A Two-Component Model of the Broad Line Region of Active Galactic Nuclei

http://universe.gsfc.nasa.gov

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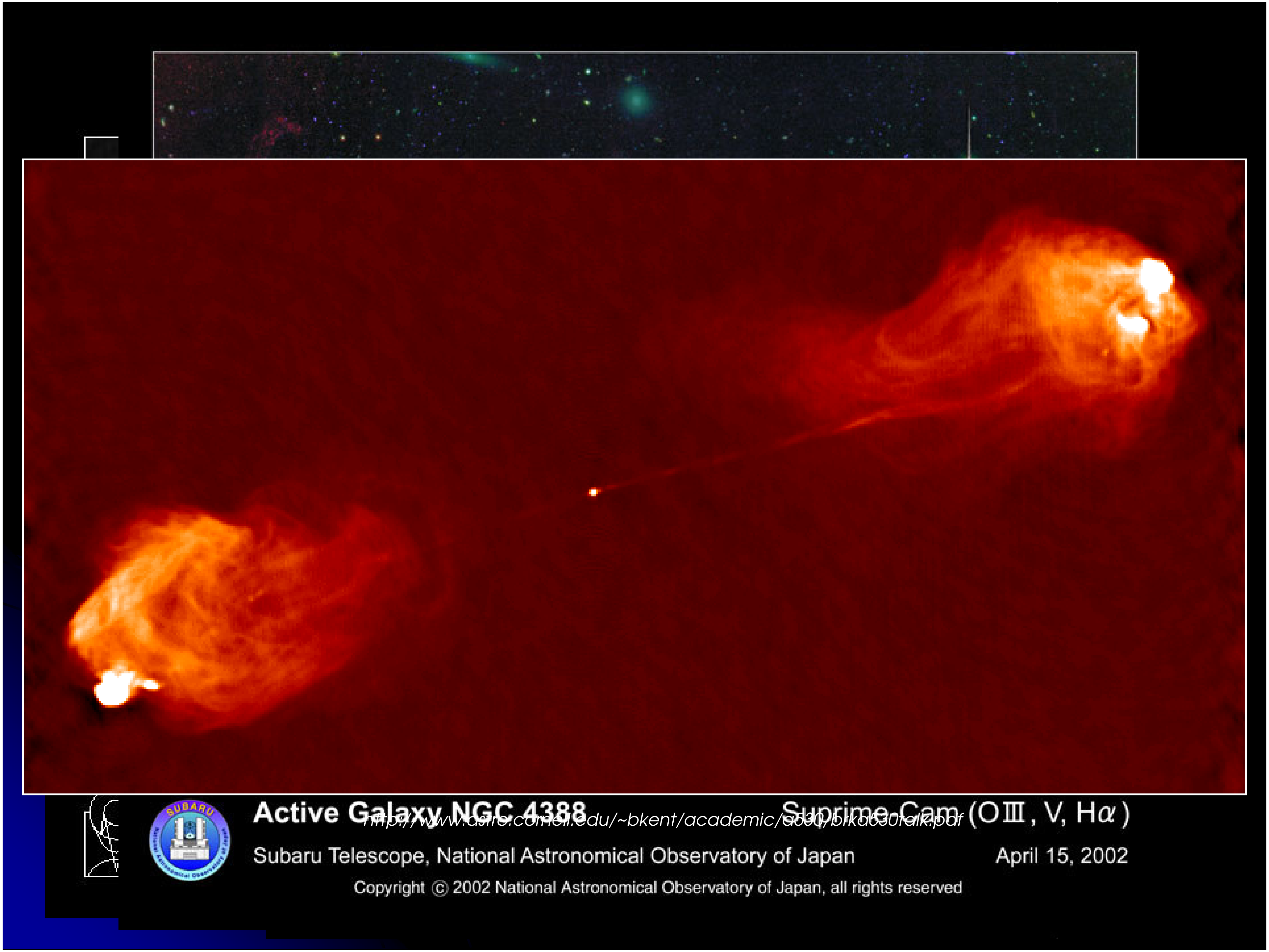
Active Galaxy NGC 4388
Suprime-Cam (OIII, V, Hα)
http://www.astro.cornell.edu/~bkent/academic/a530/bhka530talk.pdf
Subaru Telescope, National Astronomical Observatory of Japan
April 15, 2002
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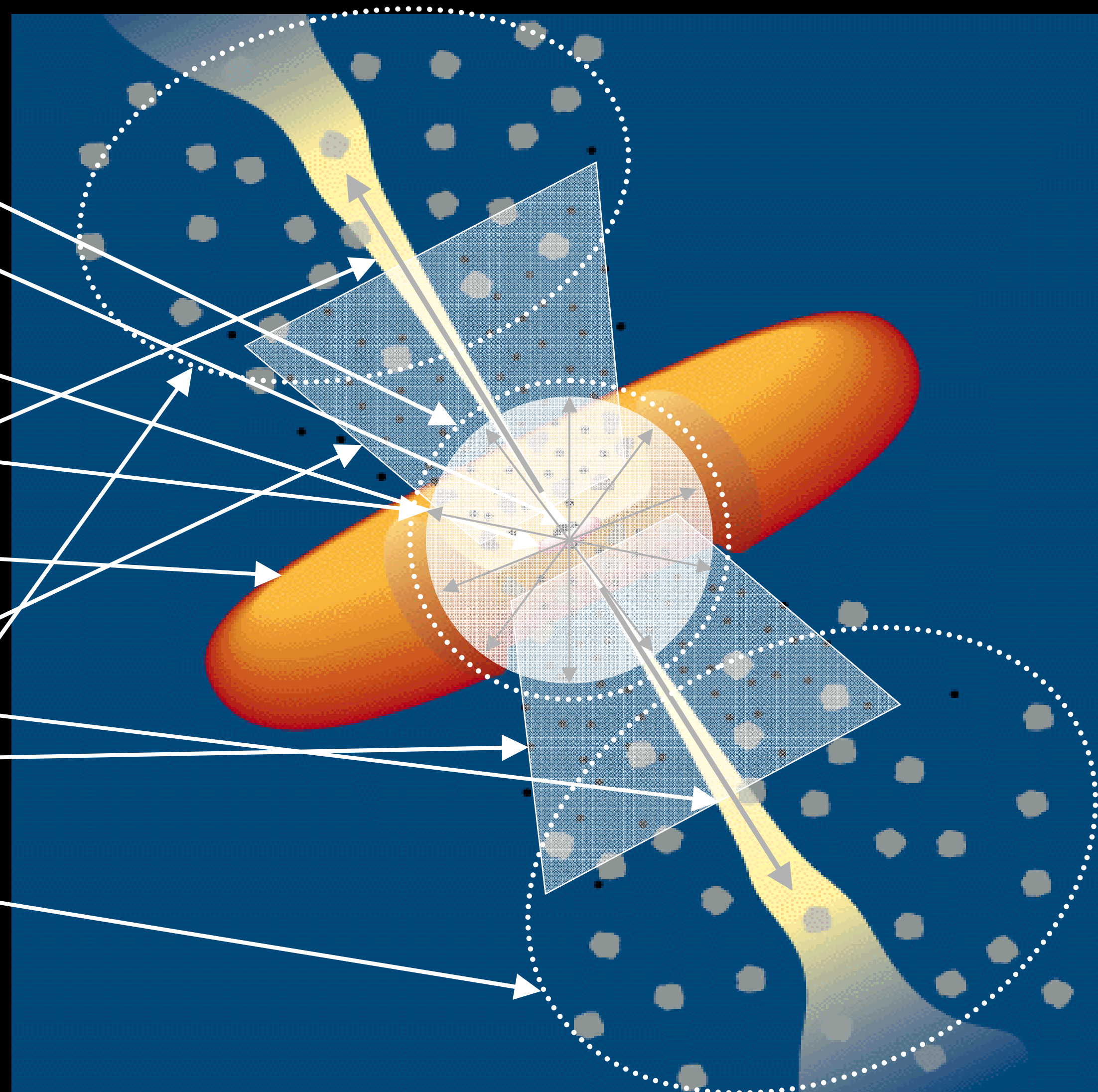
AGN Components



