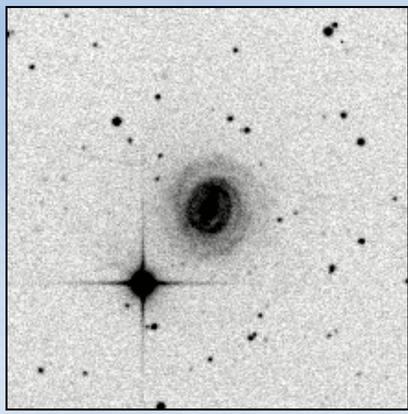
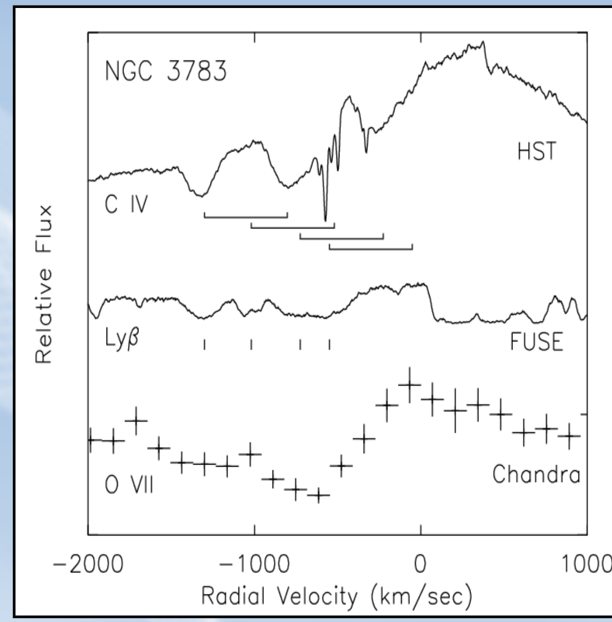
Measuring Feedback in Nearby AGN



Mike Crenshaw (GSU)
Travis Fischer (GSU)
Steve Kraemer (CUA)
Henrique Schmitt (NRL)
Jane Turner (UMBC)



1) What is the structure (location, geometry, kinematics, physical conditions) of AGN winds?
2) What is their contribution to feedback (mass outflow rates, kinetic luminosities) in moderate luminosity AGN?

→ *HST, FUSE, CXO, and XMM* observations of outflowing UV and X-ray absorbers and NLR Outflows in Seyfert Galaxies

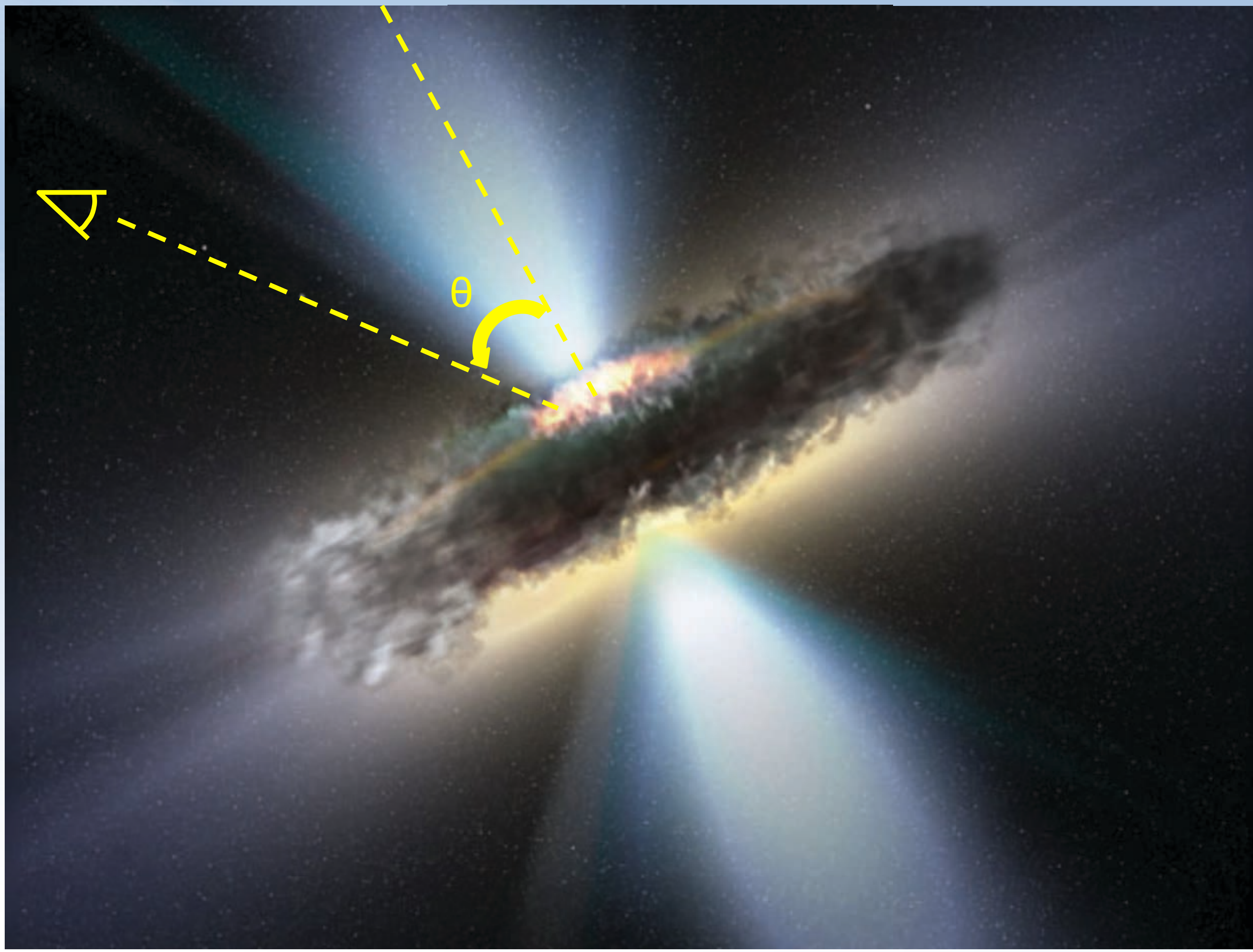
1) What is the structure of AGN winds?

