Original Title:

High Resolution Spectroscopy of AGNs and GRBs

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Quasar Wind Physics

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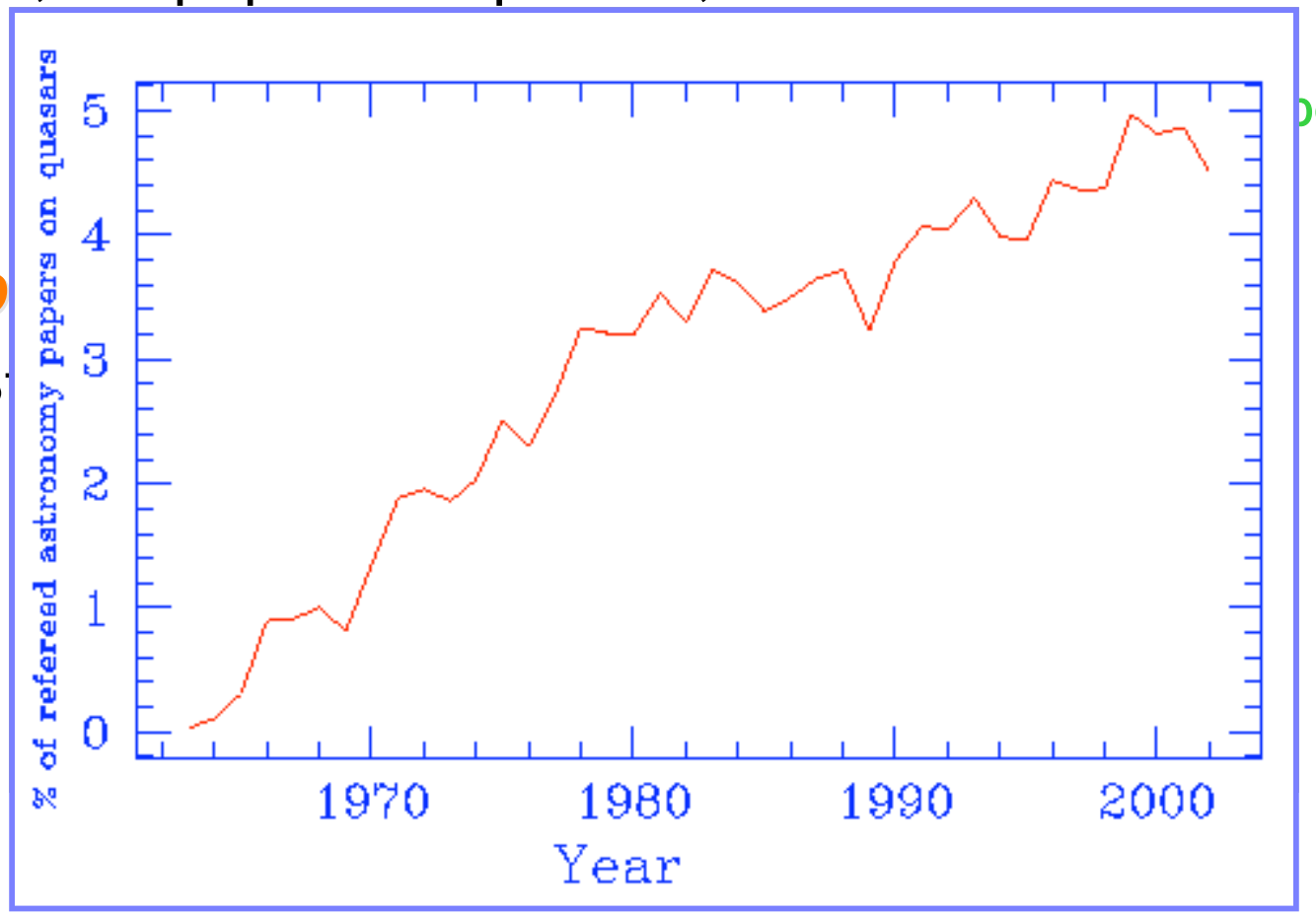
40 Years of Quasars

12,277 papers on quasars, AGN since 1963 ADS to 4/18/03



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on-spherical geometry

Physical quantities for AGNs, quasars

- **Reverberation mapping:**
  - Sizes (cm)
  - Keplerian motion
  - Black hole masses
- **Polarization:**
  - Degree of flattening/non-sphericity
  - Orientation
- **Warm absorber variability**
  - **A Con-X strong point**

Winds from AGNs & Quasars

- Newly recognized as semi-universal
- Dynamically important $m_{dot} >\sim 0.1 m_{dot}(acc)$
- Pulls together *all* atomic features in AGNs?

