Quantifying the Impact of Outflows in the Inner Regions of AGN

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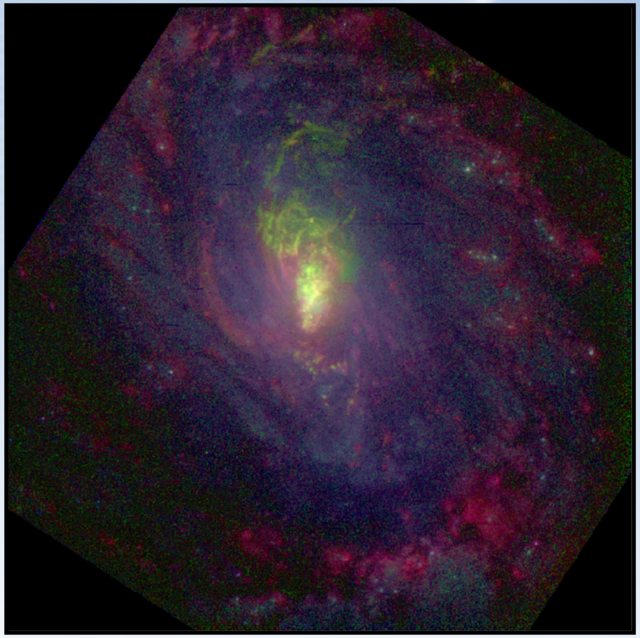
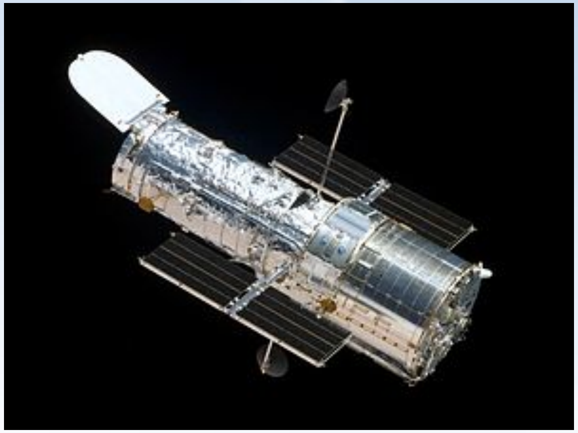
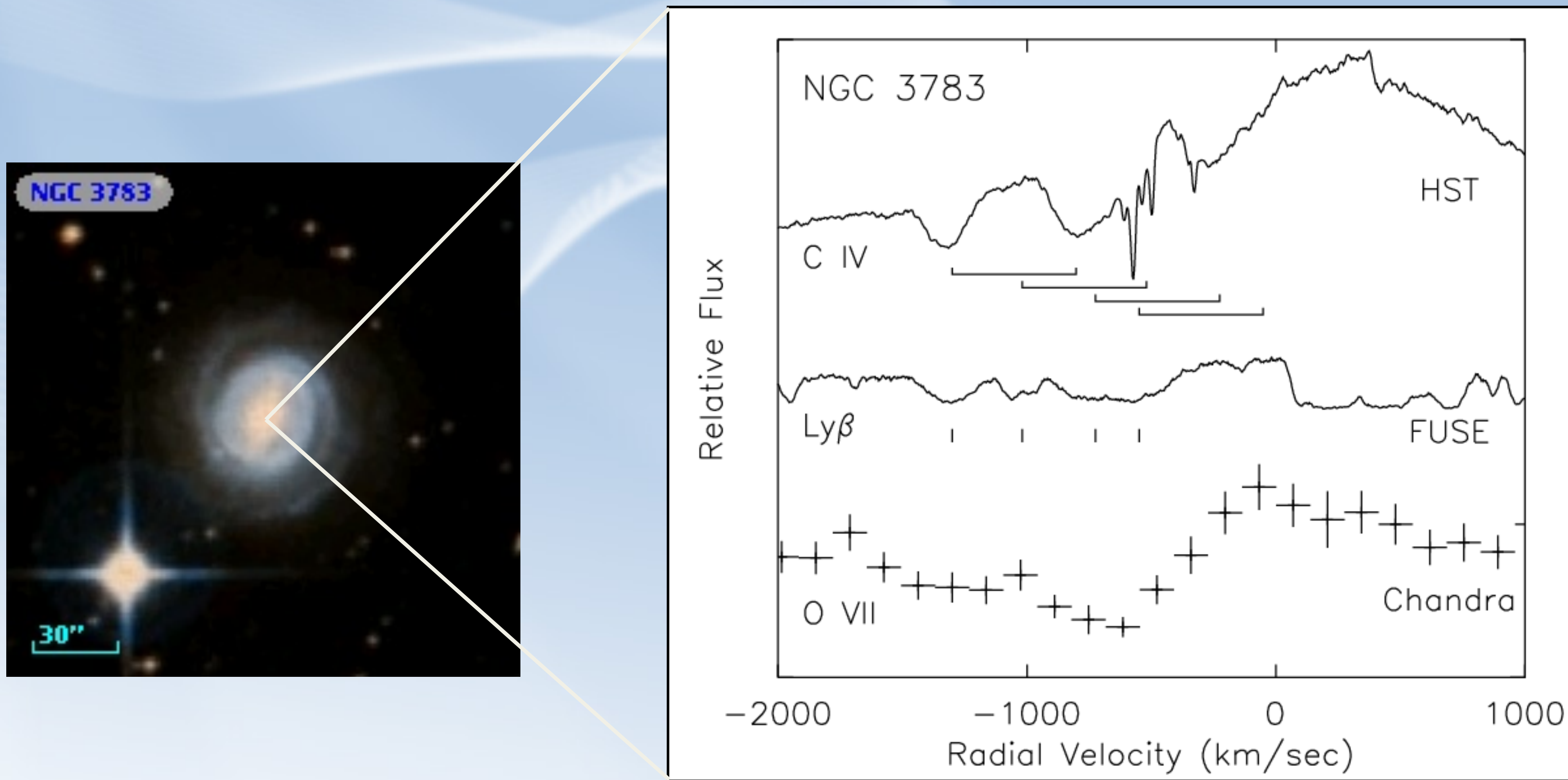