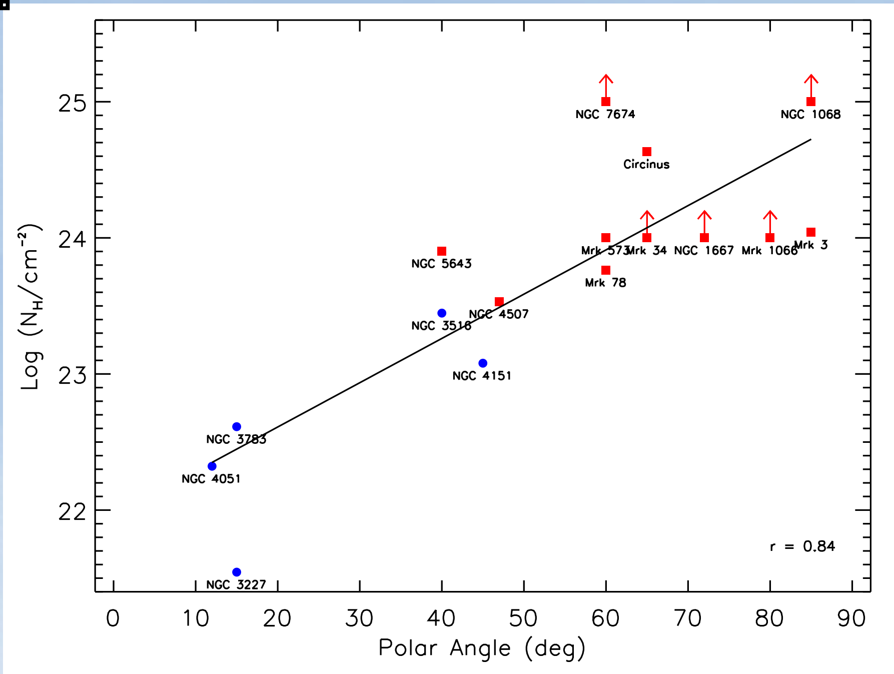
UV and X-ray Warm Absorbers in Seyfert Galaxies

- Radial velocities: $v_r = 0$ to $-$ 4000 km s^{-1}
- Velocity Widths: FWHM = 20 to 500 km s^{-1}
- LOS covering factors: $C_{los} = 0.2$ to 1.0
- Transverse velocities: $v_T \geq 0$ to 2500 km s^{-1}
- Global covering factor: $C_g \geq 0.5$
- Ionization parameter: $\log(U) = -3.0$ to 1.0
- Hydrogen column: $\log (N_H / cm^{-2}) = 18$ to 23
- Number densities: $n_H = 10$ to 10^9 cm^{-3}
- Radial locations: $r = 0.1$ to 100 pc
  - n_H from variability or absorption from excited states
  - r from $U \sim L_{ion}/n_H r^2$
- What about the geometry?