"Quasar Atmospheres"

- *Time variability -> physical quantities*
- <u>Qualitative</u> advance in understanding AGNs

AGN `Warm Absorbers'

- Discovered by Jules Halpern (Columbia) 1984
- Several talks here already: Kaastra, Blustin, Ogle, Kinkhabwala, Chartas
- OVII, OVIII edges dominate in ROSAT, ASCA. -> highly ionized (U~1)
- Photoionized:
  - respond to continuum changes
  - But in a complicated way.
- *Chandra* & XMM: ~1000km/s outflow or **wind**
- *WA have <u>potential</u> to deliver much physics*

Warm Absorber *Variability* gives physics

See: Mathur, Elvis & Wilkes 1995 ApJ 452, 230.

Nicastro, Fiore, Perola & Elvis 1999, ApJ 512, 184

Fully characterized plasma:

- Density n_e*:* recombination/ionization time lag to cont. changes
- Radial Distance, r*:* n_e, ionization parameter (n_{ph}/n_e), L_{cont}
- WA thickness, δr*:* N_H, n_e
- WA temperature, *T:* amplitude of response to cont. changes.
- Pressure, P: n_e, T
- Mass outflow rate, m_{dot}: n_e, velocity v (*$f_c \cos\theta$, as in binary masses)

Warm Absorber Variability physics

So far only a few examples:

- NGC5548 (ROSAT/IUE) *Mathur, Elvis & Wilkes 1995 ApJ 452, 230.*
- NGC4051 (ROSAT) *Nicastro, Fiore, Perola & Elvis 1999, ApJ 512, 184*
- NGC3516 (HETGS, but low state) *Netzer et al. 2002 ApJ 571 256*

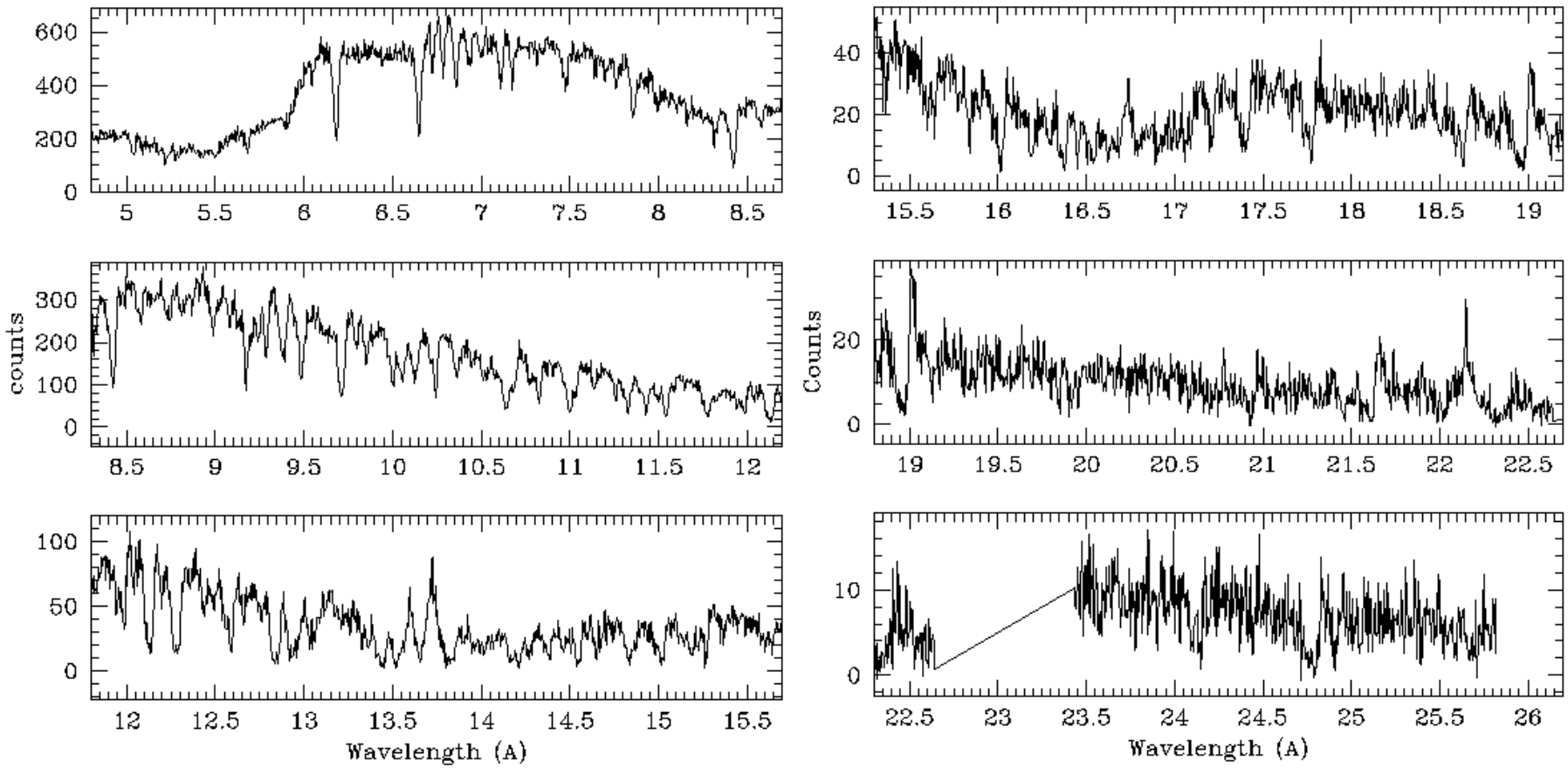
$n_e \sim 10^8 cm^{-3}$, $T \sim 10^6 K$, $r \sim 10^{16} cm$, $\delta r \sim 10^{15-16} cm$