Why do we think AGN outflows are important?

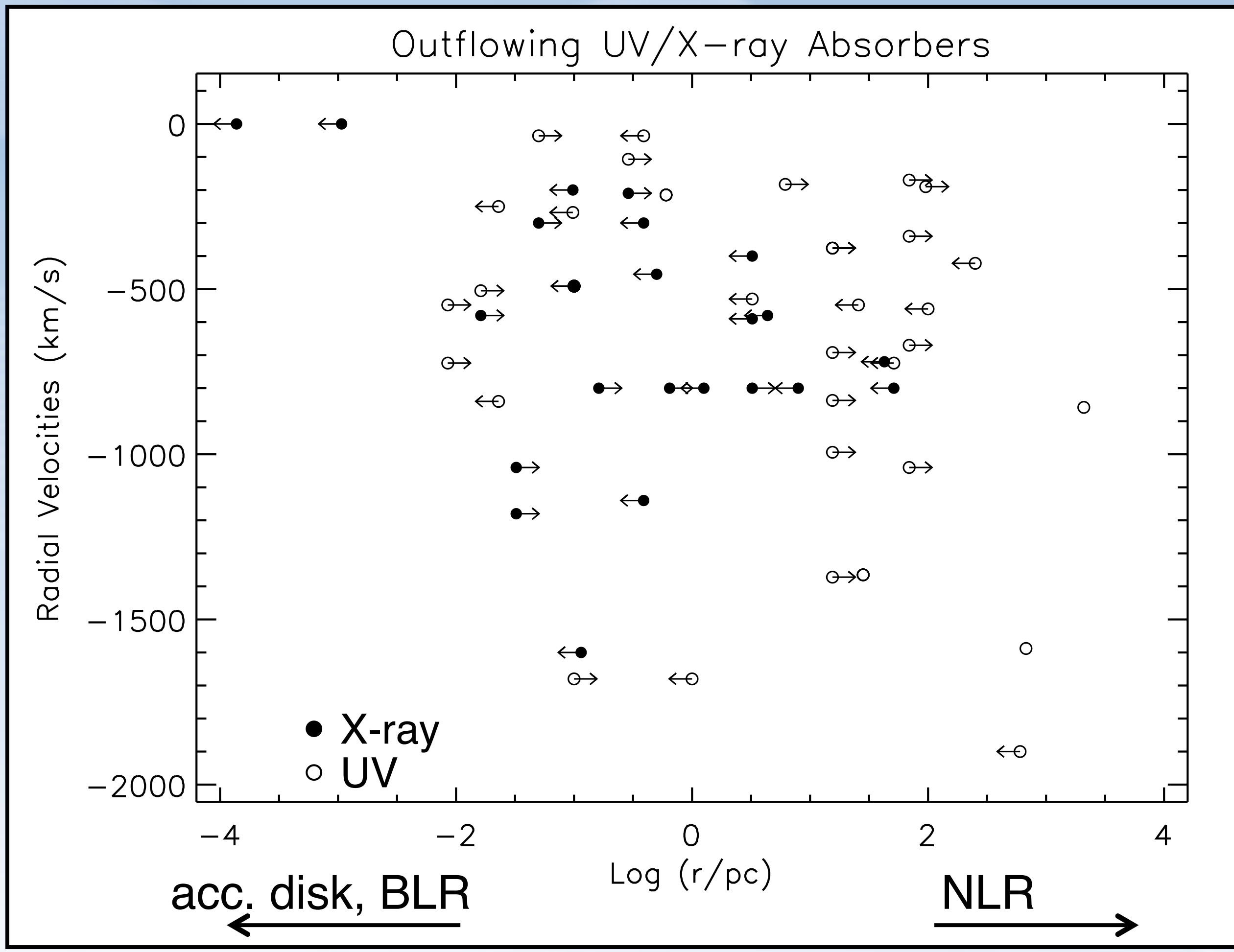
- AGN feedback plays a role in:
  - formation of large-scale structure in the early Universe.
  - chemical enrichment of the intergalactic medium.
  - self-regulation of SMBH and galactic bulge growth.
- We concentrate on AGN winds in moderate luminosity (10^{43} – 10^{45} erg s^{-1}) Seyfert galaxies.
  - UV/X-ray absorbers
  - Narrow-line region (NLR) outflows
- Do AGN winds provide effective feedback?
  - Determine mass outflow rates and kinetic luminosities.