  → dependence on polar angle (θ)

How do we get the polar angle? → NLR kinematics



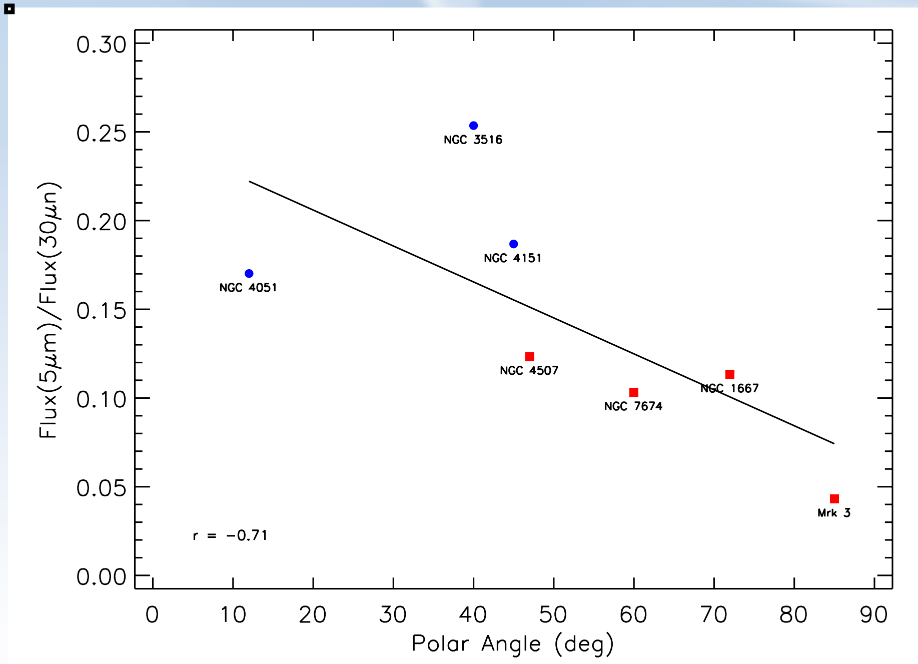


Column Density

- Ionized column increases with polar angle up to ~45°.
- Smooth transition to neutral column.
- Resembles biconical outflow in NLR.

IR Color (Spitzer IRS, Deo et al. 2009)

- F(5μm)/F(30μm) increases with decreasing θ as hot throat of torus becomes more visible.
- Consistent with above trend.



2) What is the contribution of AGN winds to feedback?

