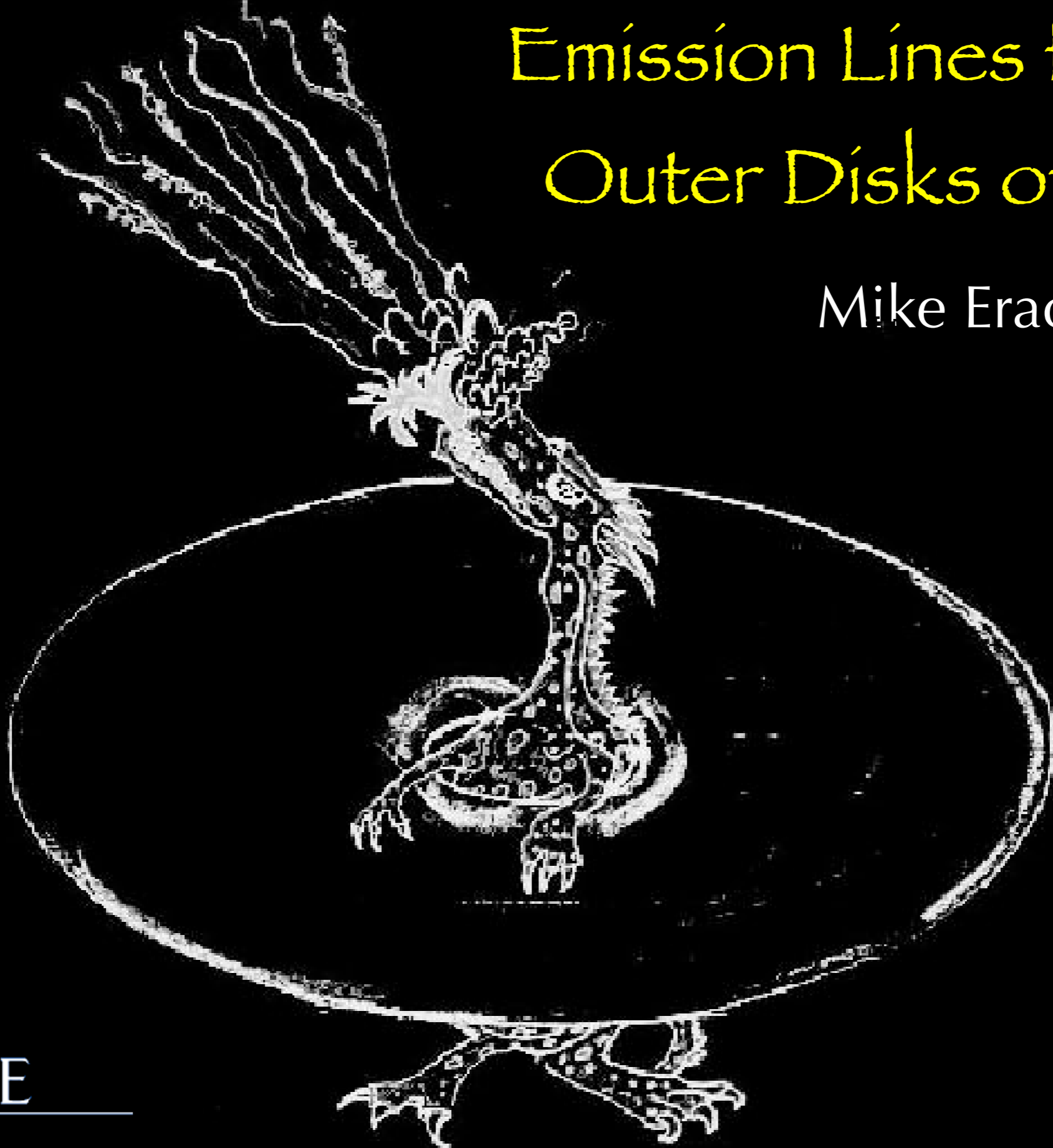


# Emission Lines from the Outer Disks of AGNs

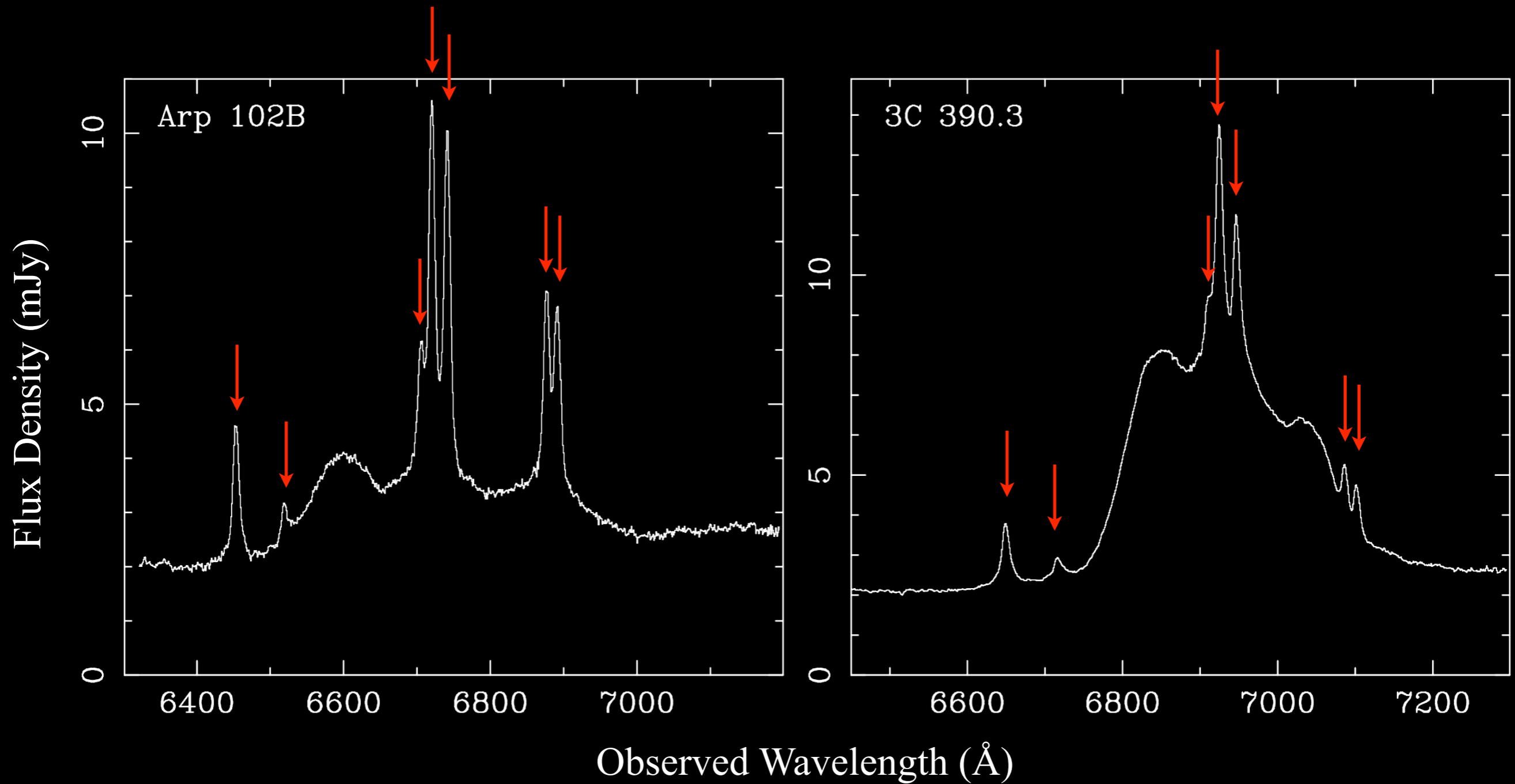
Mike Eracleous

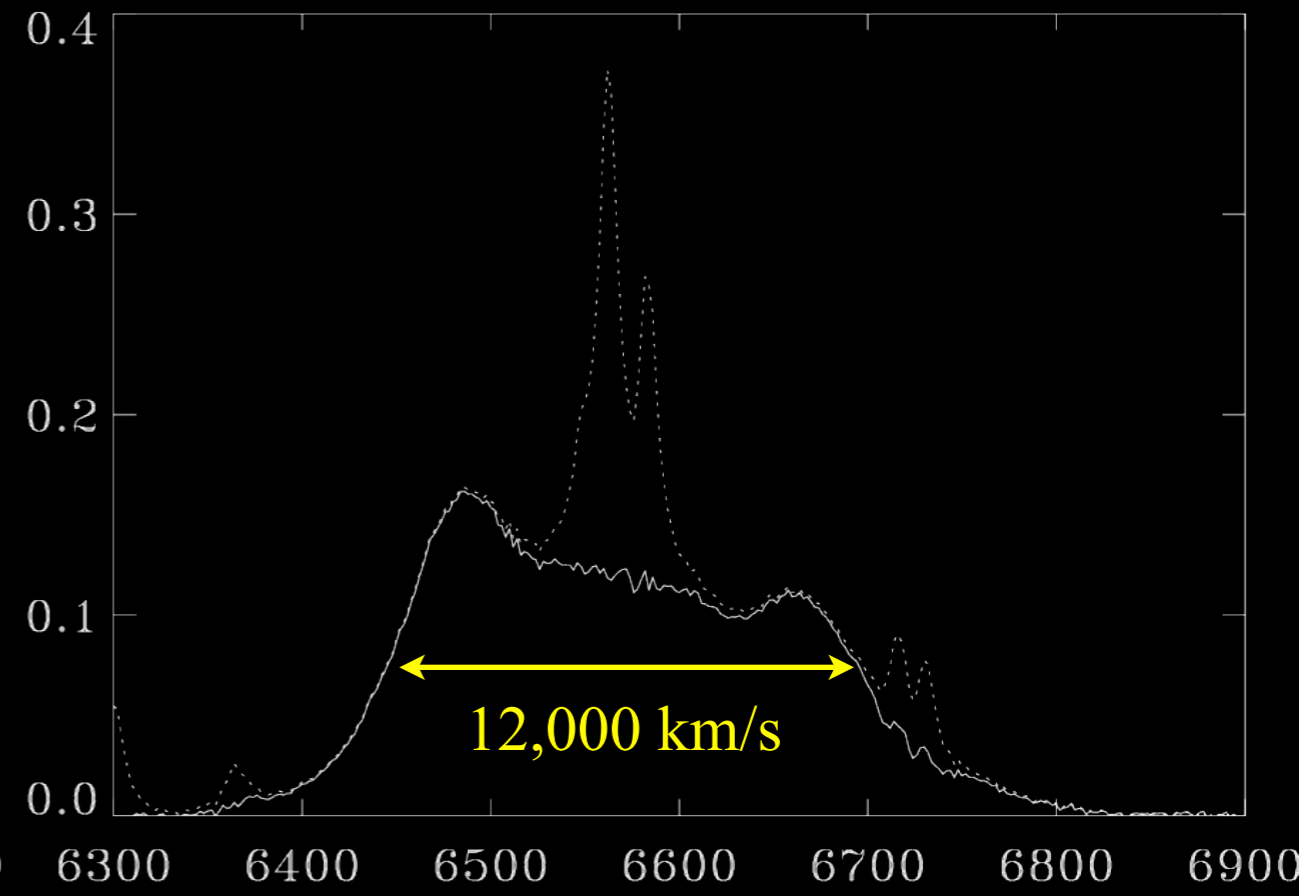
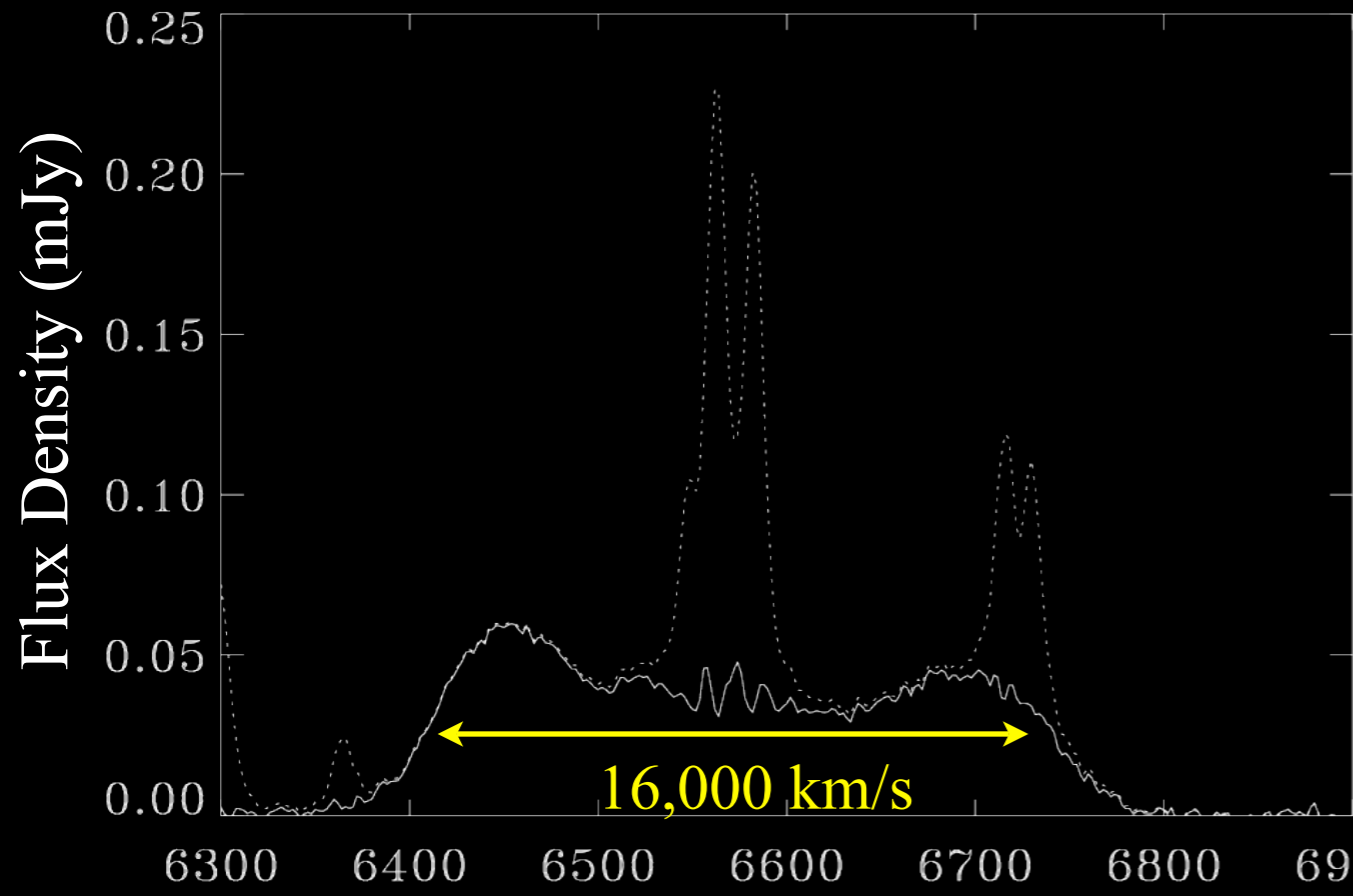