- Suggestive: P(WA)~P(BELR) Turner et al. 1993, Kaastra et al. 1995, Marshall et al. 1997

- Large *statistical* uncertainties (factor 3-10)
- *Systematic* errors from simple physics:
  - ♣ 2-edge fits OVII, OVIII
  - ♣Assumes *simple* WA to apply analysis
- *May not be the case…*

Warm Absorbers: complicated solutions

- Complex spectra – complex results
  - Chandra HETGS 850ksec spectrum of NGC 3783



Warm Absorbers: complicated solutions

- 2 physically separate absorbers Otani et al. 1996 PASJ 48, 211 [ASCA]
- 2 or more absorbers with arbitrary parameters (N_H, U)
- Relativistic lines Branduardi-Raymont et al. 2001 A&A 365, L140
- Dust Lee et al. 2001 ApJLett. 554, L13
- High iron abundances (>10x solar) Blustin et al. 2002 A&A 392, 453
- Large outflow velocities McKernan et al. 2003 astro-ph/0304403
- Continuous range of U Krolik & Kriss 2001 ApJ 561, 684
- No easy physics ***if*** many –component solutions
  - Con-X won't solve wind conditions

Warm Absorbers: a simple solution

Our* approach: first build a complete model first:

PHASE

photoionized **a**bsorber **s**pectral **e**ngine

See poster by **Krongold Y.** et al. 2003

Includes:

- ATOMDB atomic database Smith et al. 2001 ApJ 556 L91 http://asc.harvard.edu/atomdb/
- UTA approximation Behar, Sako & Kahn 2001 ApJ 563, 497
- Voigt line profiles

