Intrinsic Absorption in Active Galactic Nuclei

UV and X-ray Observations of Two Seyfert 1 Galaxies

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Introduction

- AGNs host substantial volumes of photoionized gas near their central engines, seen in absorption against the underlying continuum
- "Warm absorber" (Halpern 1984) invoked to explain Einstein observations of variable X-ray absorption in MR 2251-178 ($T \sim 10^5$ K)
- Early X-ray observations showed edges, mainly from OVII and OVIII, but with new generations of X-ray telescopes (*Chandra, XMM-Newton*) we can resolve resonant absorption lines
- Outflows~100-1000 km/s Velocity widths~100 km/s
- Approx. ½ of all low redshift AGNs show warm absorption (Reynolds 1997, George et al. 1998, Crenshaw, Kraemer, & George 2003, ARAA)
- The correspondence between X-ray absorption and UV absorption is nearly one-to-one (Crenshaw et al. 1999)
- Higher resolution in UV allows the identification of multiple velocity components

Characteristics of Intrinsic Absorption:

- Absorption is generally blueshifted with respect to z_{em} with widths indicating bulk outflows
- Absorption is highly-ionized and often variable
- Covering fractions are non-unity for many UV absorbers (absorption depth > height of continuum)

Questions:

* Where are the absorbers located?
* How do they affect the energetics of the AGN?

Absorption profile

BLR and continuum: l = line, c = continuum

$$I = R_l[C_l e^{-\tau} + (1-C_l)] + R_c[C_c e^{-\tau} + (1-C_c)]$$

$$C_l = C_c = C_{eff} \quad \longrightarrow \quad I = C_{eff} e^{-\tau} + (1-C_{eff})$$

- For doublets, where $\tau_{blue} = 2\tau_{red}$, solve for 2 unknowns
- For a line series, eg. the Lyman series, solve for optical depth and for the line and continuum covering fractions:

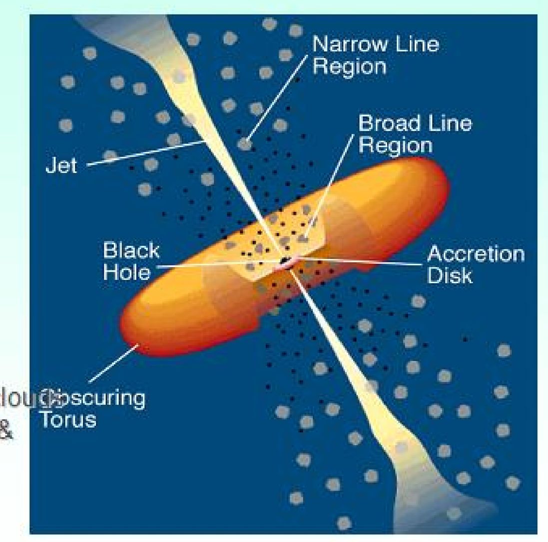
$$\chi^2 = \sum_{i=\mathrm{Ly}\beta,\ldots} \left(\frac{I_i^c - I_i}{\sigma_i}\right)^2 \qquad \tau_i^x = \frac{f^x\lambda^x}{f^\alpha\lambda^\alpha}\tau_i^\alpha$$

observed

Scott et al. 2004

Where intrinsic absorption might arise:

- Accretion disk
  - thermal, radiative, MHD winds Begelman et al. 1983, Konigl & Kartje1994, Murray & Chiang 1995, Proga et al. 2000
- Dusty torus
  - Evaporation
  - Two-phase medium
  - Analogy with dense molecular clouds in SFRs, eg. Eagle Nebula Krolik & Kriss 1995, 2001
- BELR/NELR



Urry & Padovani 1995

Ionization state of gas depends on:

- Luminosity & spectrum of the continuum source
- Distance of absorbing gas from the continuum source, line-of-sight structure
- Density & abundance of absorbing gas
- Variability of continuum source, bulk motions of absorbing gas