Padovani & Urry

Terminology

➢Active Galactic Nuclei (AGN) are found at the centers of galaxies, emitting high luminosities ($L \geq 10^{11} L_\odot$)

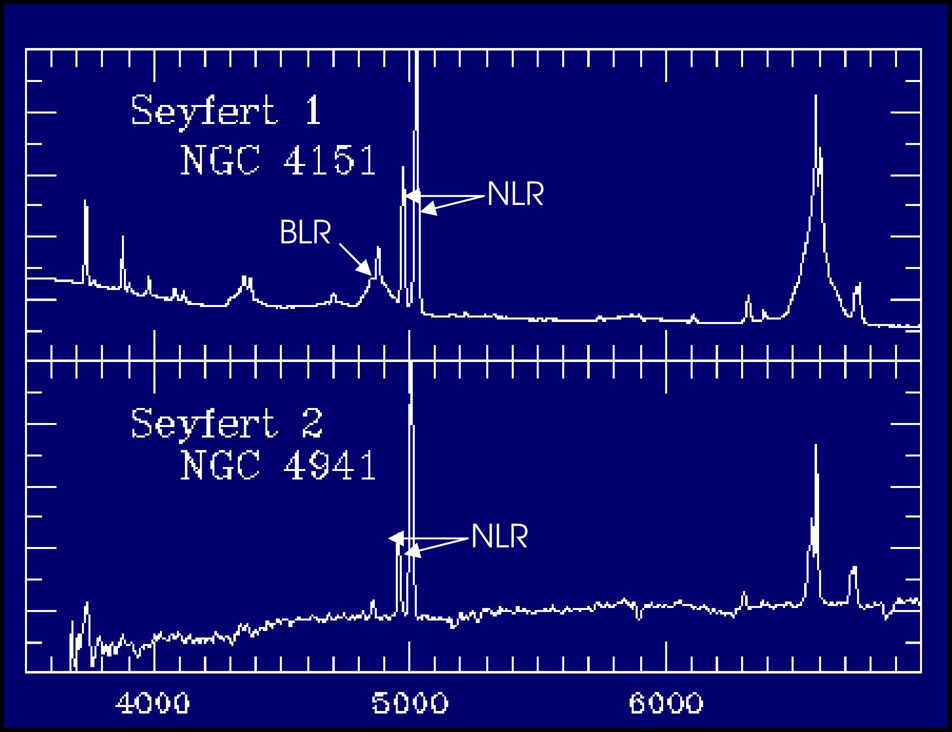
➢**Seyfert Galaxies**, discovered in the 1940s, contain AGN and are divided into two groups:

- Type 1: both BLR and NLR are observed
- Type 2: only NLR is observed

➢**Quasars** are even more luminous AGN, and can be found at high redshifts

- Recent evidence indicates that quasars can be subdivided like Seyfert Galaxies

➢There are other categories of AGN, including **blazars**, which appear when a jet is collimated with our line of sight

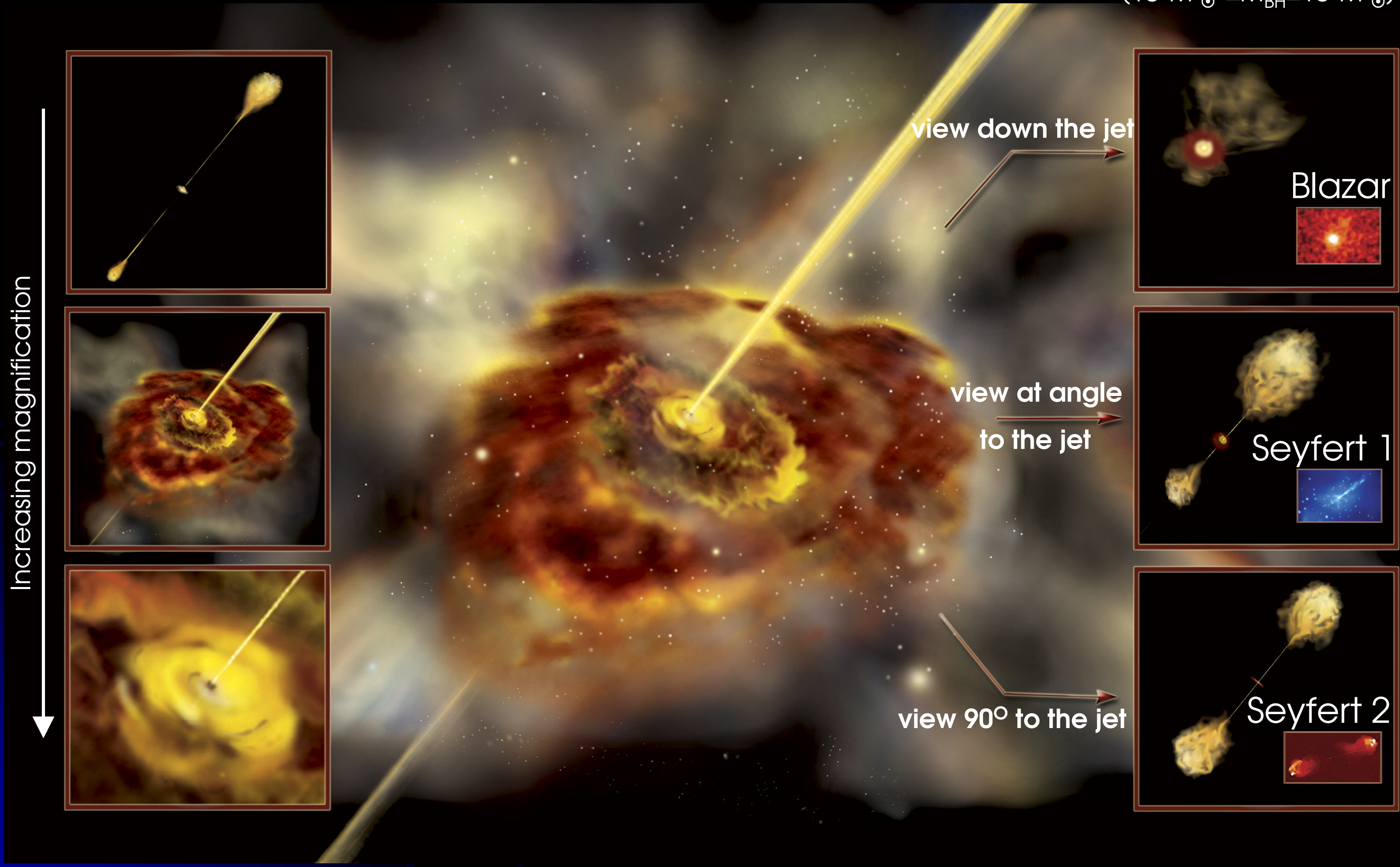


Axon presentation

Unification

➢It is thought that all AGN share a common engine: accretion onto a supermassive black hole

