A Complete Spectroscopic Map and Narrow-Band Imaging of Small PAHs in the Red Rectangle Nebula

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Outline

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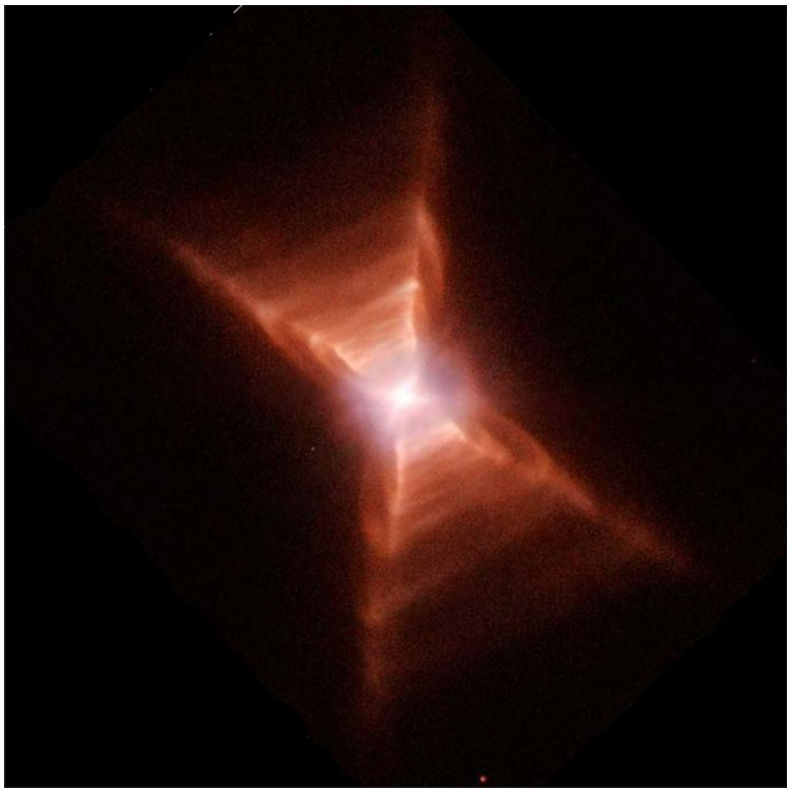
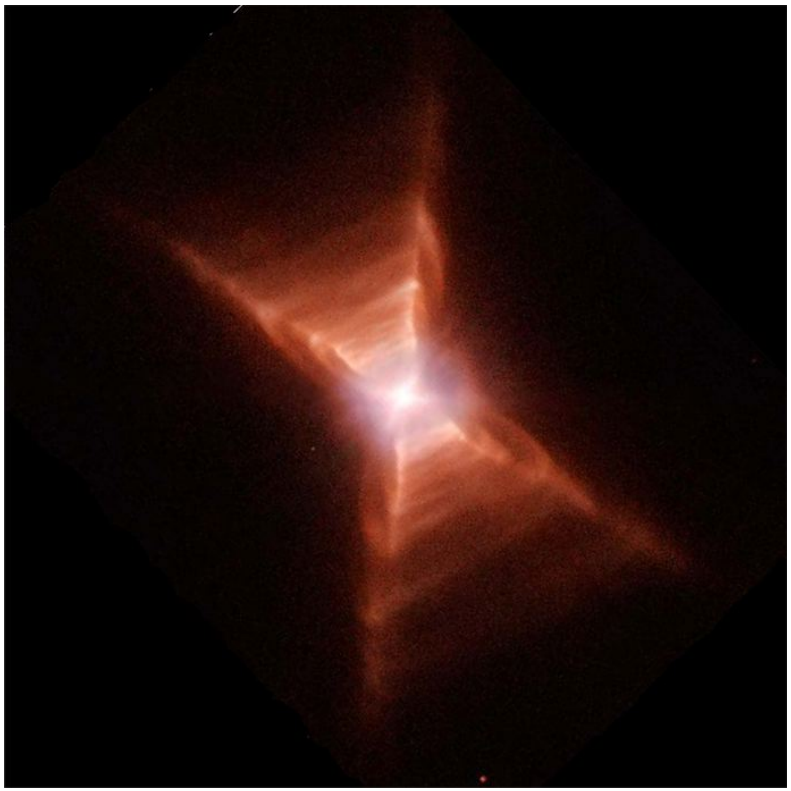
Different Morphology at Different Wavelengths.



HST WFPC2 (F622W + F467M)

AAT Kodak IIa-O + 380 nm cut-on filter (Courtesy David Malin)

Different Morphology at Different Wavelengths.



