Quasar Winds: the 4th element

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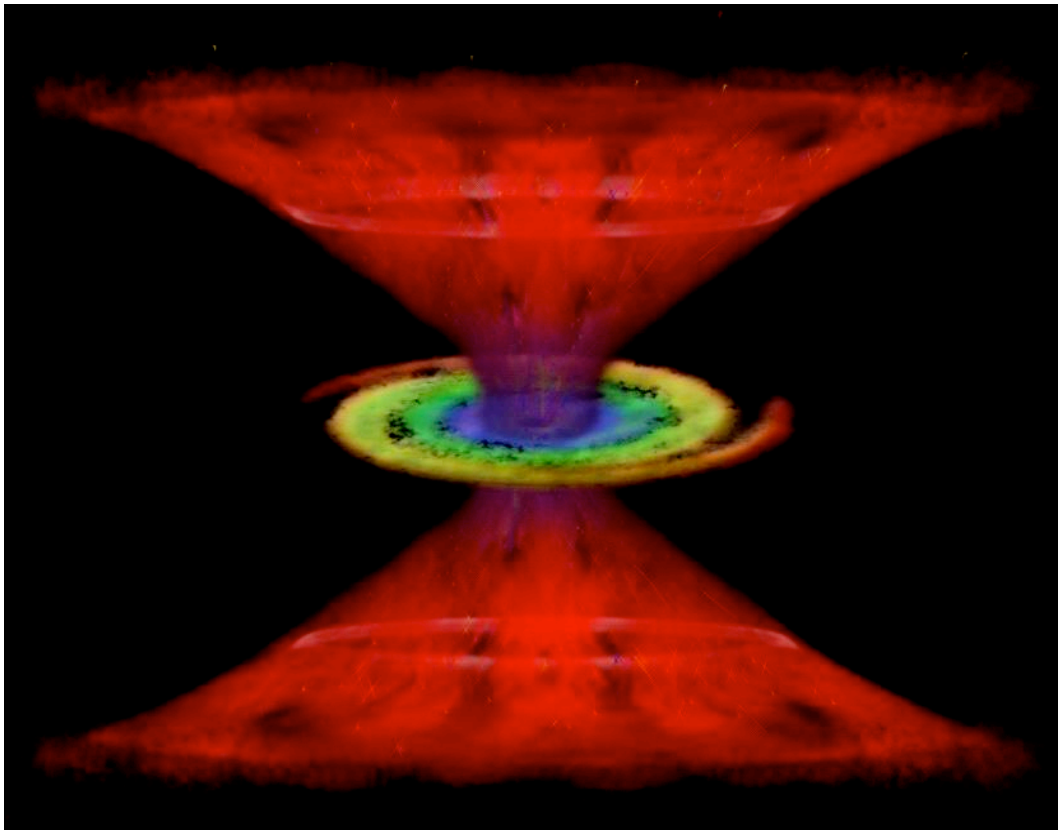
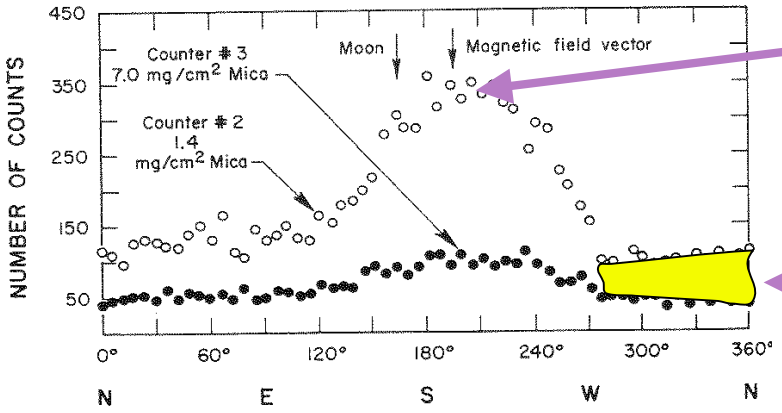