($10^6 M_\odot \leq M_{BH} \leq 10^9 M_\odot$)

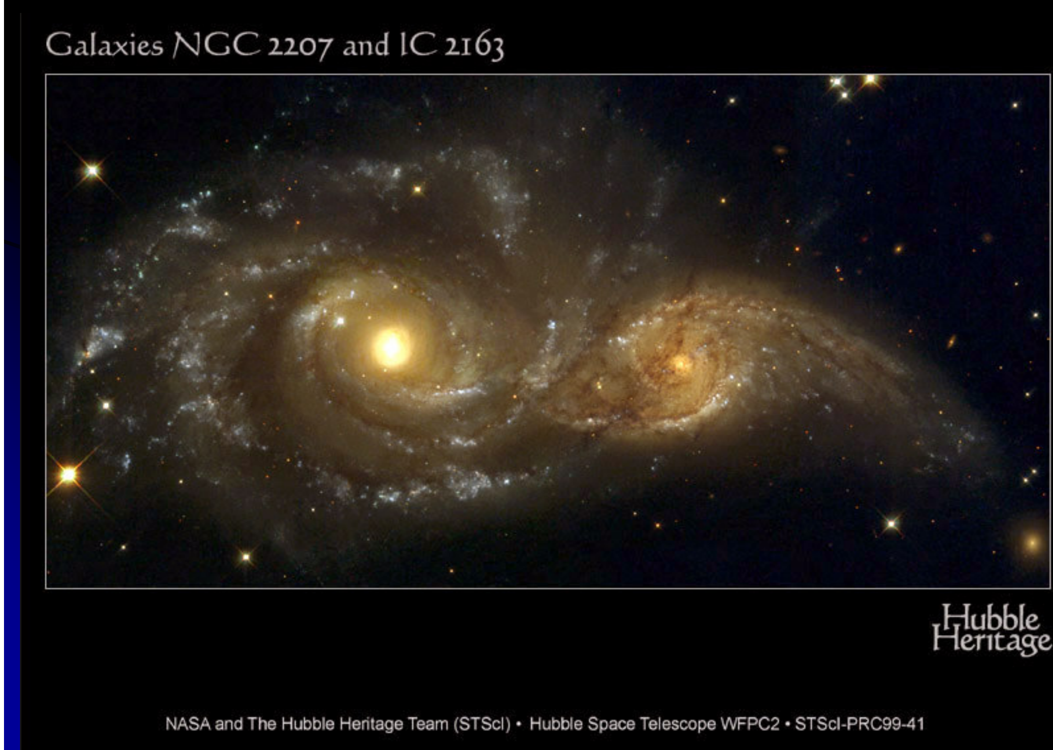


Gamma-Ray Large Area Space Telescope poster

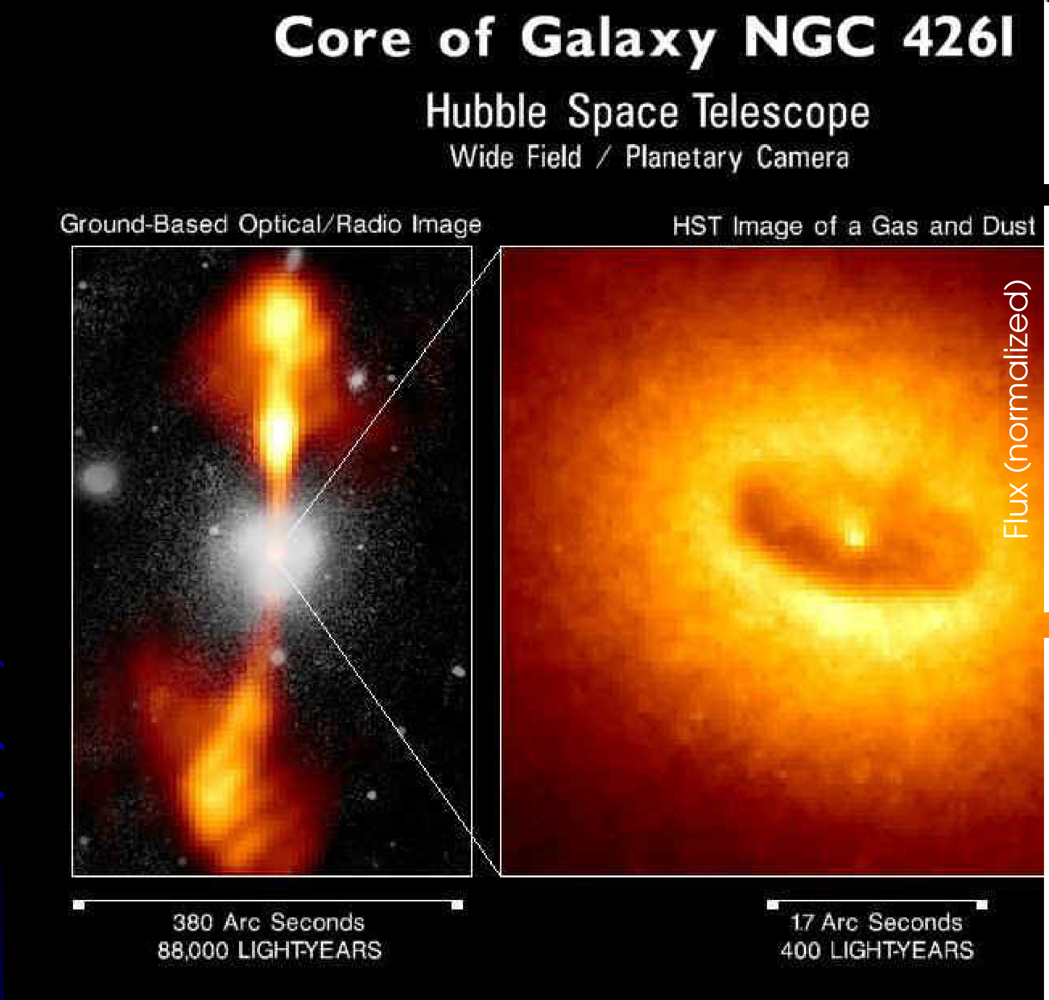
Why?