PENNSSTATE



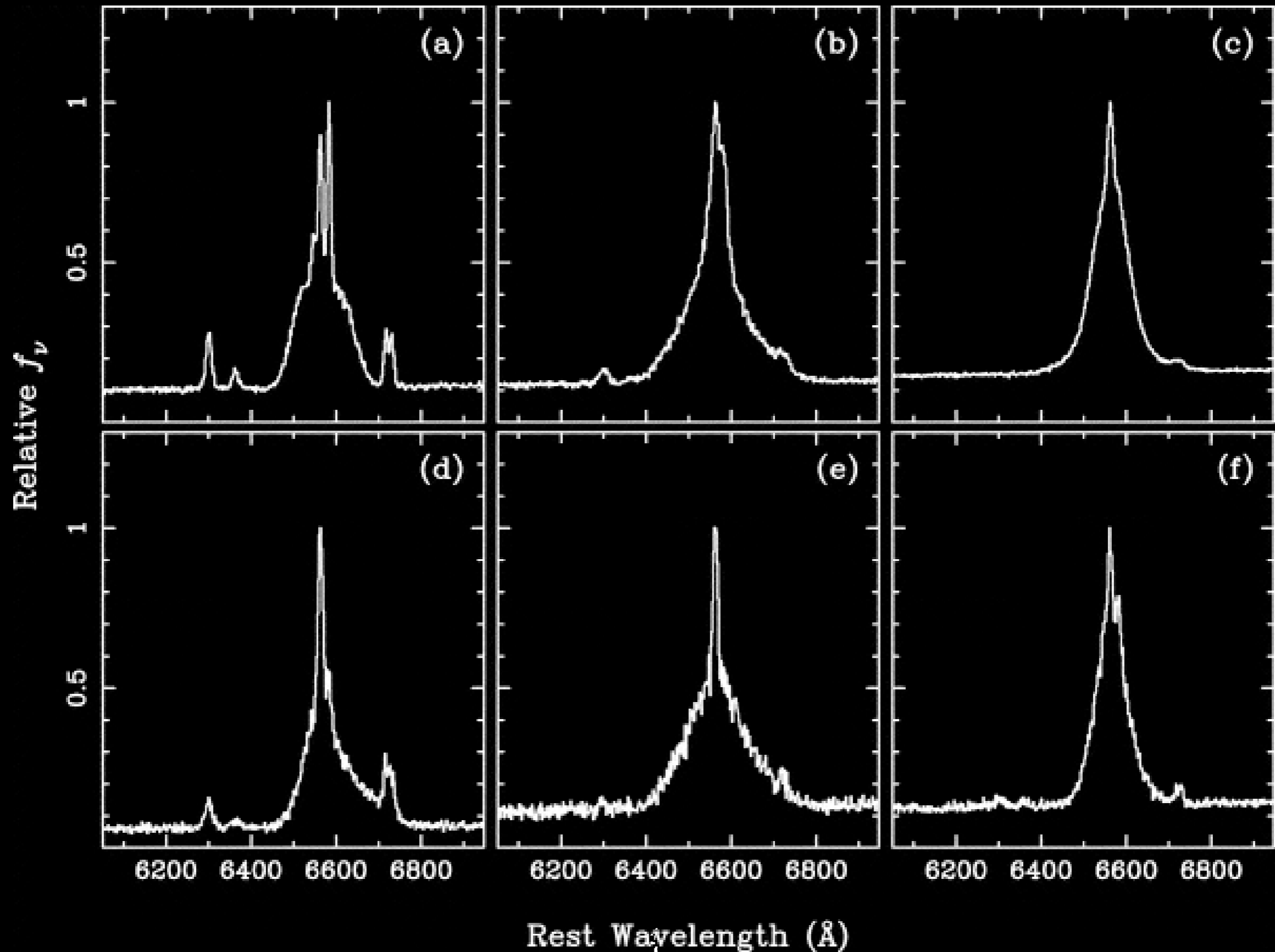
# Examples of H $\alpha$ Emission-Line Profiles



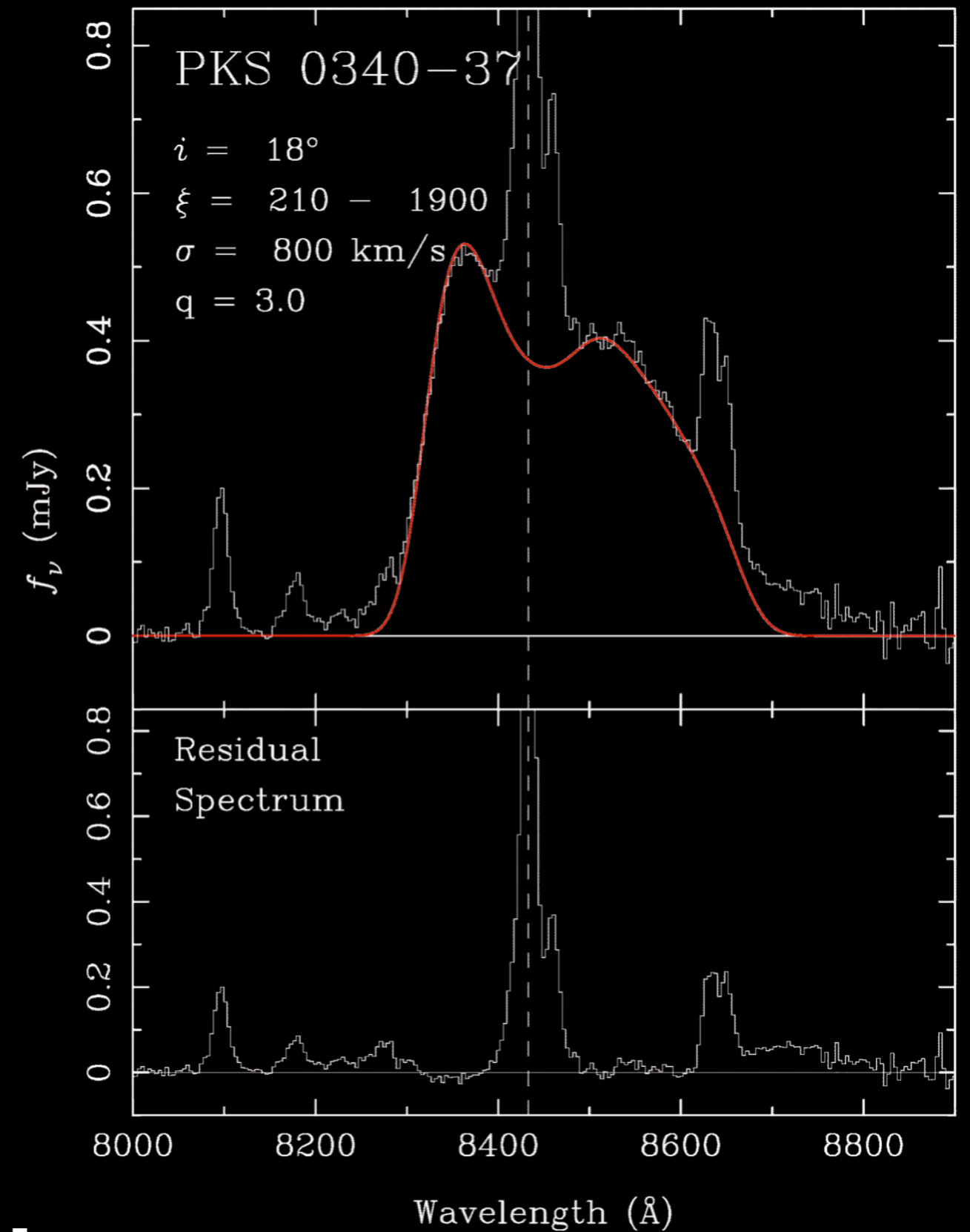
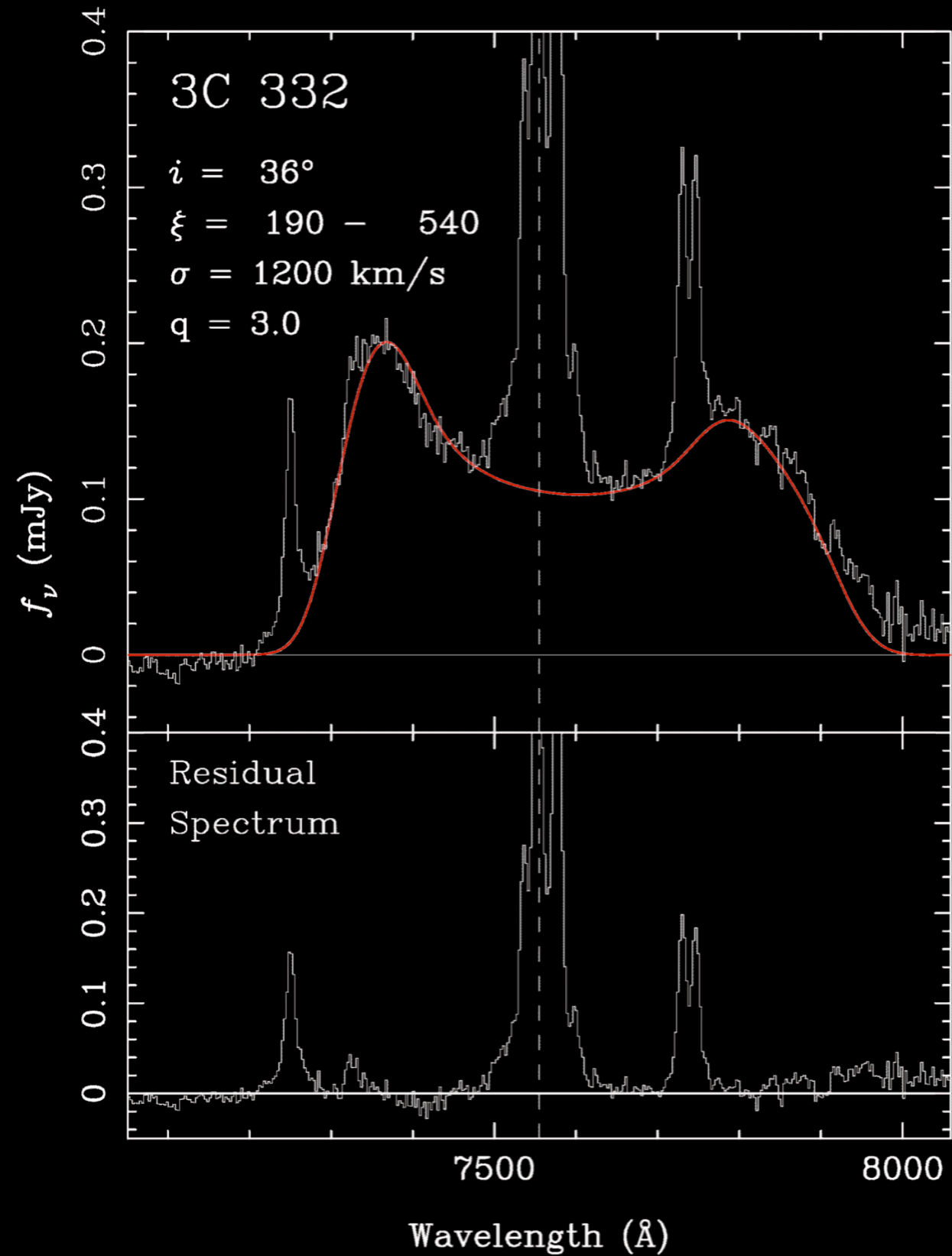