* (way) previous address: Univ. Leicester X-ray astronomy group

42 Years of X-ray Astronomy: Problem Posed & Solved

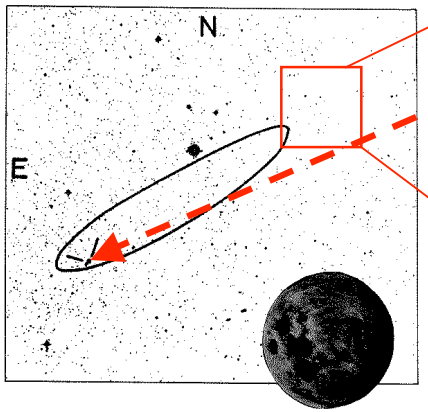


1962 Sco X-1

Good for 1 (one) Nobel Prize

X-ray background

30 Years of *Ariel V* 1974

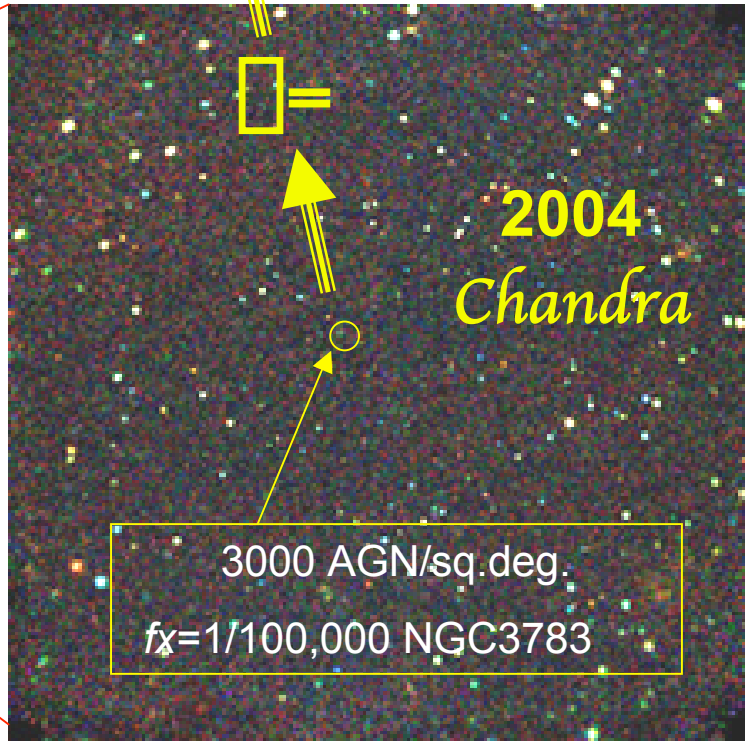


Moon to scale

good enough for my thesis

AGN [NGC3783]
Obscured AGN

fx=1/10,000 Sco X-1



41 years of Quasars: problems posed, partial solutions

3 elements established in first 10 years:

1. massive black hole

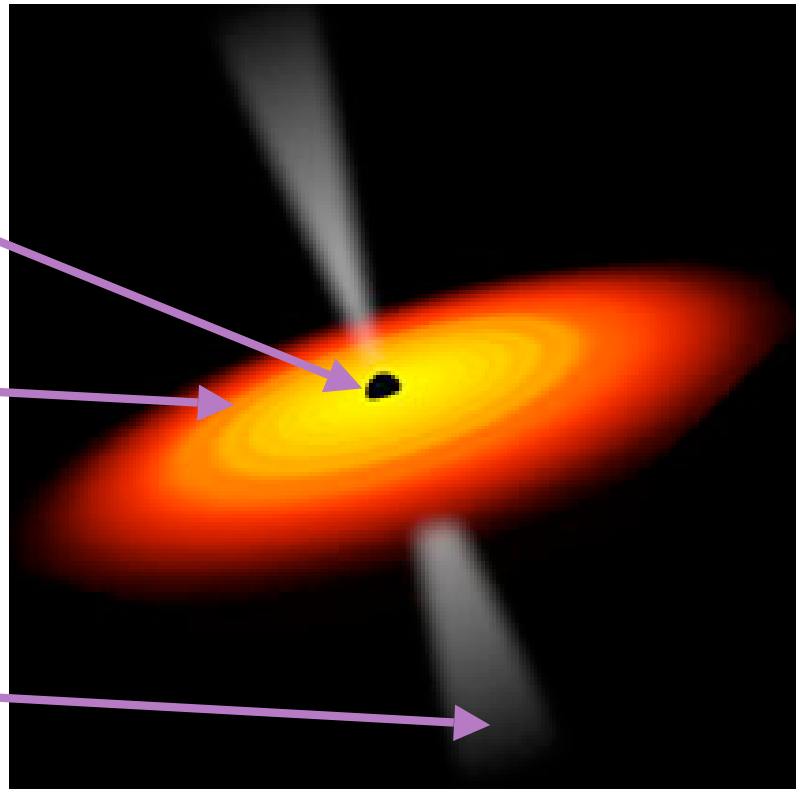
Lynden-Bell 1969

2. accretion disk

Lynden-Bell 1969, Pringle & Rees 1972,Shakura & Sunyaev 1972

3. relativistic jet

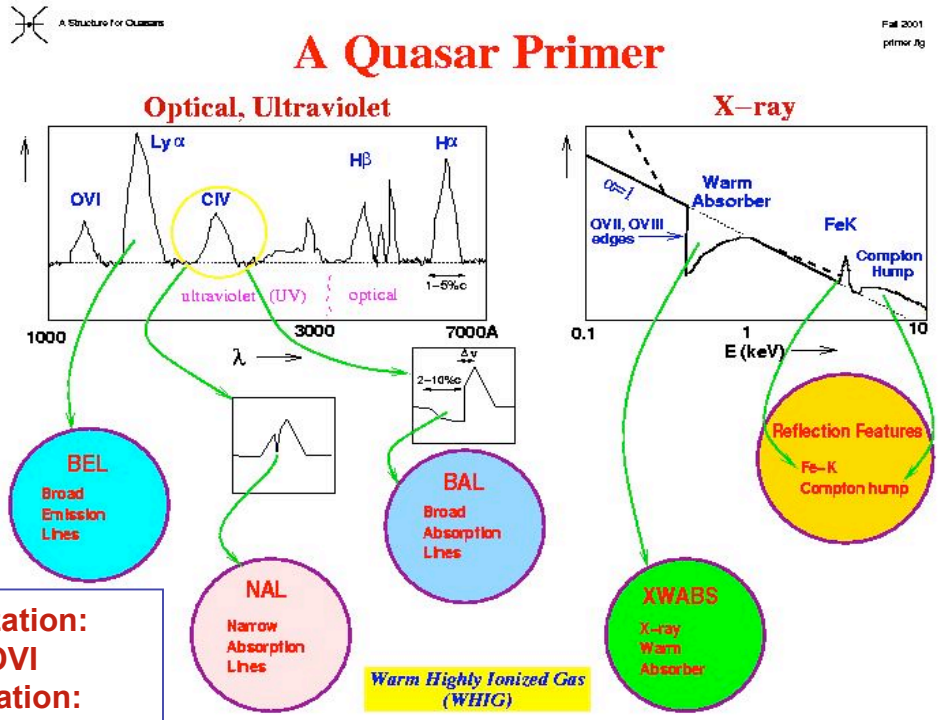
Rees 1967 [PhD], Blandford & Rees 1974



3 elements describe only a Naked Quasar

no connection to atomic physics features

1. Broad emission lines (BELs)
2. Broad absorption lines (BALs)
3. Narrow absorption lines (NALs)
4. X-ray Warm Absorbers (WAs)
5. Scattering phenomena

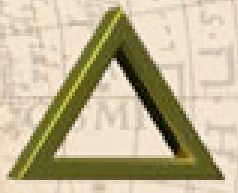


High ionization: e.g. CIV, OVI
Low ionization: e.g. MgII, FeII.

What are we missing?

What is the 4th element:
The `Quasar Atmosphere?

Fluid = jet ?



Radiation
= disk ?

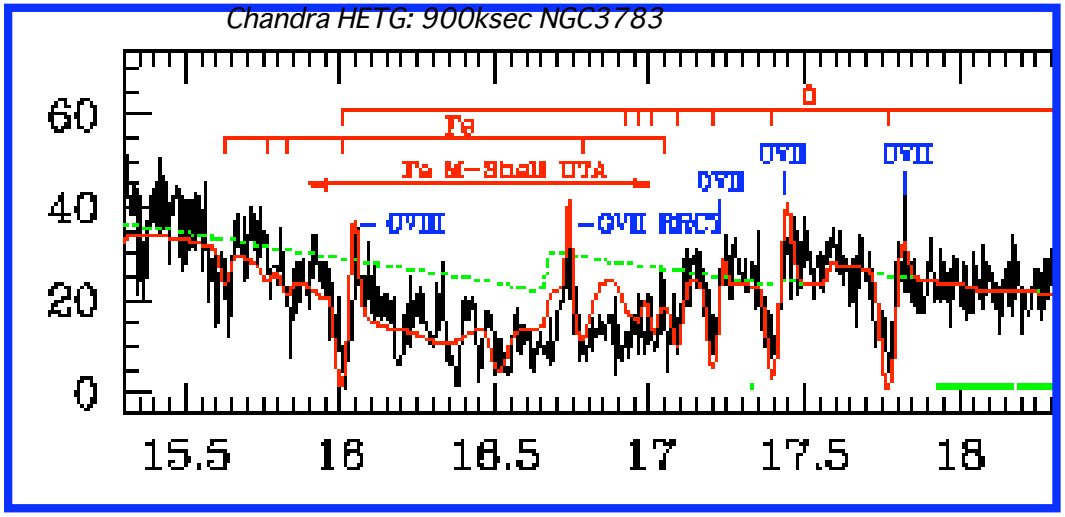
Gravity =
black hole ?

Empedocles c.400 BCE

www.chemsoc.org/timeline/graphic/0400_eawf.jpg

Quasar Winds

‘Warm Absorber’ Narrow X-ray lines



Narrow UV lines: NAL

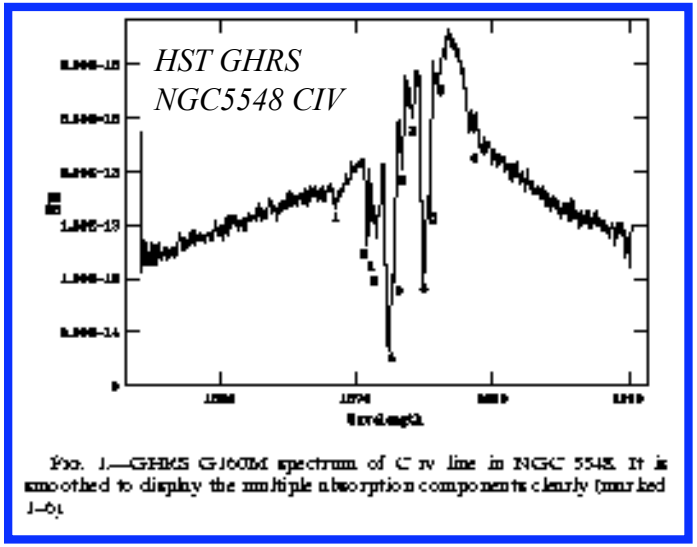


FIG. 1.—GHRS G160M spectrum of C IV line in NGC 5548. It is smoothed to display the multiple absorption components clearly (marked 1–6).