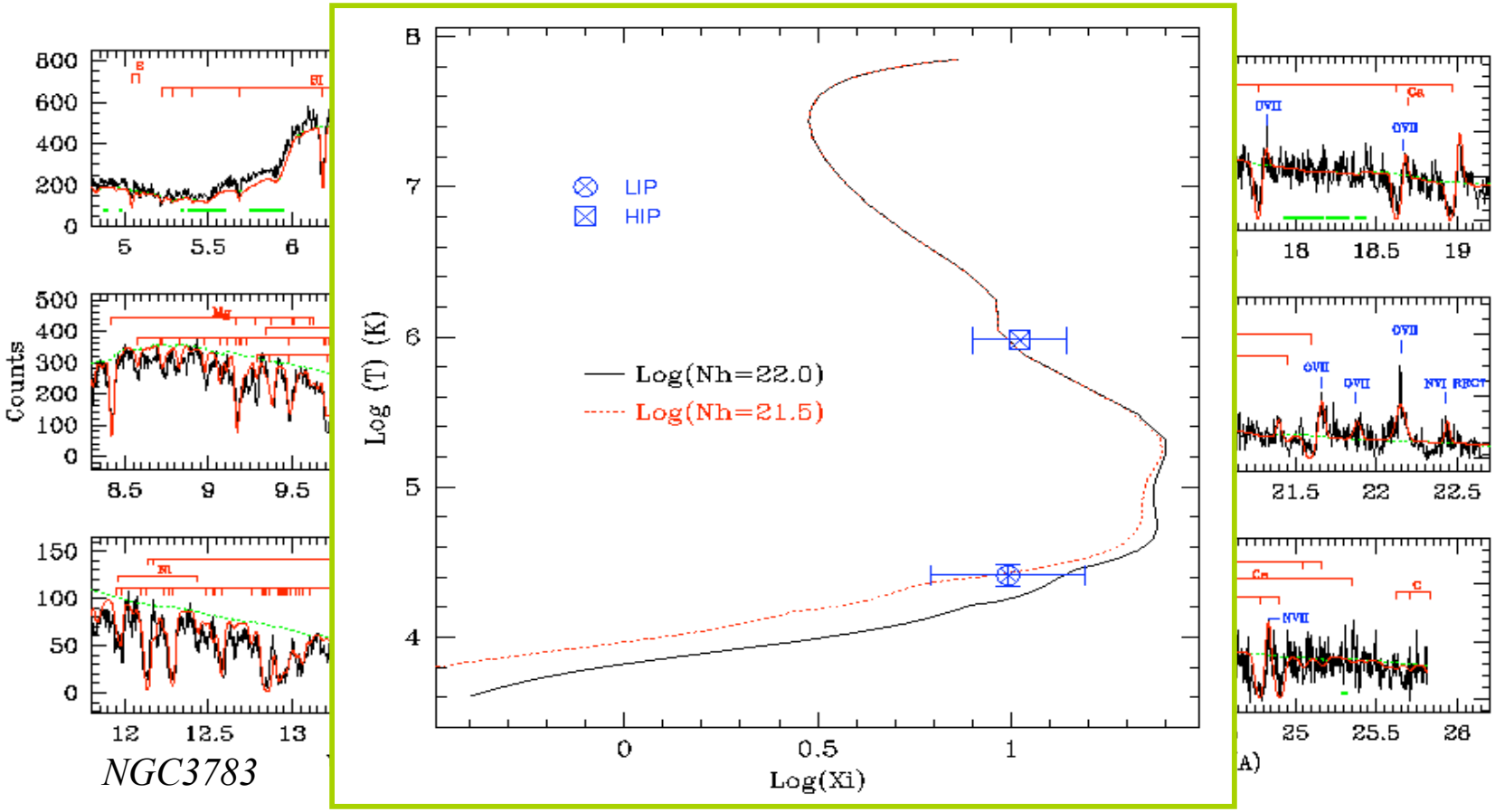
Approach:

- Global fit. Crucial for continuum level (c.f. Lyman-α forest)
- Emission/absorption mutual cancellation allowed for
- Minimum of free parameters (6)

* Krongold, Nicastro, Brickhouse, Elvis, Liedahl & Mathur 2003, ApJ *almost* submitted!

