Seyfert Galaxy Outflows in Emission and Absorption

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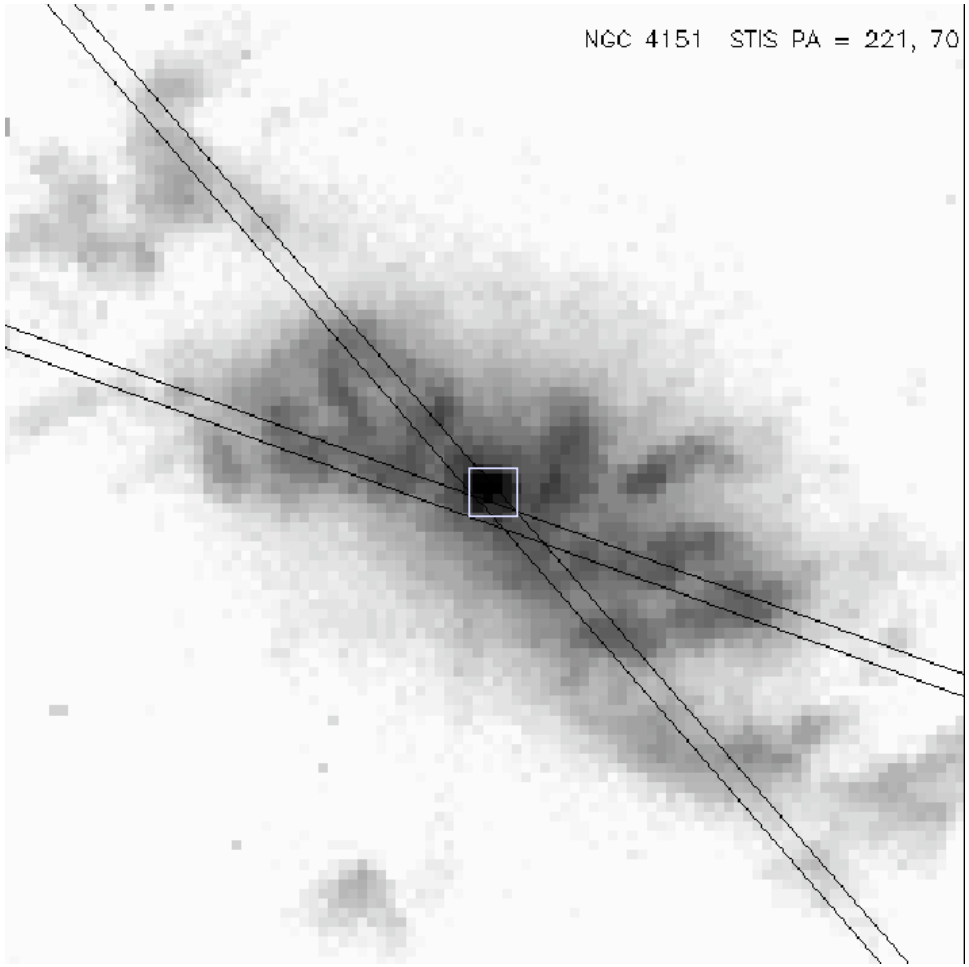
Mass outflows are found on all scales in Seyfert galaxies:

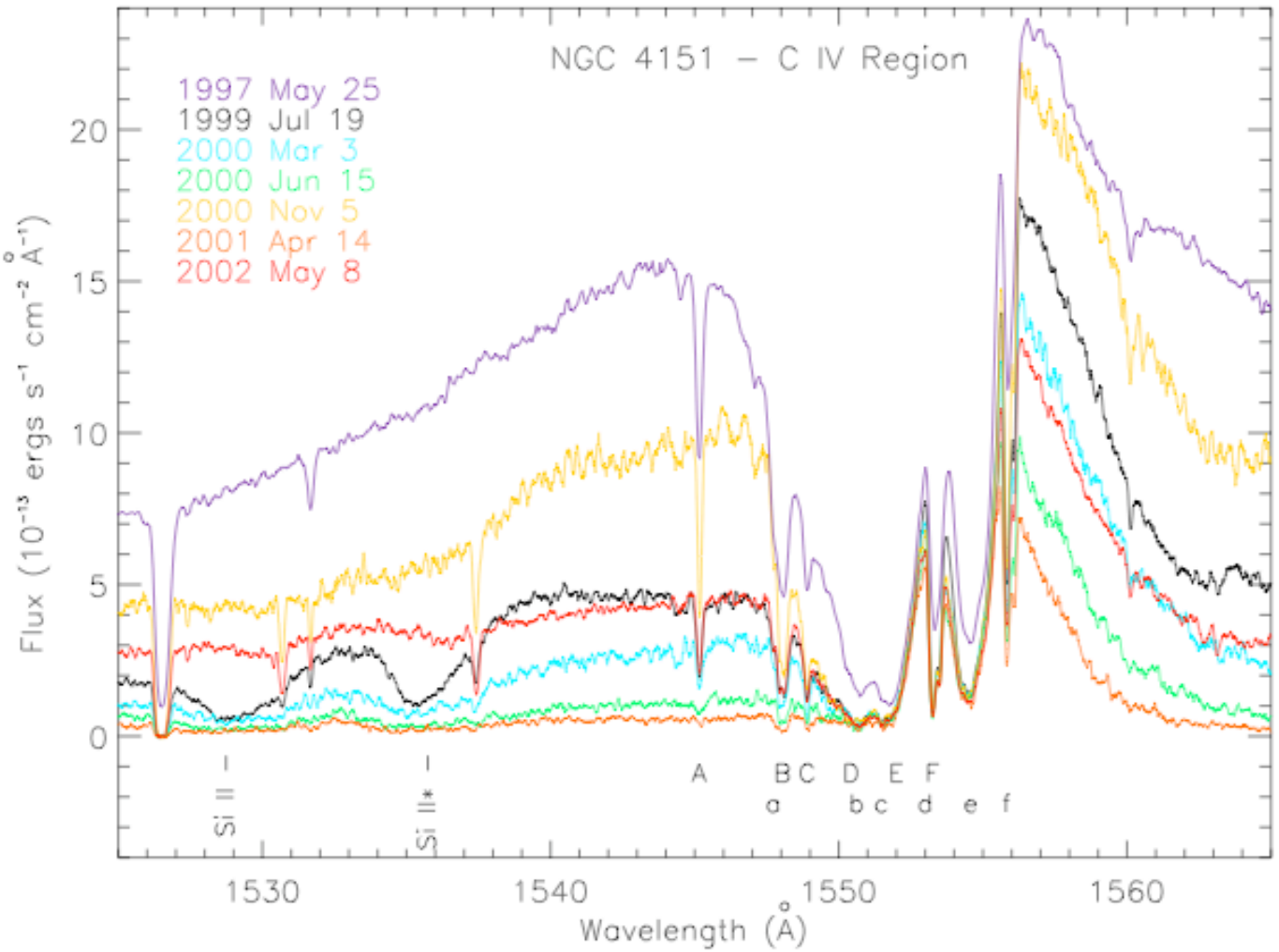
1) Close-in: High-column UV absorber in NGC 4151 located ~0.1 pc from continuum source - we have detected this component in emission.
2) In the middle: Many (most?) UV and X-ray absorbers are located tens of parsecs from the central source (inner narrow-line region).
3) Far out: The narrow emission-line regions (NLRs) of Seyferts are radially outflowing at hundreds of pcs - no evidence for jet acceleration.