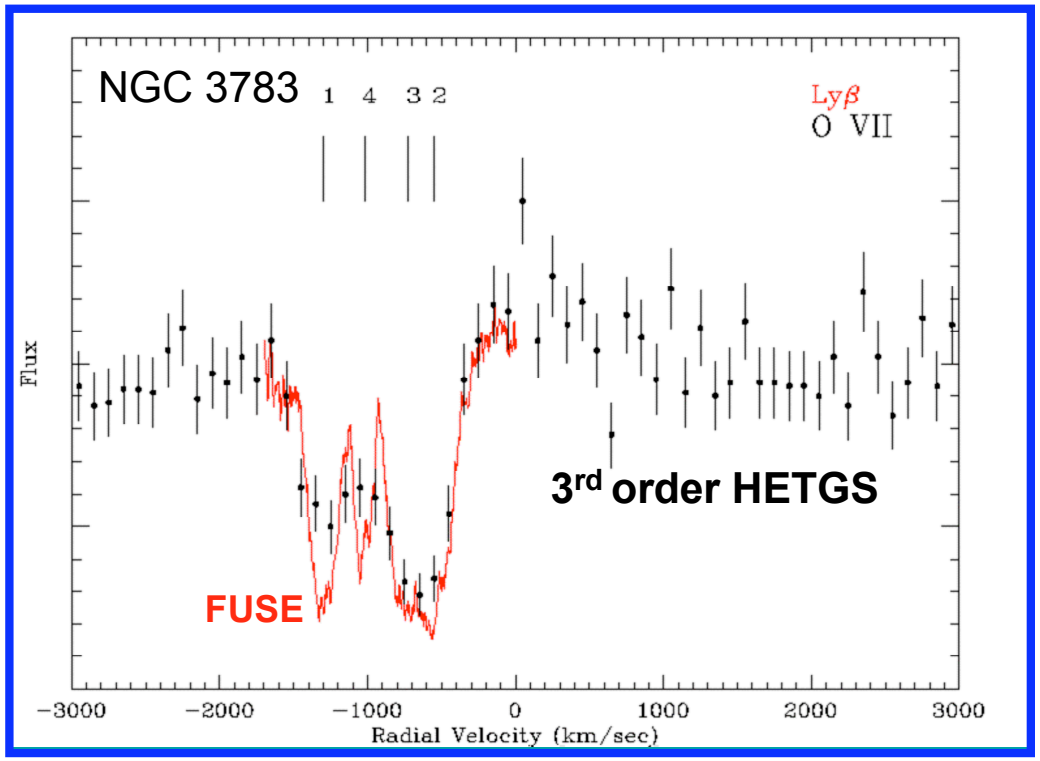
High Ionization

Same ~50% of AGN, quasars

Outflow ~1000 km s^{-1}

X-ray *AND* UV absorbing Winds

'Warm Absorber' Narrow X-ray lines = **Narrow UV lines: NAL**



Gabel et al. 2004

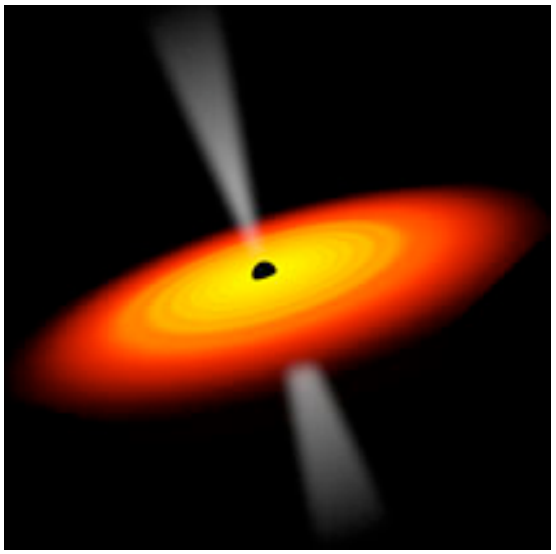
SAME WIND

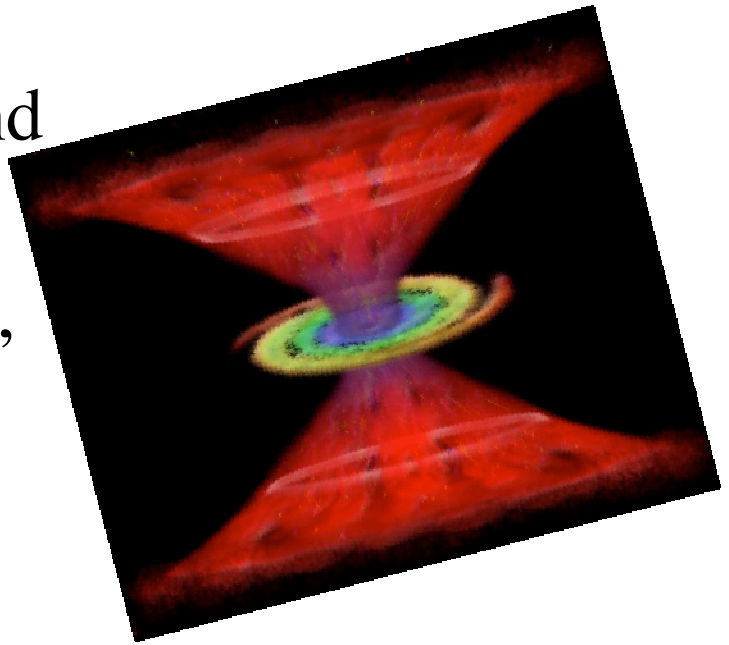
Can combine diagnostics from both bands

- **Not all X-ray gas -> UV absorption (too ionized)**
- **Not all UV gas -> X-ray absorption (too small a column density)**

AGN = black hole + disk + jet + WIND

- **Winds are the 'missing link' in AGN**
  - Black hole, disk, jet = 'naked' AGN
  - Winds let us understand the veiling gas
  - Could include 'broad line region' and BALs
- **Winds are dynamically important**
  - kinetic luminosity >=L(radiation)
  - mdot(wind) >= mdot(accretion)
  - carry off angular momentum from disk?
- ***Outward*: affect host galaxy ISM and IGM**
- ***Inward*: impose conditions on torus, accretion disk**