UV and X-ray Absorbers



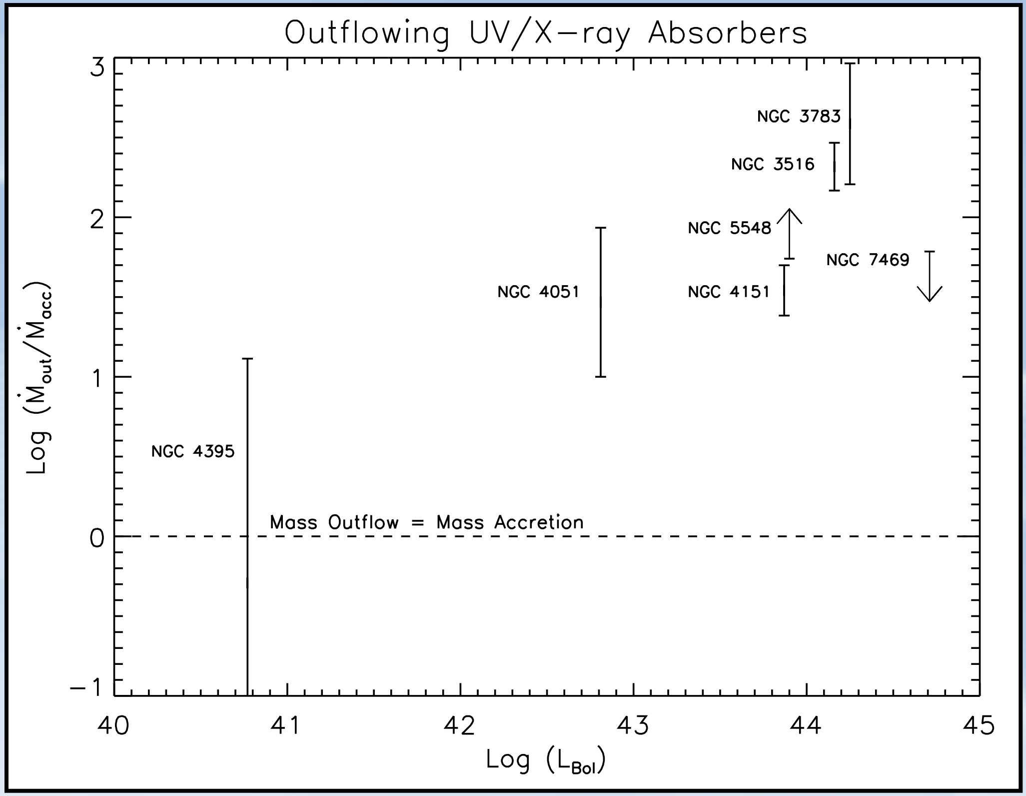
- Blueshifted UV (C IV, N V) absorption components detected in ~60% of Seyfert 1 galaxies at outflow velocities up to 4000 km s^{-1}.
- The same AGN typically show X-ray “warm absorbers” with higher ionization lines (O VII, O VIII).

Most absorbers are between the BLR and NLR.



(Crenshaw & Kraemer, 2012, ApJ, 753, 75)