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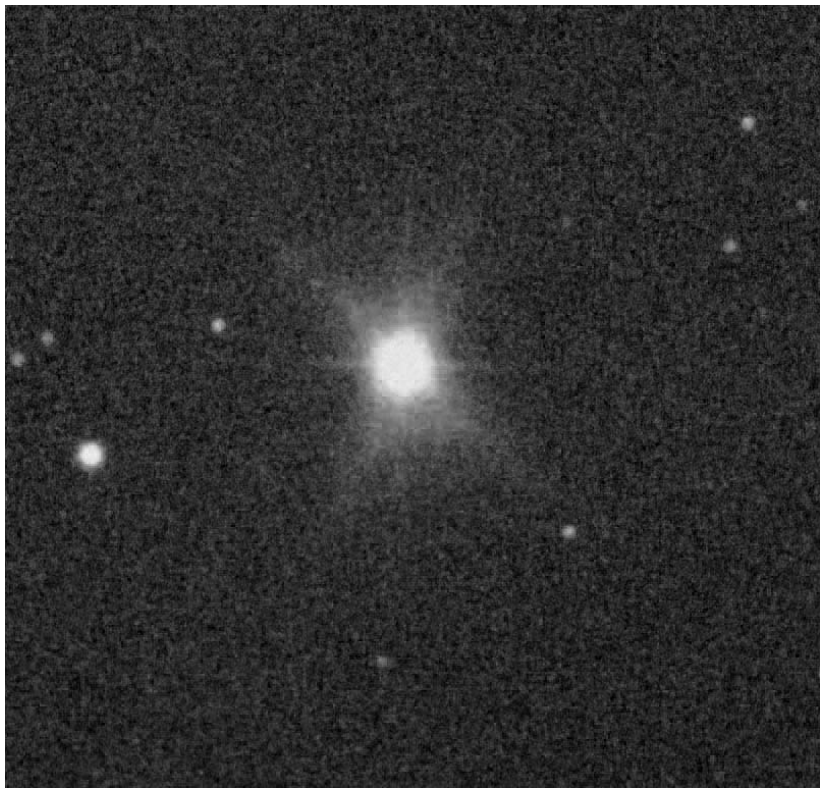
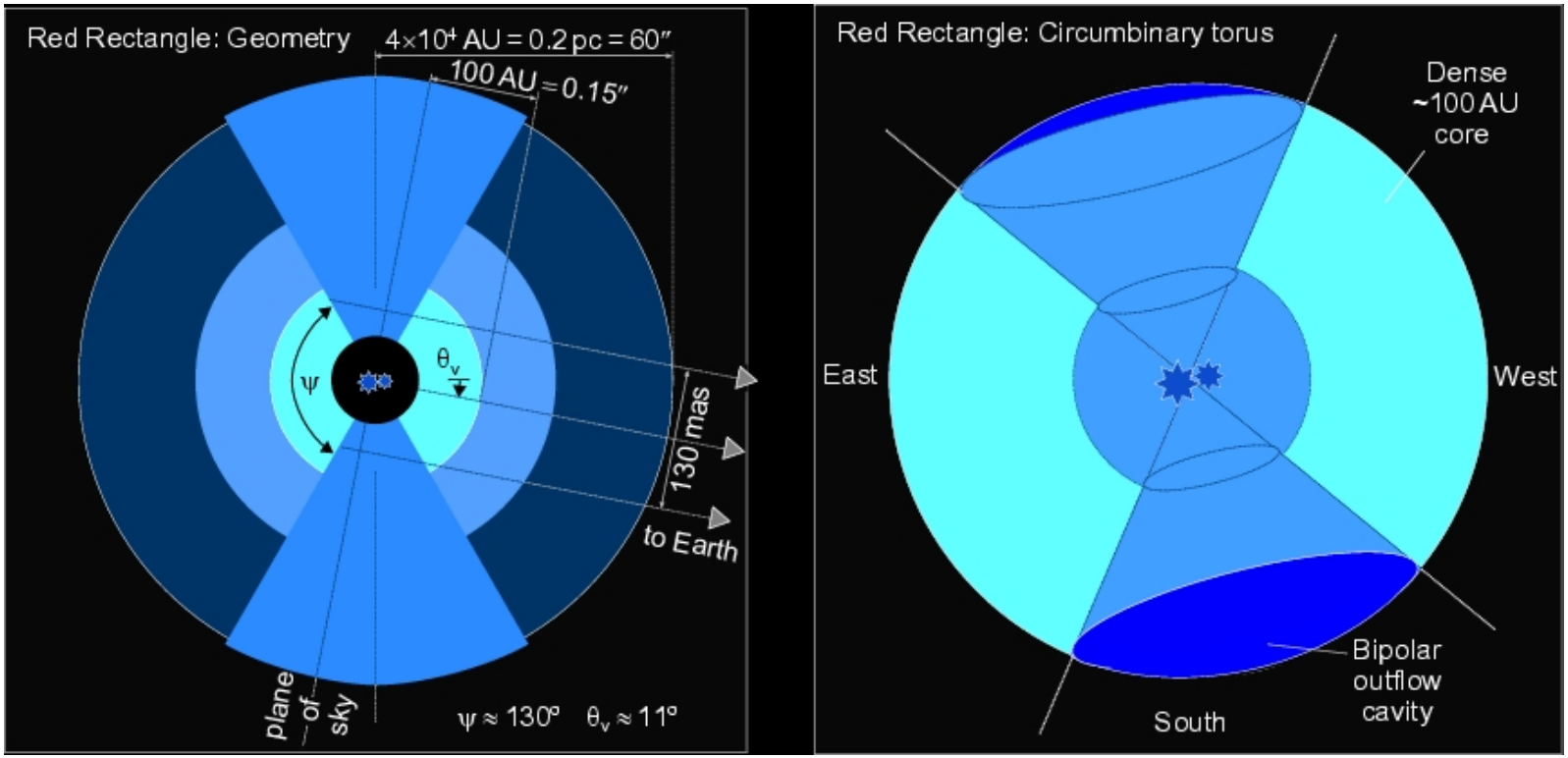


AAT Kodak IIa-O + 380 nm cut-on filter (Courtesy David Malin)

The Red Rectangle System

- Source of many dust-related emissions: ERE, UIR/AEF, BL
- First discovered source of the ERE, BL
- Brightest source of the UIR/AEF
- The central star HD44179 is a $\sim$ 6000 $L_{\odot}$ A III post-AGB star, in a stage of active dust production
- Close hot white dwarf companion ($T_{\mathrm{eff}} \sim$ 60,000 K)
- Optically thick circum-binary dust torus obscures central source from direct view
- Outflow through polar openings produces bipolar structure

Schematic Geometry



Men'shchikov et al. 2002, A& A,393,867

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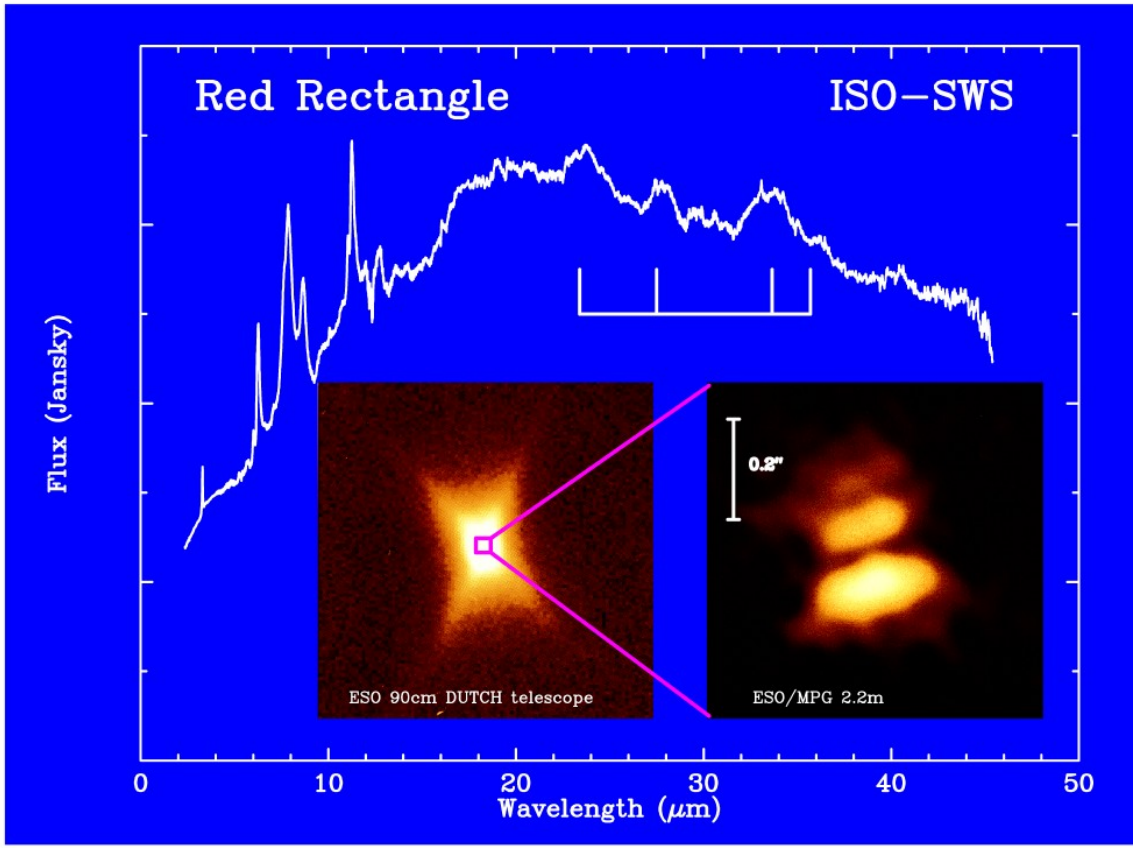
ISO Spectrum of the RR