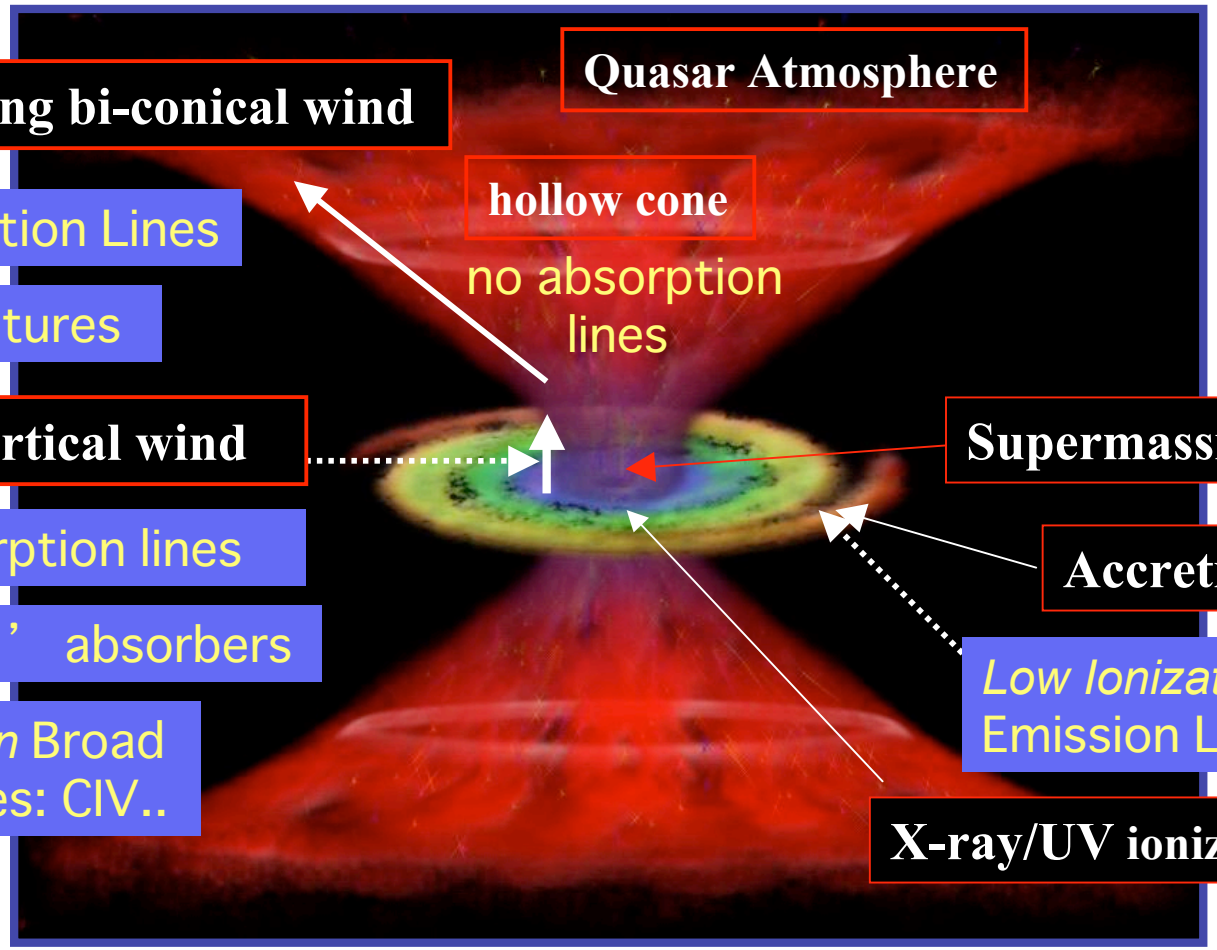


A Specific Wind Model

Elvis M., 2000, Astrophysical Journal 545, 63; 2003, astro-ph/03xxxx

A Geometric & Kinematic solution

c.f. Rees relativistic jets for blazars/radio sources



Accelerating bi-conical wind

Broad Absorption Lines

Reflection features

Thin Vertical wind

Narrow absorption lines

X-ray `warm' absorbers

High Ionization Broad Emission Lines: CIV..