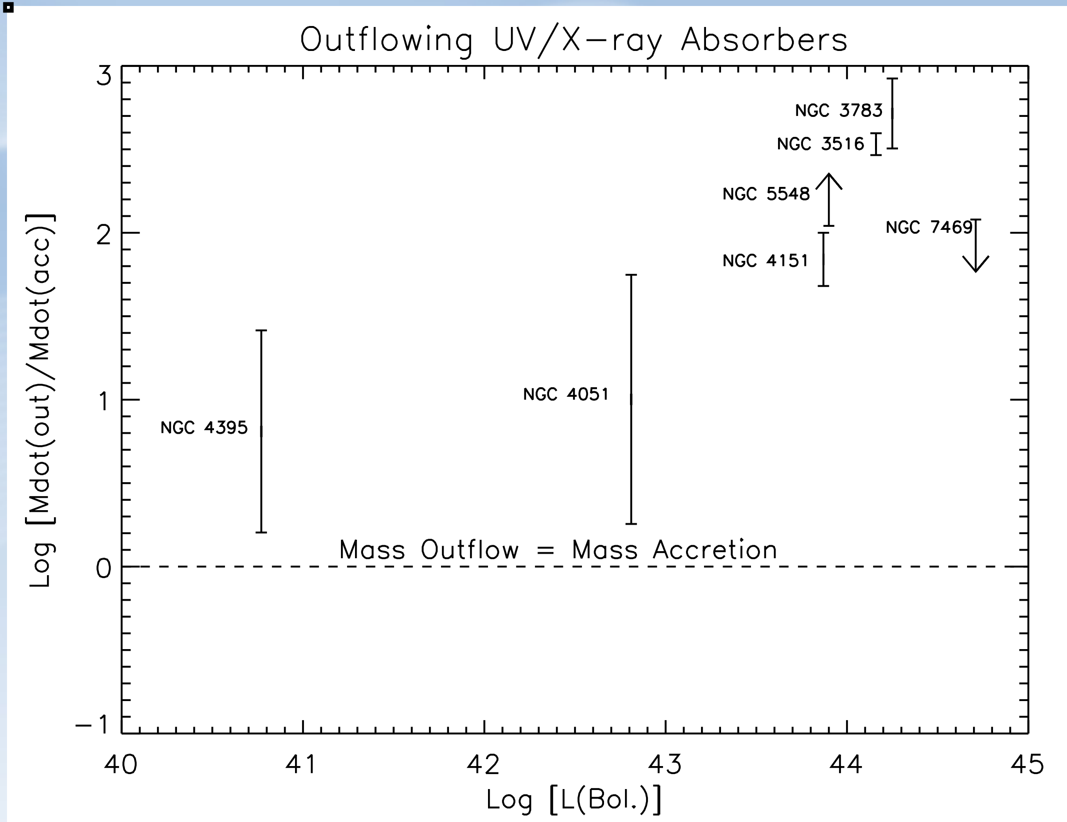
- Seyfert galaxies observed at high spectral resolution with *HST,* and *CXO* or *XMM* (current sample is 7, working on others).
- Detailed photoionization model for each absorption component (from our work and others).
- We don't assume steady state, radiatively driven, purely radial outflow (e.g, Blustin et al. 2005)
- Radial locations (or limits) for most components from variability and/or excited-state absorption.
- Determine mass outflow rates and kinetic luminosities for each component, then add them up.

$$\dot{M}_{out} = 8\pi r N_H \mu m_p C_g \mathrm{v}_r \qquad (C_g = 0.5,\ \mu = 1.4)$$