Observed Wavelength (Å)

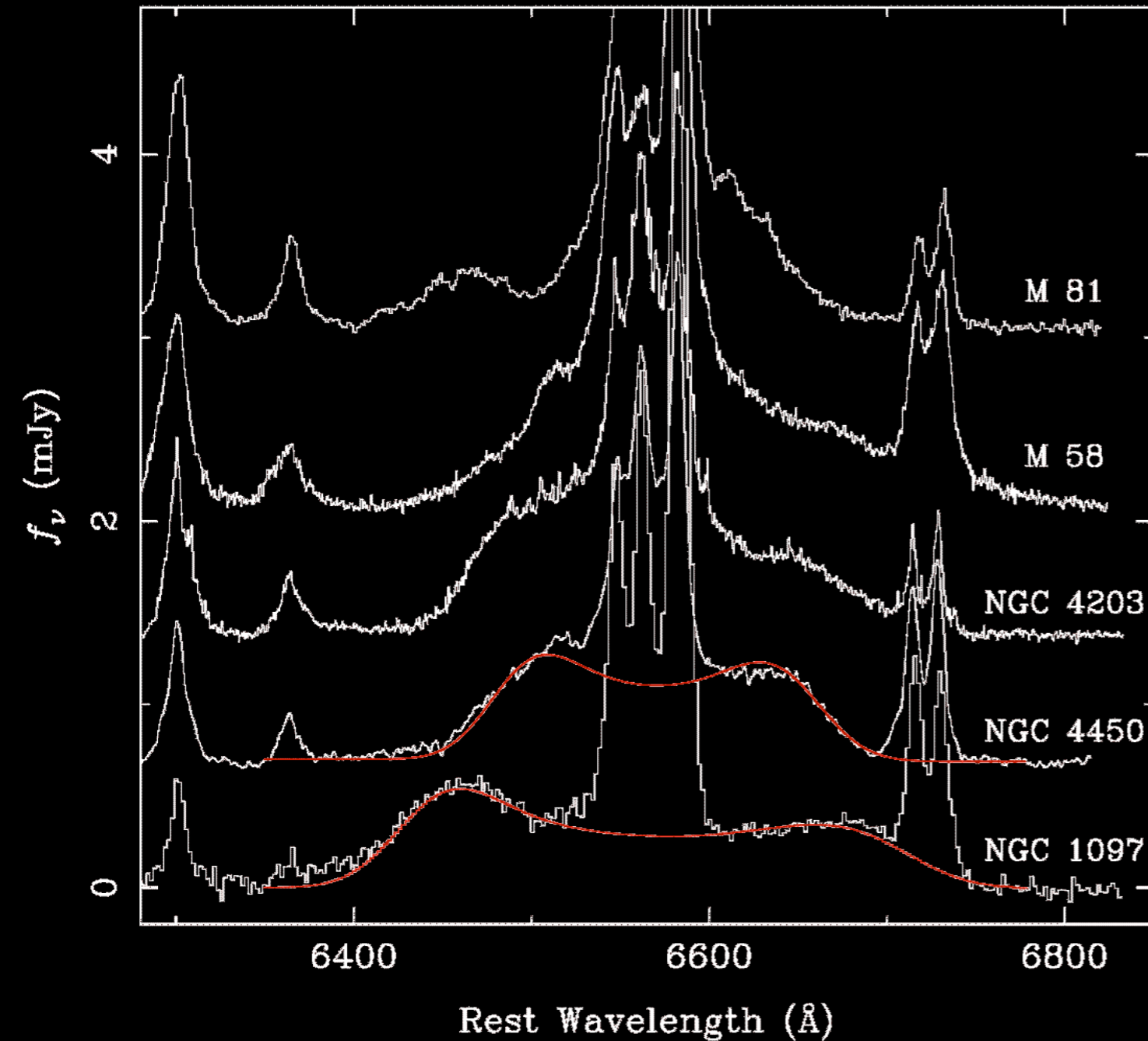
# cf, Typical AGN H $\alpha$ Profiles



# Circular Disk Model Fits

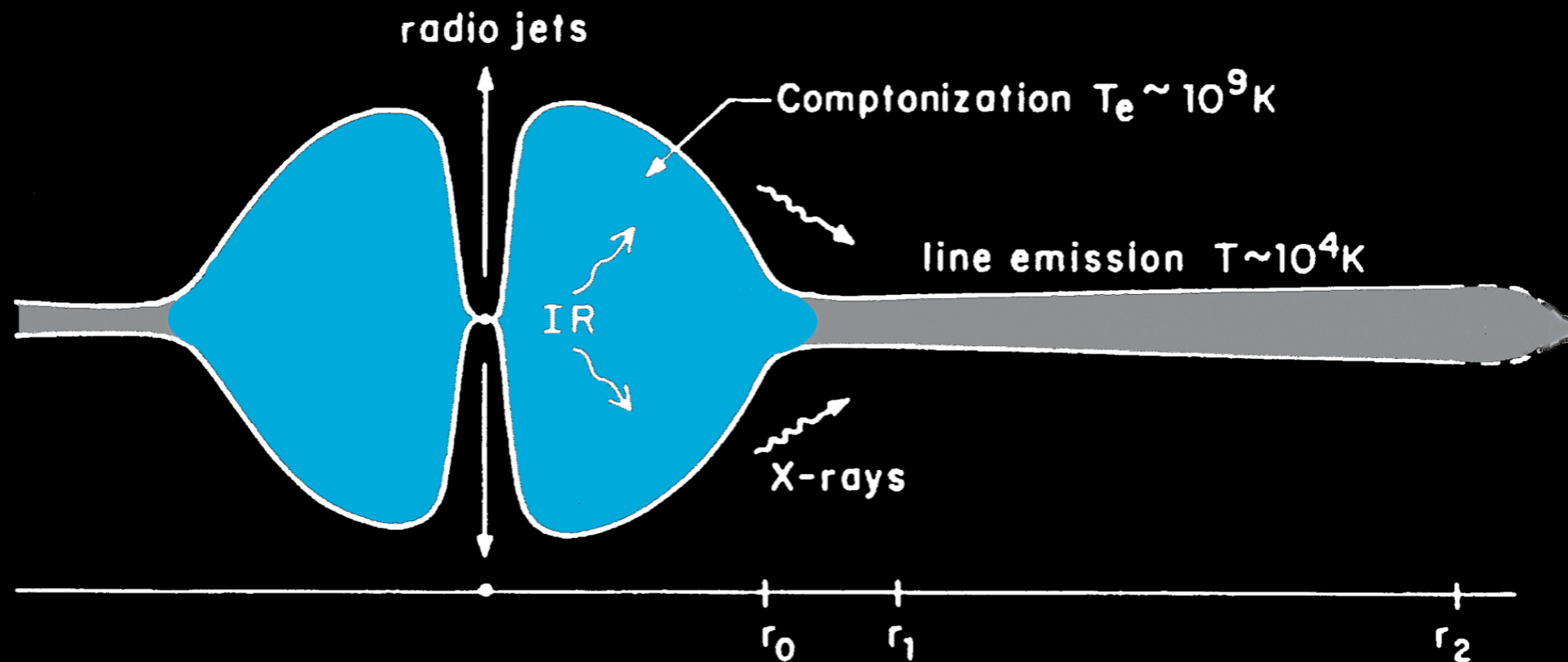


# Demography of Double-Peaked Lines



- \* Originally found in 25% of radio-loud AGNs (Eracleous & Halpern 1994, 2003)
- \* Later found in several LINERs (many authors), but true census uncertain.
- \* Recently found in 4% of ALL AGNs at  $z < 0.33$  in SDSS (Strateva et al. 2003).

- \* Energy budget and variability suggest that double-peaked emission lines are powered by “external” illumination.
- \* Vertically extended structure in inner disk provides a plausible source.



from Chen & Halpern (1989)