- ➢Extreme physics laboratories
  - ➢Matter moving at relativistic speeds
  - ➢Efficient mass-energy transfer (AGN≈10% vs. nuclear fusion≈0.7%)

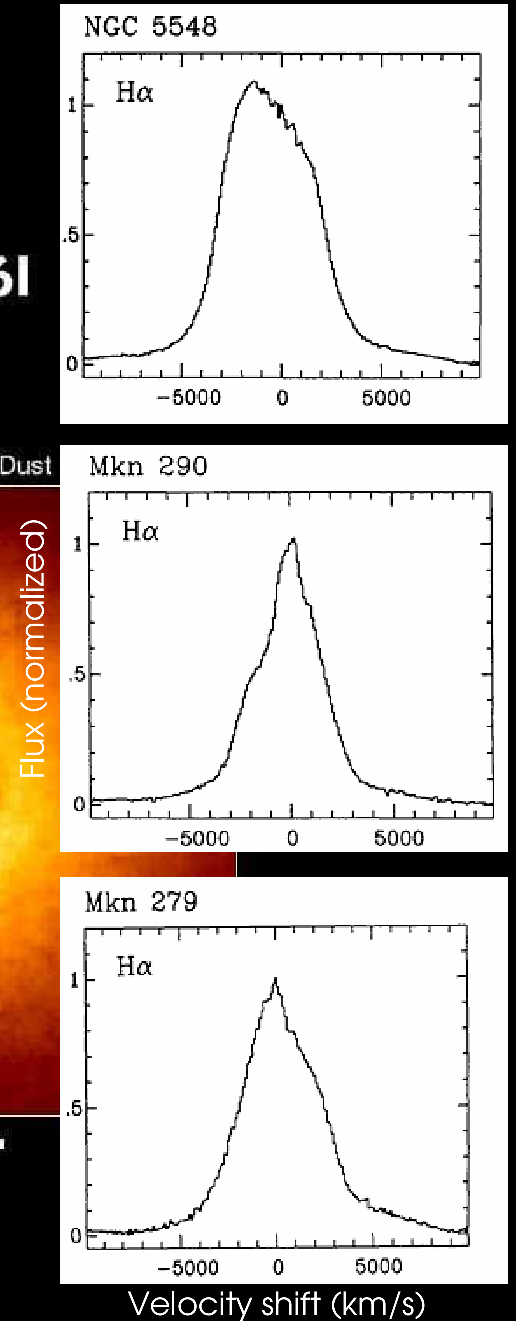
- ➢Evolution of galaxies
  - •Which came first: galaxy or supermassive black hole?
  - •Why do we see AGN, especially quasars, at high redshifts?
  - •Do all galaxies harbor central black holes?



