Playing "Hide-and-Seek" With Binary Stars:

Searching for companions and accretion disks in AGB stellar systems

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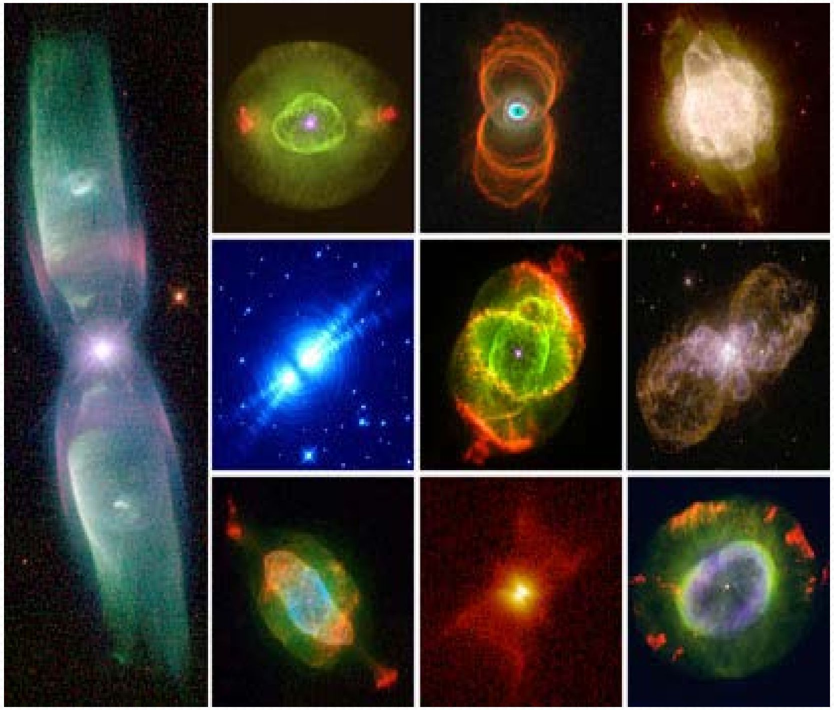
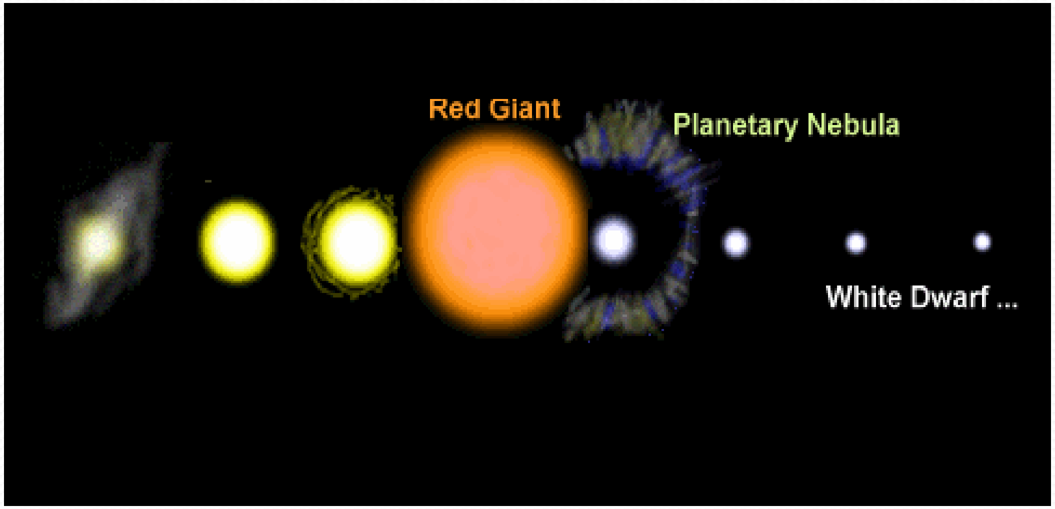
Introduction