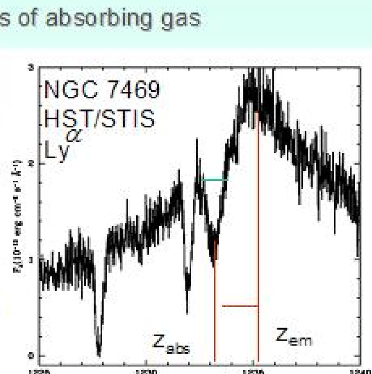
Basic Observations

- Outflow Velocity [1]
- Velocity width [2]
- Optical depth — Column density

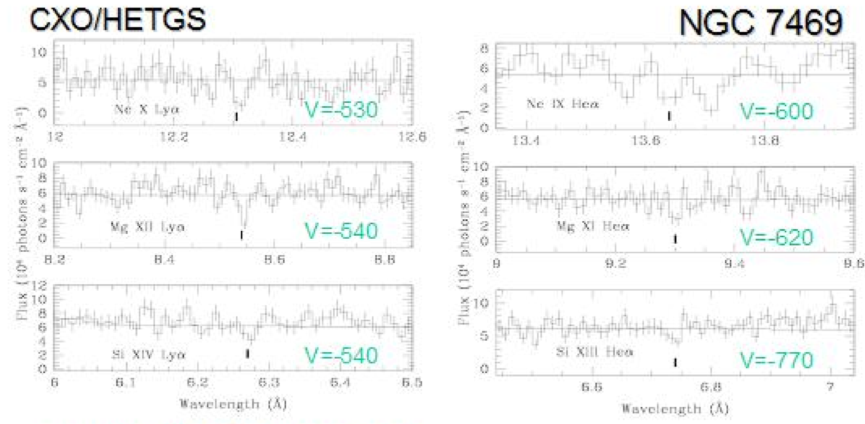
$$N(v) = \frac{m_e c}{\pi e^2 f \lambda}\tau(v)$$

(Savage & Sembach 1991)