Chandra HETGS 850ksec spectrum of NGC 3783

Krongold, Nicastro, Brickhouse, Elvis, Liedahl & Mathur, 2003

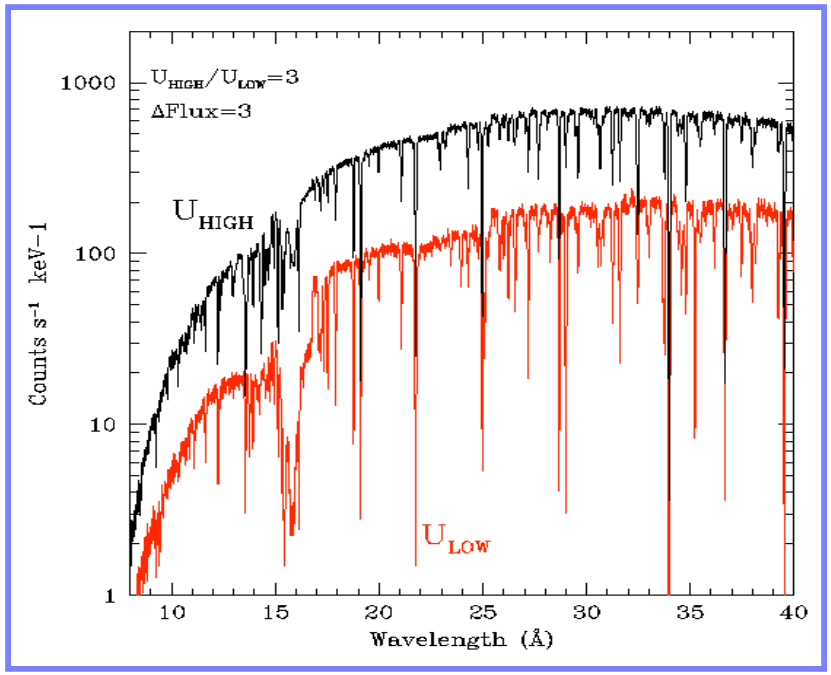


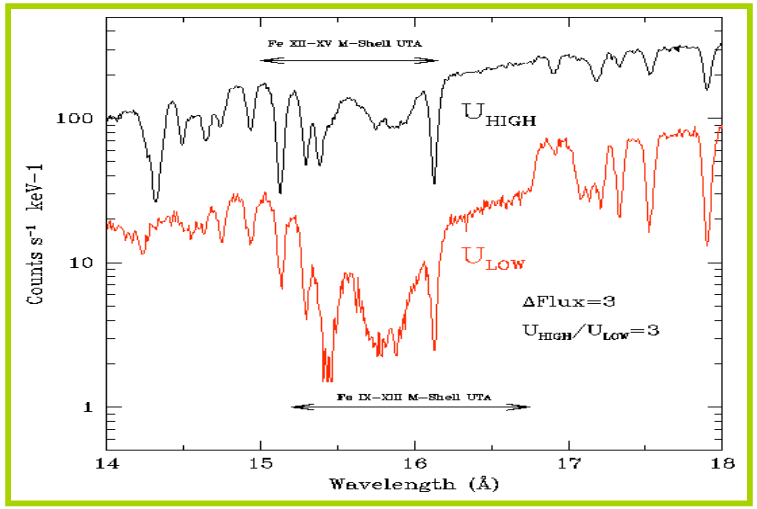
- Over 100 absorption features fitted by a 6 parameter model
- **One T~10^6 K and one T~10^4 K, in pressure balance**