Planetary Nebulae (PN/PNe) come in a variety of shapes

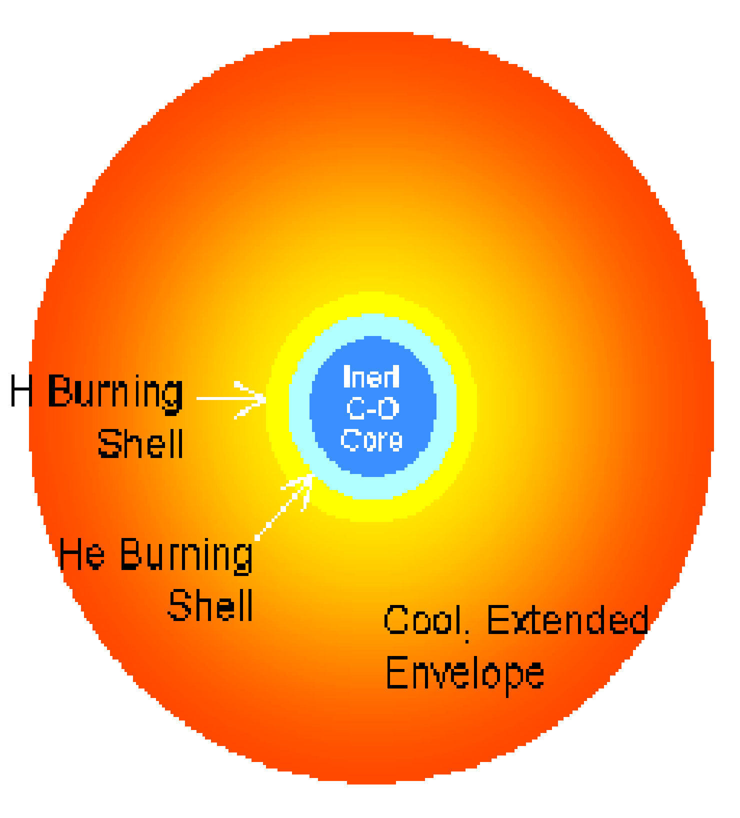
Introduction



- Why do stars evolve from spherical objects into asymmetric PNe?
- How does this impact the recycling of material back into the galaxy?
- **<u>Theories suggest companion stars may play a role</u>** (Sahai 2012)

Asymptotic Giant Branch (AGB) Stars

- Phase prior to PN stage
- “Red Giant stars”
- Inert C/O core from He fusion
- Surface temperature has decreased
- Variable stars: luminosity changes periodically (~1 year cycle).



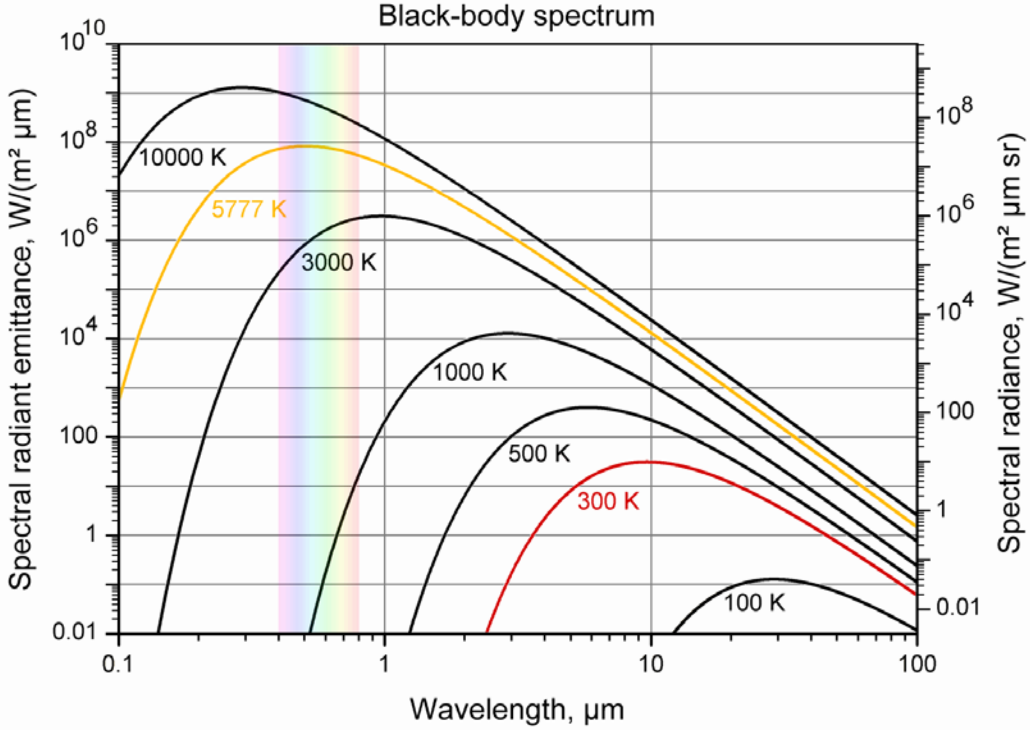
Challenges Seeking Companions

- One exception: Mira is a binary system consisting of Mira A: an AGB star, and Mira B: a WD companion
  (Riemers & Cassatella 1985)

- White dwarf (WD) & main sequence (MS) stars are smaller and thus less luminous

- Variability of the AGB star prevents certain methods of detecting the companion from being viable (Sahai 2008)

Blackbody Spectra



Hotter objects emit larger amounts of radiation as well as higher energy radiation

UV spectra were taken by GALEX of the following objects:

Name	Spectral Type (SIMBAD)	Variable Type
W PEG	M7e D	Mira
EP AQR	M8IIIv	SRb
R UMA	M3e-M9e D	Mira (O rich)
AA CAM	M5 S	Pulsating/Irr (O rich)
EY HYA	M7IIIa D	SRa
TZ HOR	M5III C	Pulsating Variable
V ERI	M5/M6IV C	SRb (O rich)
TW HOR	N0 C7	SRa (C rich)
VY UMA	C5III	SRb (C rich)
V HYA	N:C7,5	Mira (C rich)

Process

- Determine UV emission lines that can be emitted by AGB stars
- Determine UV emission lines that have been found in AGB binaries, as well as other interacting or accreting systems
- Use GALEXSpec to reduce data
- Use IRAF to plot data and measure central wavelength, flux, fwhm, and wavelength range
- Calculate flux/noise

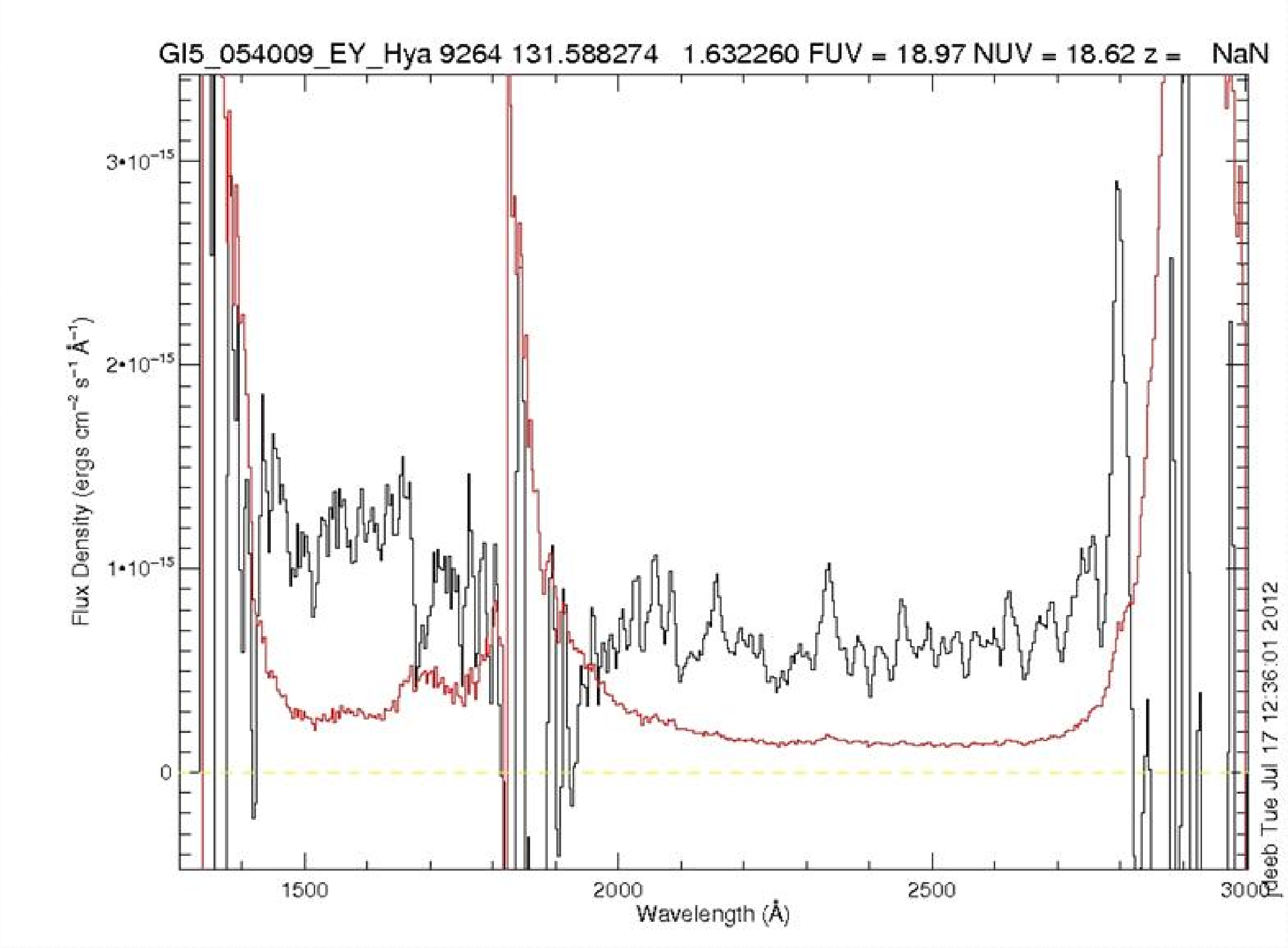
Ultraviolet Observations in AGB Systems

AGB stars (although cool) emit SOME UV light (possibly chromospheric emission):

- Mg h & k lines (centered at 2800 Å)
- Fe II lines (various) (Judge & Jordan 1991)
- C II features centered around 2325 Å (Johnson & Luttermoser 1987; Stencel 1982)

AGB stars emit relatively little flux at wavelengths less than 2800 Å due to their temperatures.