Observations



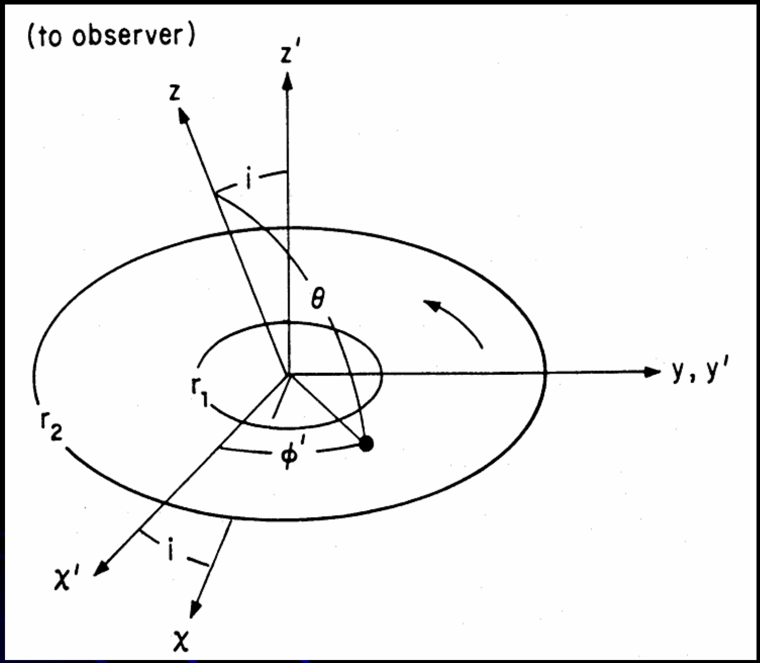
HST



Stirpe, 1990, A&AS, 85, 1049

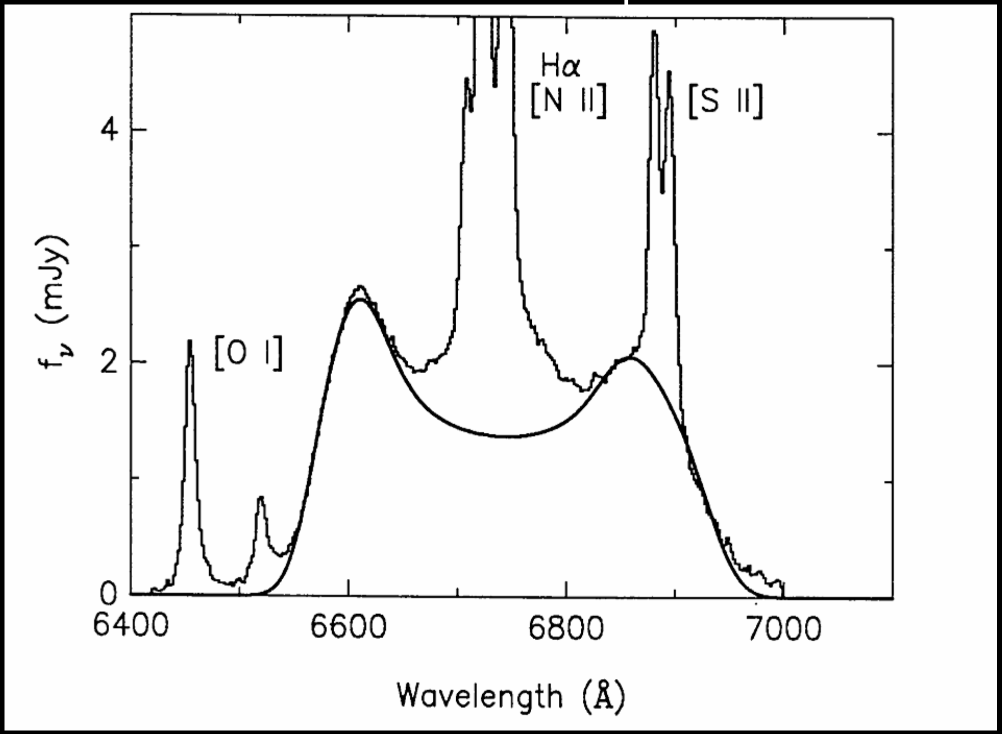
Rotating Accretion Disk Model

Geometry of the Model



Chen, Halpern, and Filippenko, 1989, ApJ, 339, 742

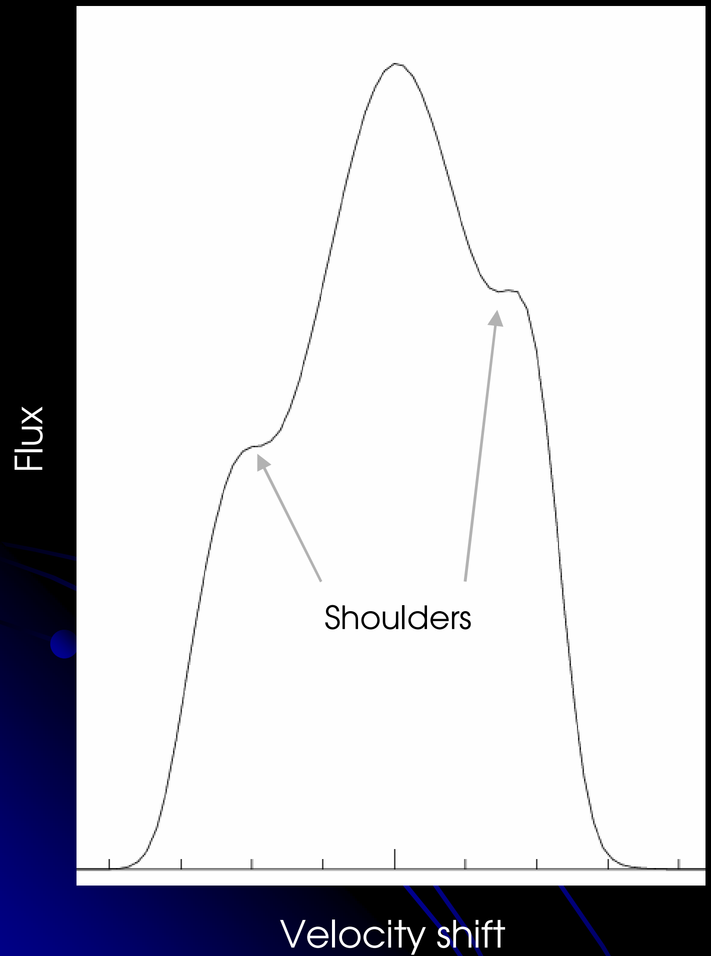
Model fit to Arp 102B



Chen and Halpern, 1989, ApJ, 344, 115

- To account for the wide variety of BLRs we see in AGN profiles, we can vary several parameters including inclination, inner and outer radii, and emissivity.
- Elliptical disks and hot spots have been added to the model to account for some irregularities.
- Works well for double-peaked profiles and shoulders, but fails to explain central component and wings.

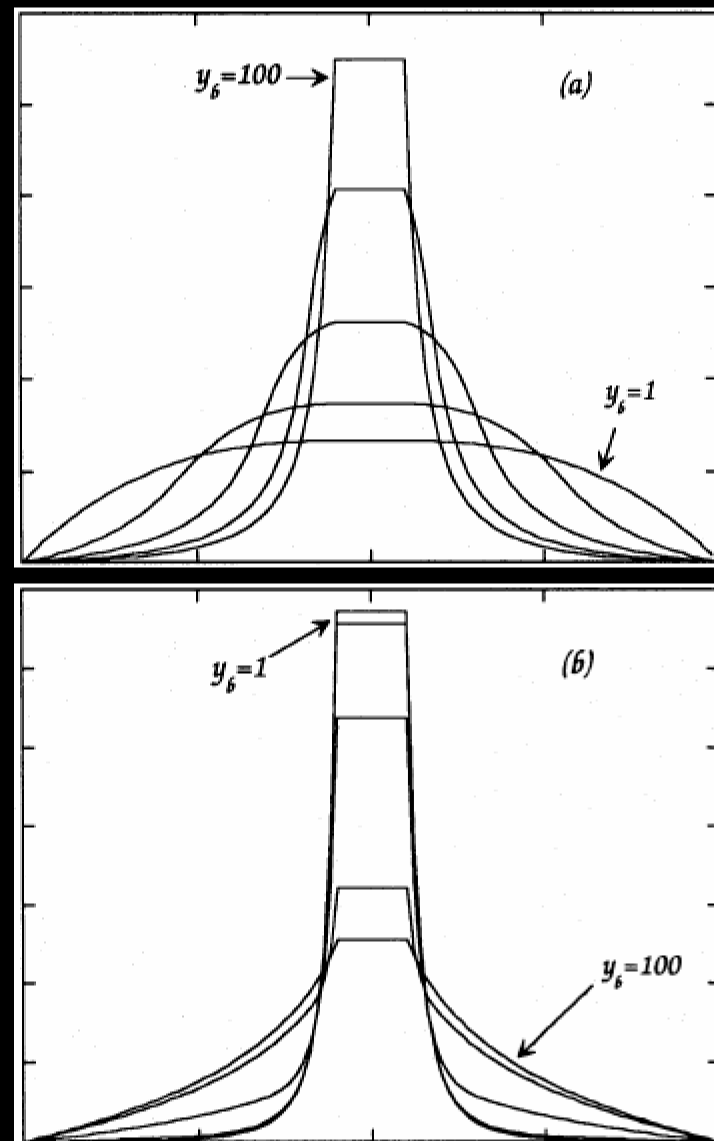
Gaussian Central Component



- To account for the central peak, we can try adding a Gaussian curve to the disk model.
- Width and relative height can be adjusted to enhance or reduce shoulders.
- Not entirely justified, and still fails to match the breadth of the wings found in BLRs.

Spherical Outflow Model

- In another model, the broad emission line is created by clouds flowing outward from the AGN.
- They are propelled by radiation pressure and winds.
- This model works well for the shape of the wings, but is not as accurate in the core and cannot produce shoulders or double peaks in the profile.



Robinson, 1995, MNRAS, 272, 647

Putting them together

Accretion Disk Model
(Chen and Halpern, 1989, ApJ, 344, 115)

$$F_X = \frac{2\epsilon_0 M^2 \cos i}{4\pi d^2} \frac{v_0}{(2\pi)^{1/2}\sigma} \int_{\xi_1}^{\xi_2} \int_{-\pi/2}^{\pi/2} d\xi \, d\varphi' \exp\left[-\frac{(1 + X - D)^2 v_0^2}{2\sigma^2 D^2} \right] D^3 \xi^{1-q} g(D)$$

+

Spherical Outflow Model
(Robinson)