Mass Outflow Rates >> Mass Accretion Rates

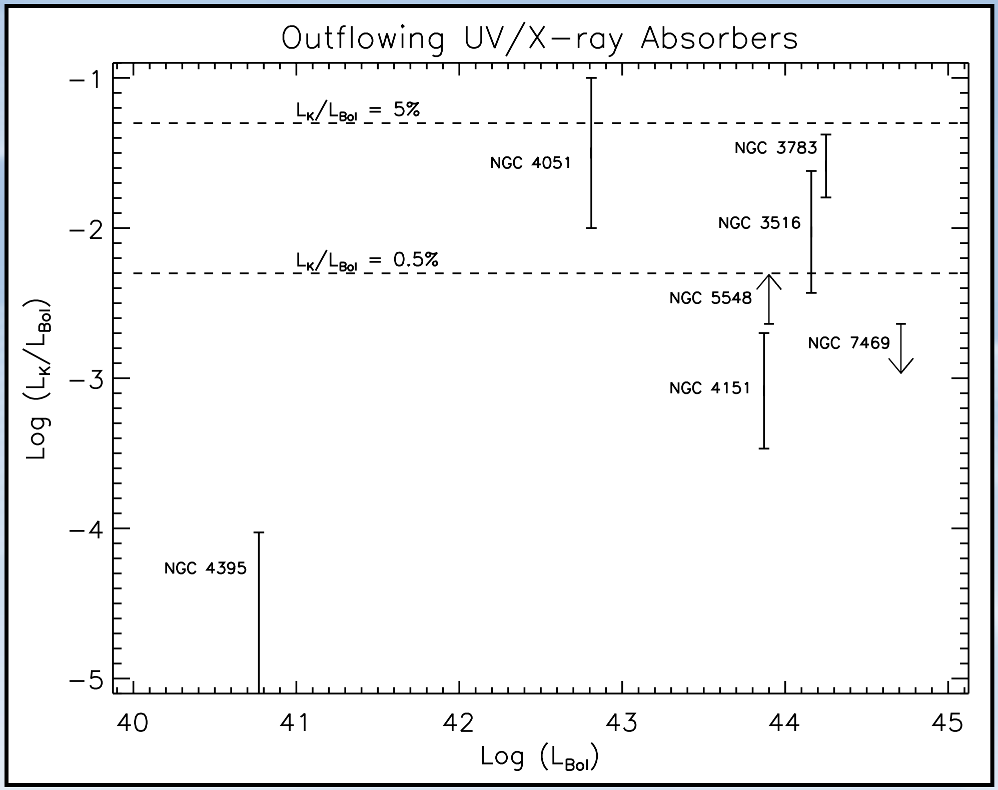


(Crenshaw & Kraemer, 2012, ApJ, 753, 75)

→ Most of the outflowing gas originates outside of the inner accretion disk (or the disk would quickly dissipate.)

→ These outflows are not accretion disk winds (although we have not included ultrafast outflows [UFOs], Tombesi et al. 2011, 2013).

Kinetic luminosity up to ~5% bolometric luminosity.

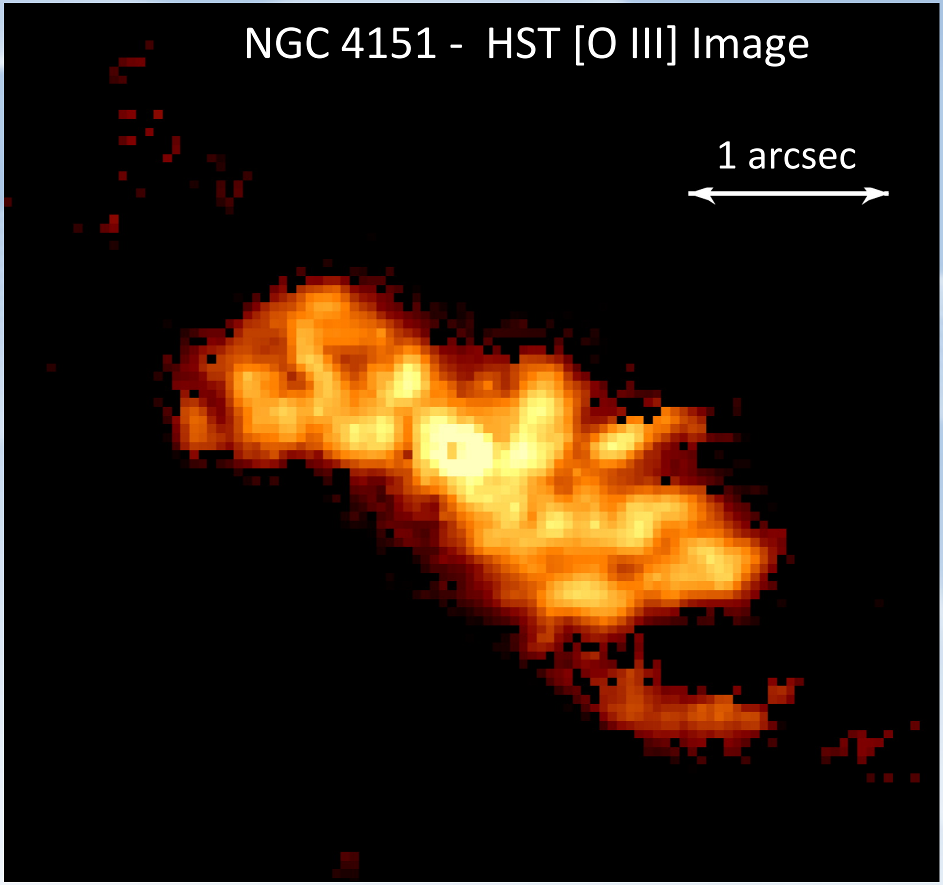


(Crenshaw & Kraemer, 2012, ApJ, 753, 75)

→ Most outflows have L_{KE} = 0.5% to 5% L_{bol} , which is required by AGN feedback models (Hopkins & Elvis 2010).

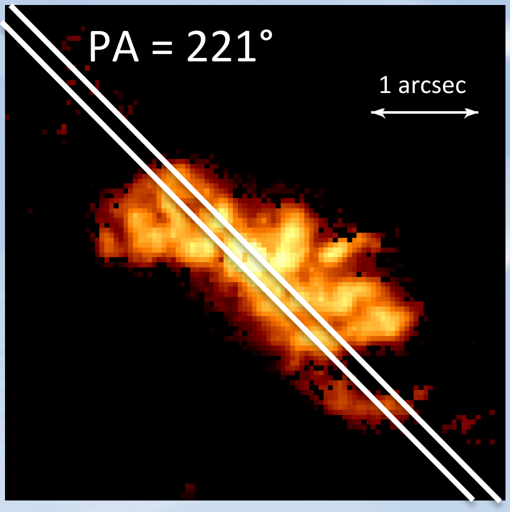
→ Absorbers contribute significant feedback in moderate luminosity AGN.