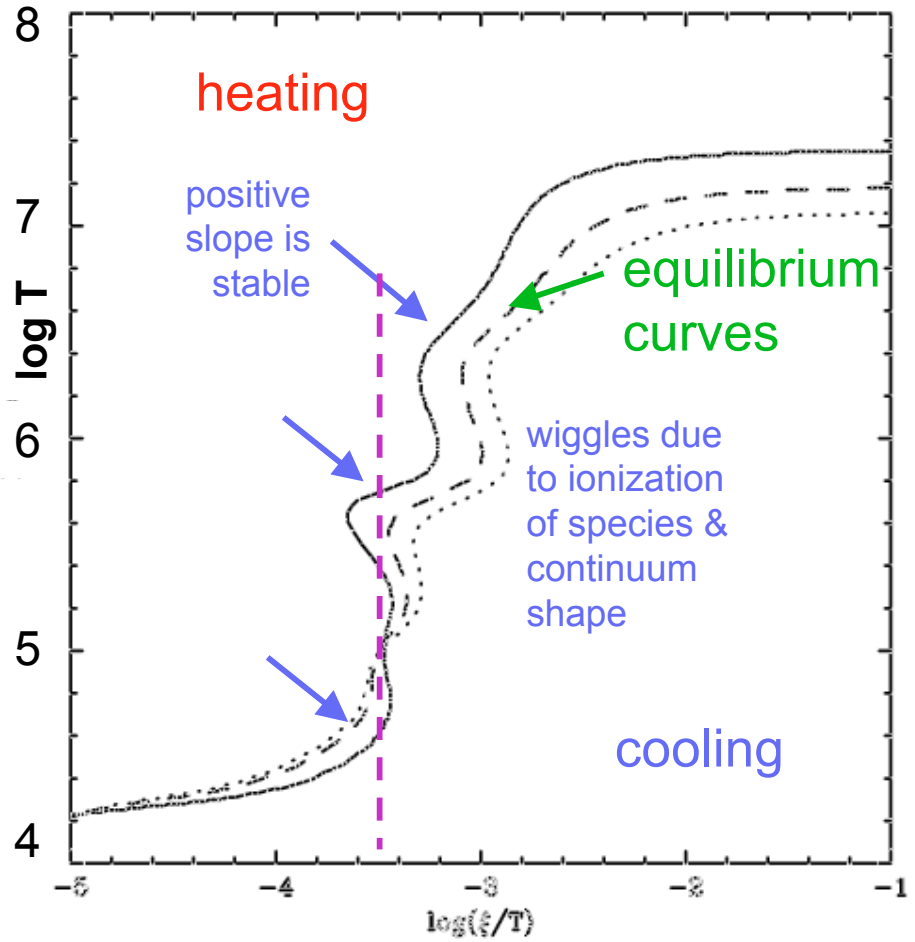
Low Ionization Broad Emission Lines: FeII..

NB: Independent of Unification; Jets not included

Photoionized Winds: 2-3 phase equilibrium

Krolik, McKee & Tarter 1981, ApJ, 249, 422

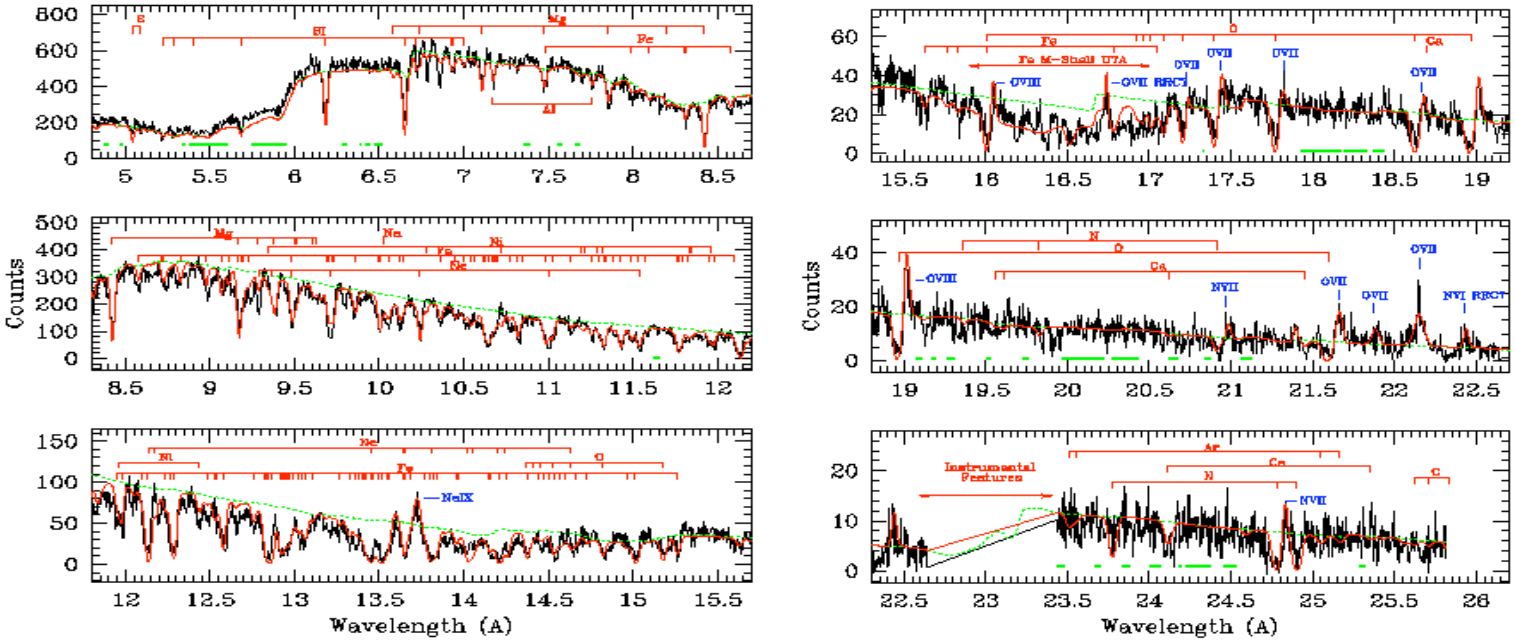
- **Photoionized gas tends to concentrate in discrete phases in pressure balance**
  e.g. Milky Way ISM
- Does not work for a static medium:
  destroys clouds, Compton thick
- so abandoned for AGN BELRs
  - ***a mistake!***
- Works fine in a wind. **dynamic**
- **Equilibrium determined solely by:**
  SED & ionization thresholds
- Prediction: similar from object to object