# Issues Worth Worrying about

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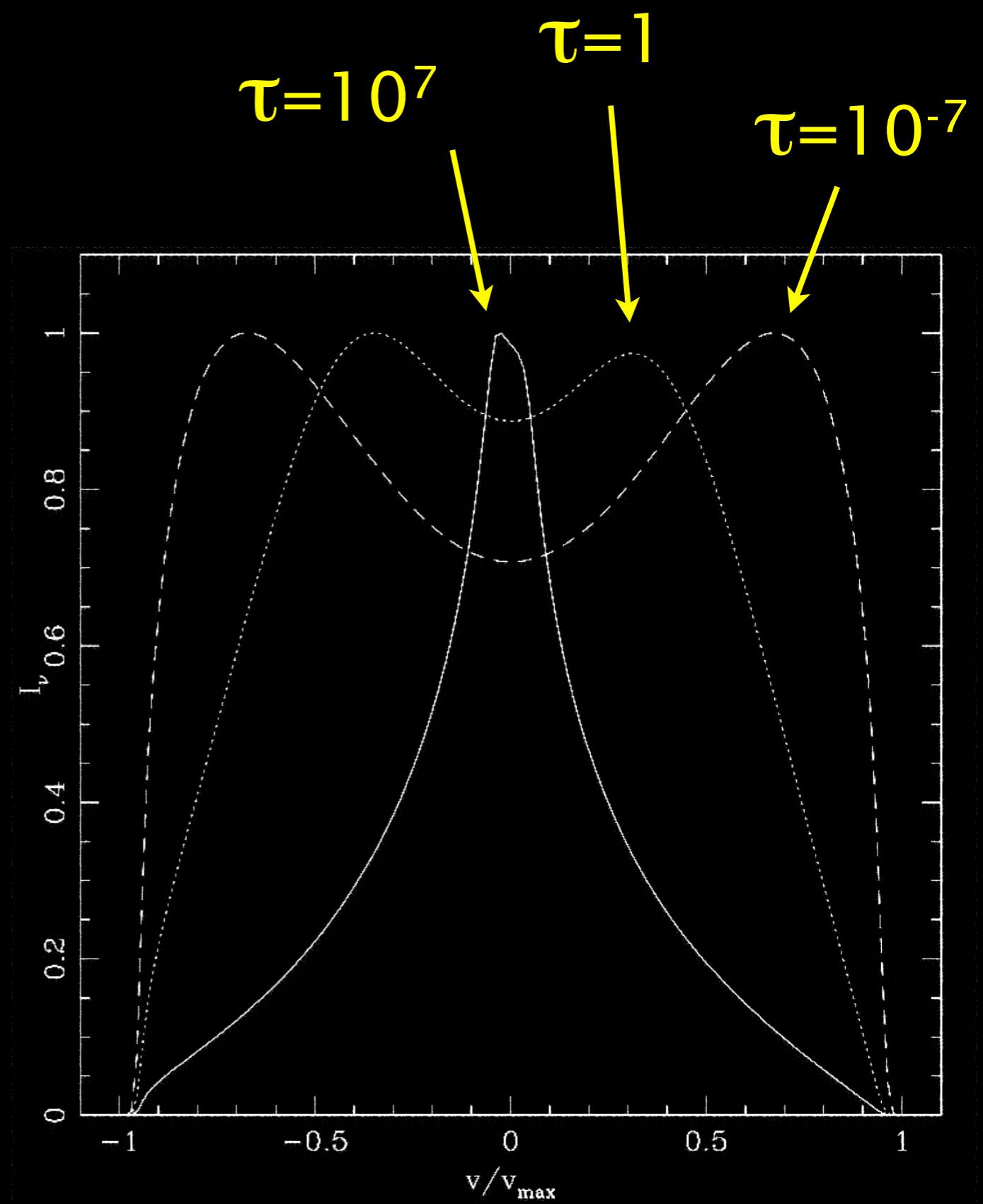
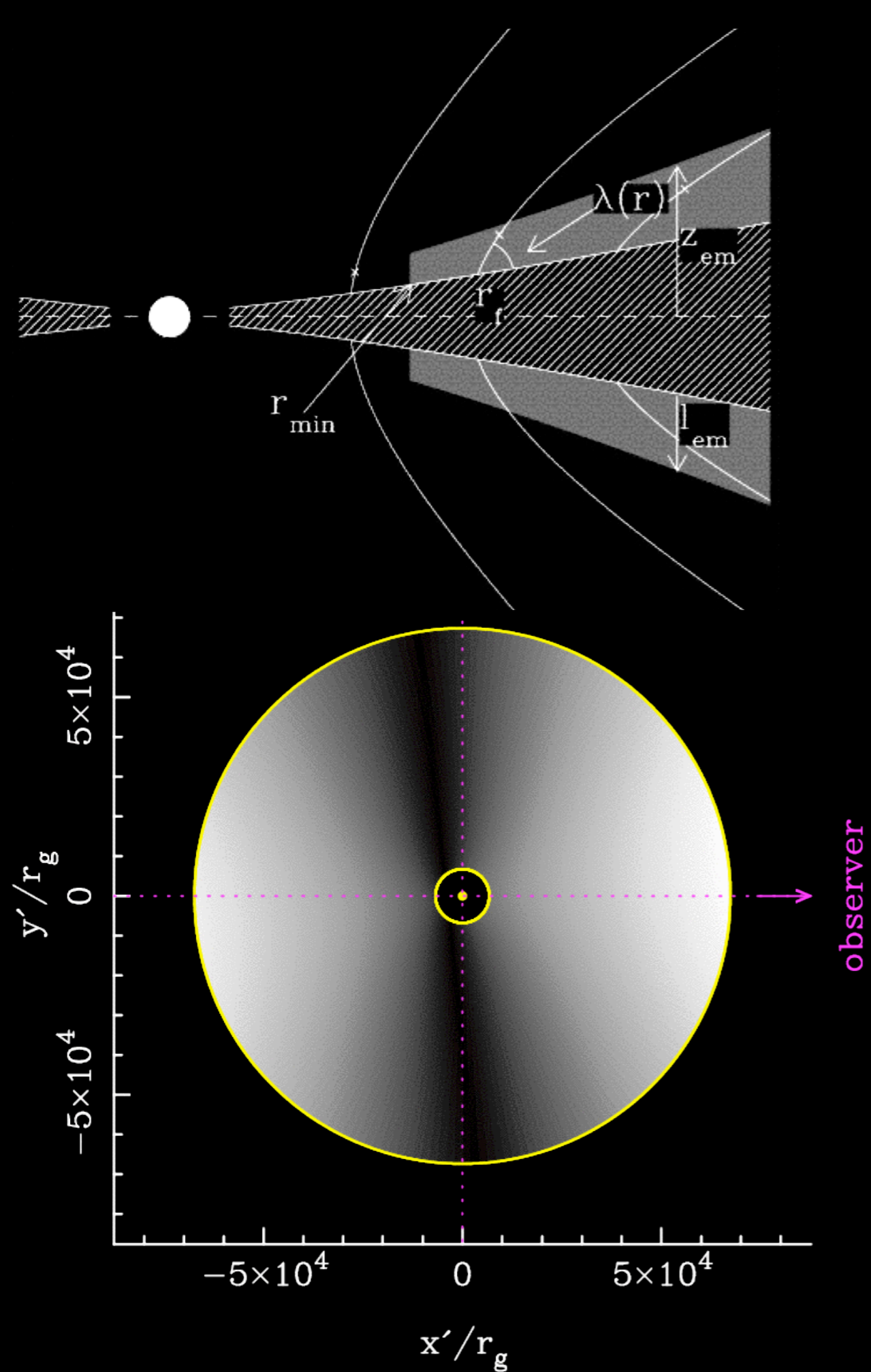
- \* Do double-peaked lines really give us a view of the accretion disk?

YES. See ~15 years of history

- \* If all AGNs have accretion disks, why only a small minority of them emit optical emission lines?

Hmmm... ~40 years of history of AGN broad-line regions





from Murray & Chiang (1997)

# Possible Variability Time Scales

Light-Crossing:  $6 M_8 \xi_3$  days

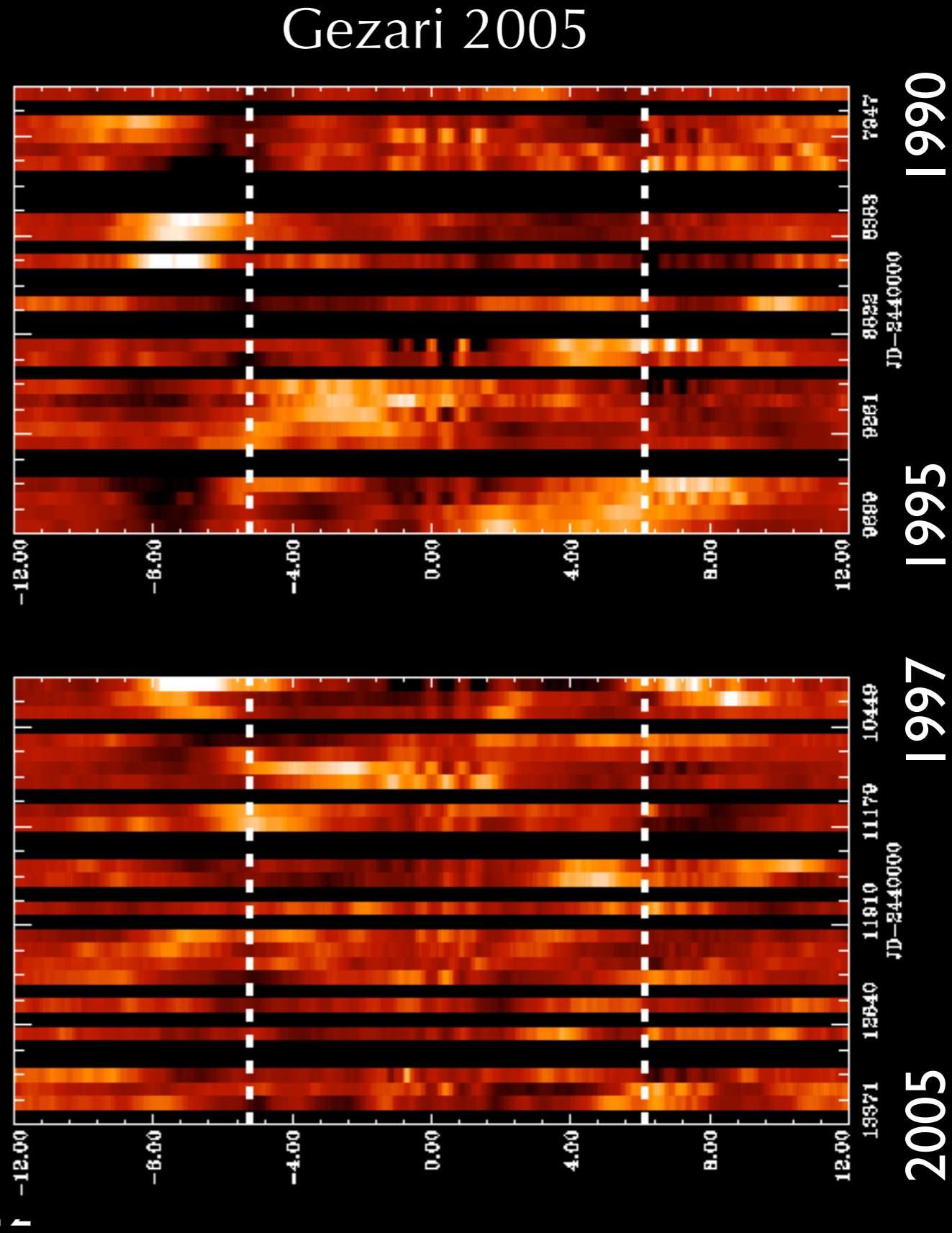
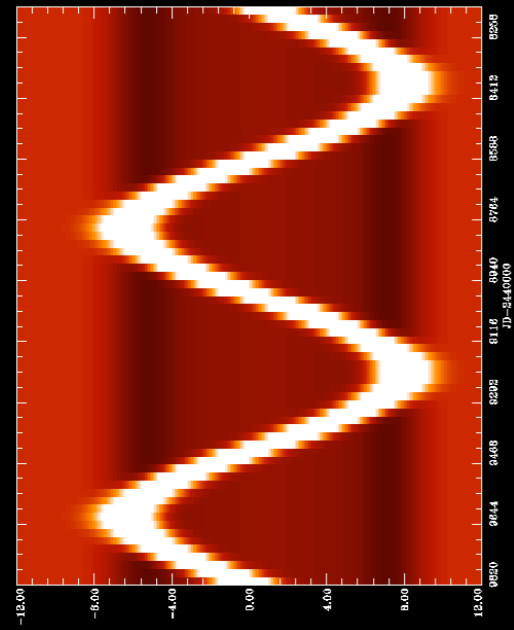
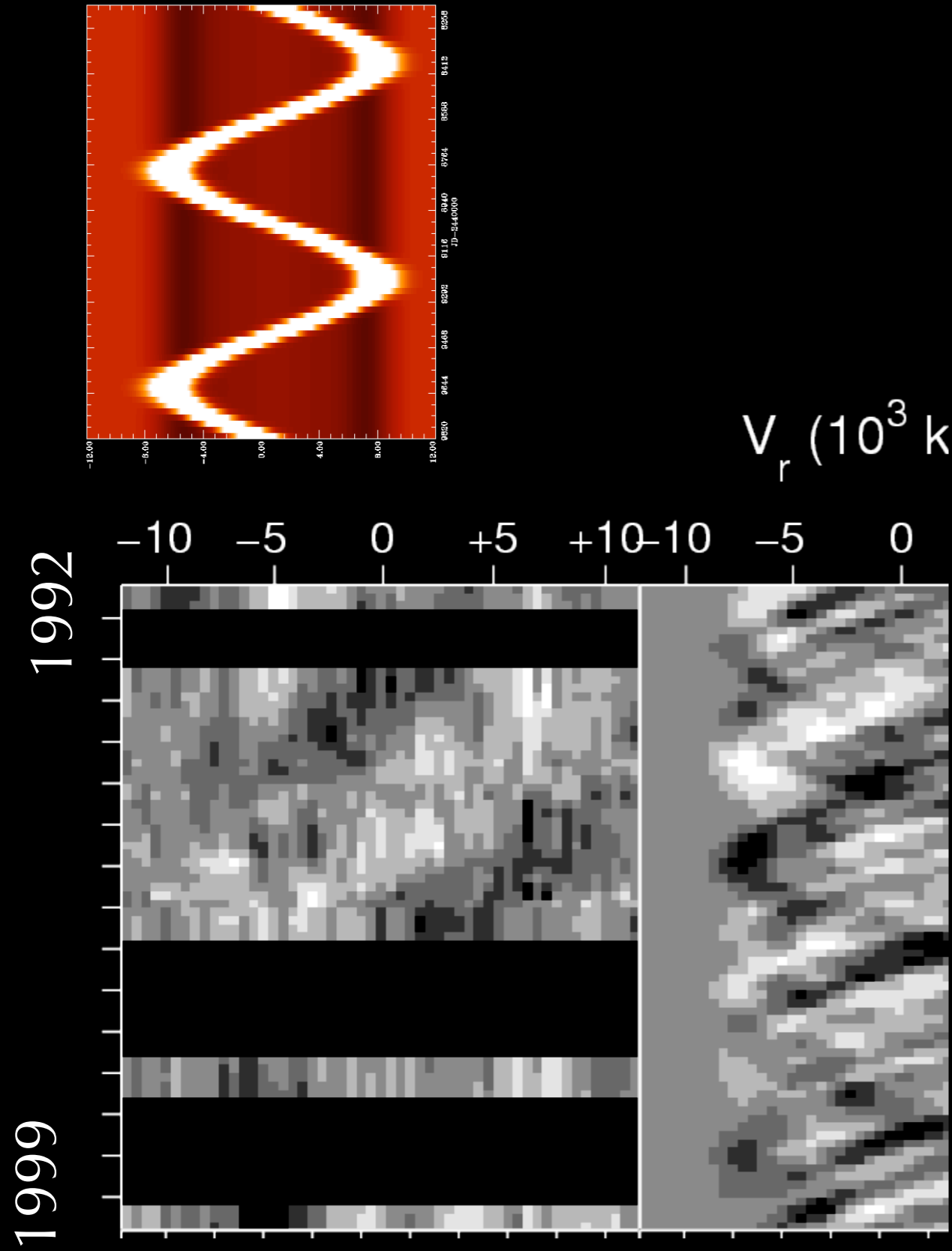
Dynamical:  $6 M_8 \xi_3^{3/2}$  months