1) Close-In: HST/STIS Observations of NGC 4151



NGC 4151
[O III] Image

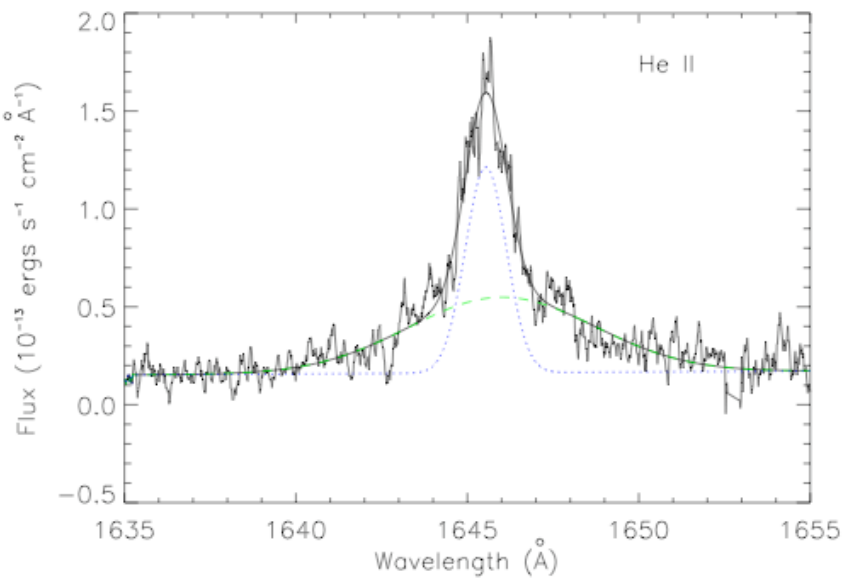
- STIS echelle observations (0.2" x 0.2" aperture) of central emission-line knot (including the nucleus)

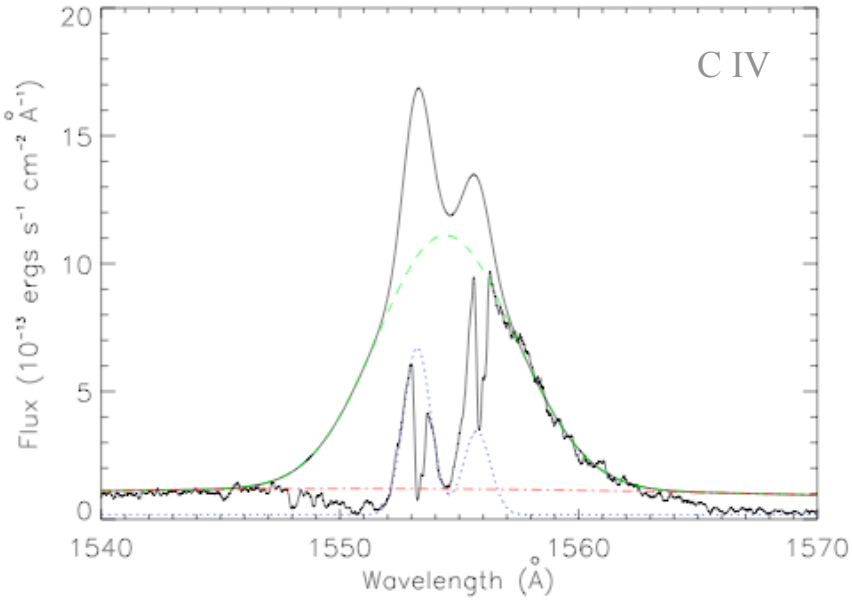


(Kraemer et al. 2005, in preparation)

- D+E (at v_r = -500 km s^{-1}) responsible for bulk of UV and X-ray absorption.
- D+E is ~0.1 pc from nucleus (based on metastable C III and Fe II)