AGN Wind Observations: 2-3 phase gas in pressure equilibrium

Krongold, Nicastro, Brickhouse, Elvis, Liedahl & Mathur, 2003 ApJ 597, 832. *astro-ph/0306460*

Chandra HETGS 850ksec spectrum of NGC 3783



>100 absorption features - 6 parameter model

➔ ***pressure balance*** **to 5%**

AGN Wind Observations: 2-3 phase gas in pressure equilibrium

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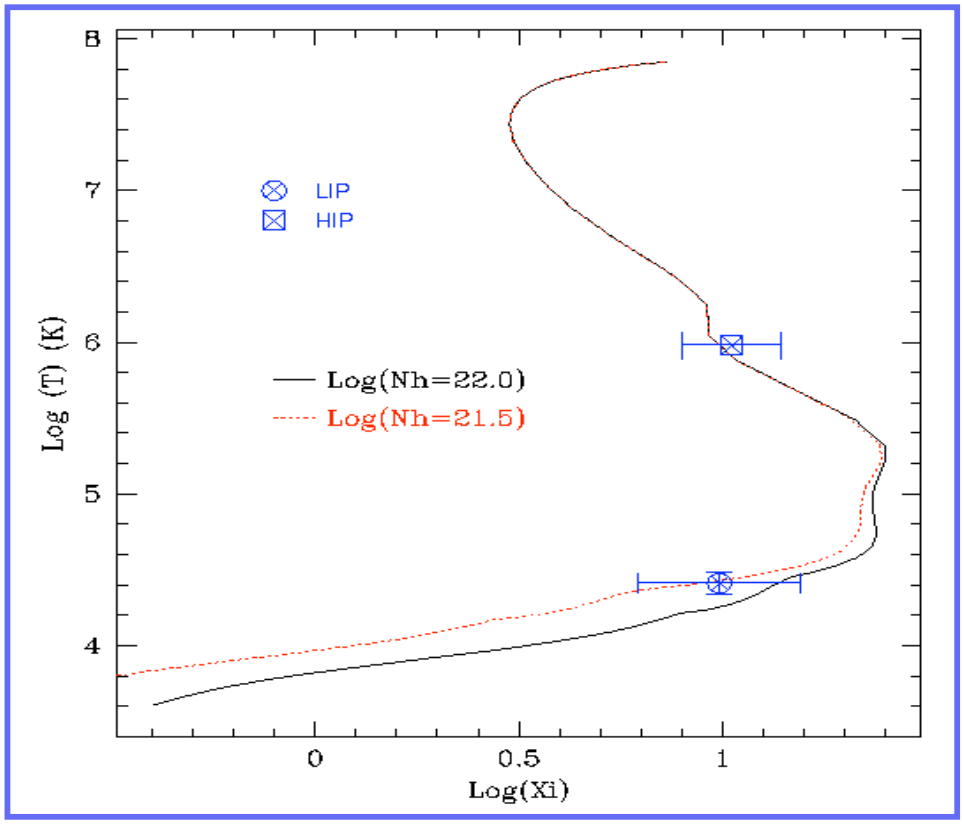