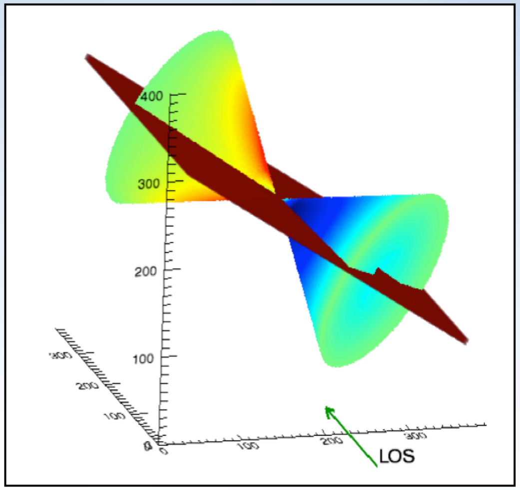
Large-Scale Outflows in the Narrow Line Region (NLR)
What is their impact?



→ They occur on the same scales as nuclear star formation (≤1 kpc), so could be crucial for black hole/bulge growth.

How do we determine mass outflow rates in the NLR?





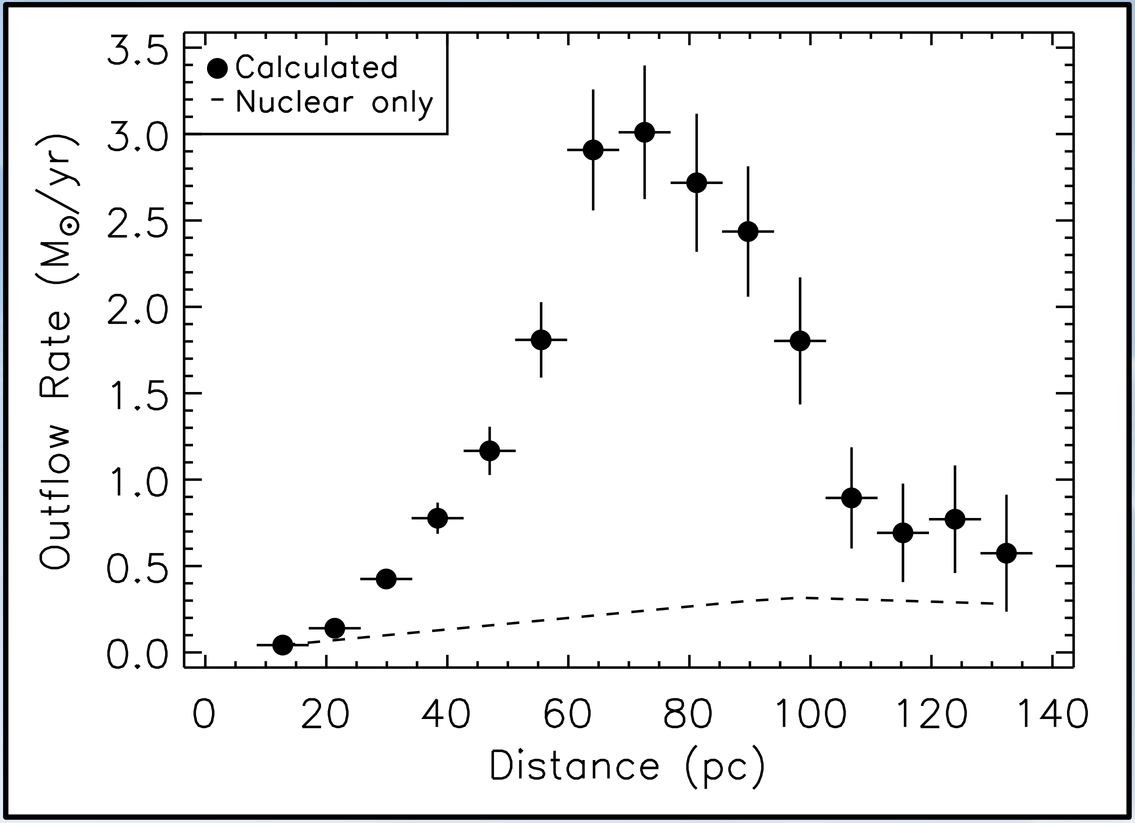
- Kinematic models from STIS medium-dispersion spectra to get velocity profile: v(r).
- Photoionization models of STIS low-dispersion spectra to get density profile: $n_H(r)$.
- Measure [O III] luminosities from HST images to get mass as a function of position (in elliptical annuli).