$$L_{KE} = 1/2\, \dot{M}_{out}\, \mathrm{v}_r^2$$

$$\dot{M}_{acc} = \frac{L_{bol}}{\eta c^2} \qquad (\eta = 0.1)$$

Mass Outflow Rate / Mass Accretion Rate

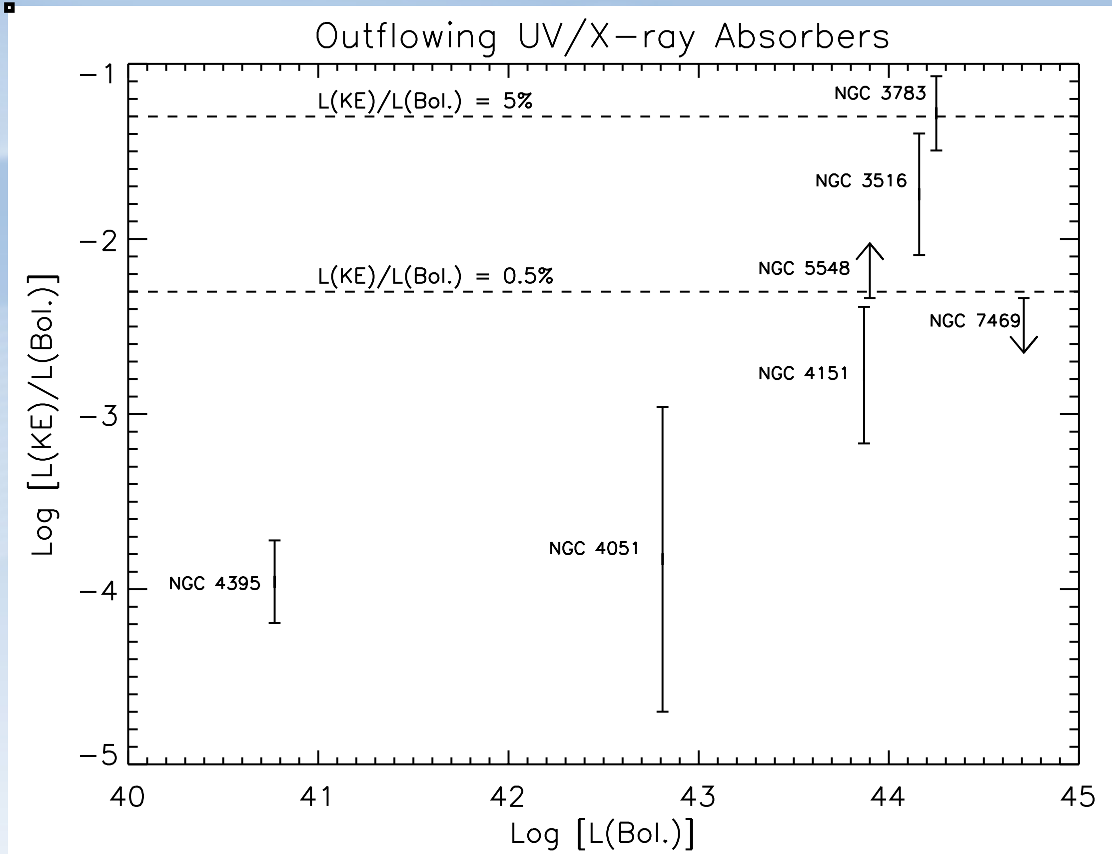


Mass outflow rate >> mass accretion rate

→ Most of the infalling gas gets blown out before reaching the inner accretion disk, or

→ A large reservoir of gas is accumulated before winds blow the fuel away.

Kinetic Luminosity / Bolometric Luminosity



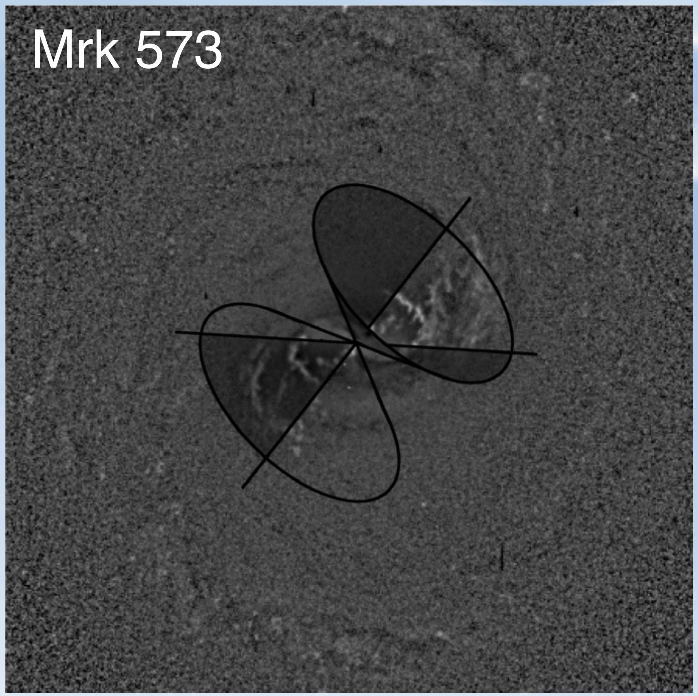
- Most are close to L_{KE} = 0.5% to 5% L_{bol}, required by AGN feedback models (Hopkins & Elvis 2010)

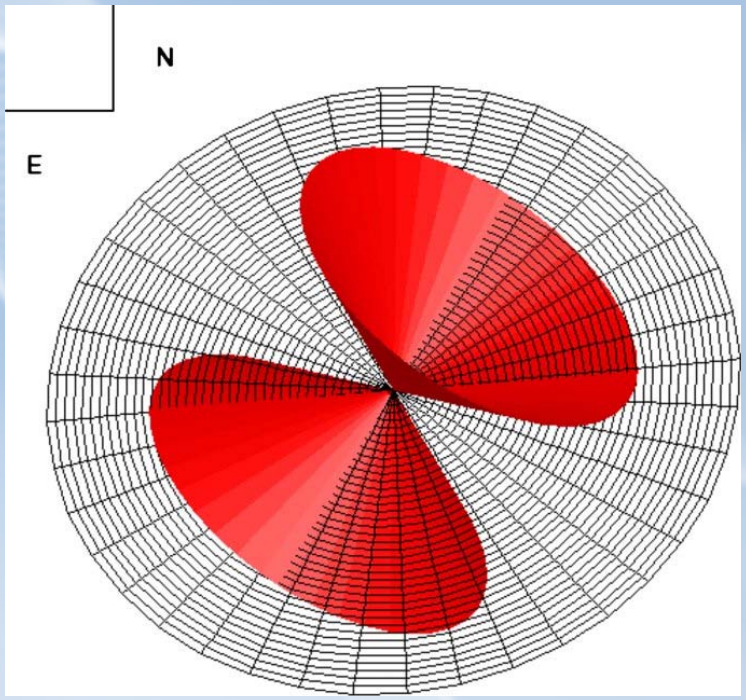
→ Winds likely provide significant feedback in moderate luminosity AGN.

