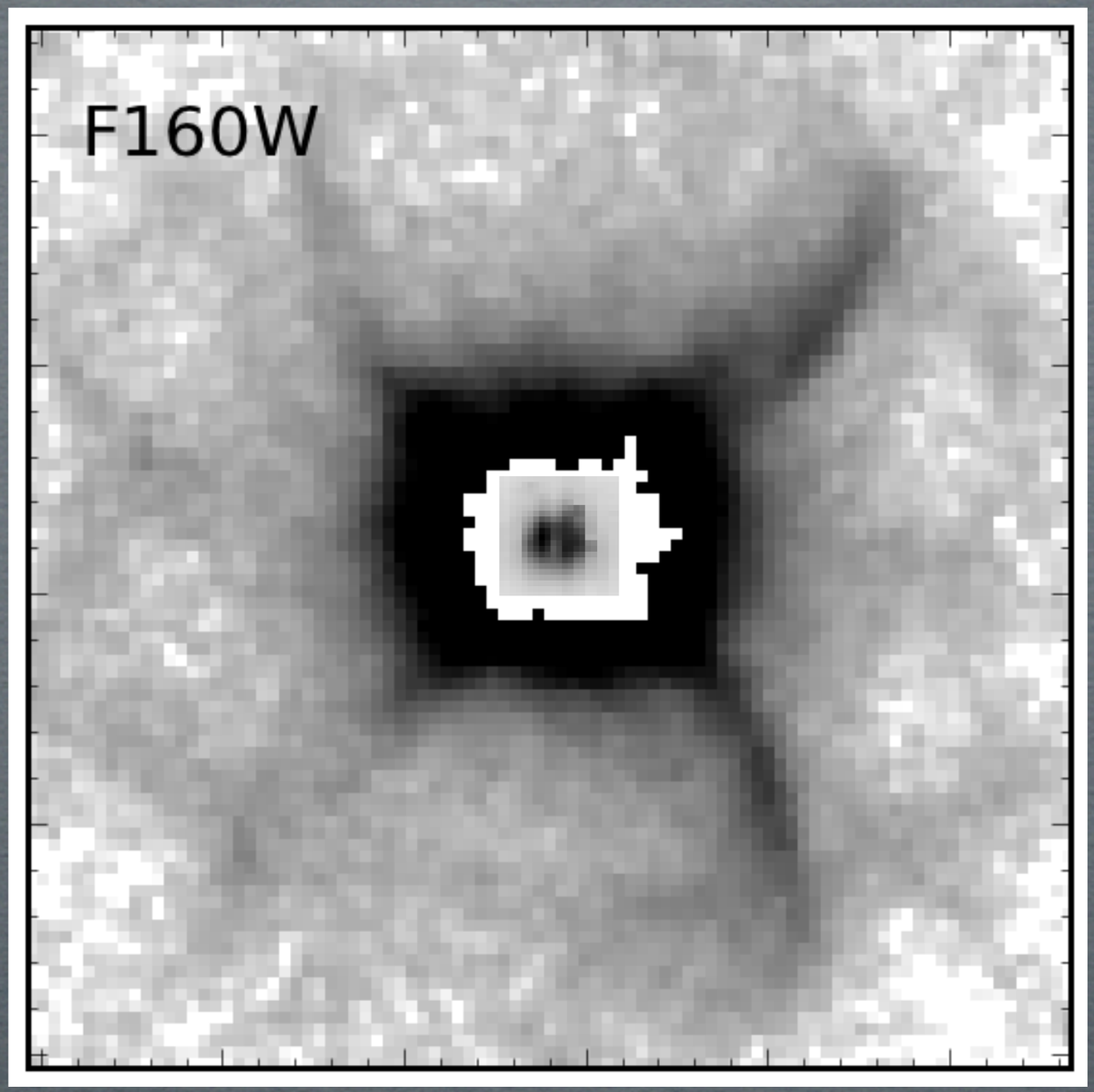


HST Images of Core



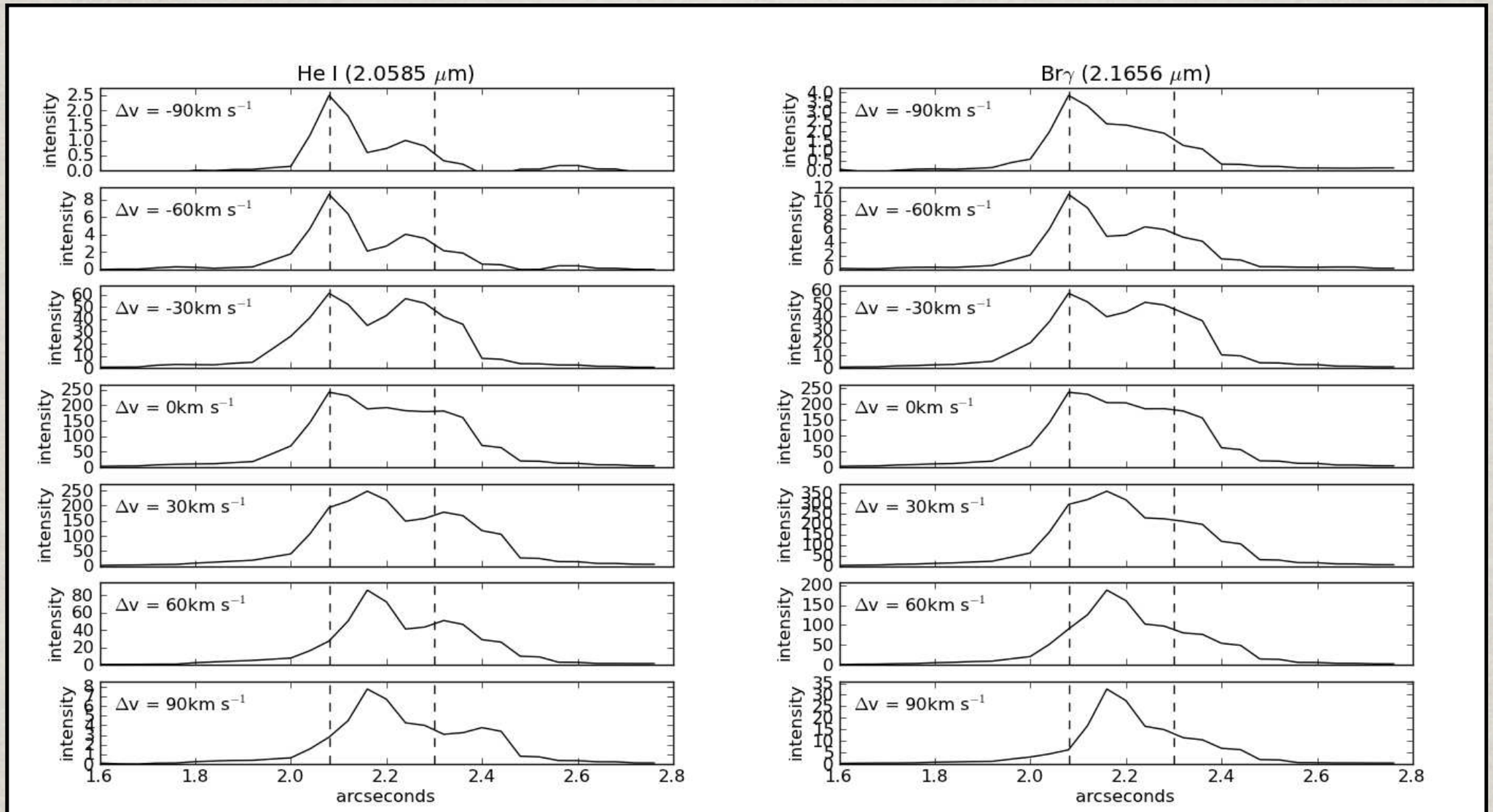
- Notice E side brighter than W side
- F658N shows lobes go right down to nucleus