$$\Delta M \propto L[\mathrm{O\ III}]/n_H$$

$$\dot{M}_{out} = \Delta M \, \mathrm{v}(r)/\Delta r$$

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

Mass Outflow in the NLR of NGC 4151

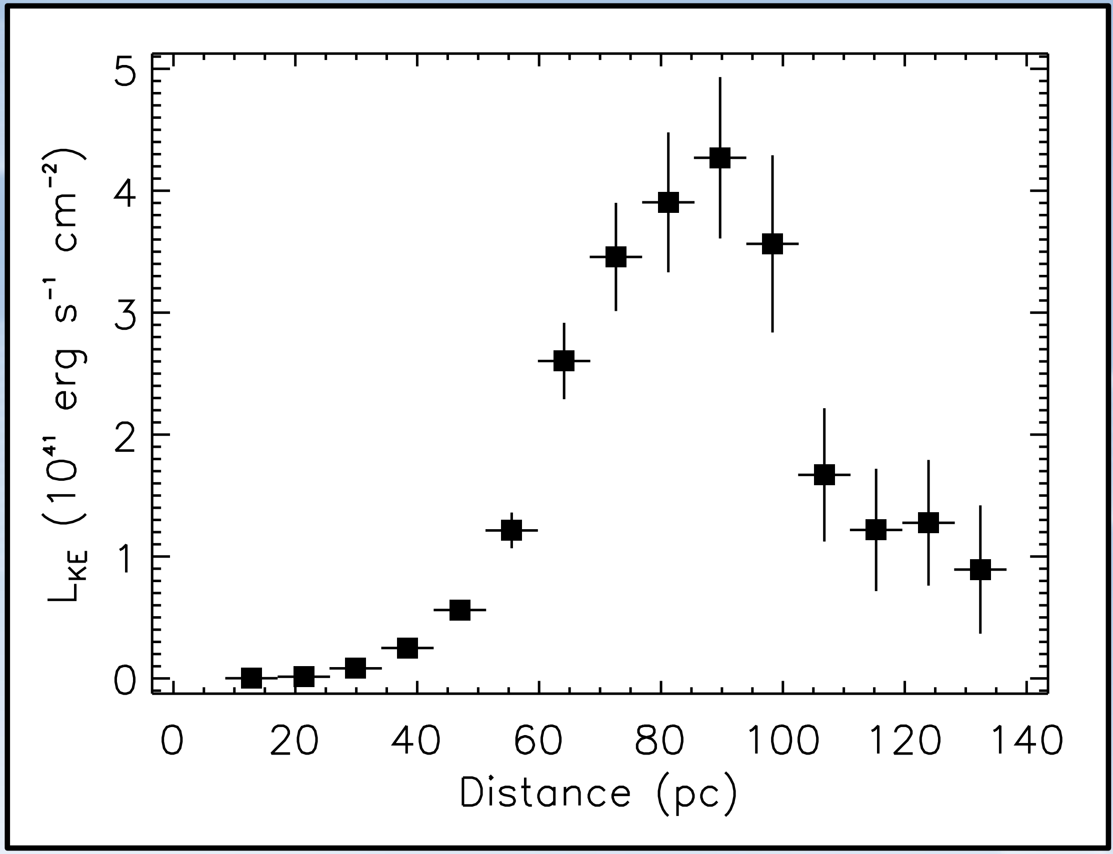


(Crenshaw et al., ApJ, in press)

- Mass outflow rate at peak is 10x that from nuclear outflow, 4 – 7x that of the UV/X-ray absorbers, and 230x mass accretion rate.

→ In situ acceleration of ambient gas in the NLR.

Kinetic Luminosity in the NLR of NGC 4151



(Crenshaw et al., ApJ, in press)

- L_{KE}/L_{bol} = 0.6% – 0.8%; (our benchmark for AGN feedback ~ 0.5%).
- Most of the kinetic energy is deposited ~100 pc from the SMBH.

Conclusions

- UV/X-ray absorbers and NLR clouds are outflowing in nearby AGN on scales of 0.1 – 1000 pc.
- Absorber mass outflow rates can be 10 – 1000 times the accretion rates.

  → Most of the outflow originates outside the accretion disk.

  Kinetic luminosities of the absorbers can be 0.5% to 5% of the bolometric luminosities.