- RR is the brightest source of mid-IR UIR bands
- Mixed O-rich/C-rich chemistry
- Strong mid-IR UIR bands, attributed to aromatic hydrocarbons (PAH)
- Emission bands of crystalline silicates

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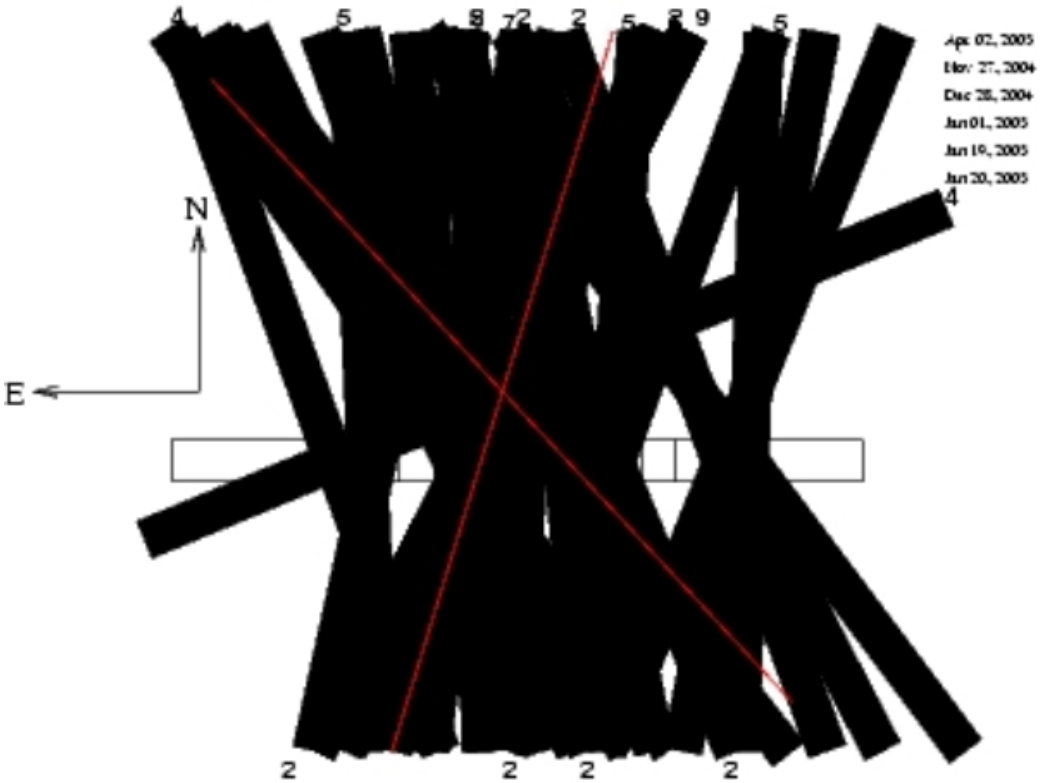
The Spectroscopic Map of the RR

At the 3.5 m telescope at Apache Point Observatory
Using the Dual Imaging Spectrograph: coverage from 370 - 900 nm

The team:

Uma Vijh, Adolf Witt (U. Toledo)
Don York, Lew Hobbs, Takeshi Oka (U. Chicago)
Ben McCall (UIUC)
Ted Snow (U. Colorado)
John Barentine & Russet McMillan (APO)

Spectroscopic Coverage



1."5 wide slit

Narrow-band Imaging

3.5 m at APO: Images using Narrow-band filters and Goddard Fabry-Perot etalon:
Narrow-band Filters: 3934/27, 4050/57, 4596/135, 5704/135, 6403/135
Etalon: 5800/15, 5855/15

The team:

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Don York, Vikram Dwarkadas (U. Chicago)
Bruce Woodgate (NASA GSFC)
Povilas Palunas (U. Texas, Austin)