EY Hya—our “poster child”



EY Hya Line Identifications

λ peak (Å)	λ average (Å)	wavelength range	Flux (ergs cm^-2 s^-1 A^-1)	gfwhm	Identity	Max Flux/Noise
1454.0	1451.0	1443-1461	6.52E-015	3.960	N III?	3.88
1467.0	multiplet?	1461-1482	7.75E-015	8.024	C I or CII multiplet?	3.935
1485.5/1492.5	1489.0	1482-1496	4.79E-015	3.099	NIV]	4.10/4.30
1500.0	1499.5	1496-1517	1.66E-015	2.174	N III?	4.33
1531.0	1531.0	1528-1538	1.91E-015	1.934	C II multiplet?	5.06
1545.0	1545.0	1538-1550	1.86E-015	3.637	C IV	5.44
1587.0	1590.0	1584-1598	2.94E-015	4.022	unknown	4.59
1629/1643	1636.0	1625-1647	1.22E-014	3.037	He II	4.71/4.08
1660/1666	1660.5	1647-1674	1.99E-014	10.049	O III	3.13
1720.0	1719.0	1713-1724	3.75E-015	3.163	N IV	2.77
1727/1734	1731.0	1724-1737	4.70E-015	3.330	N III?	2.47/2.56
1741.0	1746	1738-1755	6.32E-015	4.79	NIII]	3.09
1758.5/1765.5	1762	1751-1773	3.54E-014	21.149	C II	3.48
2157.0	2151.0	2136-2175	8.43E-015	33.110	Fe I or C II?	5.04
2332.0	2333.0	2312-2353	1.30E-014	31.010	C II	5.78
2452	2455	2437-2476	7.32E-015	31.88	Fe II	5.53
2620	2629	2606-2648	2.35E-014	58.12	Fe II	5.63
2728, 2738.5, 2752.5, 2756	multiplet	2709-2770	4.73E-014	58.23	Fe II	4.26/4.16
2798.0	~2800	2781-2818	7.09E-014	32.850	Mg II h and k	4.66