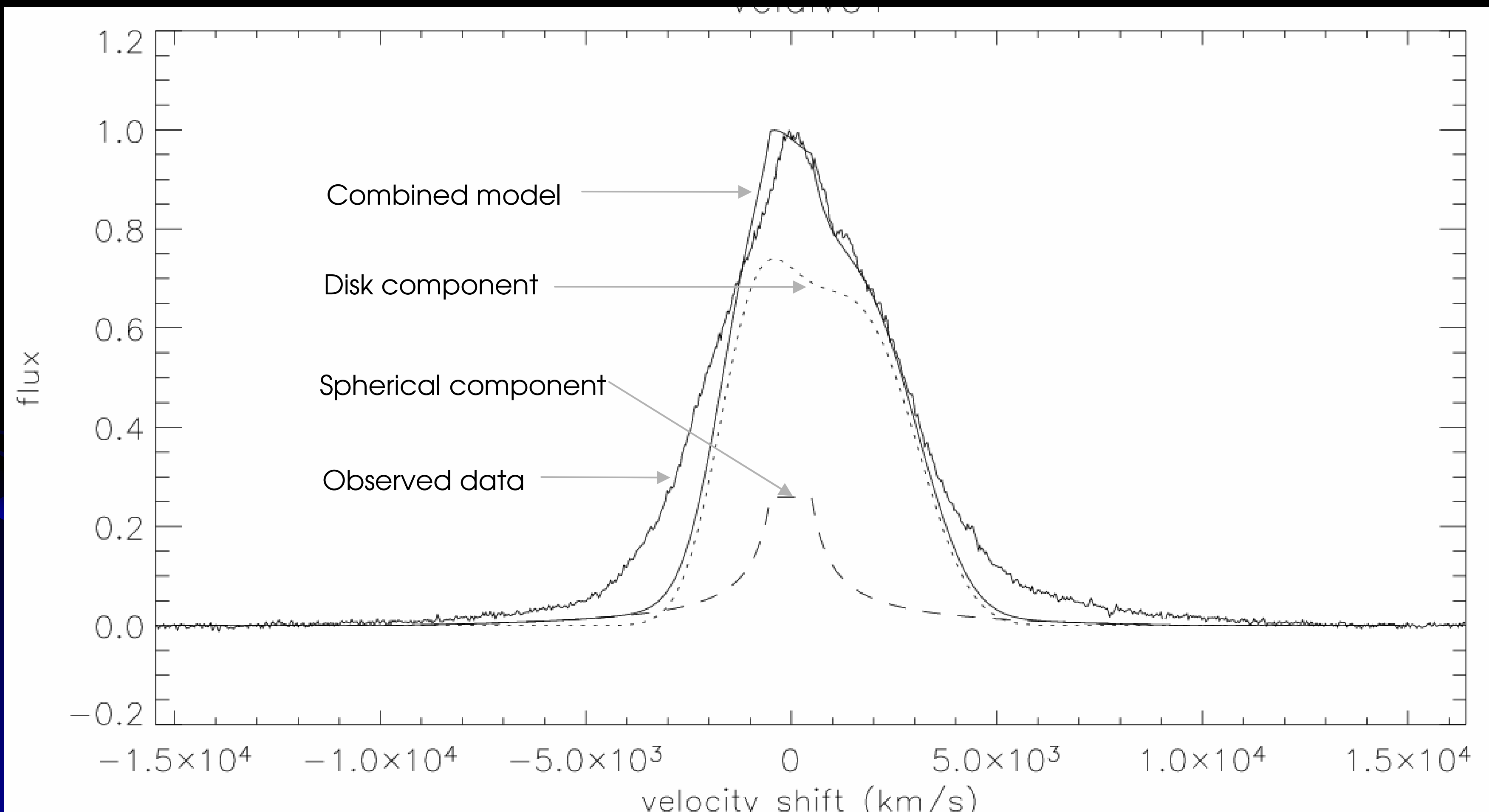
$$L_x = \frac{2\pi}{\lambda_0} \frac{\varepsilon_1 r_1^3}{v_1 |p|} \left\{ \frac{1}{\eta} \left[1 - \max(u, |x|)^{\eta} \right] - \frac{A_1 x}{\eta'} \left[1 - \max(u, |x|)^{\eta'} \right] \right\}$$

=

New Two-Component Model

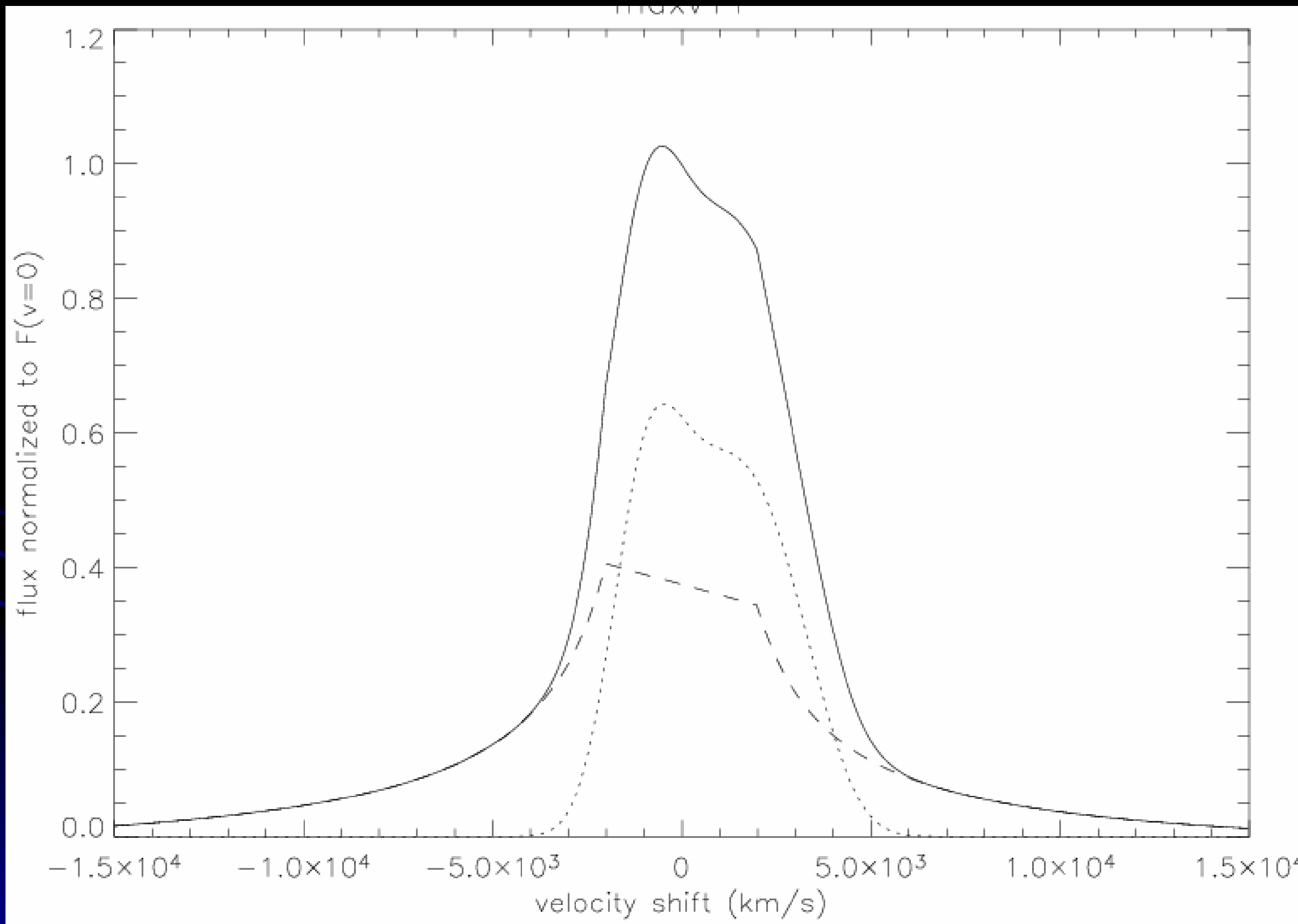
How does it compare?