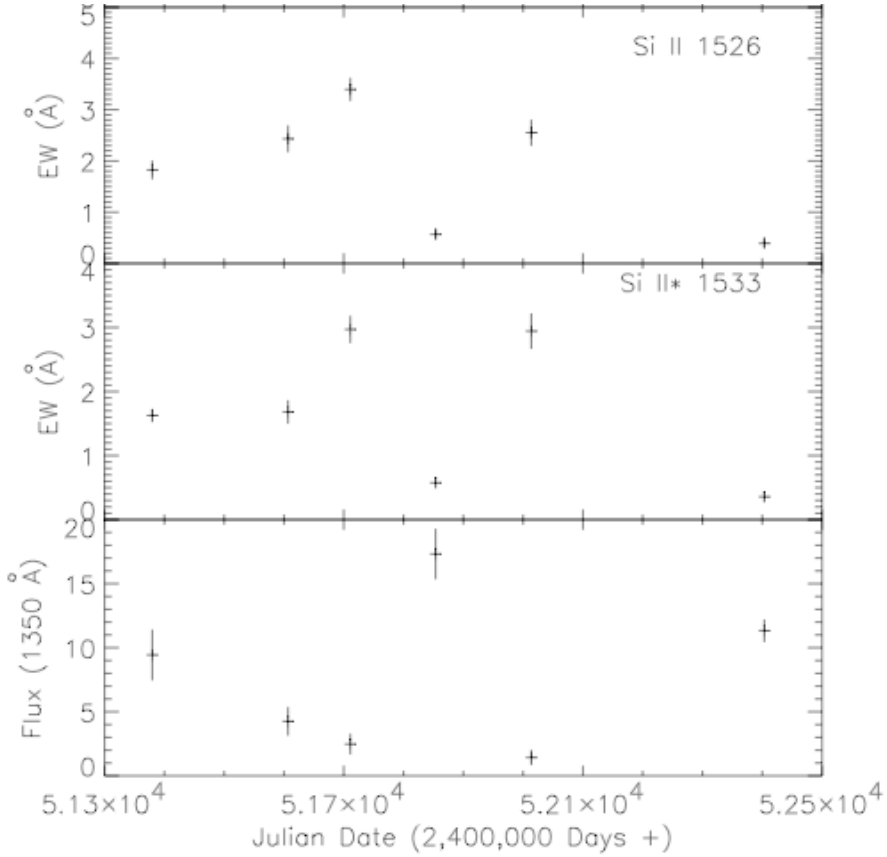
Emission-Line Profiles at Low Flux Levels





- Emission-line profiles have three components:
  narrow: 260 km s^{-1} FWHM, intermediate: 1150 km s^{-1}, broad: ~5000 km s^{-1}
- D+E absorbs intermediate component → P-Cygni - like profile?
  → likely the absorber in emission: C_g = 0.35 to 0.8 (large global covering0

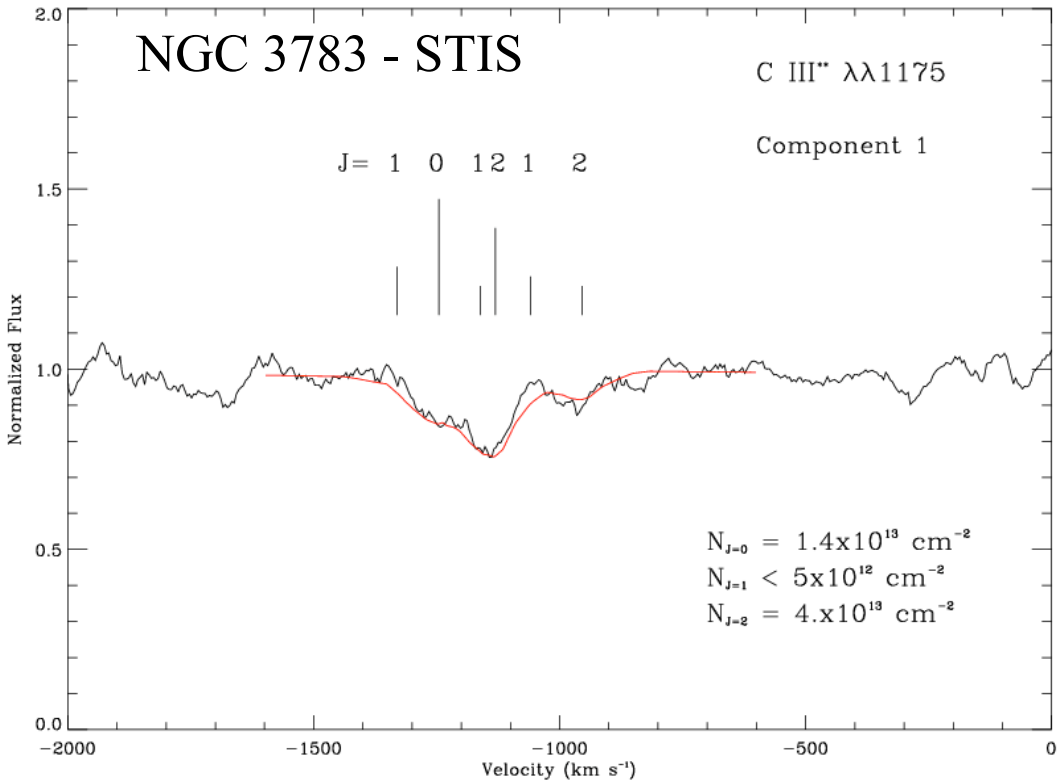
Varibility of D+E Absorption (1999 - 2002)



- EW(low-ion. lines) anti-correlated with continuum → ionization changes
- Last observation doesn't fit pattern → strong decrease in column and/or C_{los}
- Transverse velocity ≥ 1250 km s^{-1} (rotation velocity at 0.1 pc = 720 km s^{-1})

  → Expanding (rotating) spherical shell? Rotating accretion-disk wind?