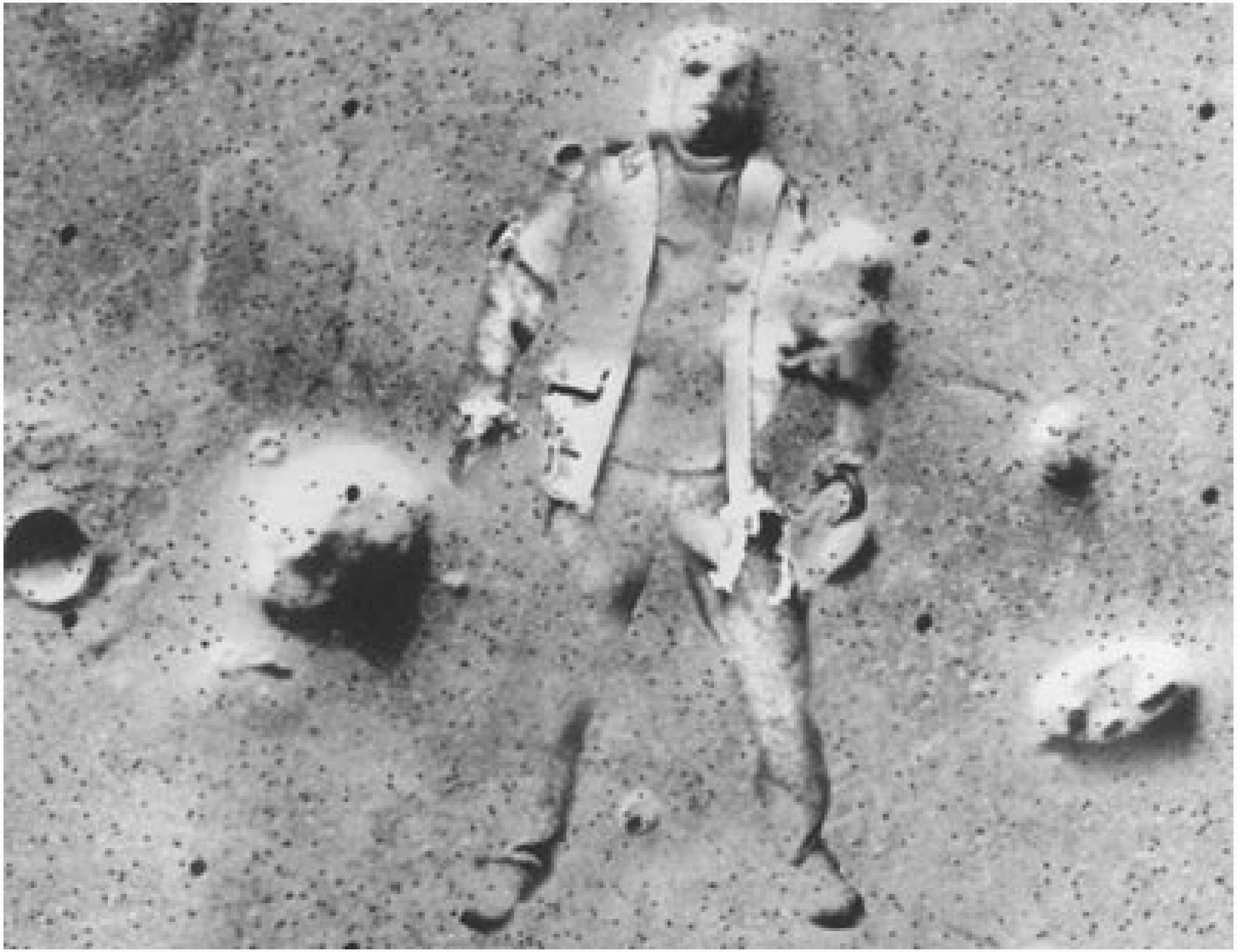
The Resolution Challenge…

- The low resolution of the GALEX grism made it challenging to identify lines…

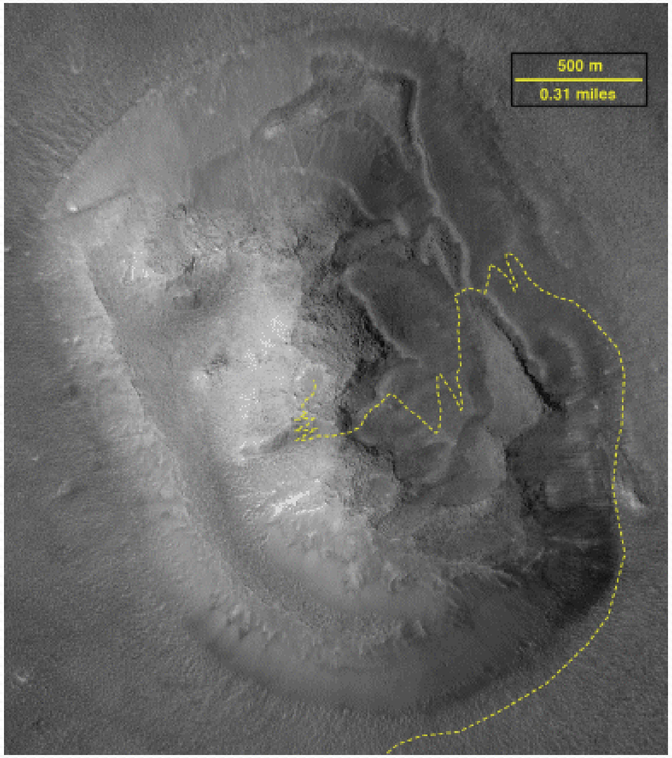
The Resolution Challenge…

Example:
"Face on Mars"