Thermal:  $5 \alpha_{-1}^{-1} M_8 \xi_3^{3/2}$  years

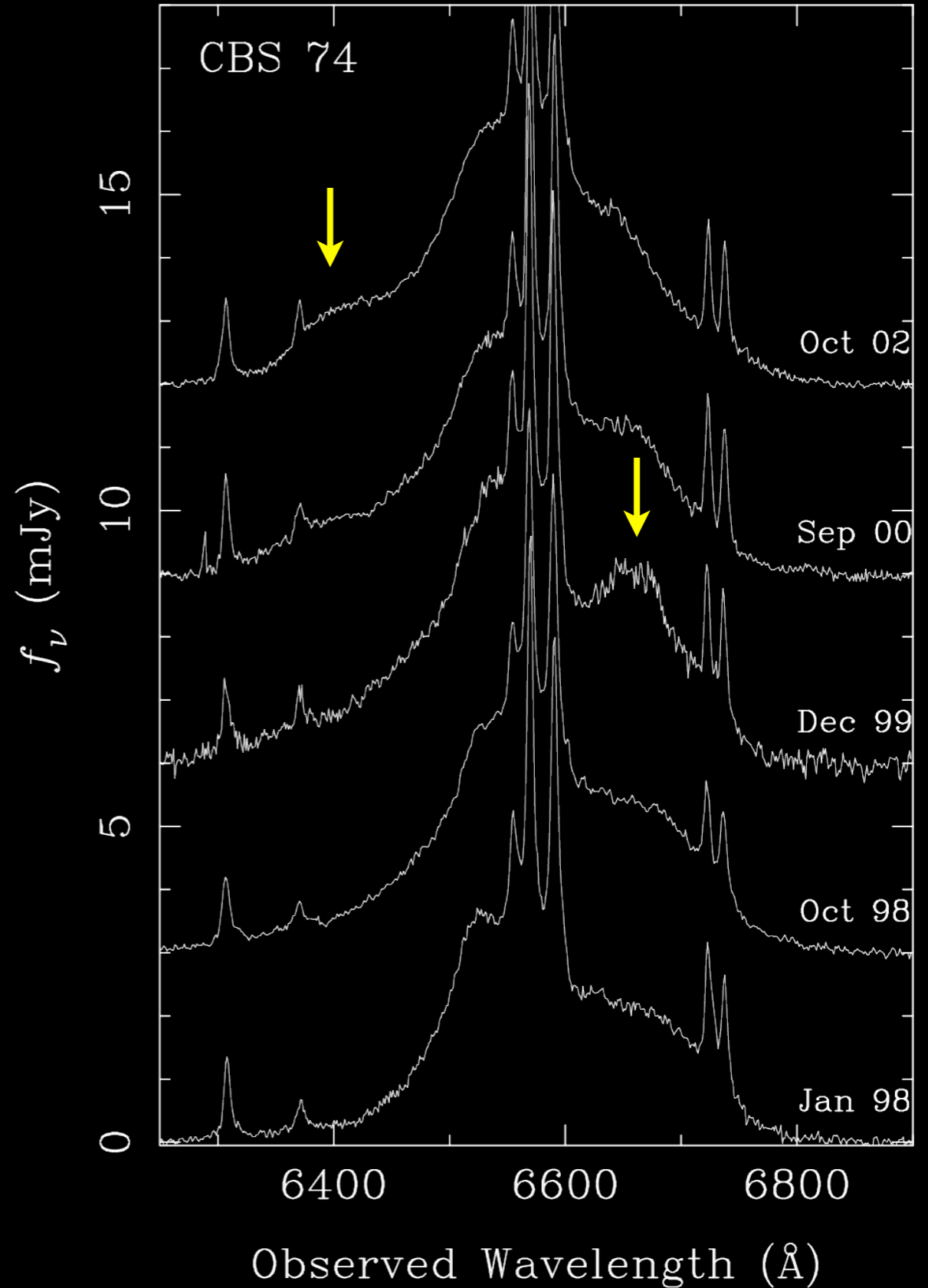
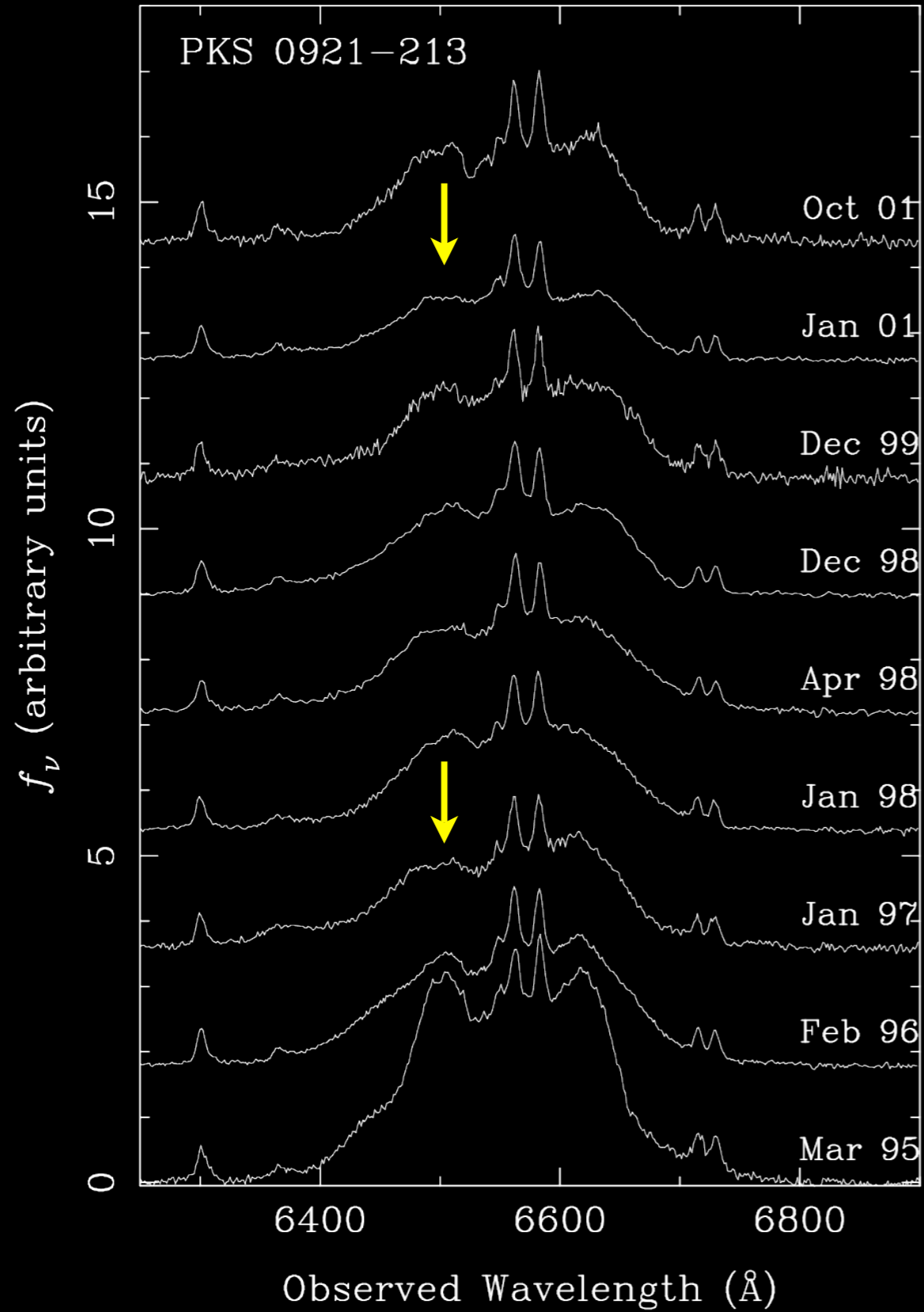
Sound-Crossing:  $70 M_8 \xi_3 T_5^{-1/2}$  years

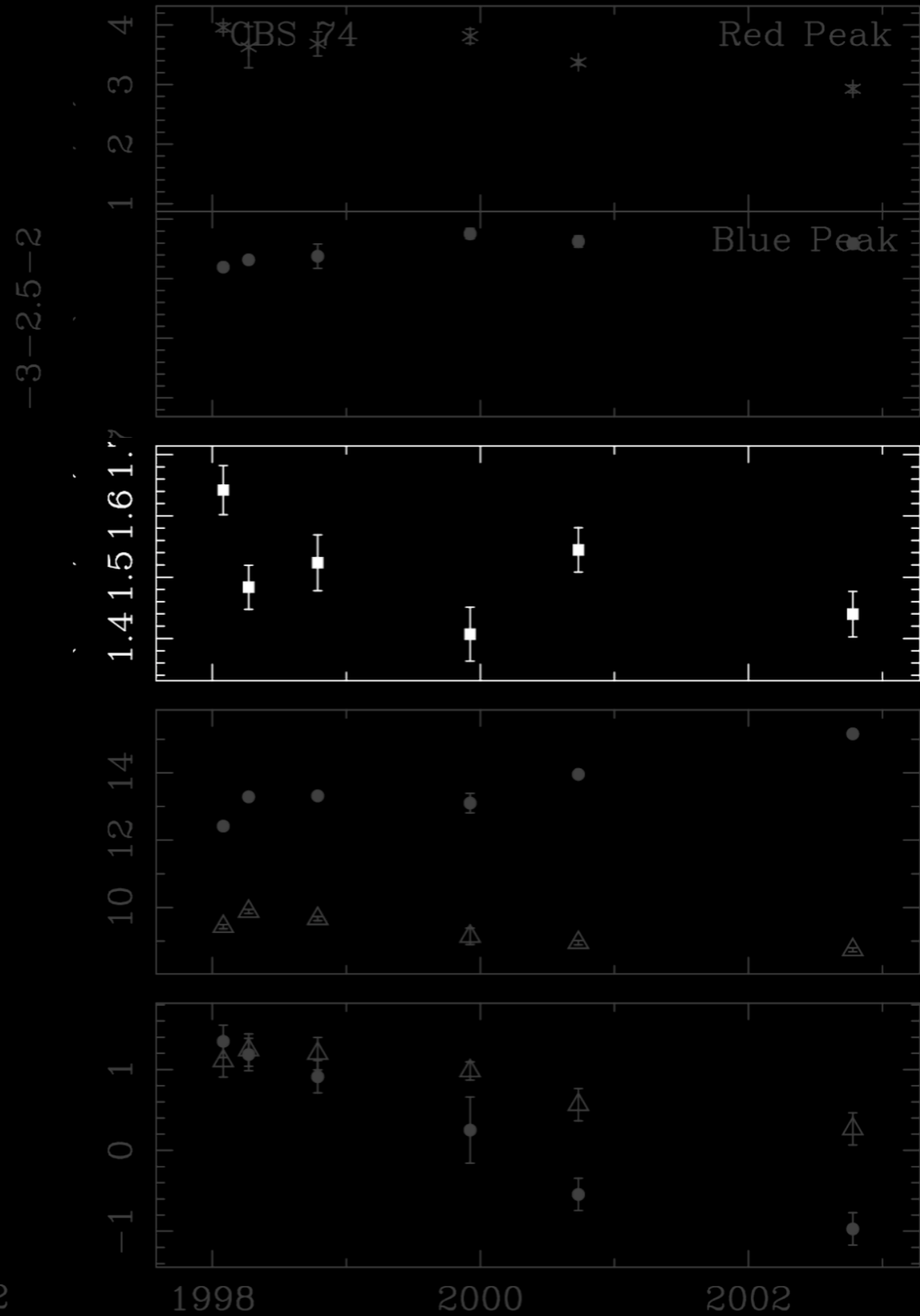
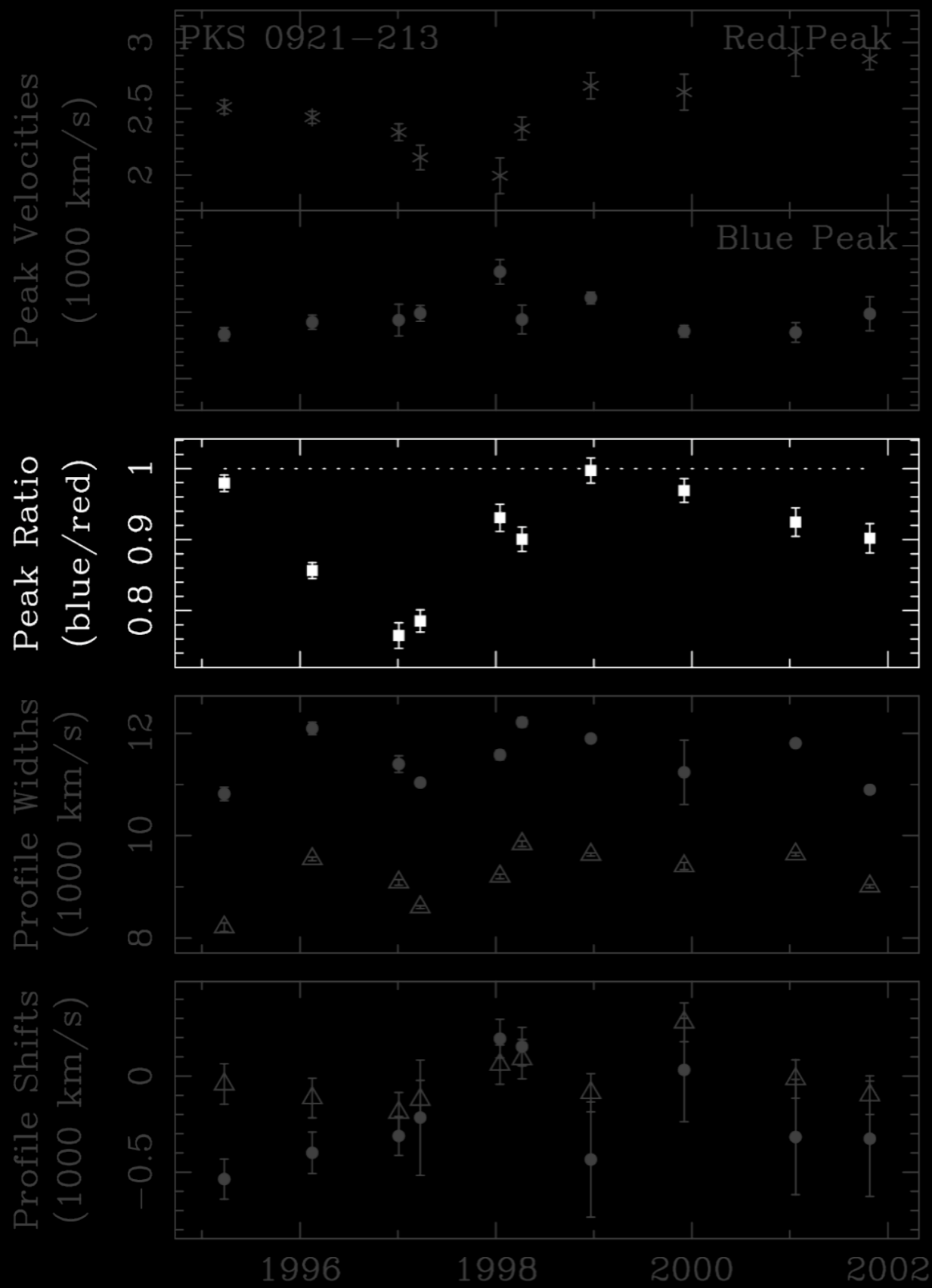
Viscous:  $10^6 \alpha_{-1}^{-4/5} M_8^{3/2} \xi_3^{5/4} m_{-1}^{-3/10}$  years