Core: NIFS HST comparison



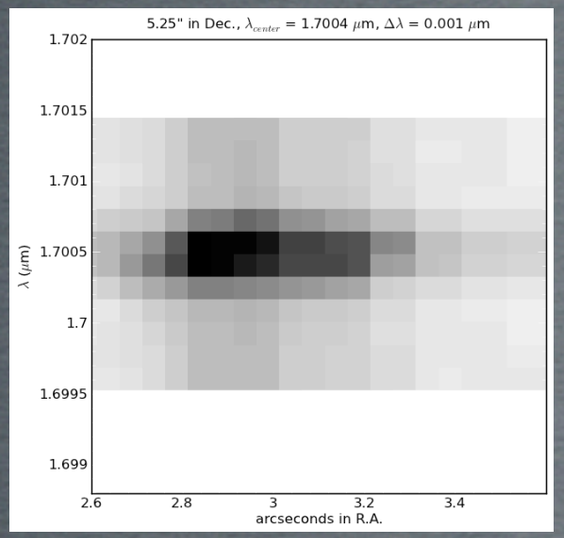
- F160W HST image overlaid with a NIFS image of the core in the He I (2.0585 μm) line at a velocity shift of -30 km/s from the line center

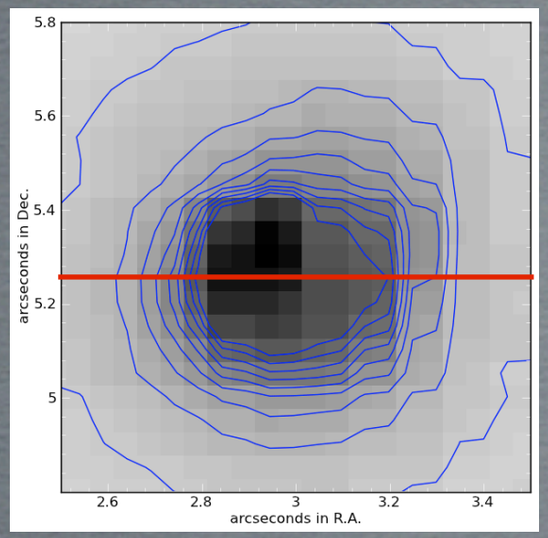
1-D Cuts Across Nebula

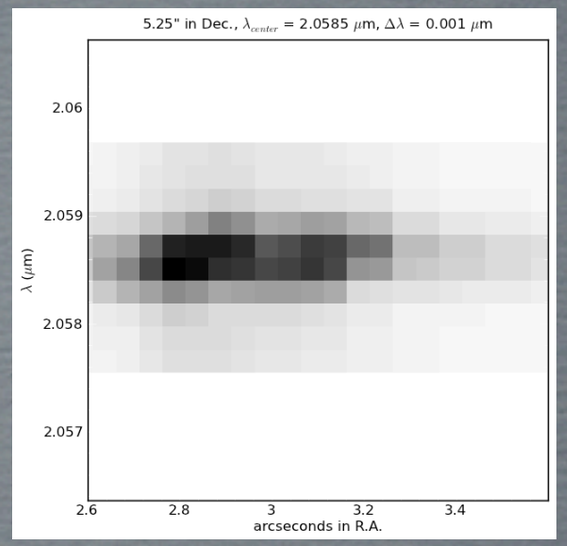


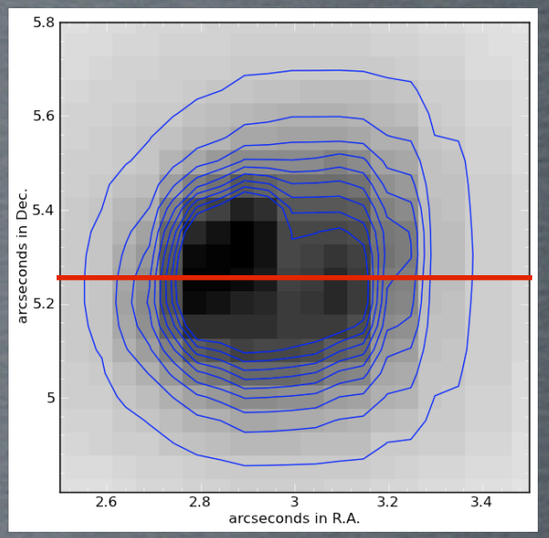
- Horizontal plots in intensity across core
- Prominent double peaks in He I (2.0585 μm) and Brγ
- General, downward slope
- Shift in profiles, left to right, from -90 km s^{-1} to 90 km s^{-1}