Viking 1



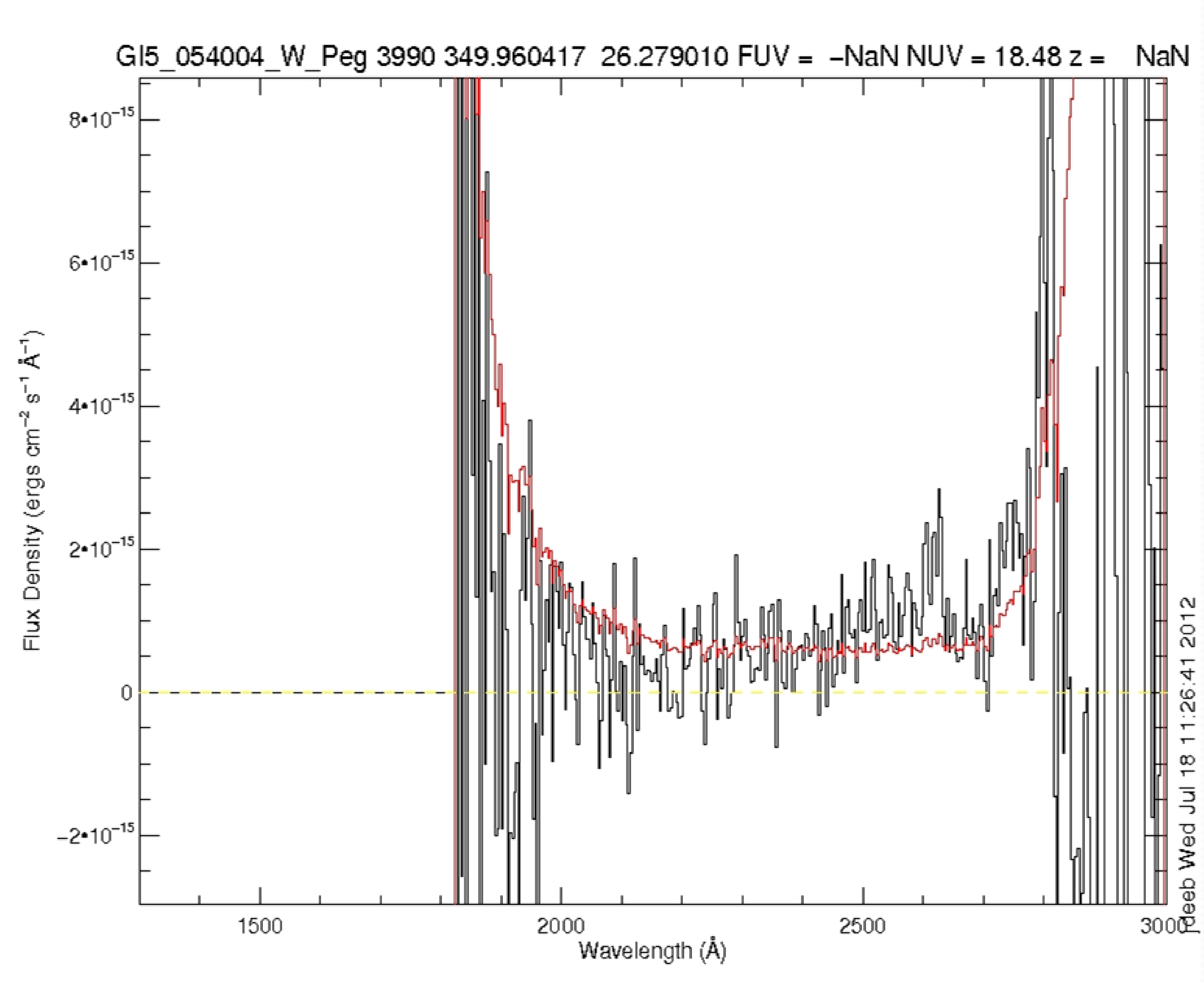
The Resolution Challenge...



W Peg

Wait…what spectrum?

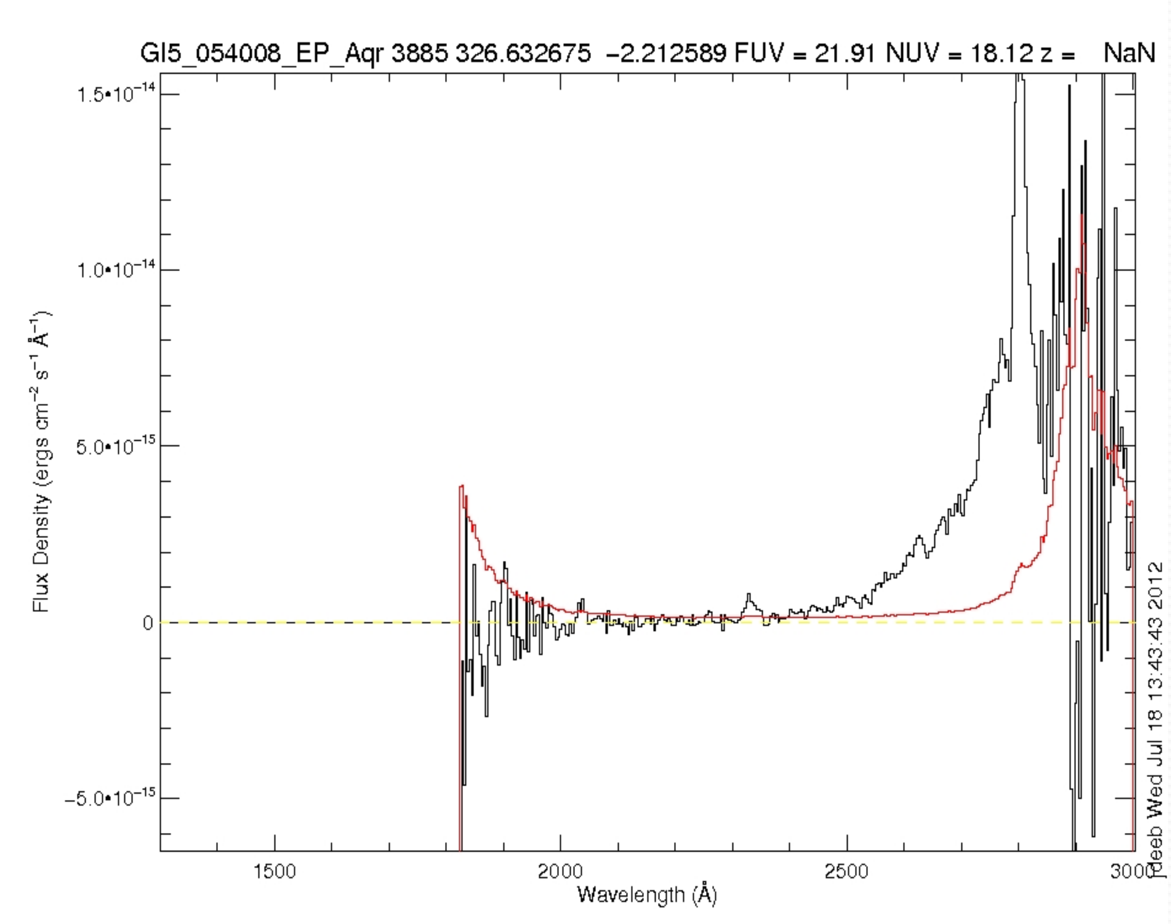
Phase affects the UV output of AGB stars (Luttermoser 2000)