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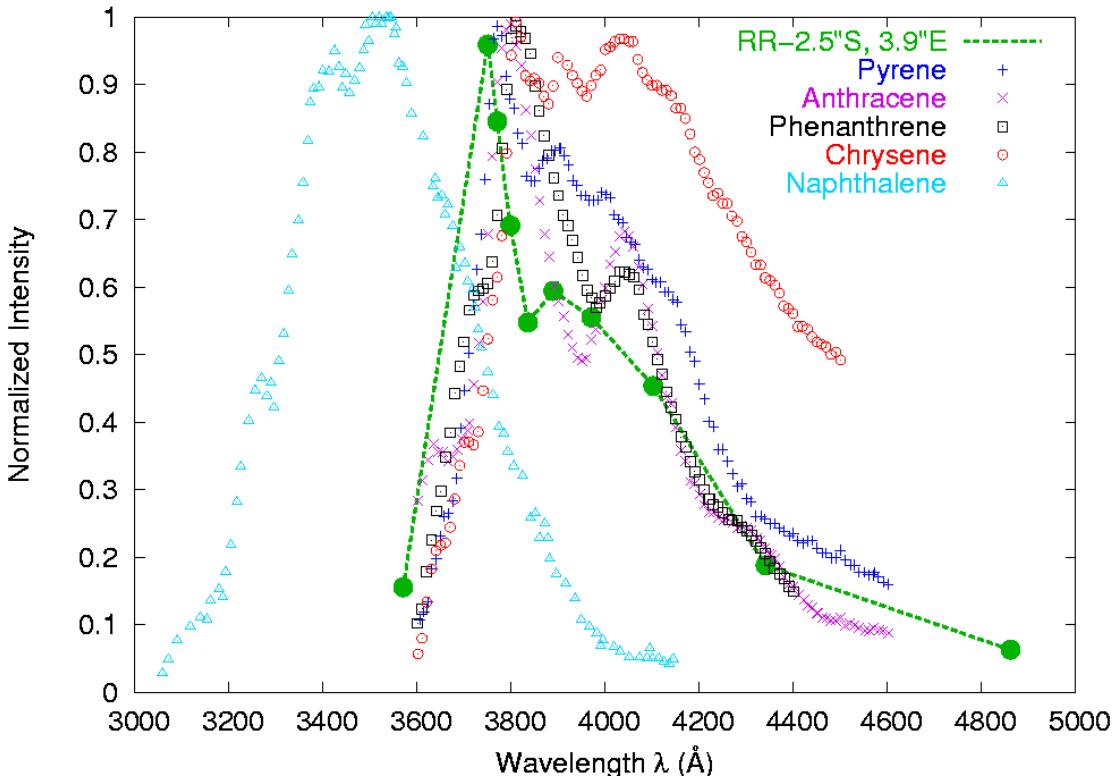
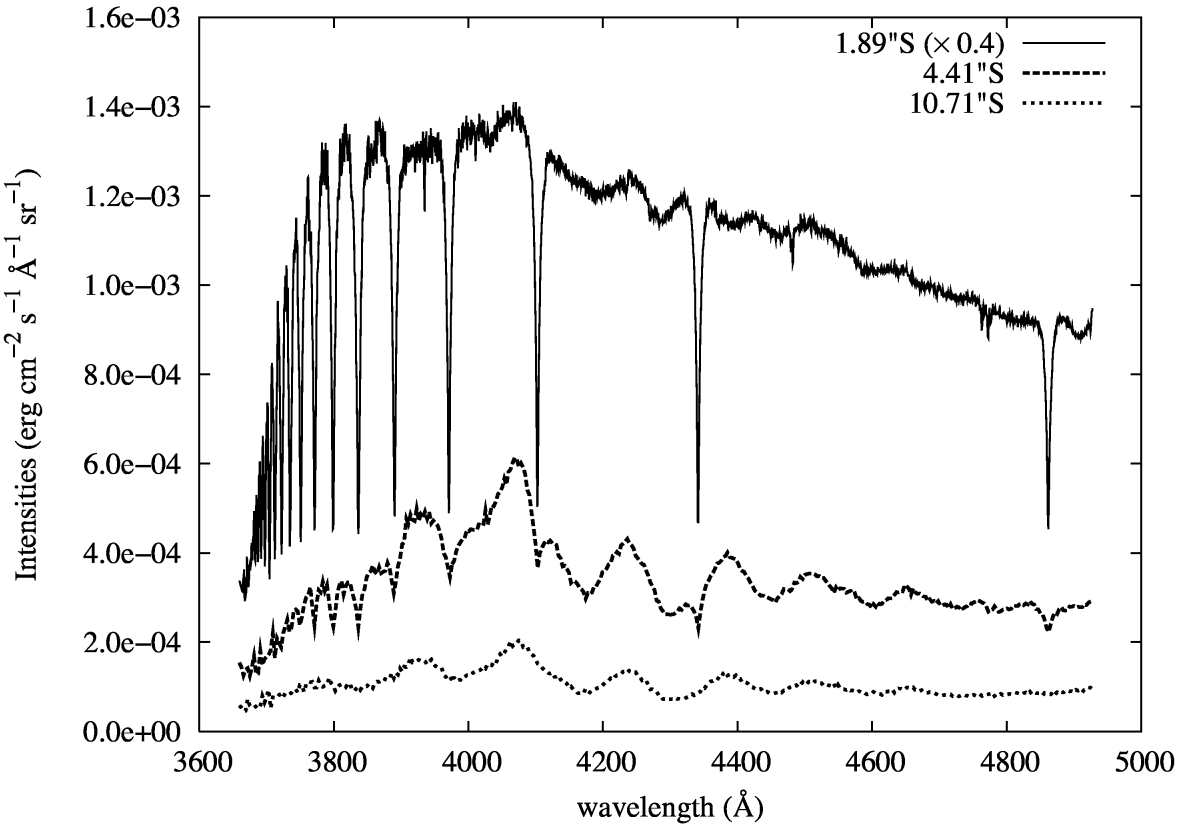
Initial Detection of the BL Spectrum



Spectrum from 2."5 S 3."9 E, compared to fluorescence from small, neutral PAHs (Vijh et al. 2004, ApJ, 606, L65)

The Resolved BL Spectrum



Nebular spectra along a slit at PA -24°. (Vijh et al. 2005, ApJL submitted)