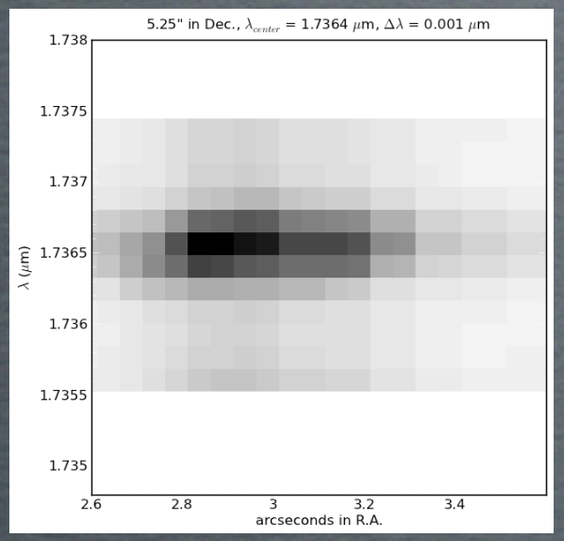
2-Dimensional Spectra

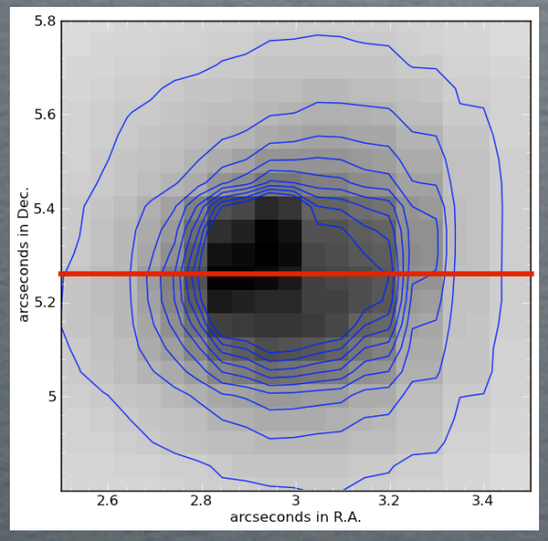


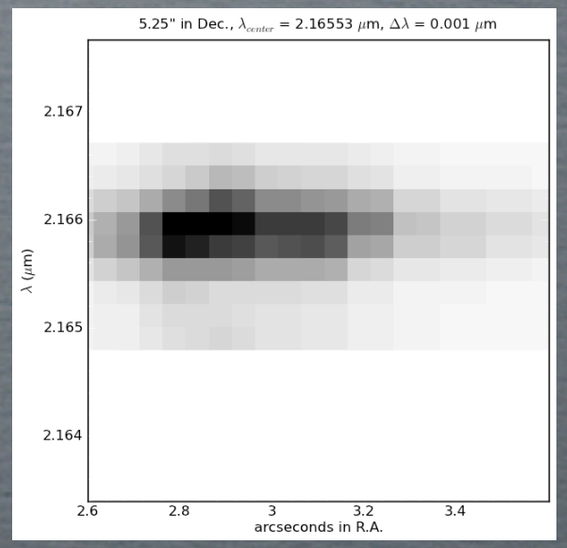


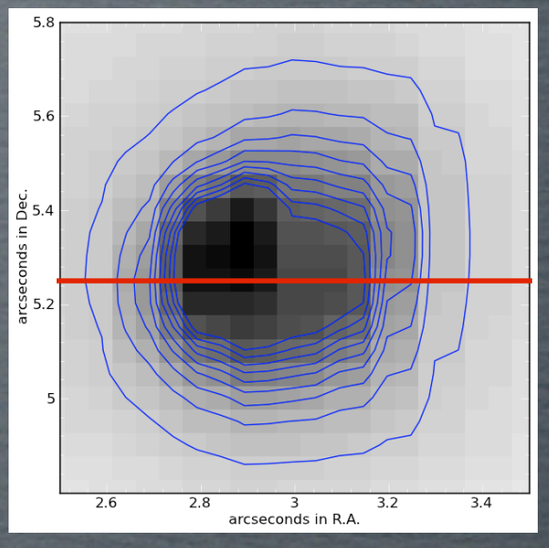






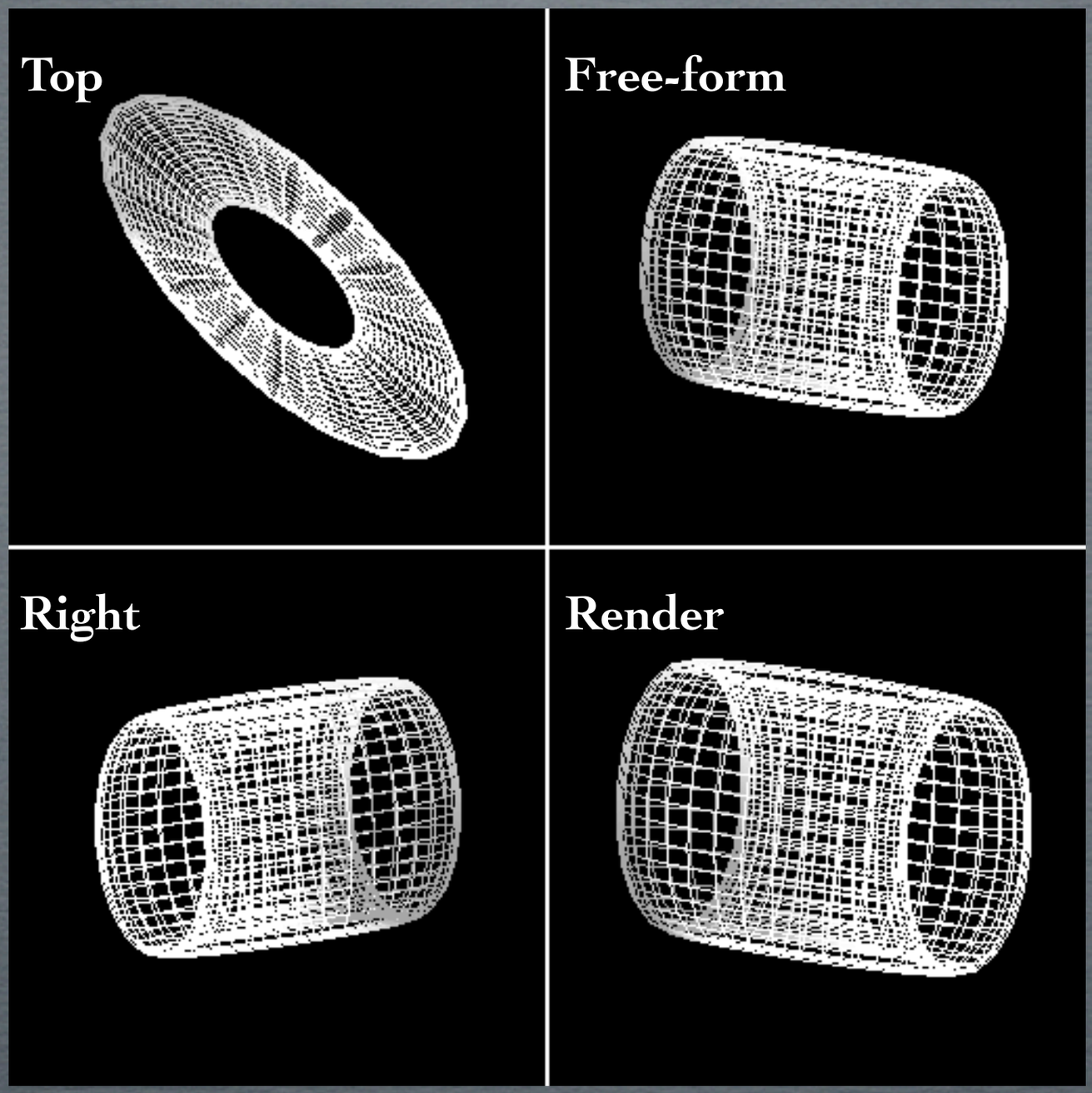