- Covering fraction

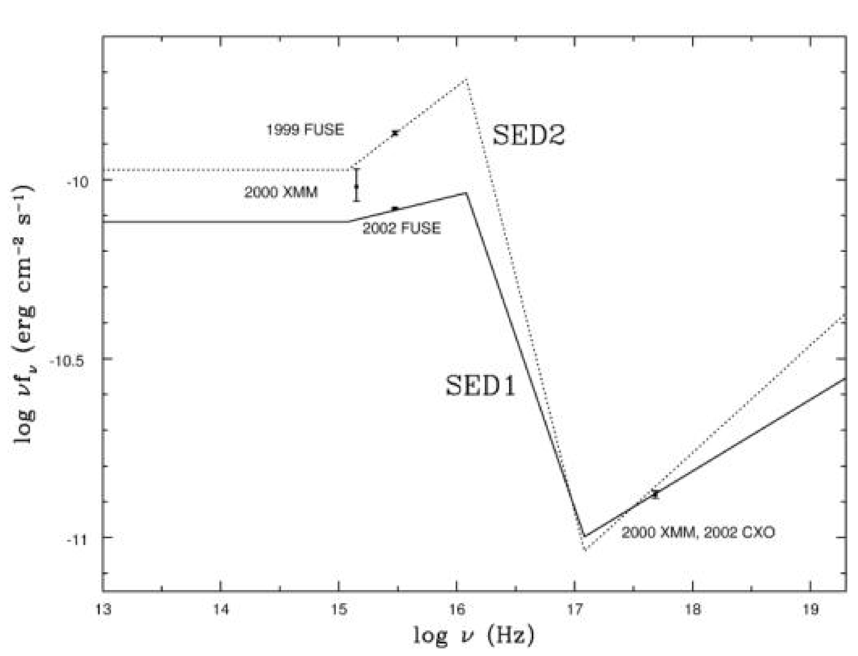


CXO/HETGS

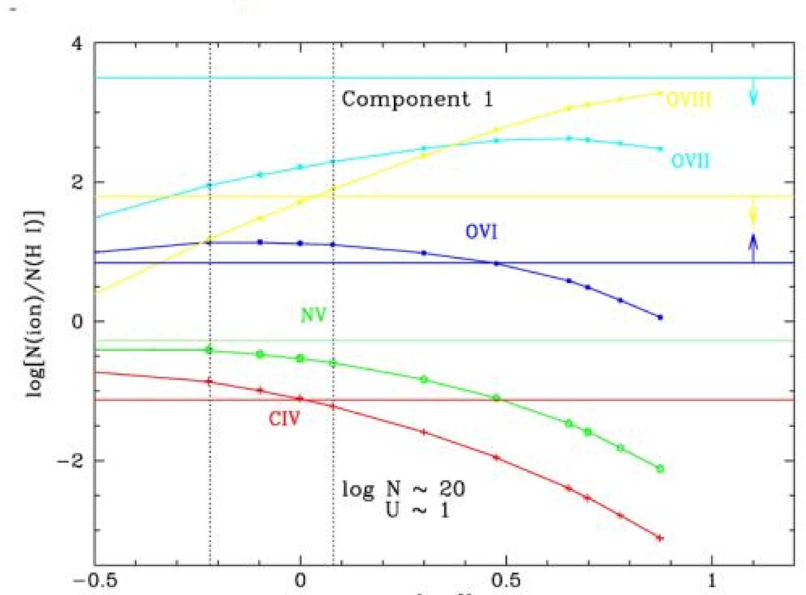


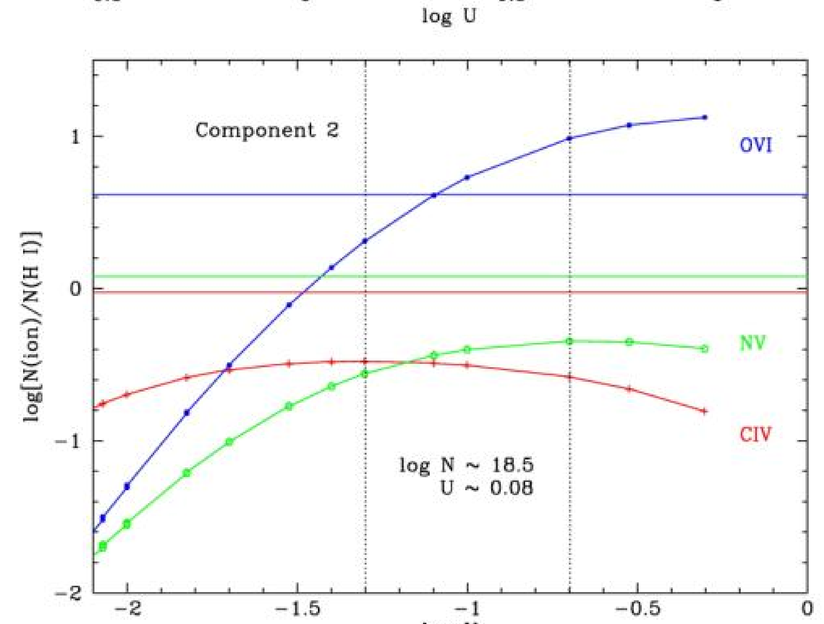
- H-Like and He-Like Ne, Mg, & Si
- V_{out} consistent with Component 1 of UV absorption

Scott et al. 2005



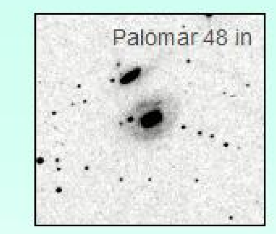
FUSE, STIS, CXO simultaneous observations provide important constraints on ionization state through HI, CIV, NV, OVI, OVII, OVIII column densities + AGN SED all measured at the same time