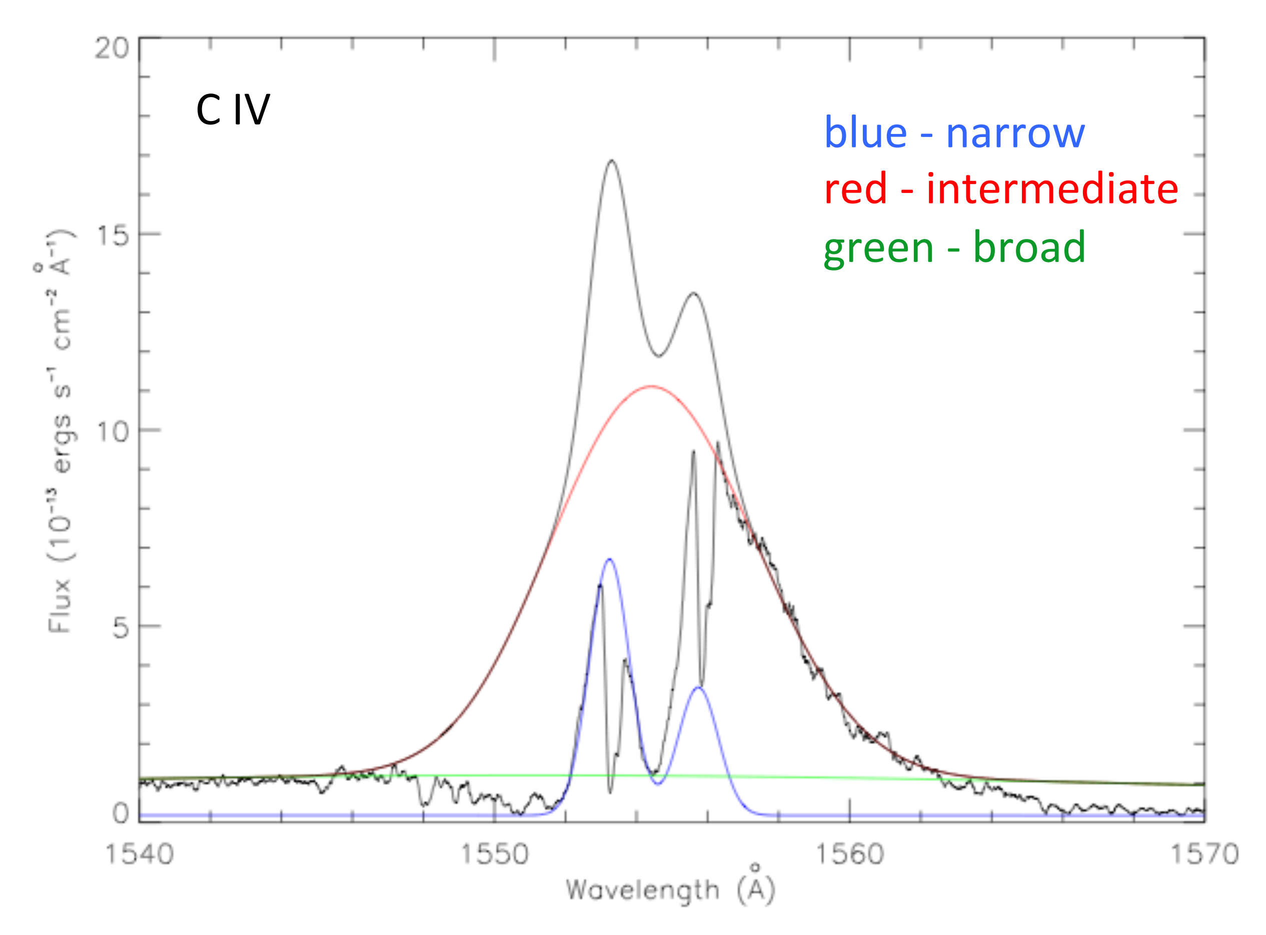
  → They likely provide significant feedback in these AGN.
- NLR outflows may provide even more feedback than outflowing absorbers (based on NGC 4151).

  → In situ acceleration from a fueling flow and/or reservoir of gas.

  → Occur on scales appropriate for termination of star formation.

The End

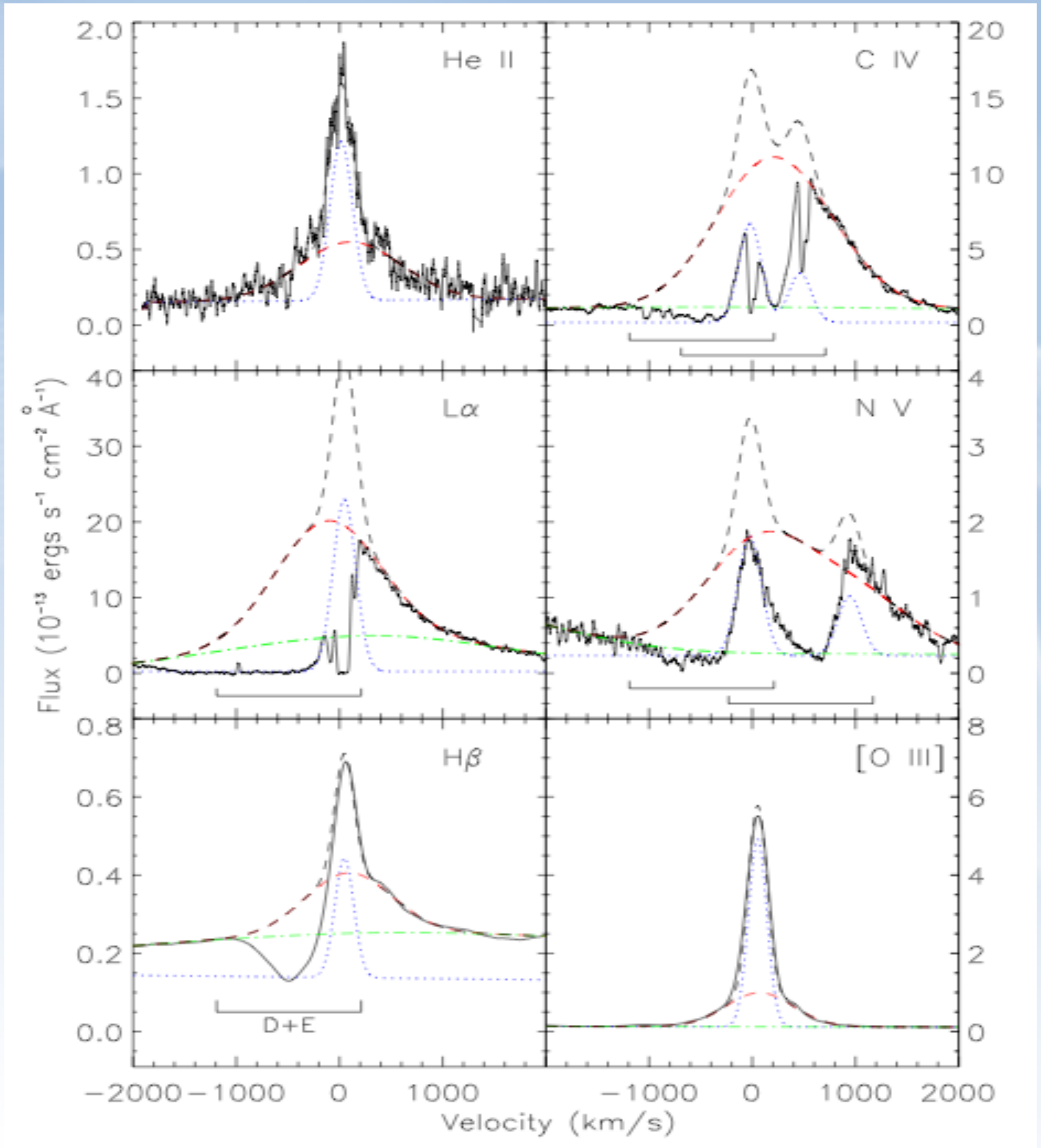
NHC 4151 has an Intermediate-Line Region (ILR).