- Profile shift also evident in 2-d spectra

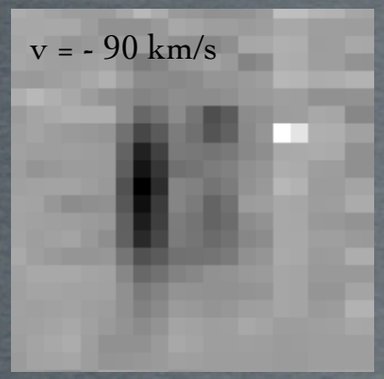
Shape Model of Core

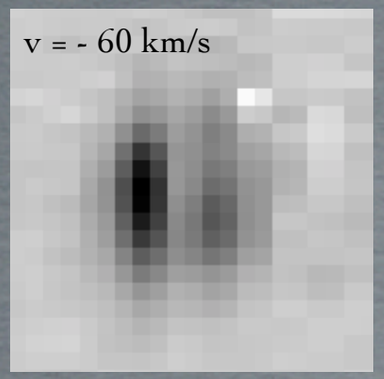


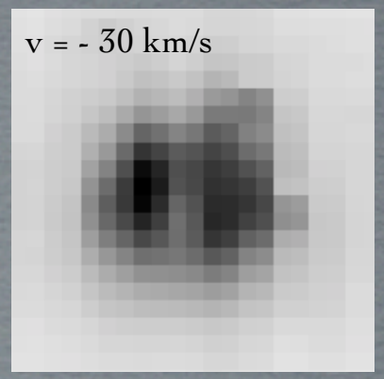
- Top, Free-form, and Right views are enlarged to show model more clearly
- Render matches output by Shape
- P.A. = -5°, inclination = 5° toward observer

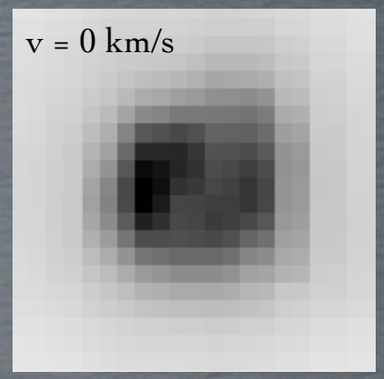
Shape Model of Core

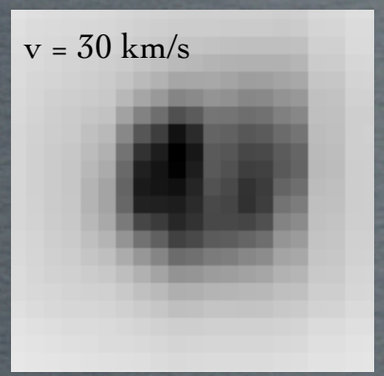
He I (2.0585 μm)