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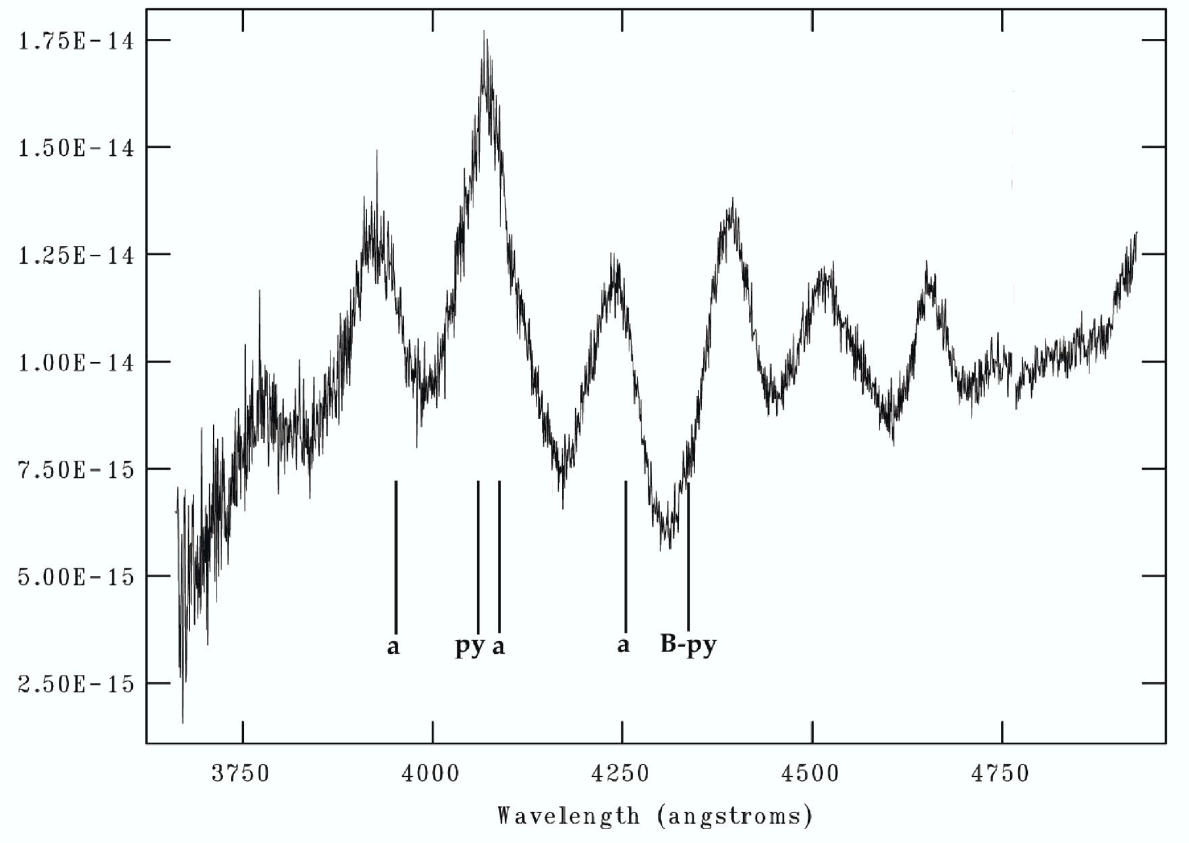
Identification of the BL Spectrum.



- BL spectrum consists of seven bands between 370 nm and 470 nm
- Likely source: Fluorescence by two or more different aromatic hydrocarbon molecule species

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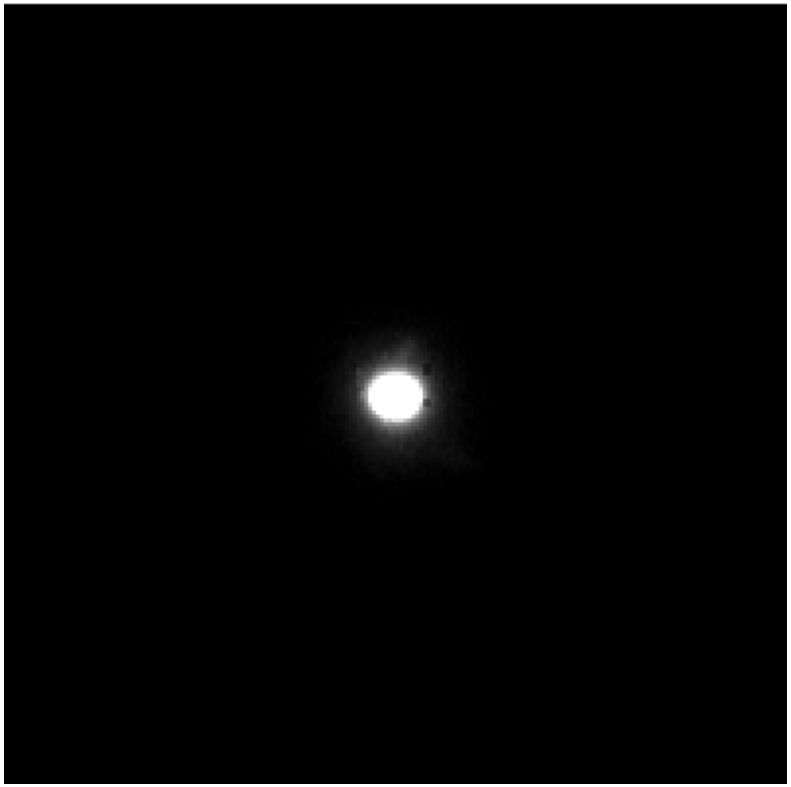
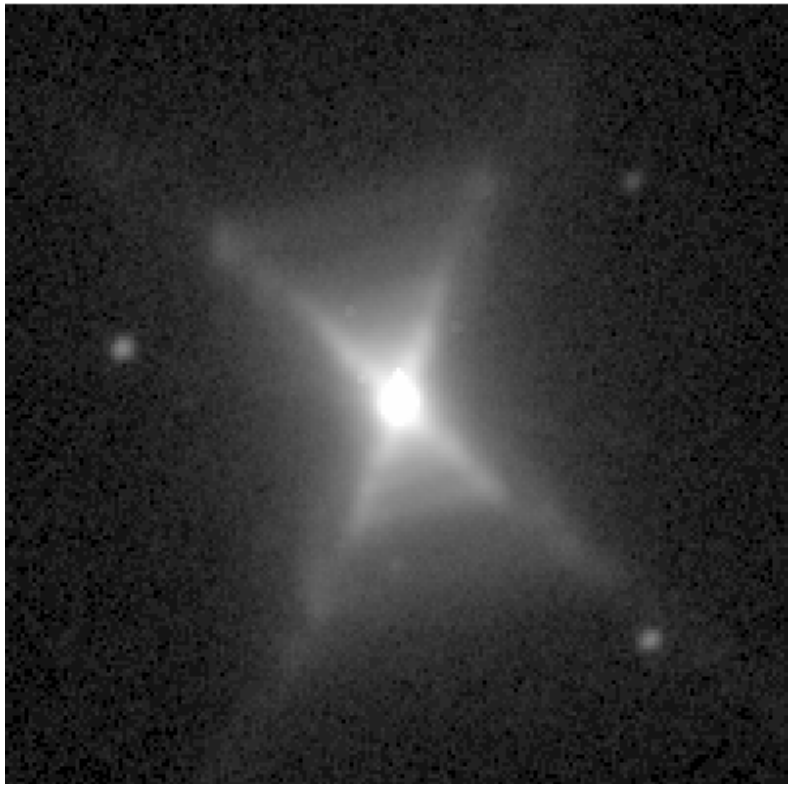
Narrow Band Images