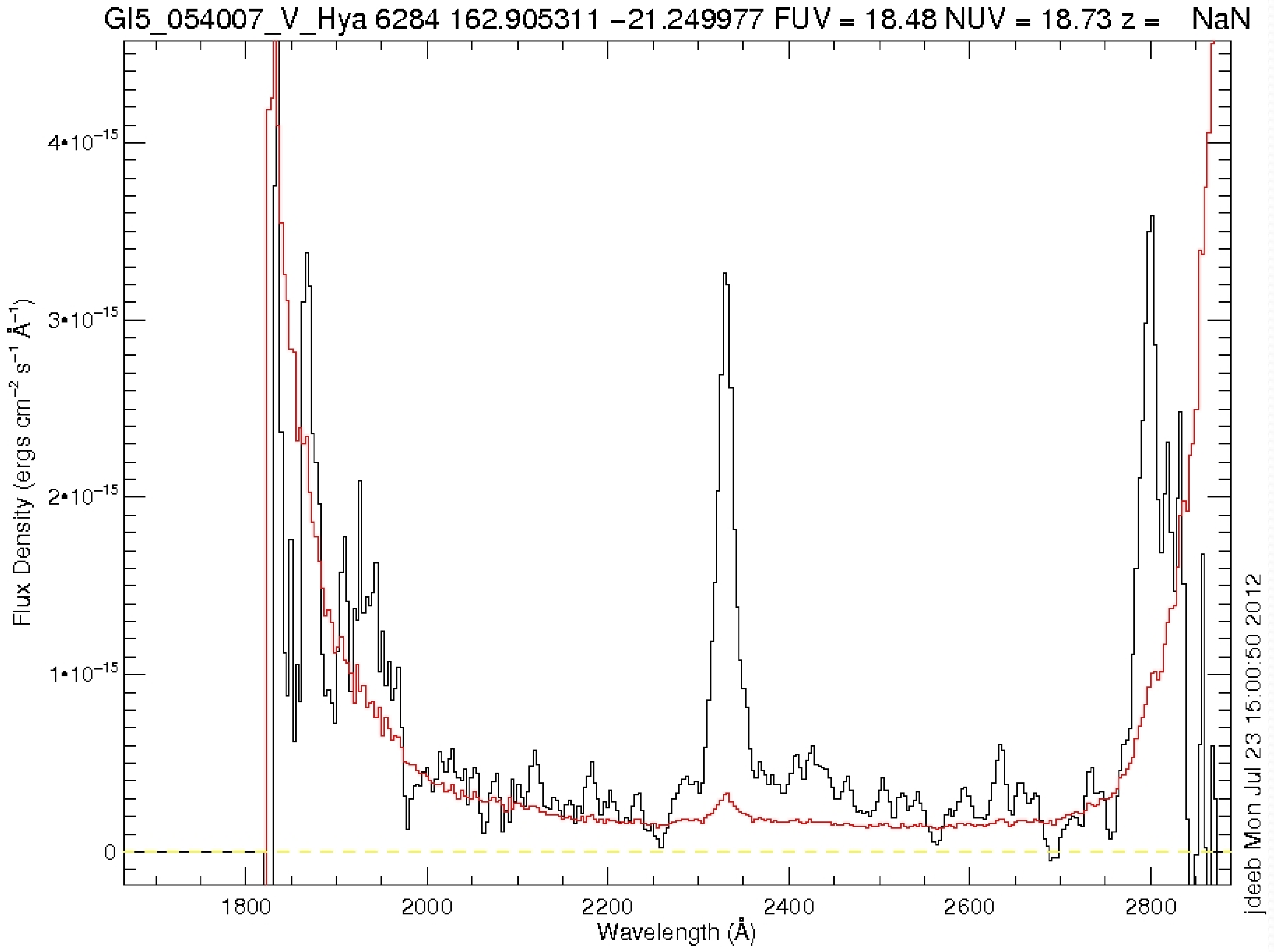
EP Aqr

Asymmetric double line profiles seen in CO lines (Kerschbaum & Oloffson 1999). C II line shows similar structure.

Common in O-rich AGBs. Suggested to be caused by a multiple shell structure with differential mass loss rates



V Hya


GI5_054007_V_Hya 6284 162.905311 −21.249977 FUV = 18.48 NUV = 18.73 z = NaN
Flux Density (ergs cm⁻² s⁻¹ Å⁻¹)
4•10⁻¹⁵
3•10⁻¹⁵
2•10⁻¹⁵
1•10⁻¹⁵
0
1800
2000
2200
2400
2600
2800
Wavelength (Å)
jdeeb Mon Jul 23 15:00:50 2012

Challenges Faced

- The low resolution certainly affected the observations and analysis
- FUV observations are only available for EY Hya as there was an instrument failure
- The emissions of variables can vary by phase, which may impact the observations and analysis (Luttermoser 2000).
- Some spectra had very odd shapes, likely due to winds (Shore 1993).

Summary

- FUV observations are critical to identifying companions. NUV features are theorized to be primarily AGB chromospheric features
(Riemers & Cassatella 1985; Judge and Jordan 1991; Johnson & Luttermoser 1987).
- EY Hya is the only object with FUV data. Due to the low resolution, the findings thus far only **weakly** suggest an accretion disk (and thus a companion) may be present
- Other researchers indicate V Hya likely has a companion (Evans 2009), but our data is inconclusive.
- Phase, line shape, and chromospheric dynamics are important to consider

Next Steps

- A proposal is being written to obtain FUV via the Cosmic Origins Spectrograph (COS) on board the Hubble Space Telescope. The lowest resolution still exceeds the resolution of GALEX.