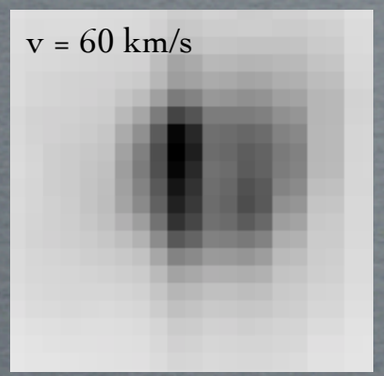


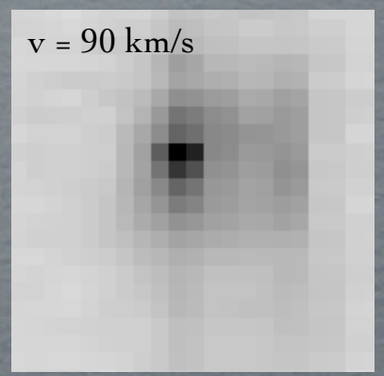


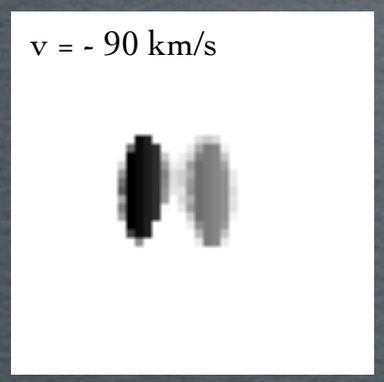


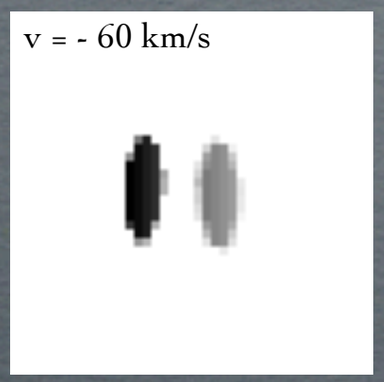


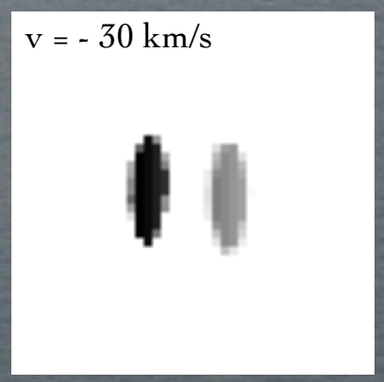


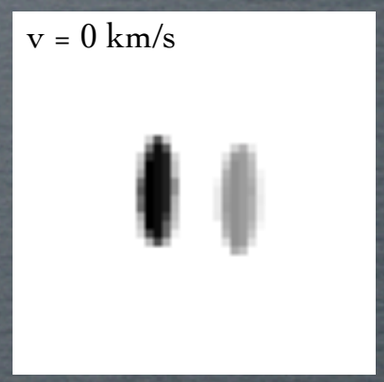


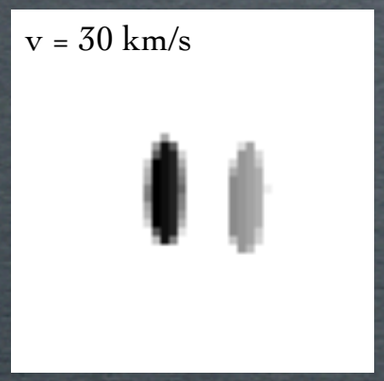


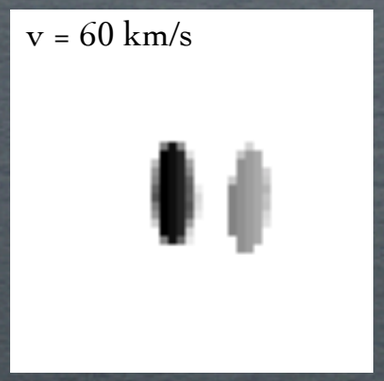


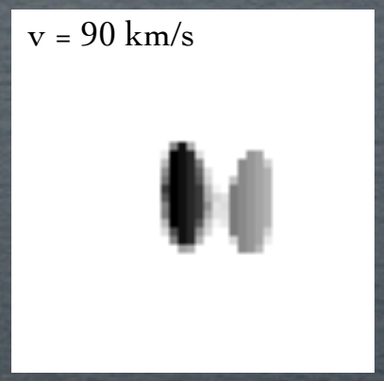












Conclusions

- Lobes bright in [Fe II], N lobe red shifted, S lobe blue shifted

- Core dominated by Br γ and He I (2.0585 μm)

- Lobes 30 times wider than inner torus

- Position of walls of inner torus shift with velocity
  - Modeled as an elongated, tilted, inclined torus

References

- Bonnarel, F., Fernique, P., Bienaymé, O., et al. 2000, A&AS, 143, 33
- Hora, J. L., & Latter, W. B. 1996, ApJ, 461, 288
- Vaytet, N M. H., Rushton, A. P., Lloyd, M., Lopez, J. A., Meaburn, J., O'Brien, T. J., Mitchell, D. L., & Pollacco, D. 2009, MNRAS, 398, 385