Rough fit to profile of Akn 120



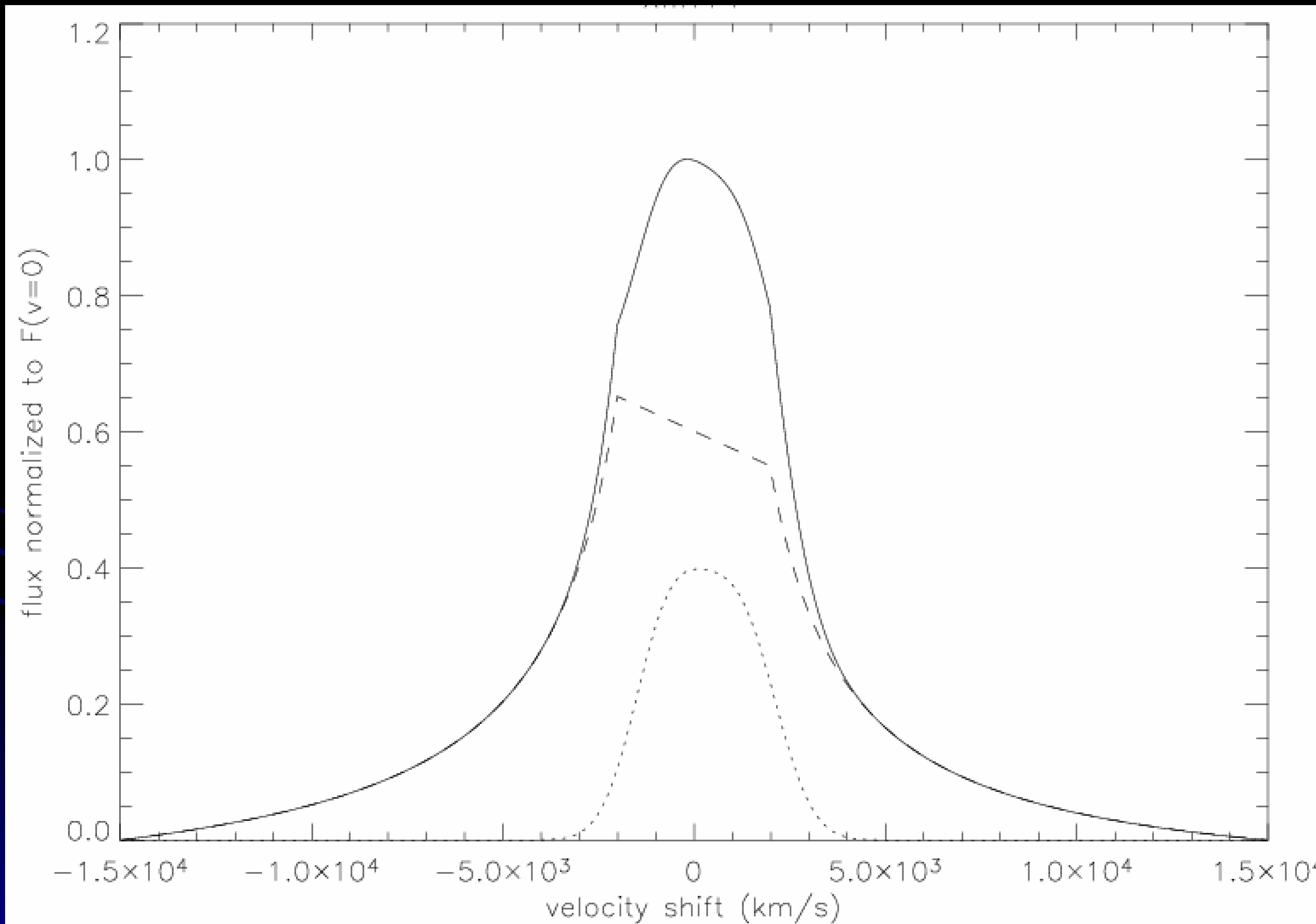
Effects of Varying Parameters

Maximum velocity of gas in spherical outflow component



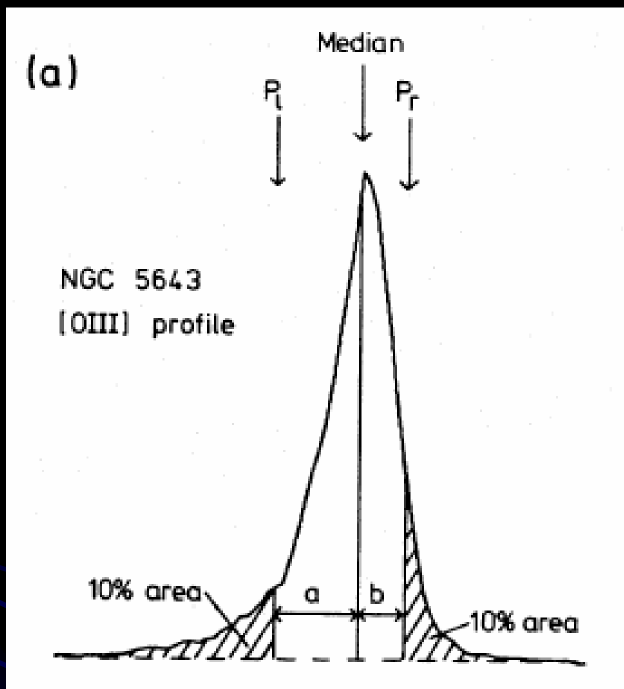
Effects of Varying Parameters

Inner radius in accretion disk component



A Statistical Analysis

Interpercentile velocity, asymmetry, and kurtosis

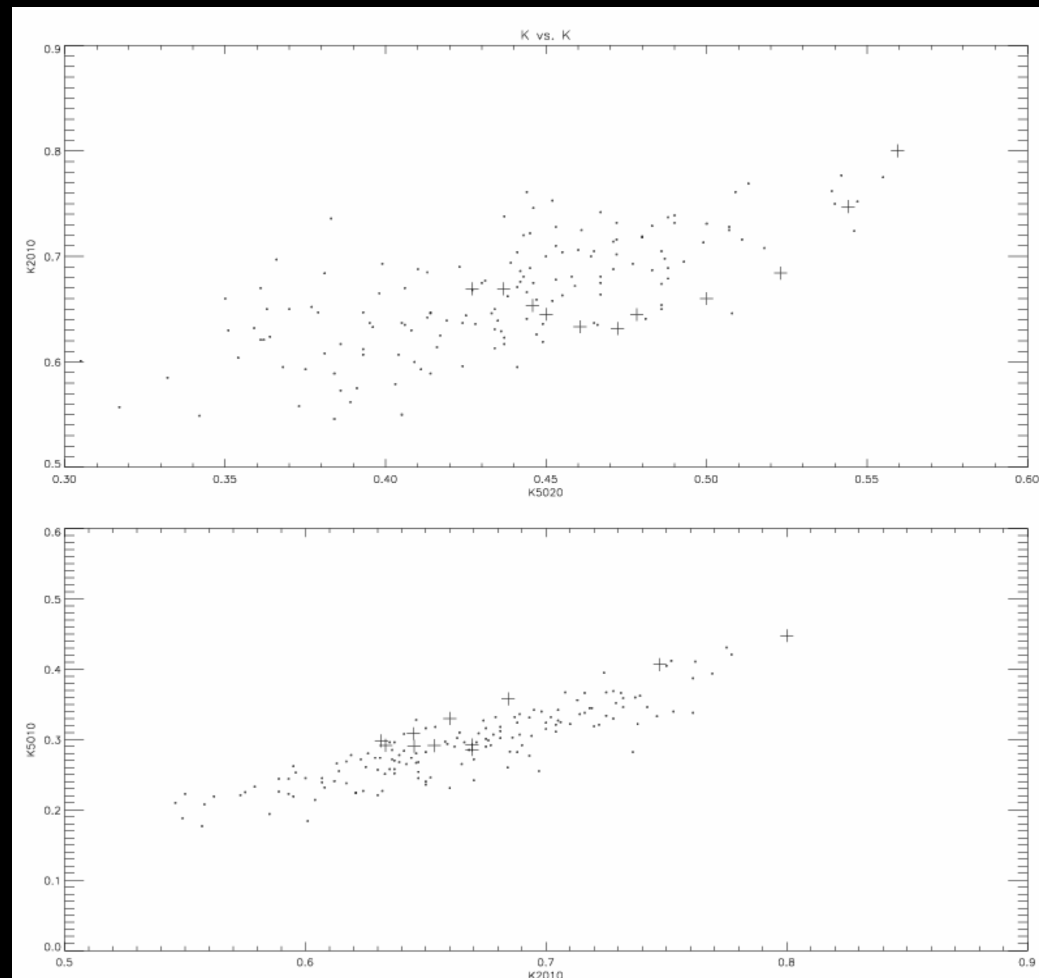


$$IPV(\%) = a + b$$

$$A(\%) = \frac{a - b}{a + b}$$

K(a%b%) = IPV(a%) / IPV(b%)

Whittle, 1985, MNRAS, 213, 1

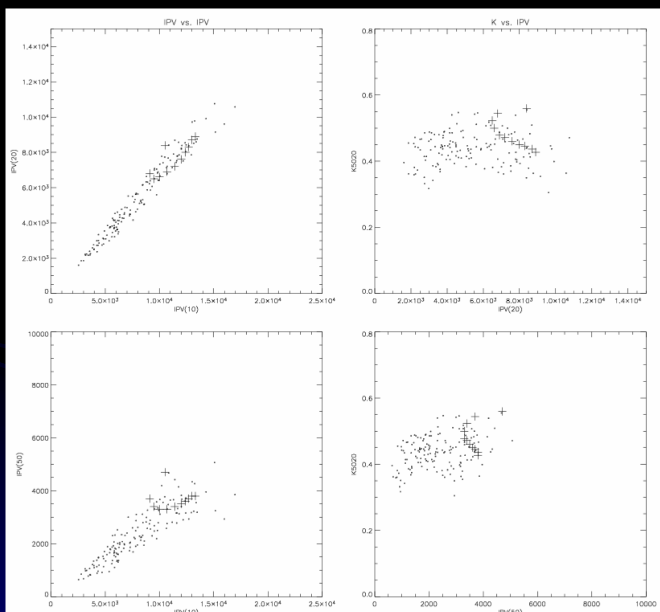


The kernel is "stumpy."

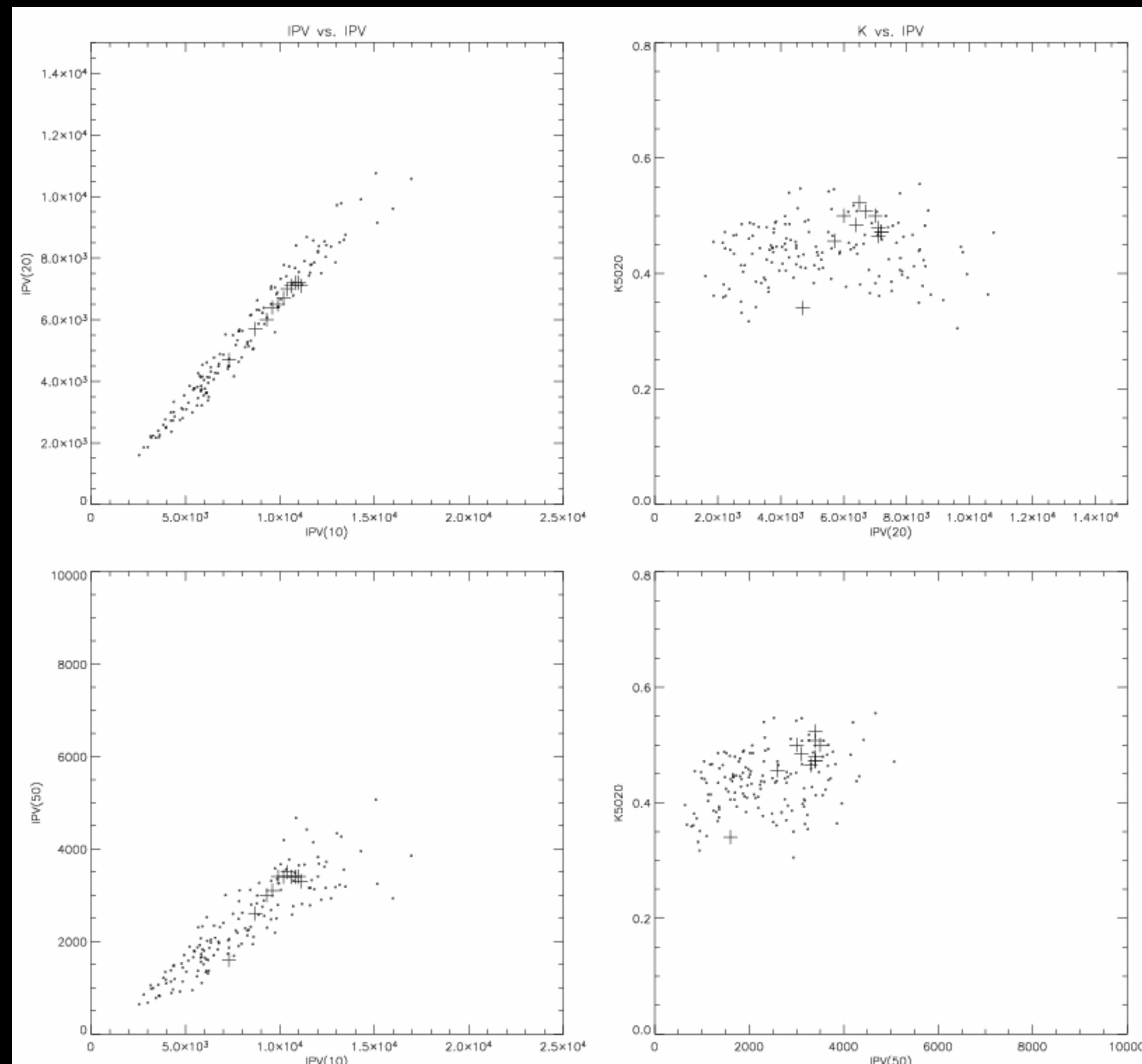
The disk model fits better.

A Statistical Analysis

Interpercentile velocity, asymmetry, and kurtosis



Inner radius of accretion disk



Minimum velocity of spherical outflow

Conclusion

- The two-component model improves upon both the accretion disk model and the spherical outflow model.
- The new model is supported by visually approximating the shape of observed profiles and by statistical comparisons to various widths from a large sample of AGN.
- Future work includes narrowing the acceptable parameter ranges and finding which parameters are most influential in causing the diversity we observe in AGN profiles.

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