(Crenshaw & Kraemer, 2007, ApJ, 659, 250)

- FWHM (ILR) = 1170 km/s.
- Matches broad absorber in velocity extent and physical conditions, at ~0.1 pc from SMBH.

Emission-Line Profiles in NGC 4151 .

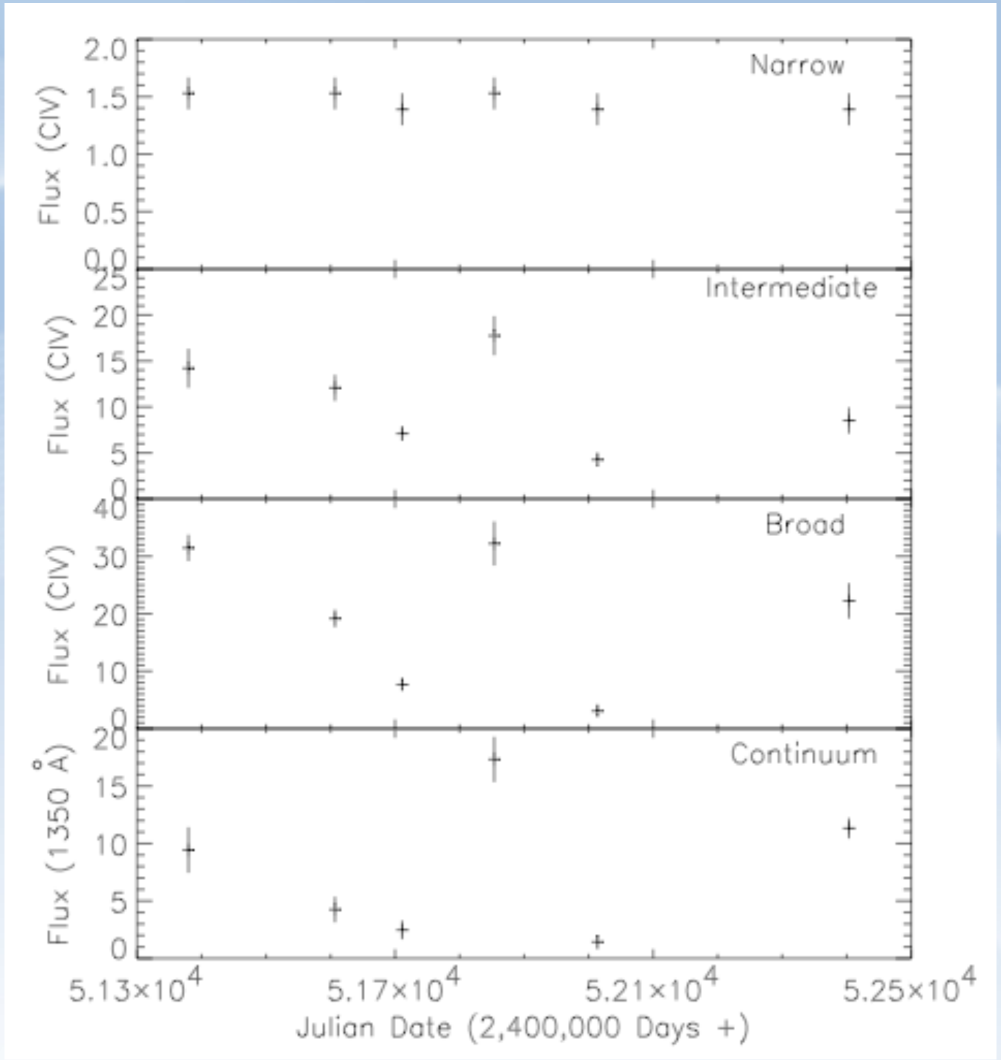


blue - narrow

red - intermediate

green - broad

Variability of C IV Emission Components



- Both BLR and ILR respond positively to continuum changes
- Size of ILR ≤ 140 light days (0.12 pc)