- Additional NUV observations may be made as well due to the resolution challenges faced
- X-ray observations may also be considered down the road.

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References

- Abia, C. & Isern, J., 1997, MNRAS, 289, L11.
- Blanco et al., 1982, A&A, 115, 280.
- Böhm-Vitense, E., 1982, ApJ, 258, 628.
- Carpenter et al. 1997, ApJ, 486, 457.
- Dušek, J., Mikulášek, Z. & Papoušek, J., 2003, Contrib. Astron. Obs. Skalnaté Pleso, 33, 119.
- Evans, T.L., 2009, AIP Conf. Proc., 1094, 964.
- Groenewegen, M.A.T., van den Hoek, L.B., de Jong, T., 1995, A&A, 293, 381
- Judge, P.G. & Jordan, C., 1991 ApJ, 77, 75.
- Johnson, H.R. & Luttermoser, D.G., 1987, ApJ, 314, 329.
- Kenyon et. Al, 1991, ApJ, 101, 637.
- Kerschbaum, F. & Hron, J. 1994, A&A, 106, 397.
- Kerschbaum, F. & Oloffson, H. 1999, A&A, 138, 299.
- Knapp et al., 1999, A&A, 351, 97.
- Luttermoser, D.G. 2000, ApJ, 536, 923.
- Luttermoser, D.G. & Mahar, S. 1998, ASPC, 154, 1613.
- Morrissey et al., 2007, ApJ, 173, 682.
- Munari, U. & Buson, L.M., 1994, A&A, 287, 87.
- Nakashima, J., 2005, ApJ, draft.
- Nakashima, J., 2006, IAU, 234.
- Olivier, E.A. & Wood, P.R. 2003, ApJ, 584, 1035.
- Percy, J.R., Wilson, J.B., Hengy, G.W., 2001, ASP, 113, 983.
- Ramstedt et al., 2012, A&A, 543, A147.
- Riemers, D. & Cassatella, A. 1985, ApJ, 297, 275.
- Sanad et al., 2009, ApJ, 137:3479.
- Sahai, R. 2012, GALEX proposal #54.
- Sahai, R. et al., 2008, ApJ, 689, 1274.
- Shore, S.N. & Aufdenberg, J.P. 1993, ApJ, 416, 355.
- Stencel, R.E., 1982, 392, 137.
- Wallerstein et al.., 2011, A&A, 535, A101
- Wood & Karovska, 2000, ApJ, 535, 304.