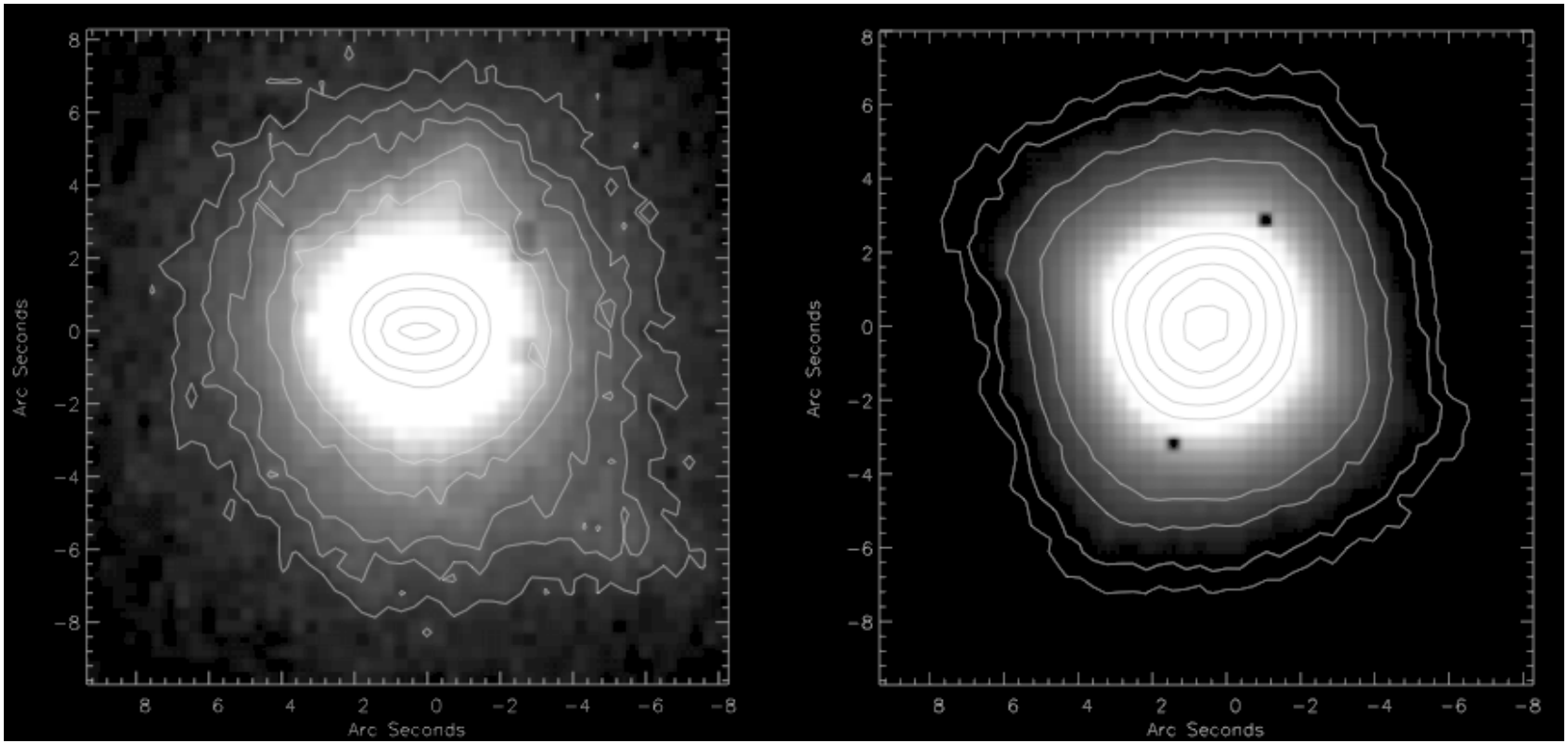


3934 Å (27 Å wide): BL band



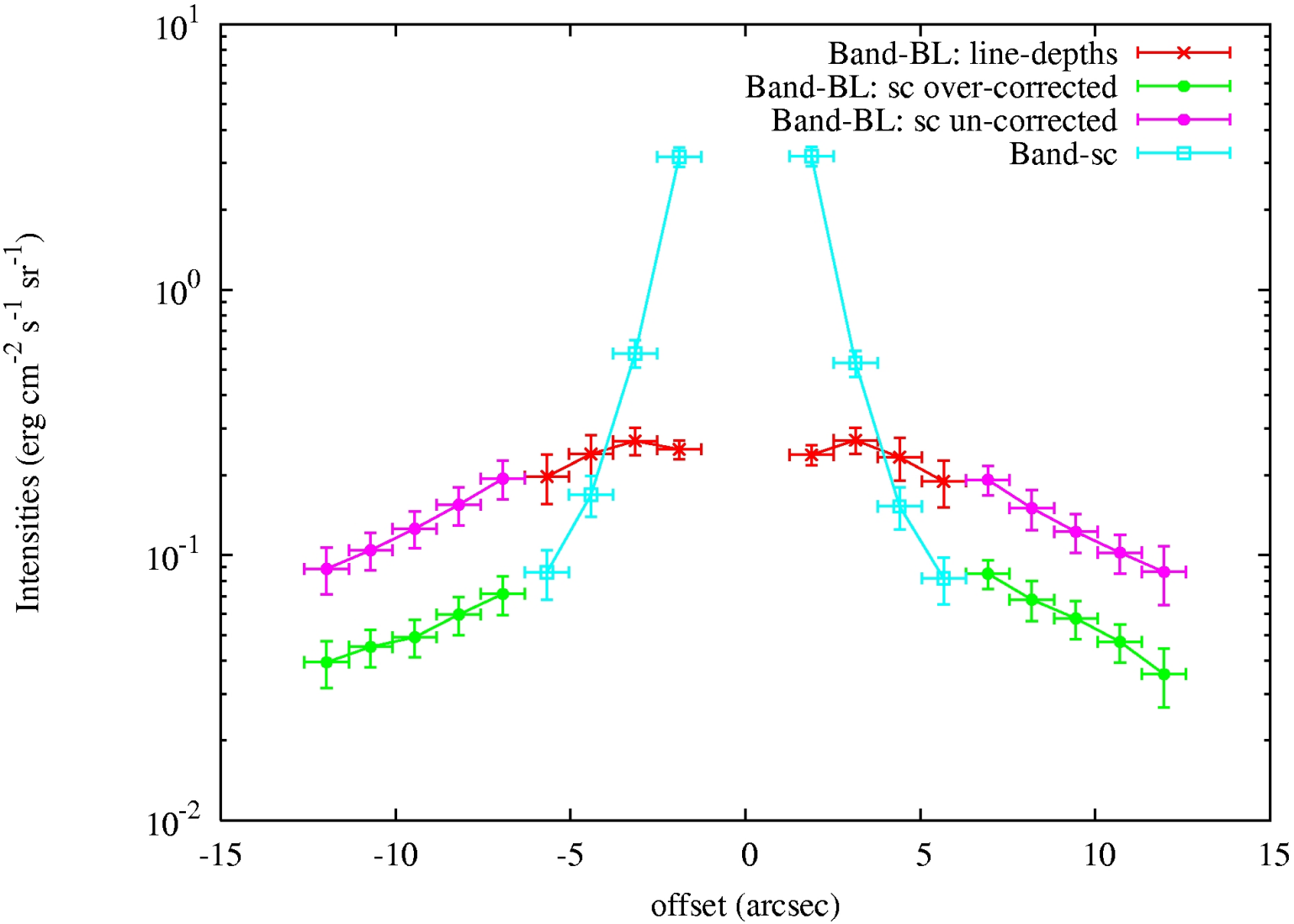
6400 Å (135 Å wide) : ERE band

Contour Images