# "Fragmented" Disk in Arp 102B



# Obvious Variability Patterns

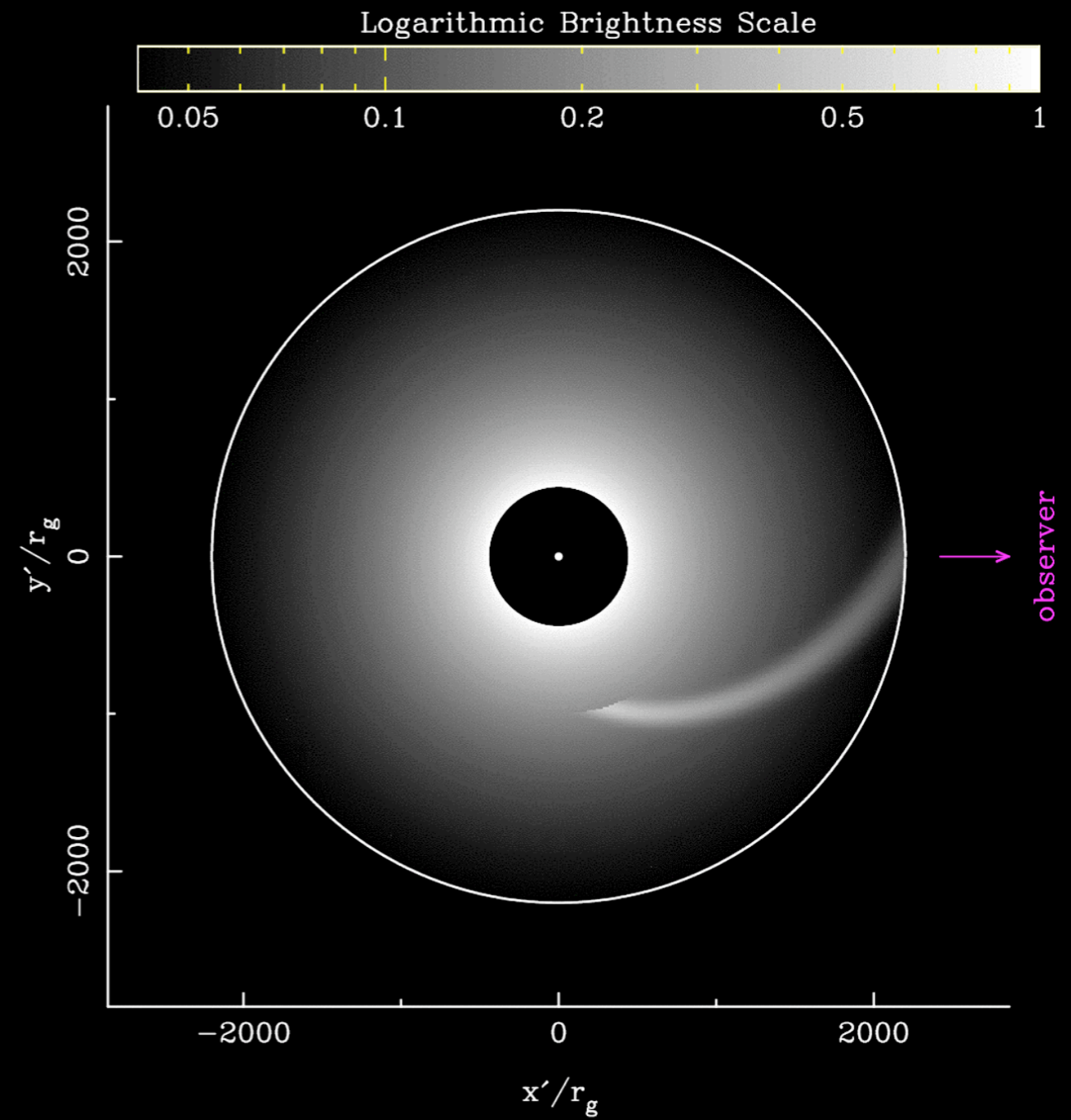
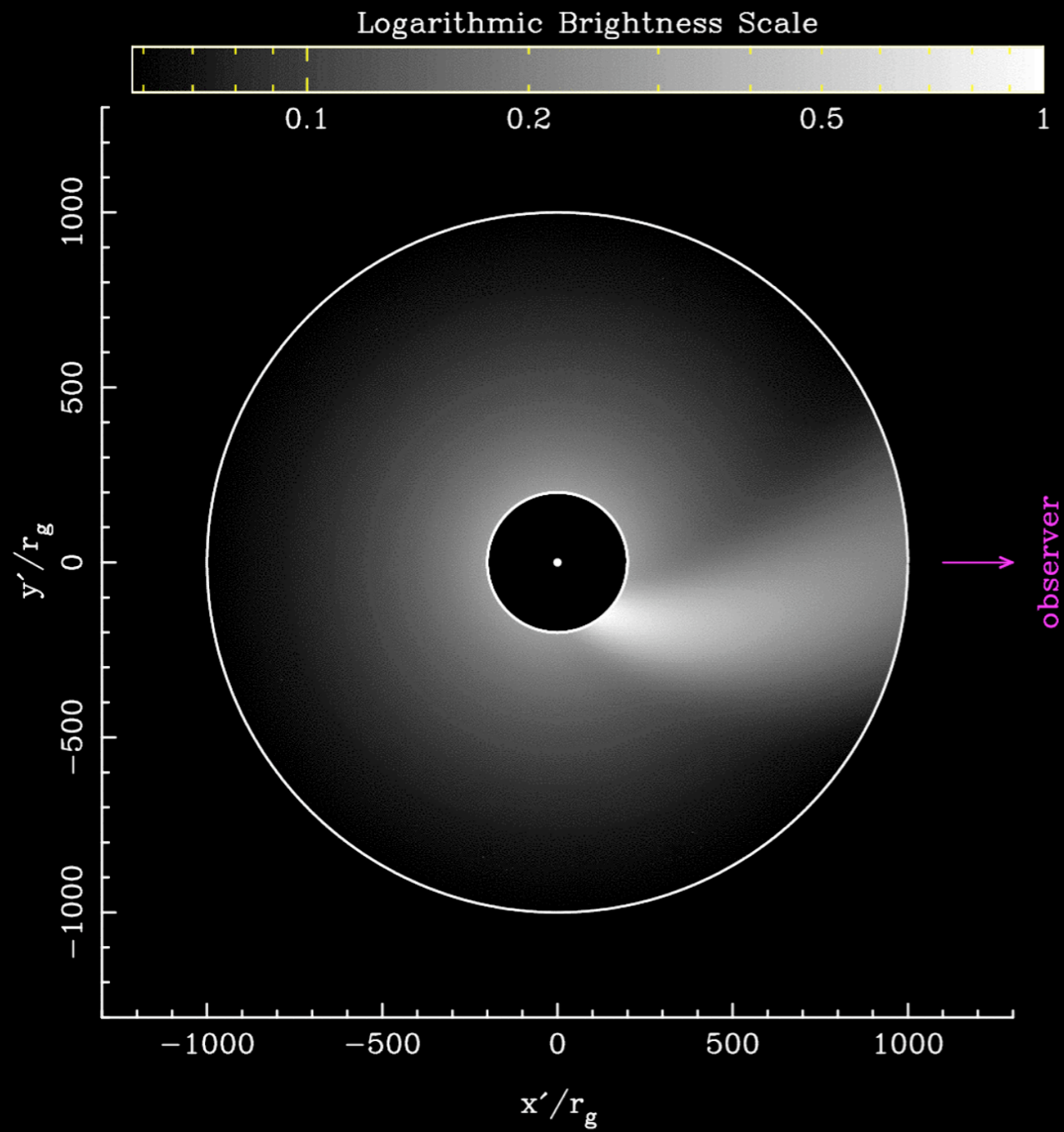