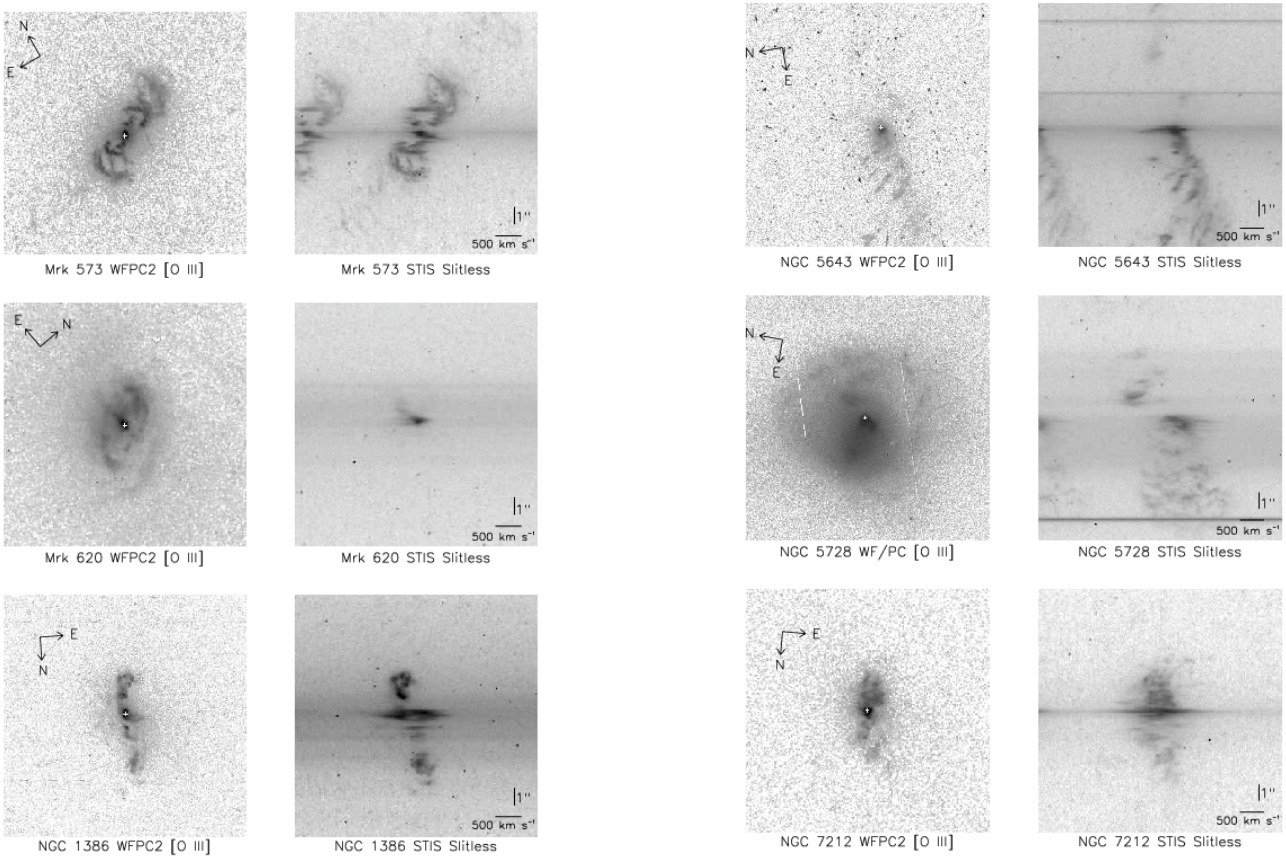
2) In the middle: UV absorber in NGC 3783



(Gabel, et al. 2005, ApJ, 631, 741)

- J=1 not populated: $n_H = 4 \times 10^4$ cm^{-3}
- Ionization parameter: U = 0.025 → r ≈ 25 pc ($U \propto L/r^2 n_H$)
- Other UV and X-ray absorber estimates: tens of parsecs
  (Crenshaw, Kraemer, & George, 2003, ARAA, 41, 117)