2-phase gas in equilibrium

Quasar winds: prime Con-X science

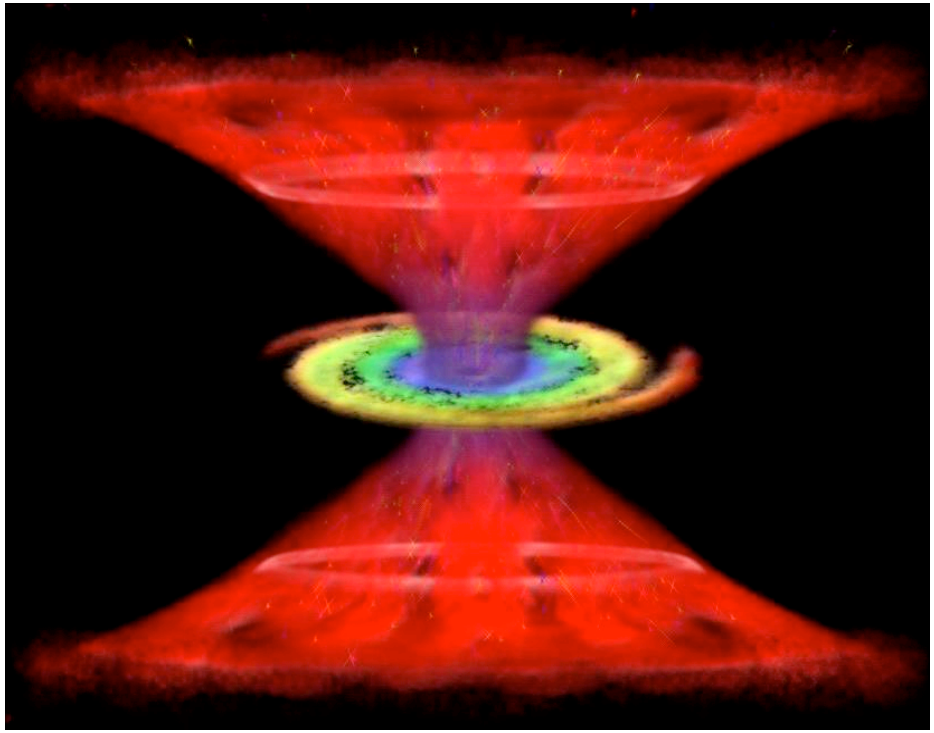
- Simple 2-component solution:
  -> Variability analysis will work
- Con-X area gives similar spectra in
  20ksec @ ~1 mCrab
- Hence for
  t_{recomb} > 20 ksec (n_e < $10^8 cm^{-3}$)
  Con-X will solve AGN wind physics
- Not necessarily in equilibrium at t=0
  - > need ~20 x t_{recomb} each.
- Few dozen AGN available
  - Needs ~8 Msec (20 AGN x 20t_{recomb})
- UTA shape is a prime diagnostic
  - Broad
  - R~1000 is sufficient





Quasar winds: prime Con-X science

- Are WA, BELR, BAL, scatterers all part of the wind?
  "Quasar Atmospheres"
  - Work back to disk, continuum physics
- Mass loss rate into IGM?
  - IGM enrichment at high z?
- Dust creation at high z?
  Elvis, Marengo & Karovska 2002 ApJLett. 566, L107.
  - Catalyzes high z star formation?



Quasar winds: more resolution

- R=1000 OK for this physics, but…
- R~ 5000 gives *much* more
- OV, OVI ->no need for simultaneous UV spectra
- resolve multiple components down to turbulent width (~30km/s)

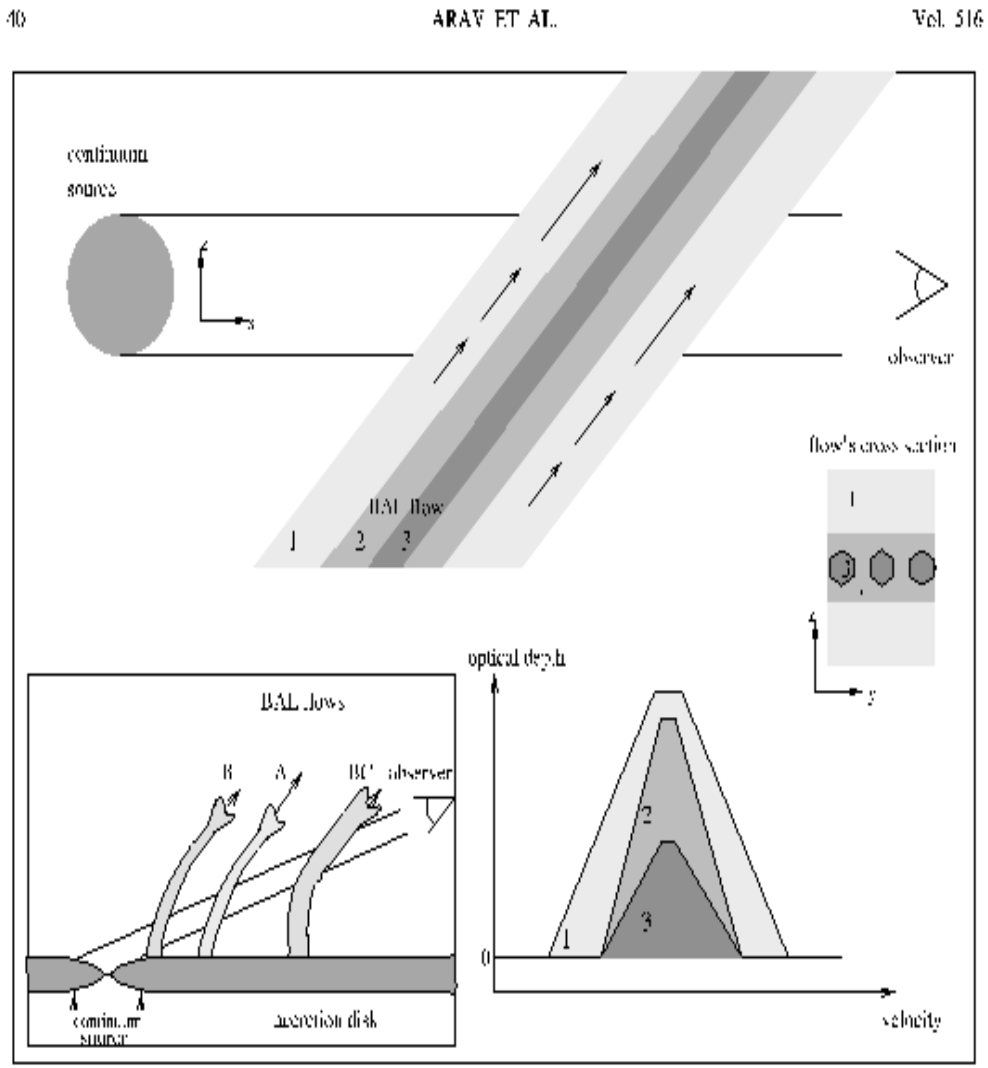
  -> does $T_{thermal}$ reach T_{ion}?
- Measure covering factor vs. velocity in each line