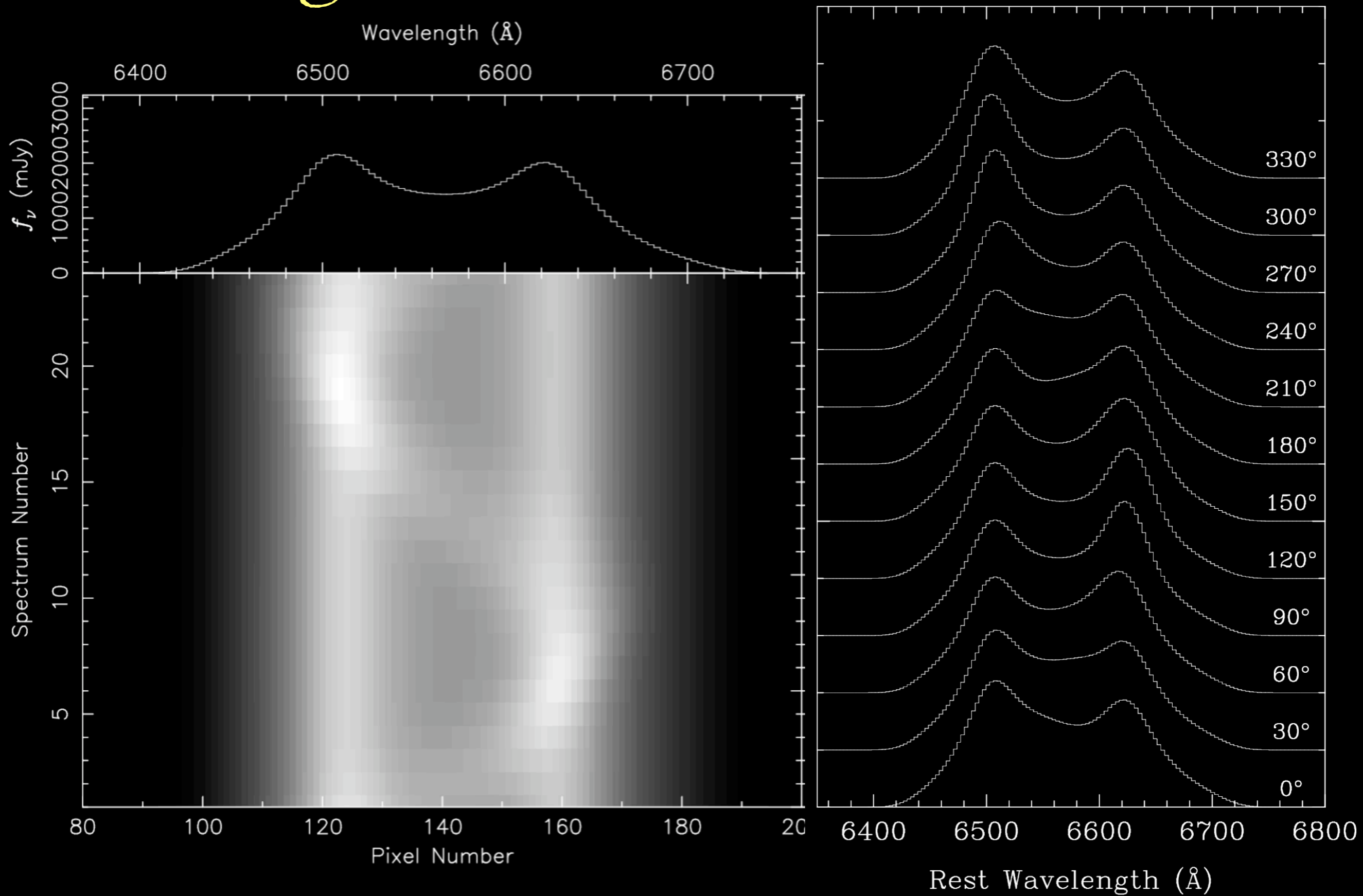
# Parametric Models We've Thought of Trying

- \* Eccentric Disk
- \* Orbiting Bright Spot
- \* Disk with  $m=1$  spiral
- \* Warped Disk
- \* Gravitational Microlensing

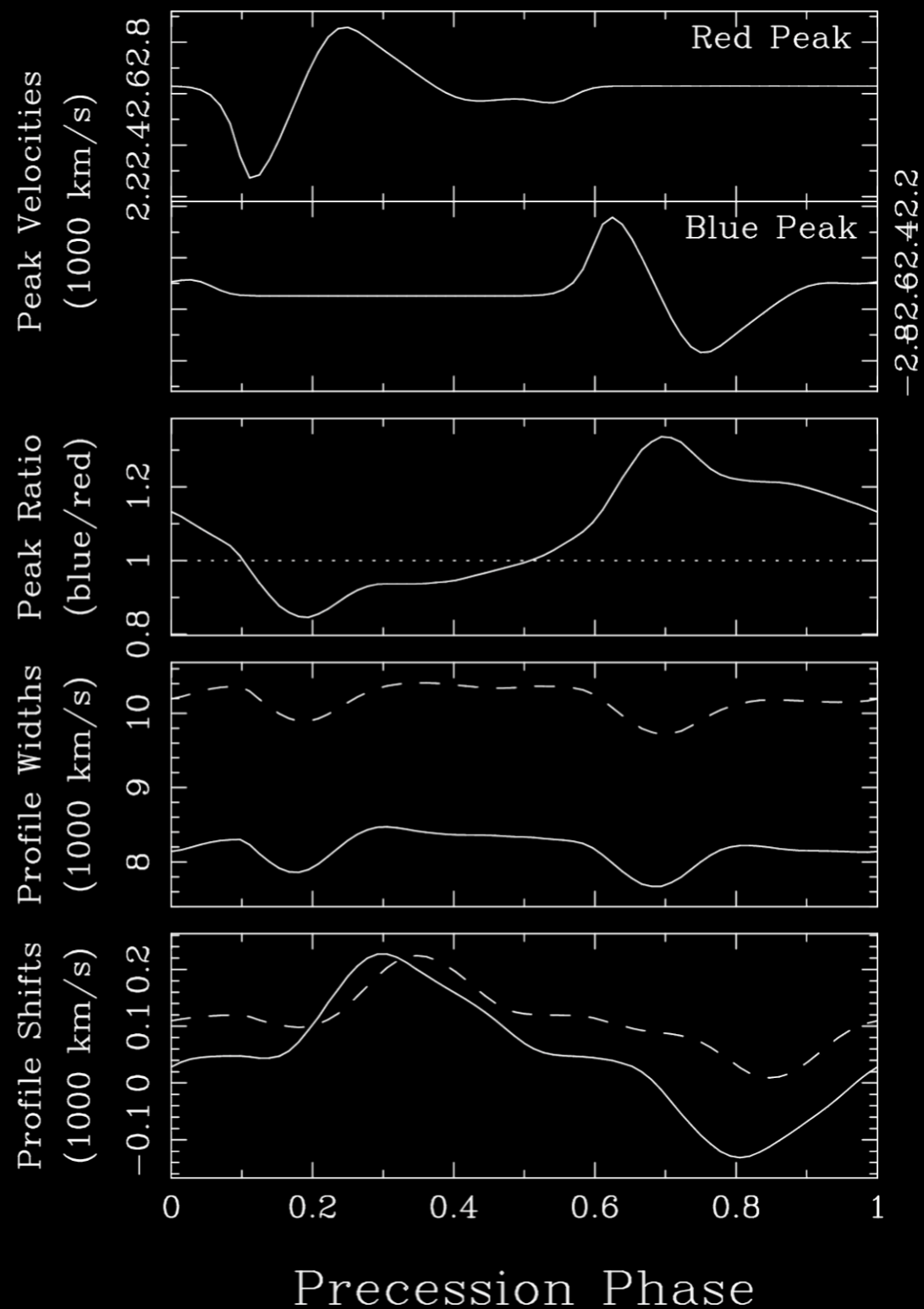
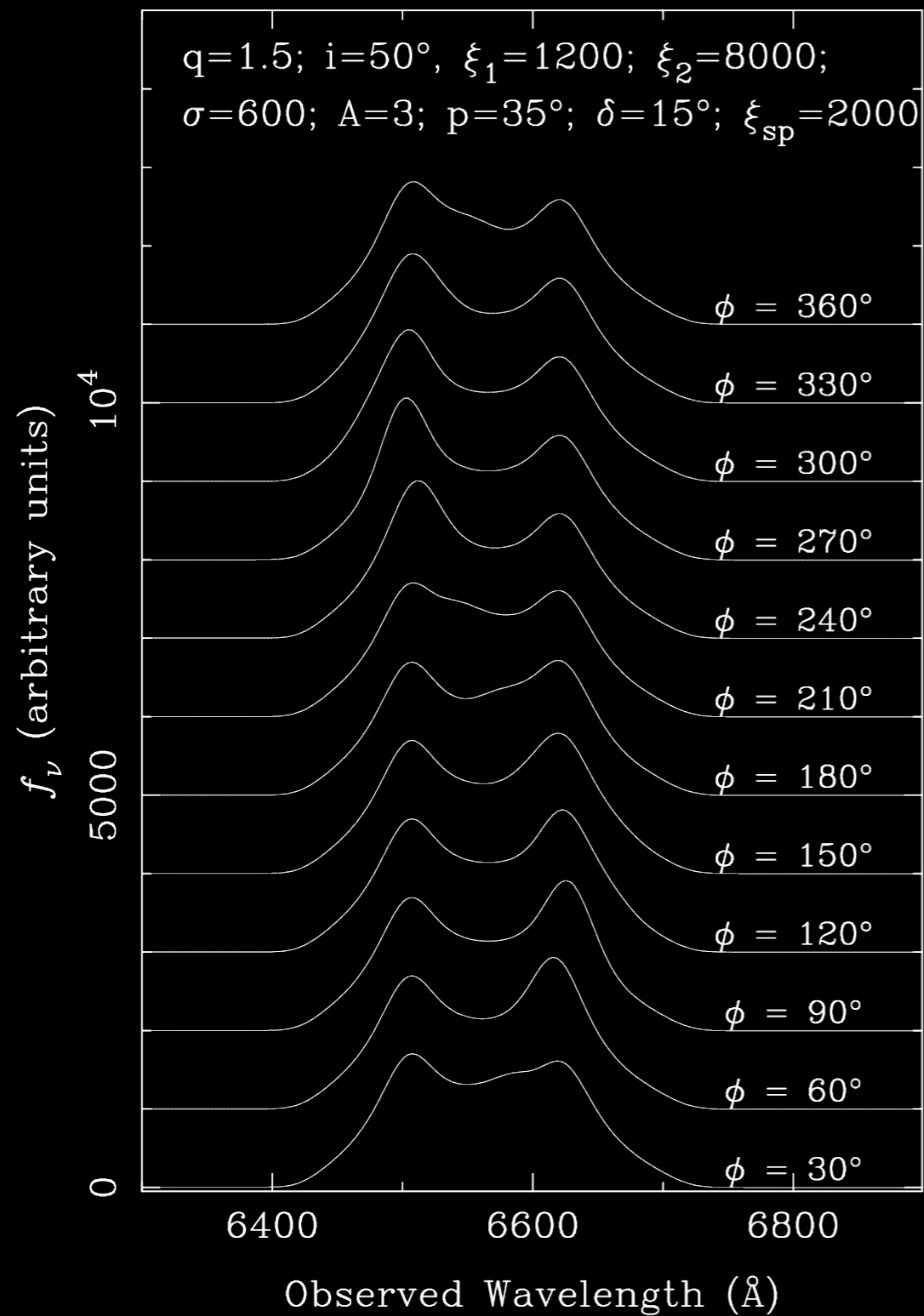
# Example Spiral Patterns