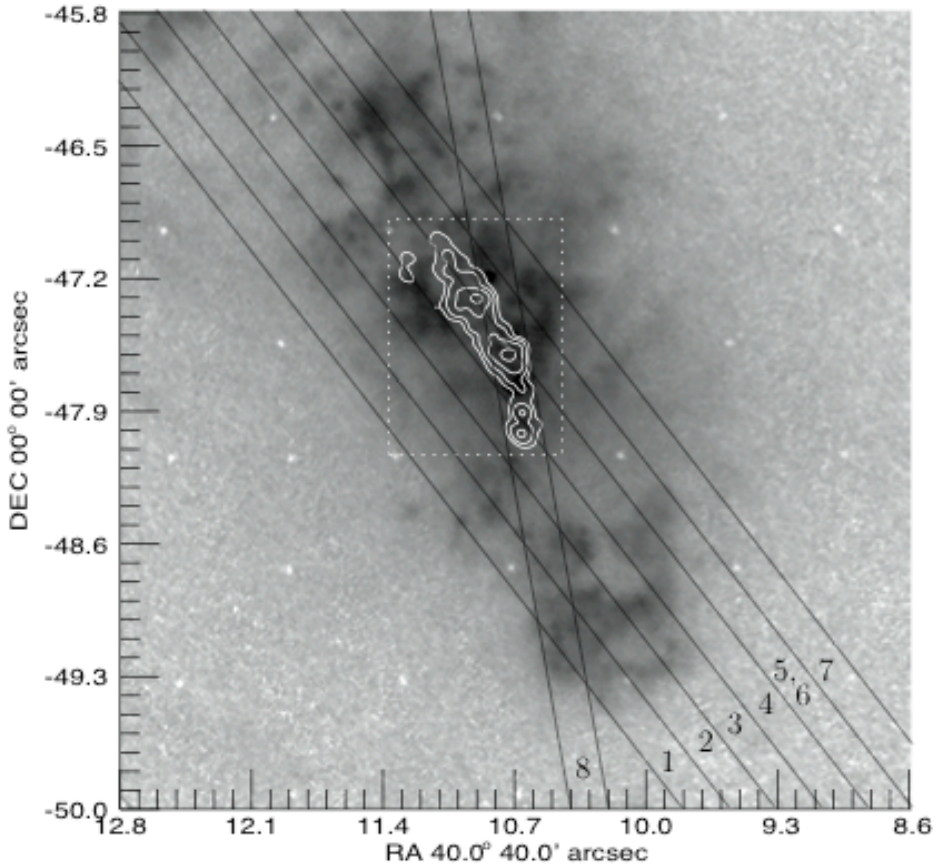
STIS Slitless Spectra of Seyferts



(Ruiz et al. 2005, AJ, 129, 73)

- Central emission-line knots: sizes on the order of tens of parsecs, velocities (HWZI) up to ~1000 km s^{-1} (similar to UV absorbers)
- Many UV absorbers arise from a diffuse component in the inner NLR (Crenshaw & Kraemer 2005, ApJ, 625, 680)

3) Far-out: Long-slit Spectroscopy of the NLR

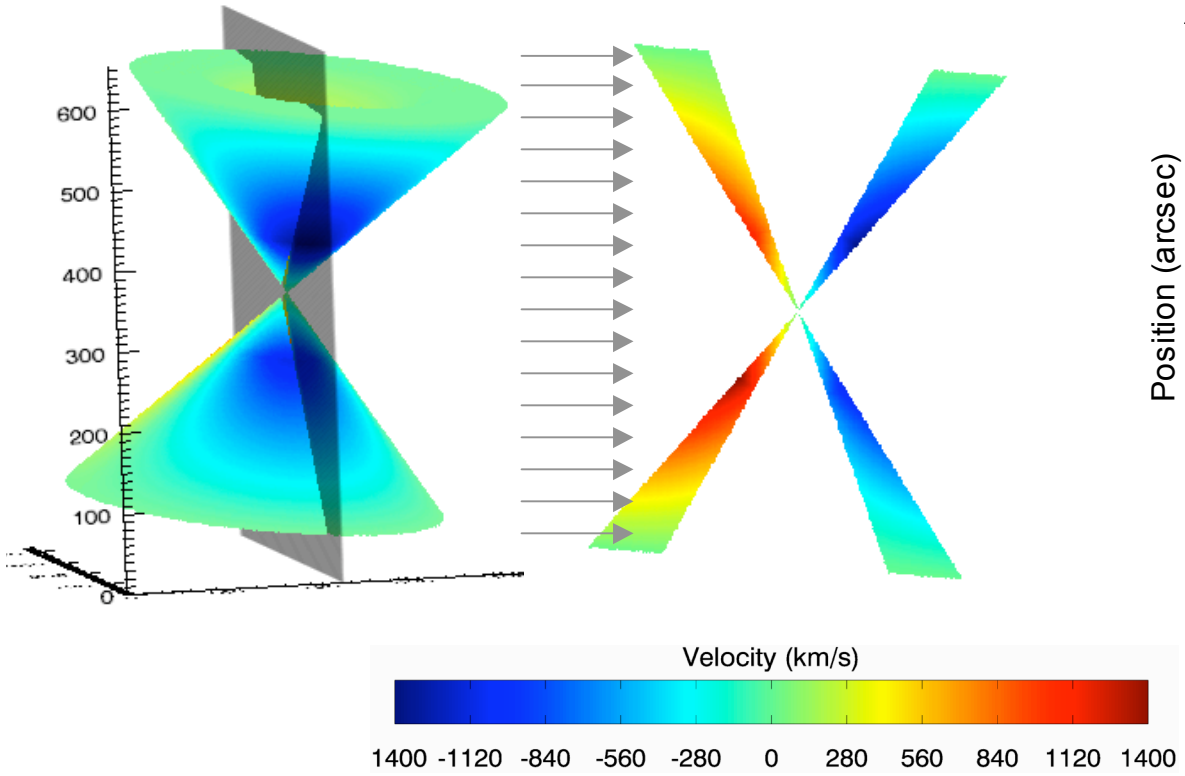


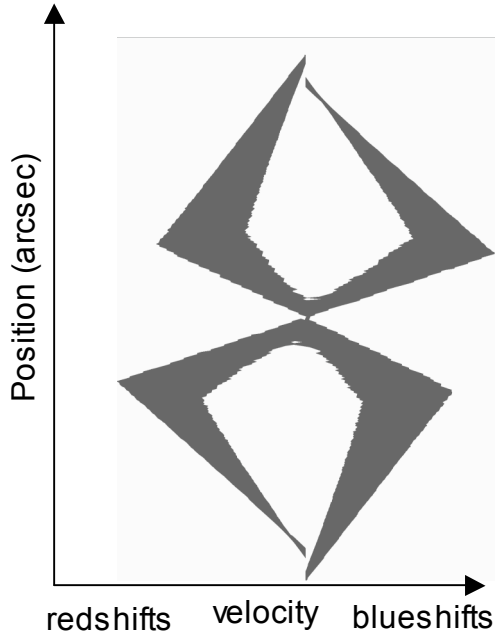
NGC 1068
[O III] Image

(Cecil et al. 2002; Das et al. 2005, in prep.)