→ They may not be effective at low luminosities (< ~10^{43} ergs s^{-1}).

▪

3) What is the connection between geometry and feedback?





(Fischer et al. 2010, AJ, 140, 577)

- Dust spirals (fueling flow) cross into the NLR ionizing bicone.
- Large velocity gradients near ionized spirals indicate *in situ* acceleration.
  → Are AGN winds blowing away the original fueling flows?

AGN Winds: Conclusions

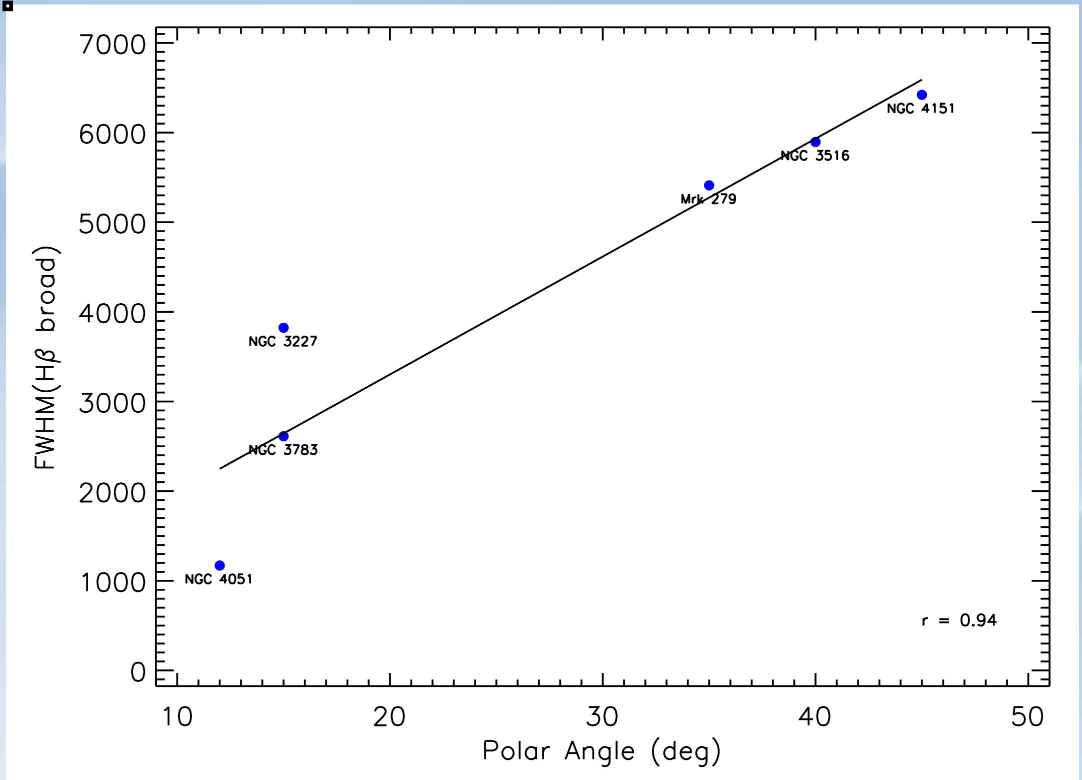
- UV/X-ray absorbers and NLR clouds are outflowing in a biconical geometry (with fuzzy edges) on scales of 0.1 – 1000 pc.

  → Increasing column density with polar angle.
- Mass outflow rates can be 10 – 100 times higher than accretion rates.

  → Most of the infalling gas gets blown out, or a large reservoir is built up before outflows begin.
- Kinetic luminosities can be 0.5% to 5% of the bolometric luminosities.

  → Winds can provide significant feedback in moderate luminosity AGN on scales of 10s to 100s (e.g., to disrupt the fueling flow).

Bonus! FWHM (broad Hβ) vs. θ



Geometry of the Broad-Line Region (BLR)

- Evidence for a non-spherical (e.g., rotational) component to the BLR kinematics?
- Are the black-hole masses in narrow-line Seyfert 1 galaxies (NLS1s) underestimated (and L/L_{Edd} overestimated) ?