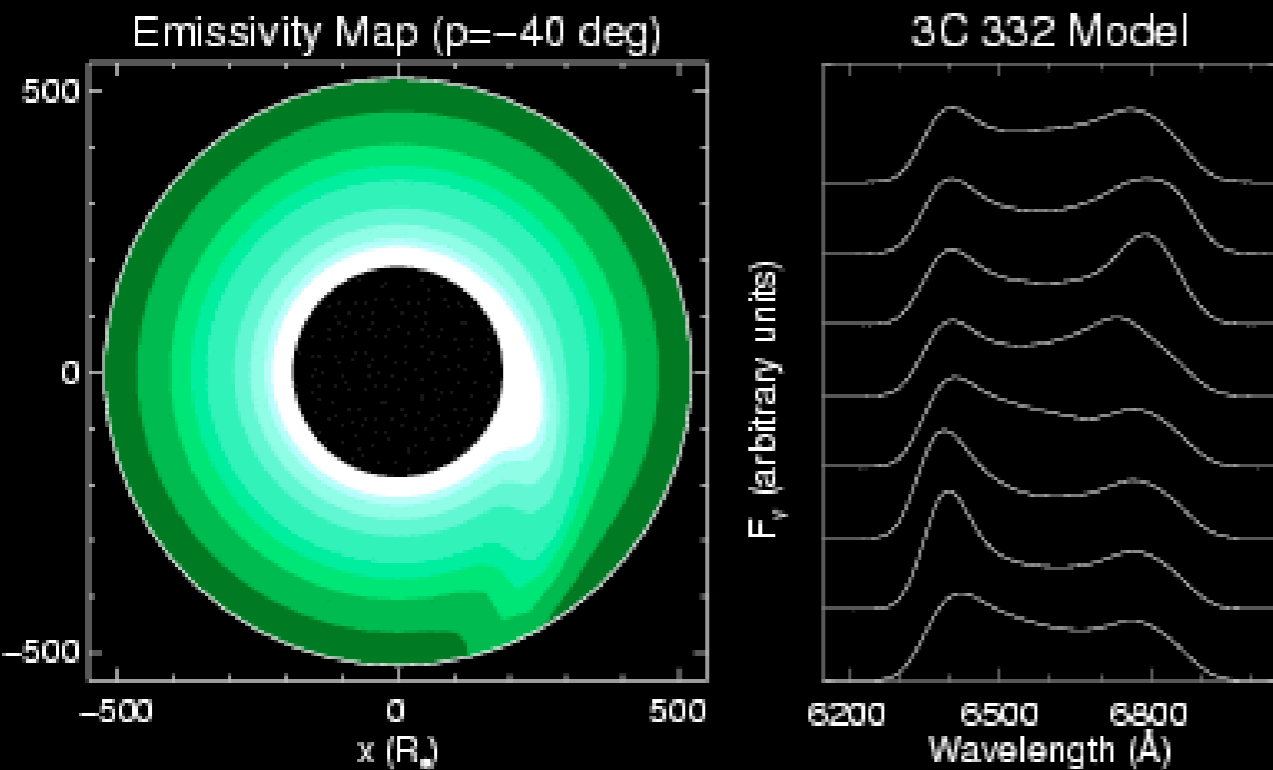
# Resulting Line Profiles



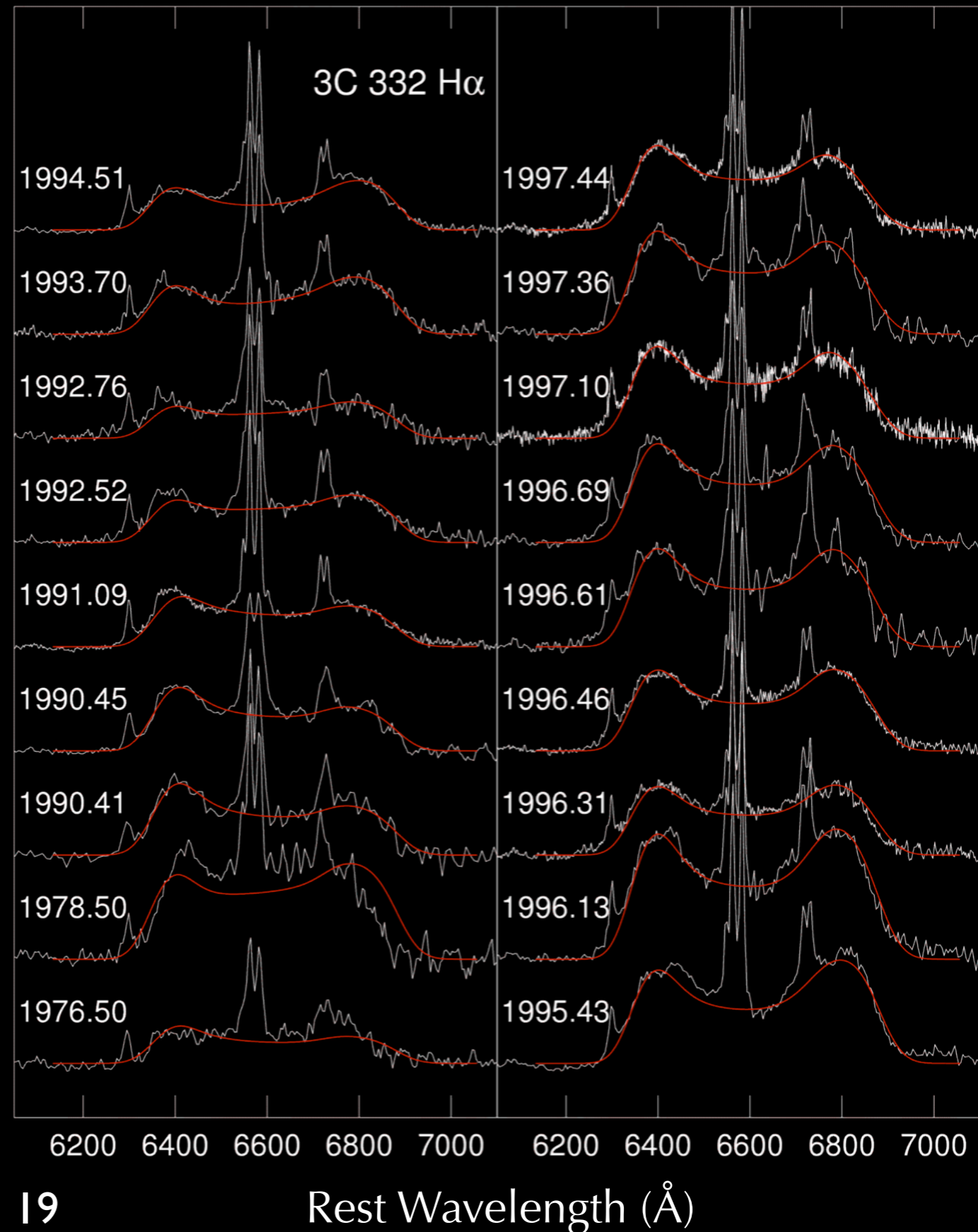




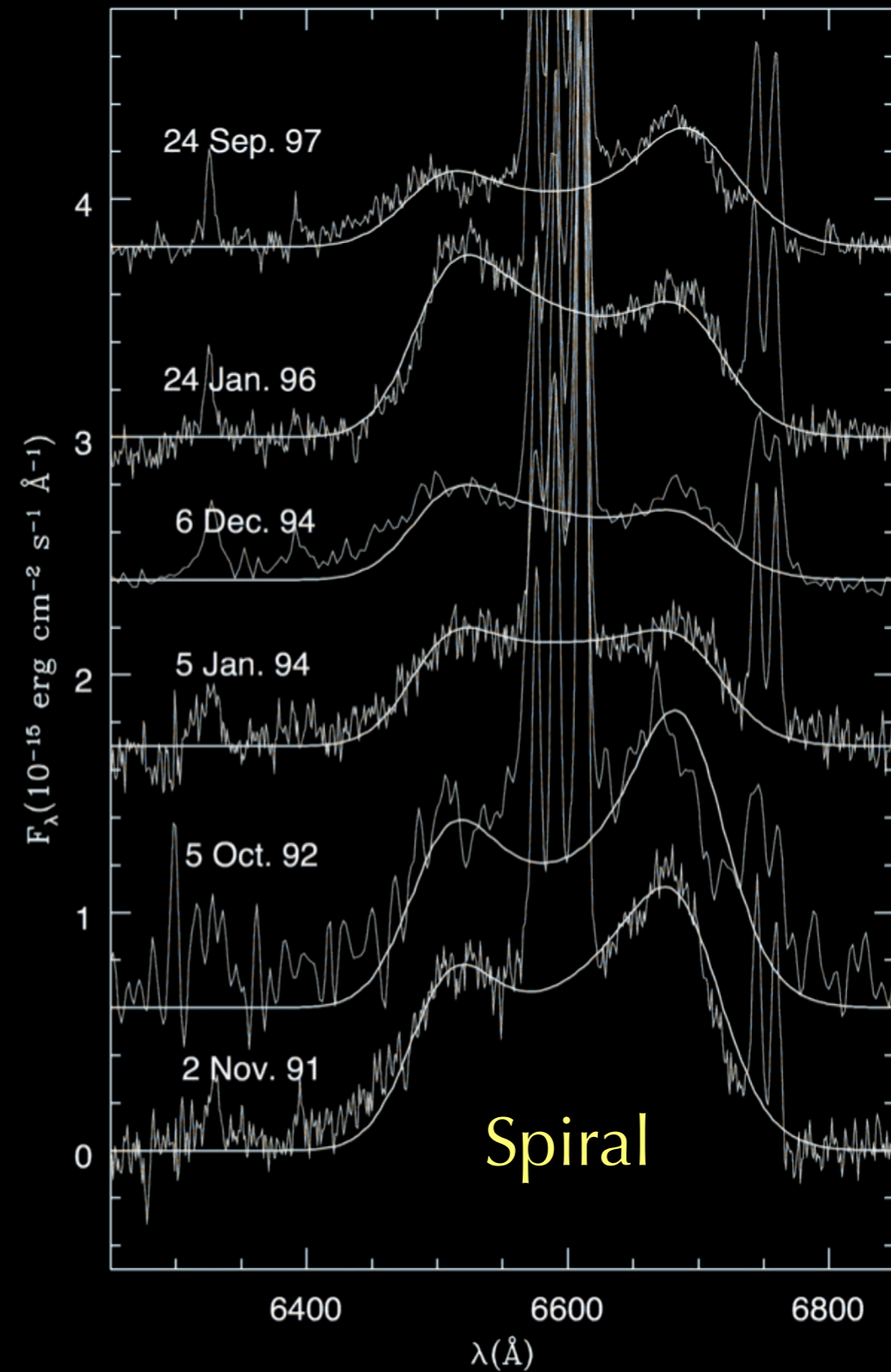
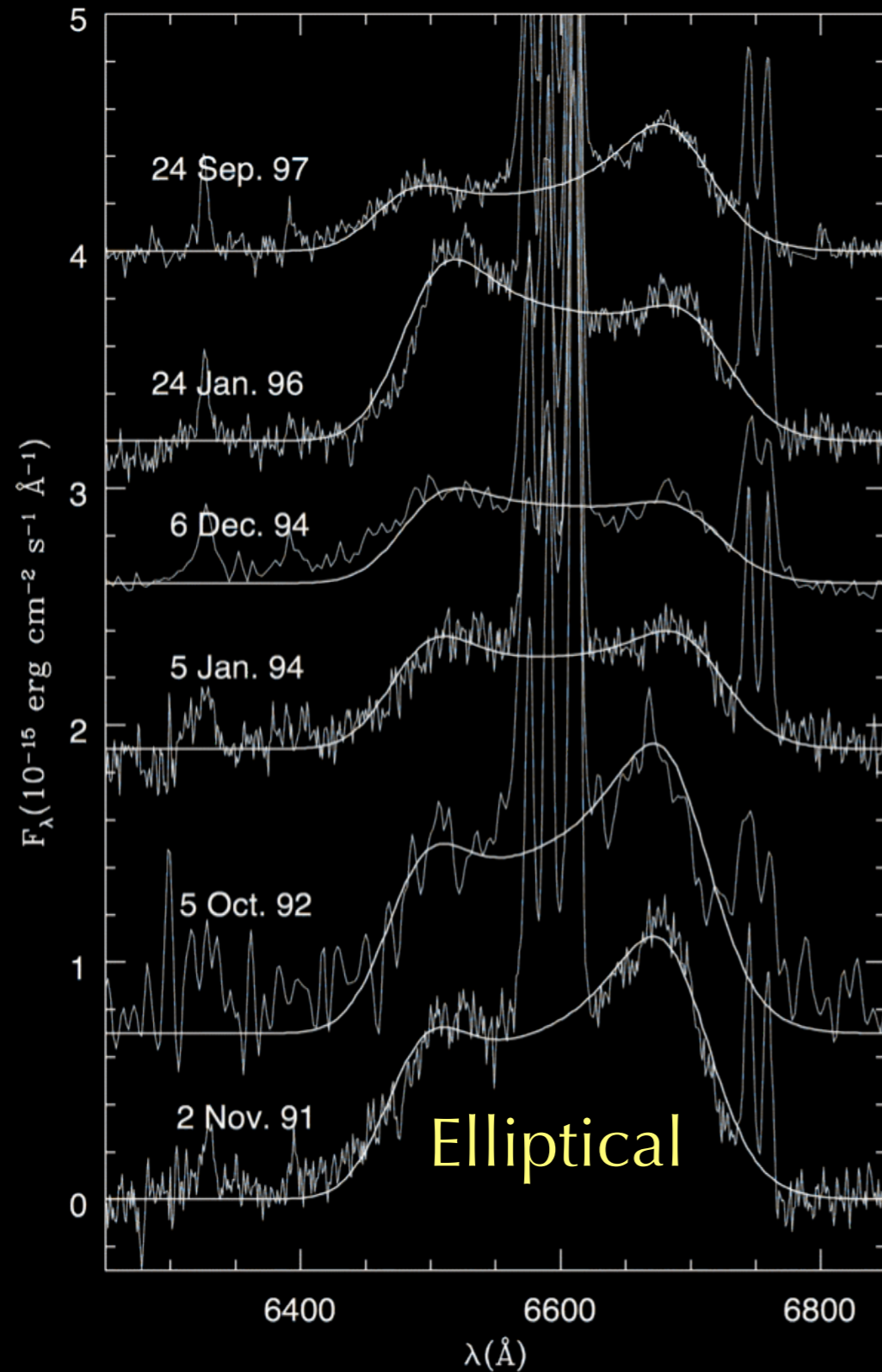
# Specific Application to 3C 332



Pattern precession period of order 10 dynamical times.



# Specific Application to NGC 1097



# So Far, So Good, So What?

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## \*“Common” Variability Patterns:

- Are the variability patterns common and ubiquitous? Do all objects vary in the same way?
- Do variations they repeat? If so, on what time scale? Are they periodic?

## \*Test More “Models” for Variability:

- Is there a universal model that explains most objects? Do we see the signature of waves in the outer disk?
- Do we see transient perturbations? What are their lifetimes, onset and decay times?

## \*Help From Theory:

- Predictions of the relevant times scales.
- Connection between disk properties and excitation/properties of perturbations.

The End