BL image and 4050 Å scattered-light image

Distribution of the BL



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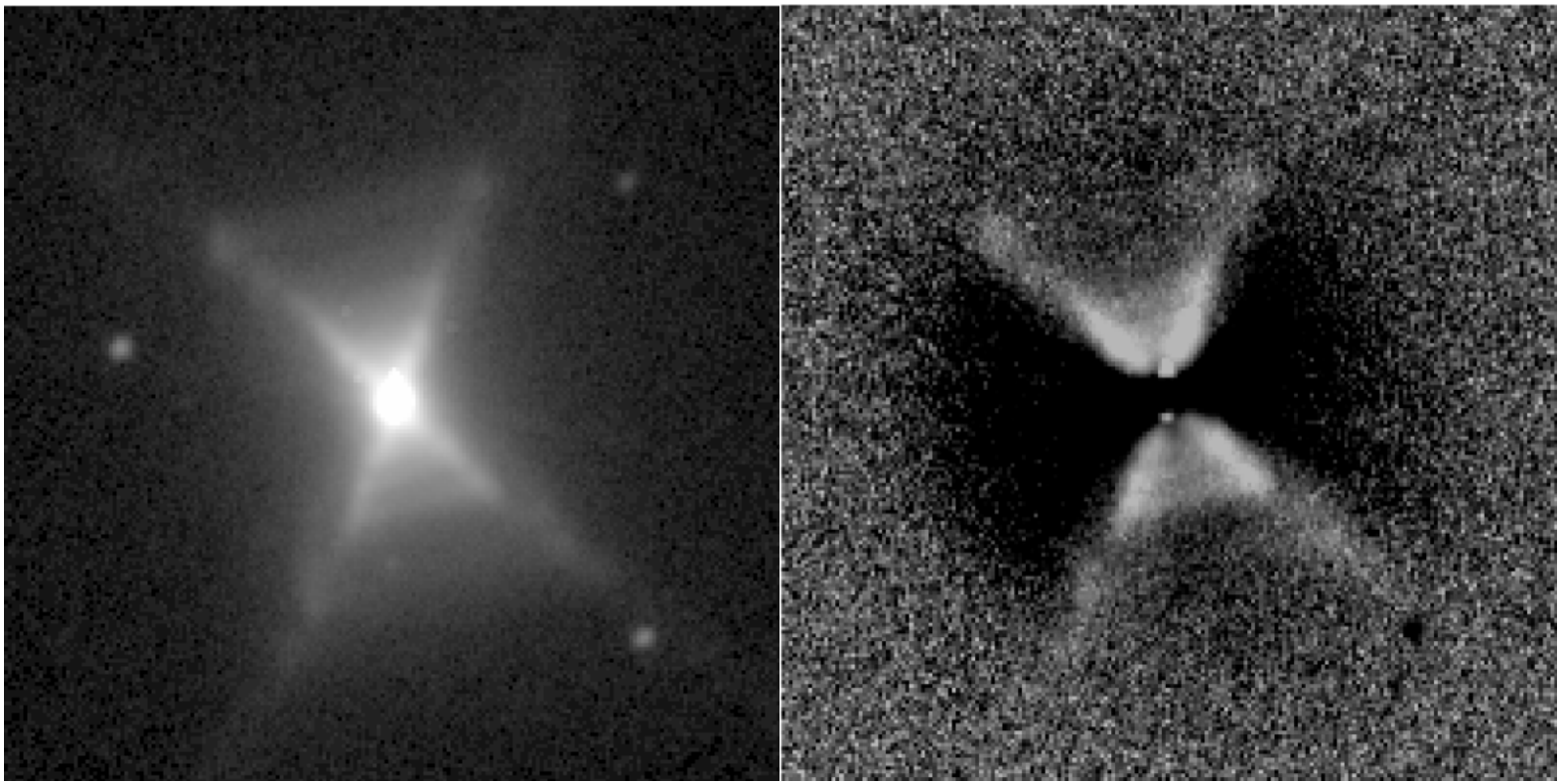
ERE Images