  c.f. Gabel et al. 2002 astro-ph/0209484

  – Accelerating wind crossing line-of-sight?

    Arav et al. 1999 ApJ 516, 27

  – **> map continuum source?**



advertisement

The Ionized Absorber in NGC 3783

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ABSTRACT

We present a self-consistent model for the ionized absorbing gas evidenced in the 900 ks *Chandra* HETGS spectrum of NGC 3783. The analysis was carried out with PHASE, a new code designed to model X-ray and UV absorption features in ionized plasmas. The model includes a total of six free parameters, and consists in a simple two phase absorber with differences of 35 in the ionization parameter and differences of 1 in the column density in the two phases. It can reproduce more than 100 features in the spectrum. The two absorption components appear to be in hydrostatic equilibrium with each other, and are consistent with a single outflow (750 km s^{-1}), a single turbulent velocity (300 km s^{-1}), and with solar chemical abundances. Further implications of these results are discussed.

1. The Models PHASE.

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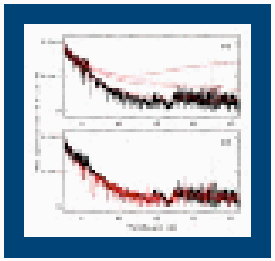

Figure 1. Stacked MEG first-order spectrum of NGC 3783. (a): continuum fitted to the spectrum. The dotted line shows the Galactic absorption. (b): Residuals. The dotted line represents the power law continuum. Galactic absorption, and continuum further modeled by the two phase absorber model. The dotted line represents the predicted power law continuum from the Blackbody continuum. By two phase absorption model plotted for comparison.

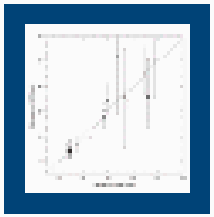

Figure 3. Measured EW vs model predicted EW's for individual lines in the NGC 3783 spectrum. A line with slope equal to one is preferred for comparison.

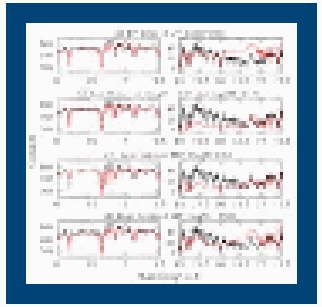

Figure 4. Different models describing the right overdensities observed in the data by the PHASE code. Different values for the ionization parameter in the two phases, or a third component are unlikely.

3. Model Evaluation.

[illegible]