- High-resolution spectra (R = 9000) confirm our claims of radial outflow from earlier, low-resolution (R = 1000) STIS spectra
- Based on kinematic models with a biconical geometry, clouds appear to accelerate to 1000 km s^{-1} at ~100 pc, then decelerate to systemic at ~400 pc

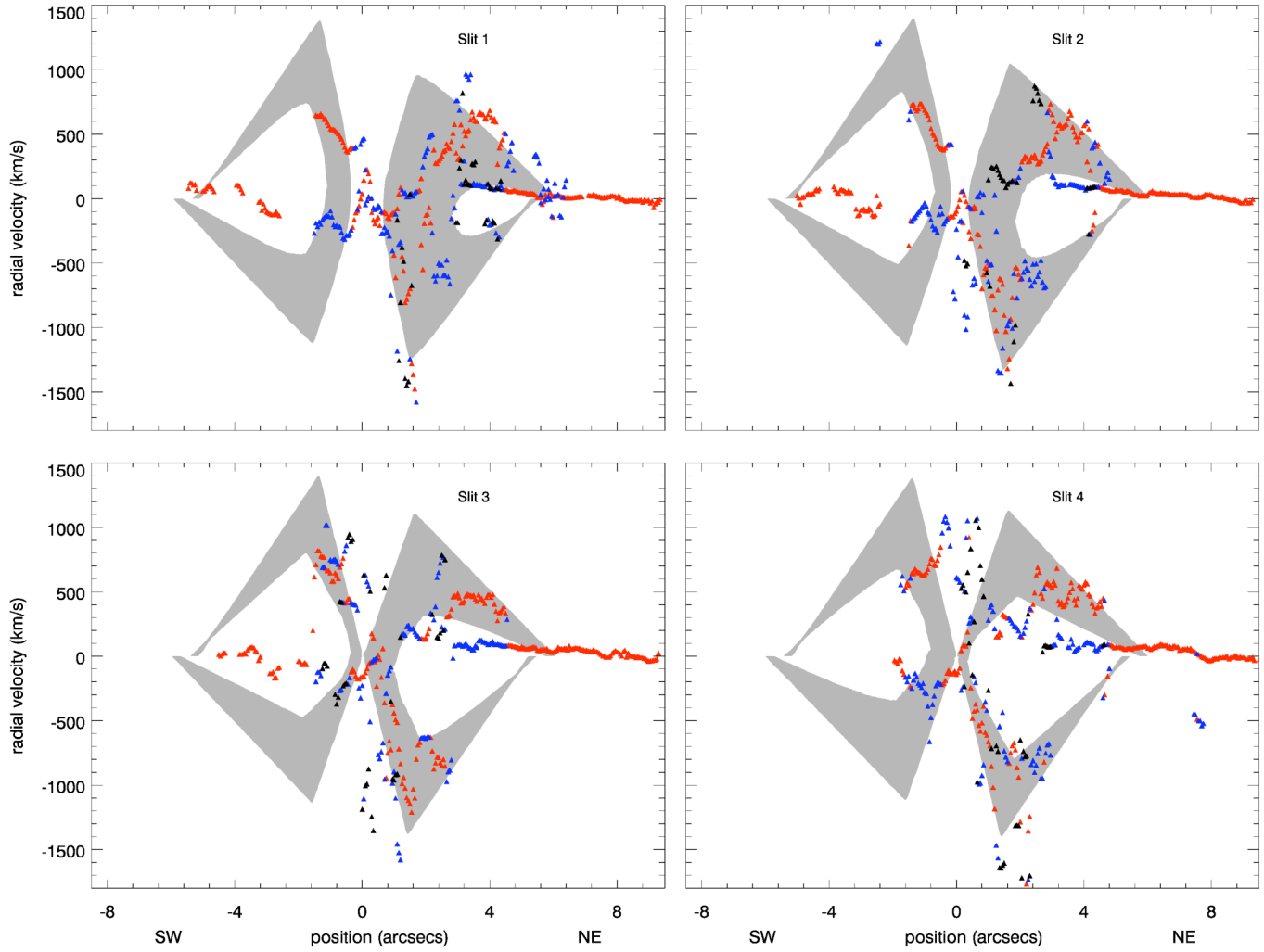
Kinematic Model of NGC 1068





Outer θ = 40°
Inner θ = 20°
Inc. θ = 5°
P.A. θ = 30°
Max Vel. = 2000 km s^{-1}
Turn. Pt. = 140 pc
Height of cone = 400 pc