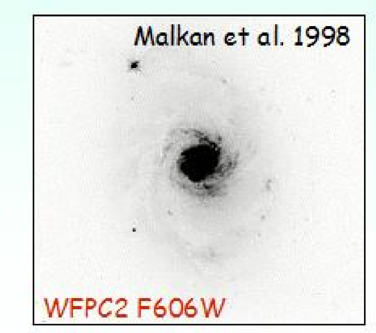


NGC 7469

- Seyfert 1 galaxy, z=0.0164
- Studied previously with FUSE (Kriss et al. 2003) and XMM-Newton observations separated by one year (Blustin et al. 2003)
- 2002 Dec.- Obtained FUSE, STIS, and Chandra/ HETG spectra, the first set of simultaneous, high-resolution UV and X-ray observations
- Two primary components in the UV:
  - V_{sys}= -570 km/s Component 1
  - V_{sys}= -1900 km/s Component 2
- Component 1: high-ionization X-ray absorption and emission component, C_l=0.5 it is coincident with or interior to the BELR
- Component 2 is of lower ionization and has no associated X-ray absorber

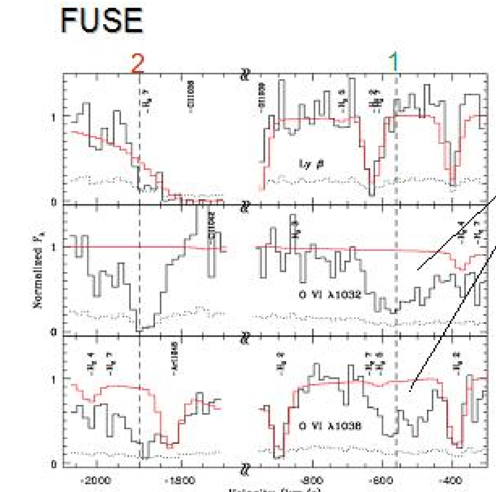


3 arcmin



0.6 arcmin

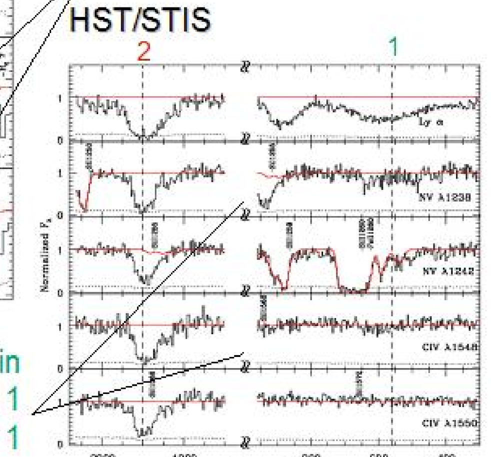
FUSE



NGC 7469

O VI in Component 1 saturated

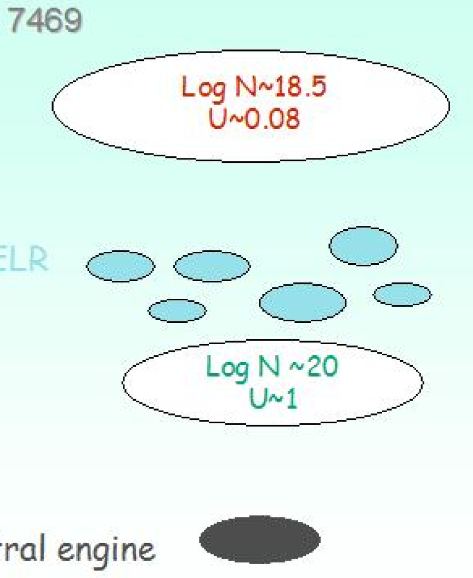
HST/STIS



Weak N V, C IV in Component 1 constrains U ~ 1

Scott et al. 2005

NGC 7469



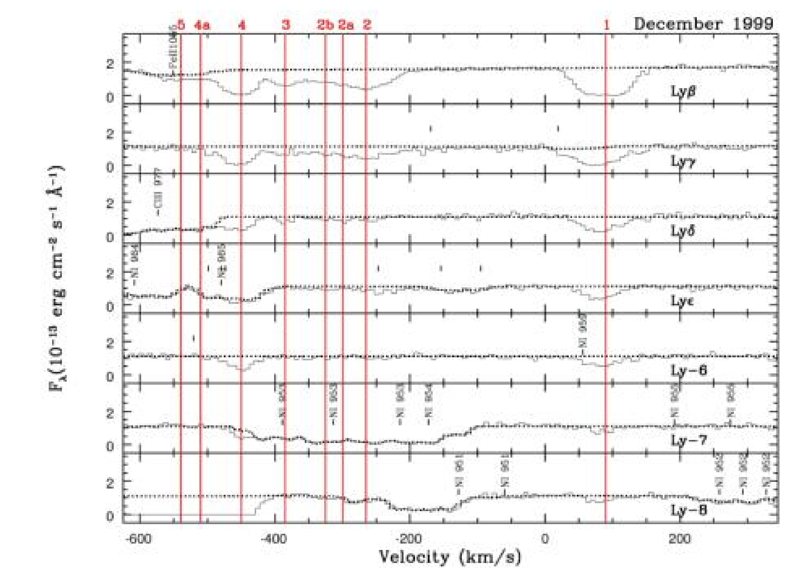
Component 2
V=1900
Lower ionization, not seen in X-ray

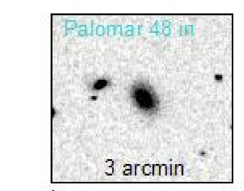
Component 1
V=570
Variable, small covering fraction, high U, absorption in X-ray

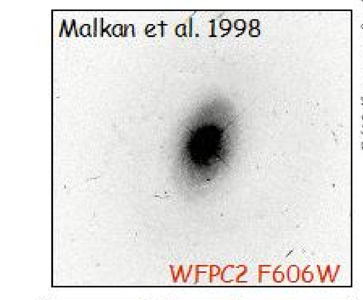
Blustin et al. 2003

Mrk 279

- Seyfert 1 galaxy z=0.0305
- Five velocity components of UV absorption, 4 FUSE epochs