6400 ERE image and 6400/5700 ratio image

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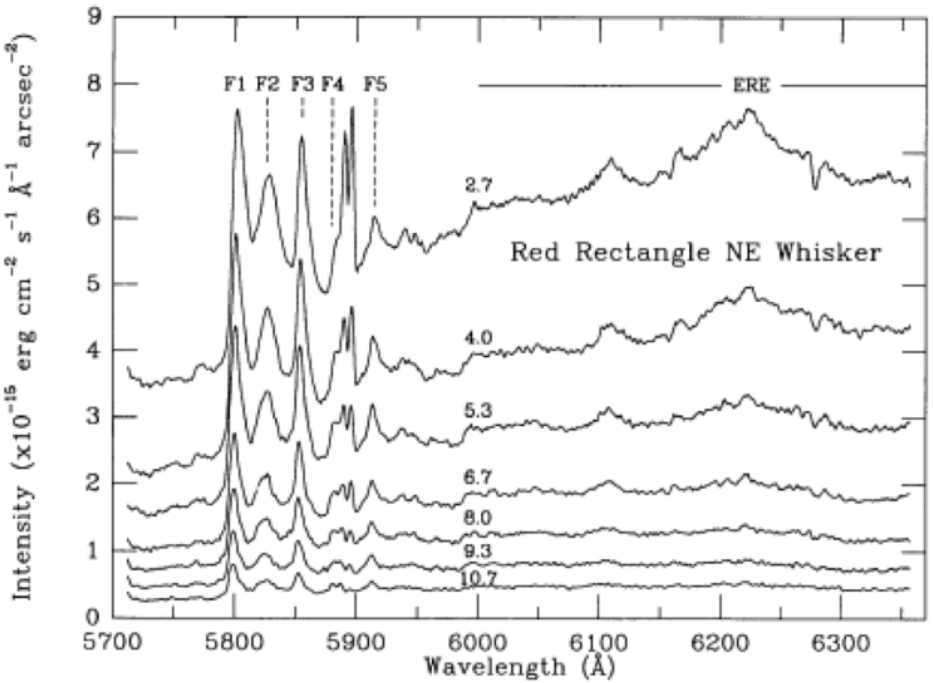
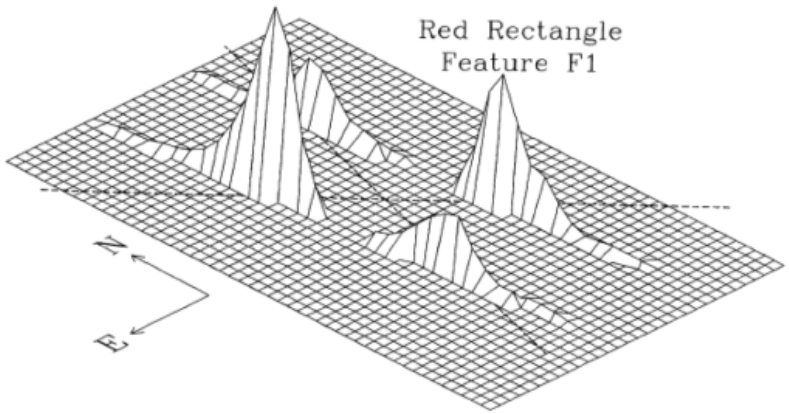
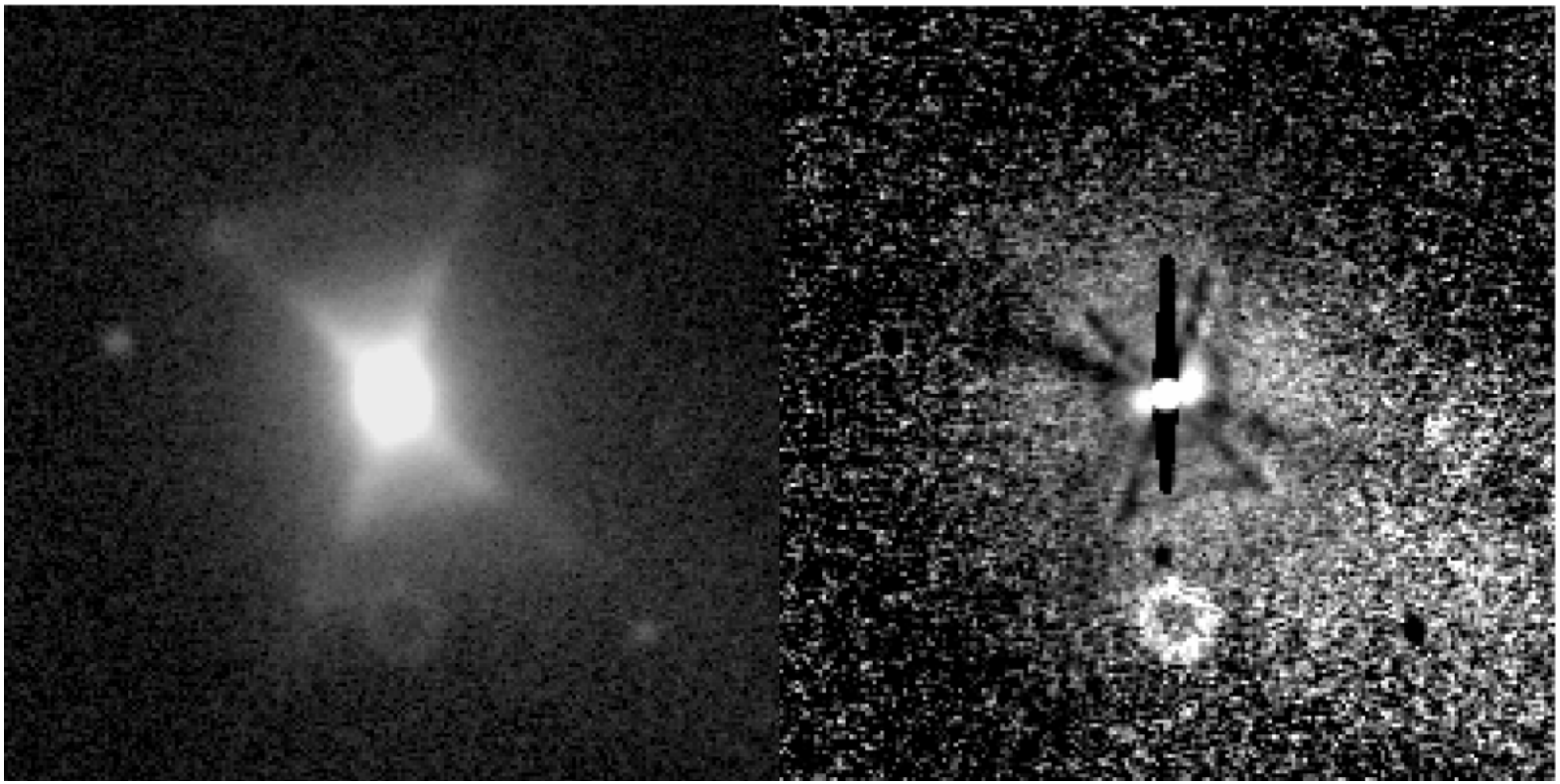
Sharp Red Emission Features





(Schmidt & Witt, 1991, ApJ, 383, 698)

Sharp Red Emission Features



5800 Å image and 5800/5700 ratio image

Summary

- BL spectrum resolved into seven discrete bands between 370 nm and 480 nm
- Interpreted as evidence for fluorescence by neutral PAH molecules (3-, 4-, 5-ringed PAHs)
- Extended Red Emission (ERE) is seen preferentially on the walls of the outflow cones (Consistent with ERE excitation requiring E > 10.5 eV photons)
- Blue luminescence and ERE are observed in mutually exclusive environments in the RR