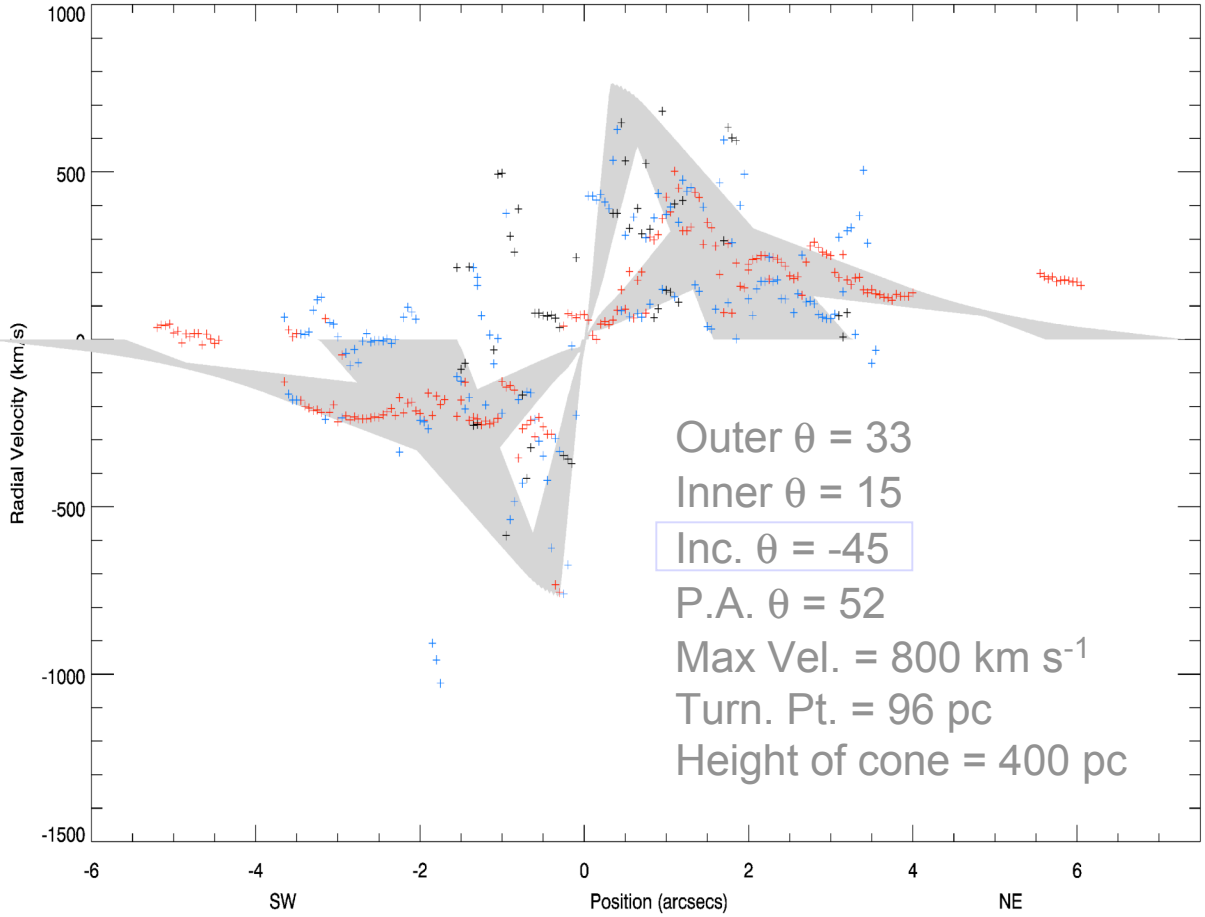
NGC 1068: Fit to Observed Radial Velocities



Components:
Red - bright
Blue - medium
Black - low flux

(Das et al. 2005, in prep.)

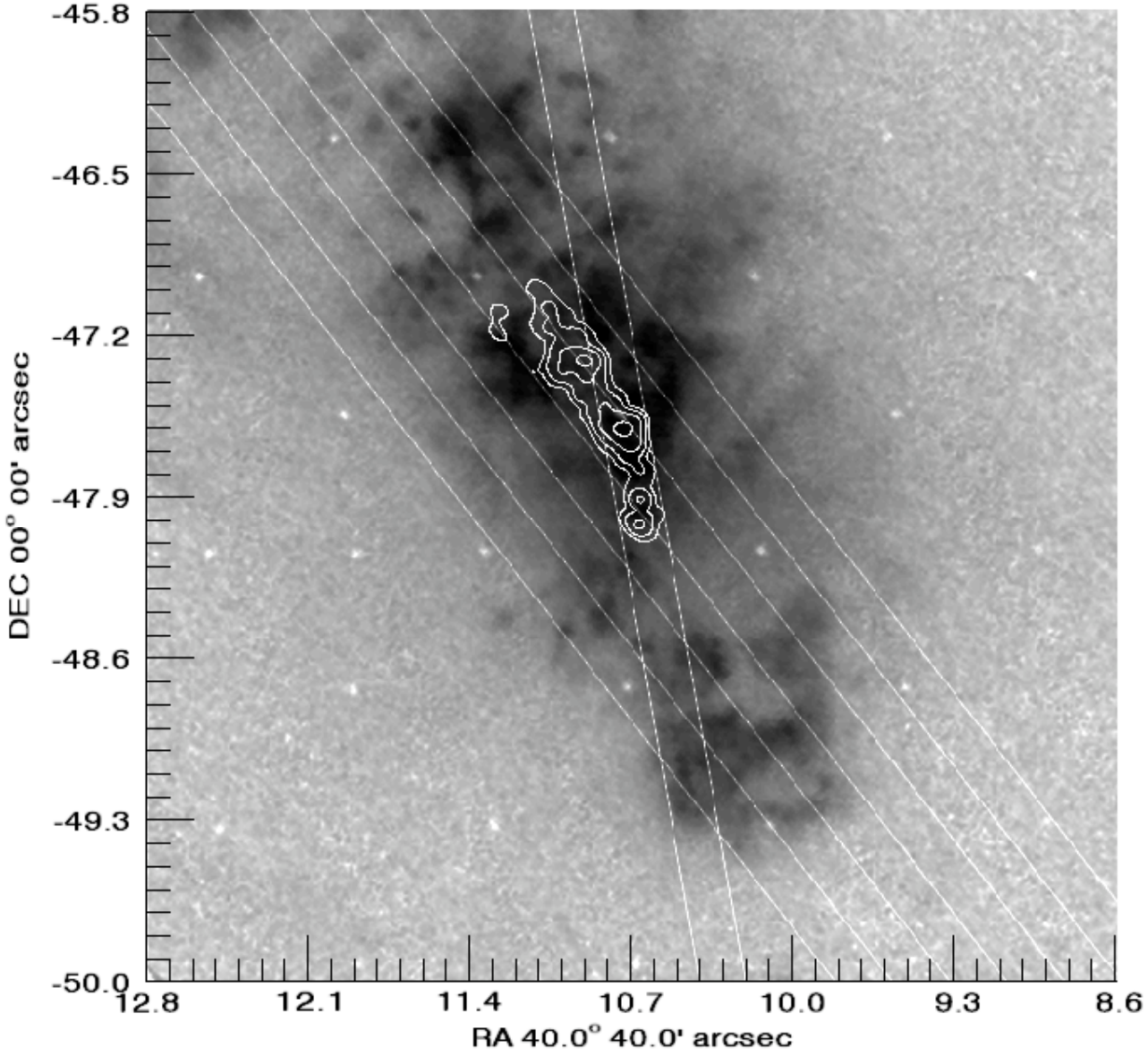
NGC 4151: Fit to Observed Radial Velocities