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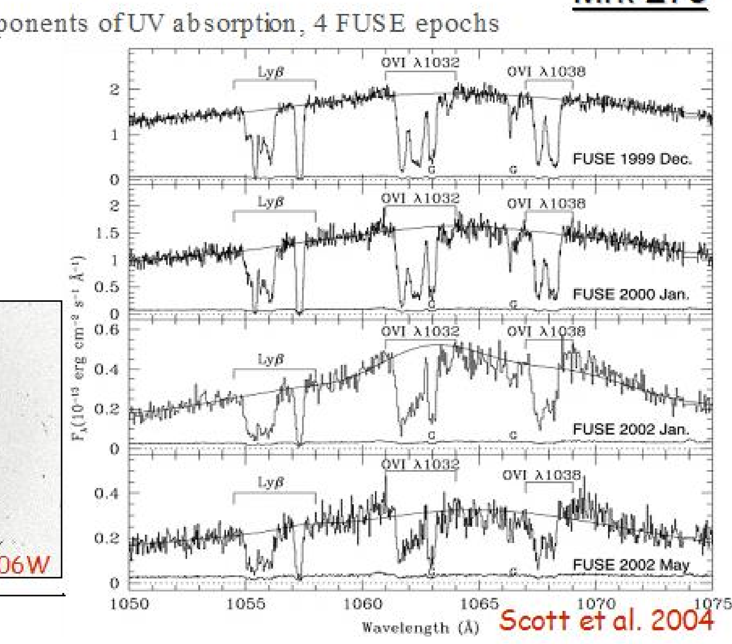
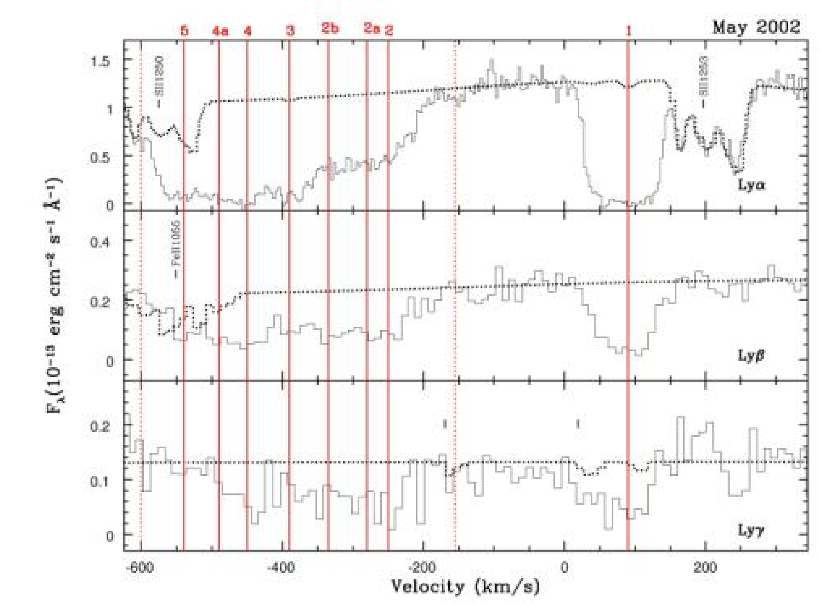
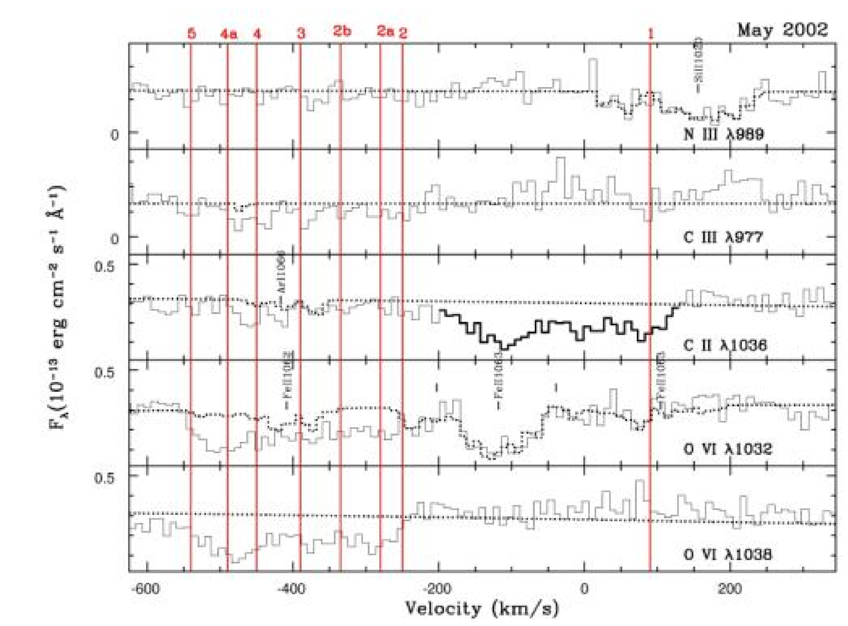


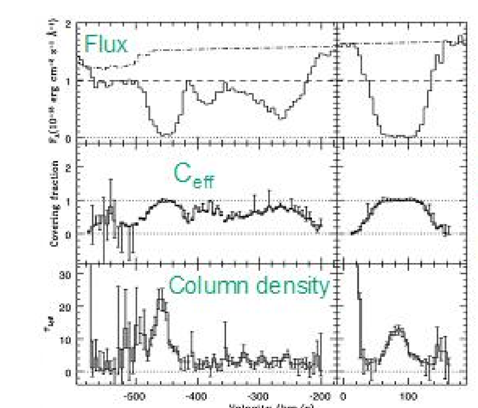
Scott et al. 2004



- Mrk 279 FUSE spectrum covers Lyman series to Ly-8! (Dec 1999)
- Last epoch (2002 May): simultaneous FUSE, HST, & Chandra spectra
- AGN in a low state- limited Ly series coverage, no X-ray absorption detected