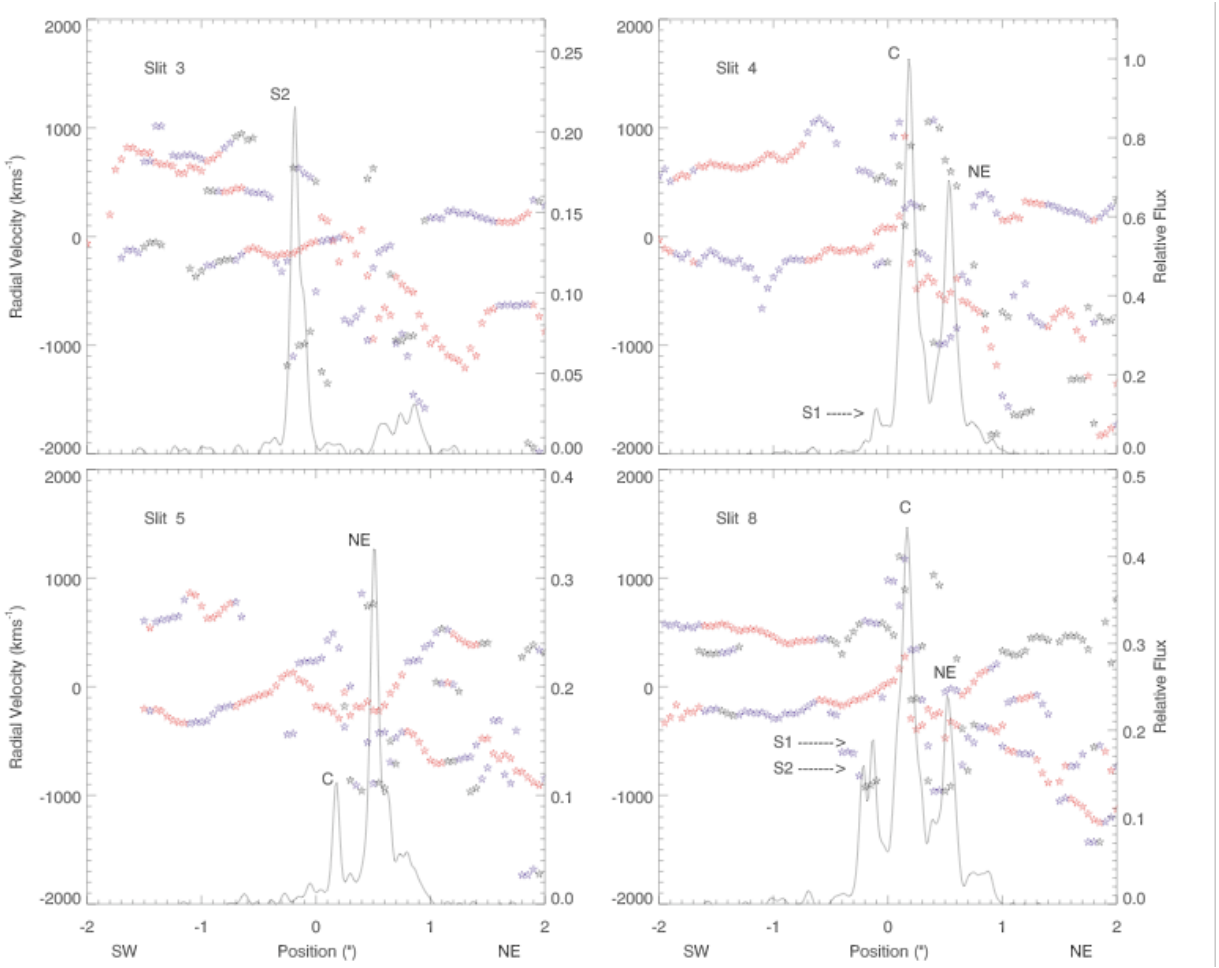
(Das et al. 2005, AJ, 130, 945)

- Mostly blueshifted in the SW, redshifted in the NE (Hutchings et al. 1997)
- Model closely resembles that for NGC 1068 (except for inclination)
  → Similar kinematics (radial accel. + decel.) in a Seyfert 1 and a Seyfert 2

Radio Knots in STIS Slits



NLR Kinematics and Radio Jet in NGC 1068



Components:
Red - bright
Blue - medium
Black - low flux

- Radio knots do not affect kinematics of bright NLR clouds
  (however they appear to be linked to the faint clouds)
  → No evidence for radial or lateral acceleration of bright clouds by jet

Summary

- High-column absorber in NGC 4151 is ~0.1 pc from nucleus
  - High transverse velocity, comparable to rotation velocity
  - Seen in emission → Global covering factor = 0.35 to 0.8
  - Strongest candidate yet for accretion-disk wind?
- High-velocity absorber in NGC 3783 is ~25 pc from nucleus
  - Other estimates for UV and X-ray absorber give tens of parsecs (but these are often upper limits)
  - Absorbers from a diffuse component in the inner NLR?
- NLR clouds at 10 - 400 pc are radially outflowing
  - Accelerated to ~1000 km s^{-1} or more at ~100 pc (not likely due to jets)
  - Decelerated to host galaxy velocities at ~ 400 pc
  - Drag force from surrounding medium?