Scott et al. 2004

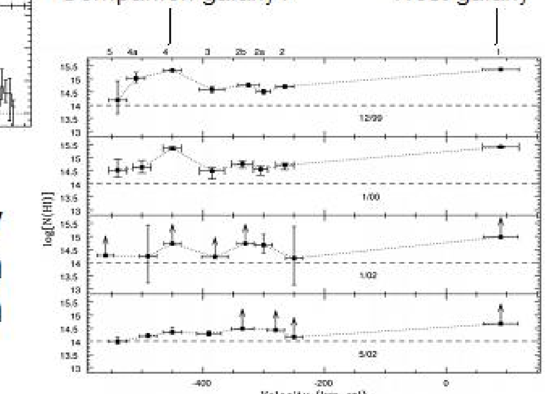




Mrk 279

Trace covering fraction and column density across absorption profiles

Companion galaxy? Host galaxy



Column density changes with observation epoch

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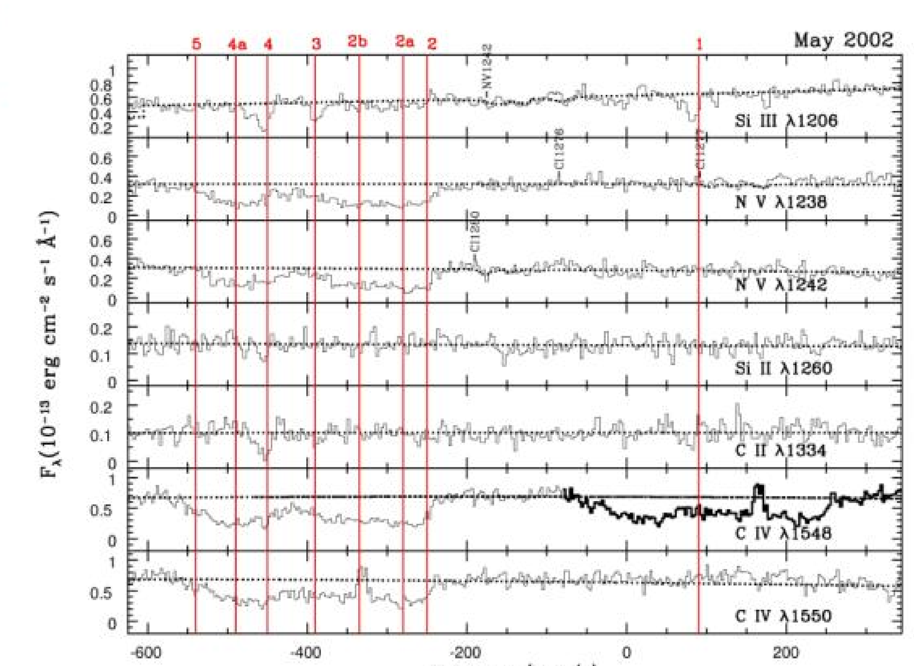

Mrk 279

- Component 1: Large N_{HI}, C_{eff}=1, no variability
- Component 2: strong HI, O VI, few low-ionization metal lines, C_{eff} < 1, variable absorption
- Component 4: strong H I Lyman series, prominent C III, N III, & Si III, detectable C II, N II, & Si II, strong O VI, C IV, & N V, C_{eff} = 1
  - High-ionization profiles different from those of the low-ionization lines velocity offsets and larger velocity widths.
  - N_{HI} decreased by a factor of 10 as the UV continuum flux decreased by a factor of 7
  - Host galaxy ISM contributes to the total absorption in this component
- Components 3, 5: low-ionization lines with profiles different from high-ionization lines and marginal variability like Component 4's, but C< 1 and large v_{out} Galactic fountain? Interatction with companion, MCG+12-13-024?