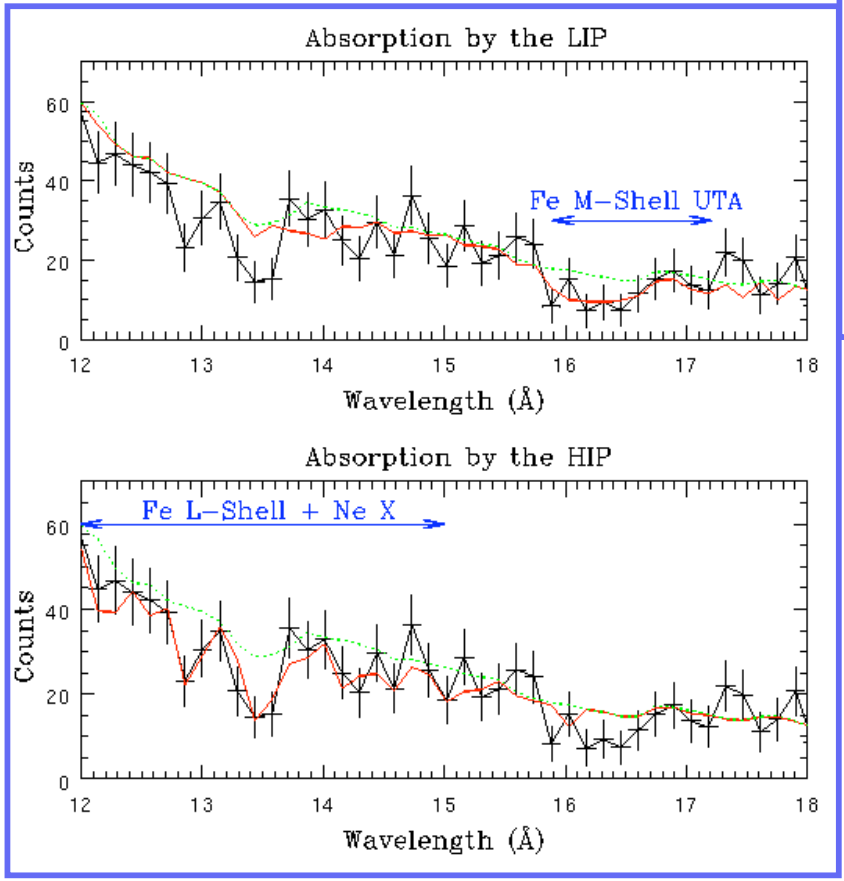
2-phase gas in pressure equilibrium

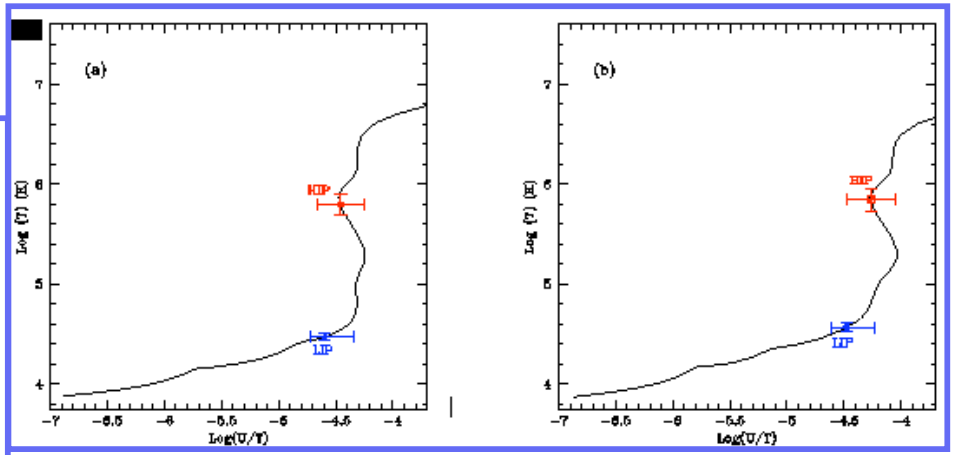
NGC 985:

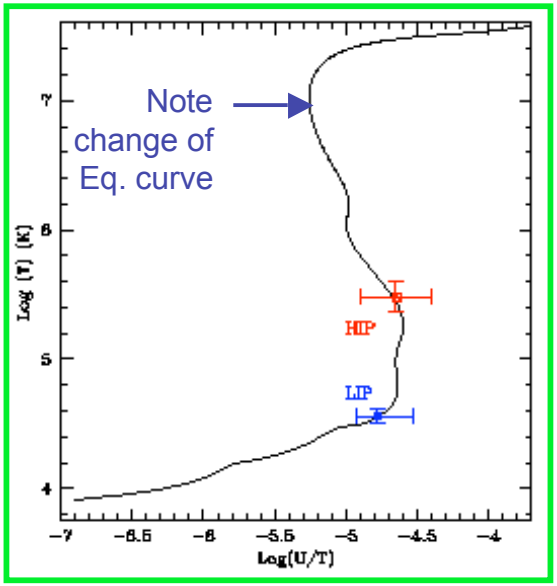
another example of pressure equilibrium in an AGN Wind

Krongold et al. 2004, ApJ, submitted

NGC985 Chandra





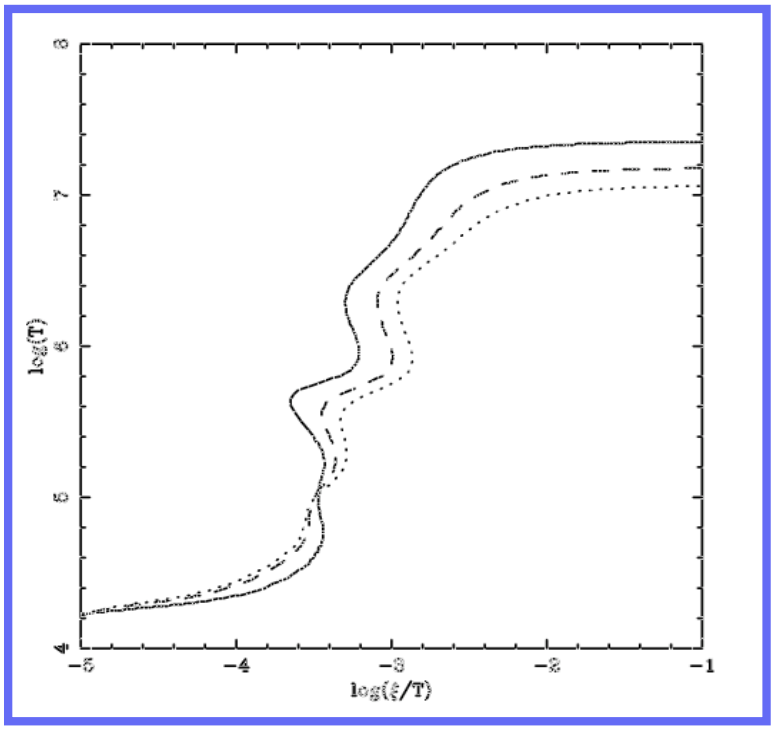


Maintains P equilibrium though SED, flux change

NGC985 Beppo-SAX

Winds & Accretion Disk Physics

- Successful disk models *must* produce winds
- ~10^6K phase depends critically on SED, Reynolds & Fabian 1995, Komossa & Fink 1995, Nicastro 1999
- Use absorber (T,x) to determine shape of invisible EUV SED
- EUV SED tests models of accretion disk at
  - inner edge ill-defined- boundary condition
  - 'plunging region' Krolik et al.



Torus or Disk: Where is the Wind?

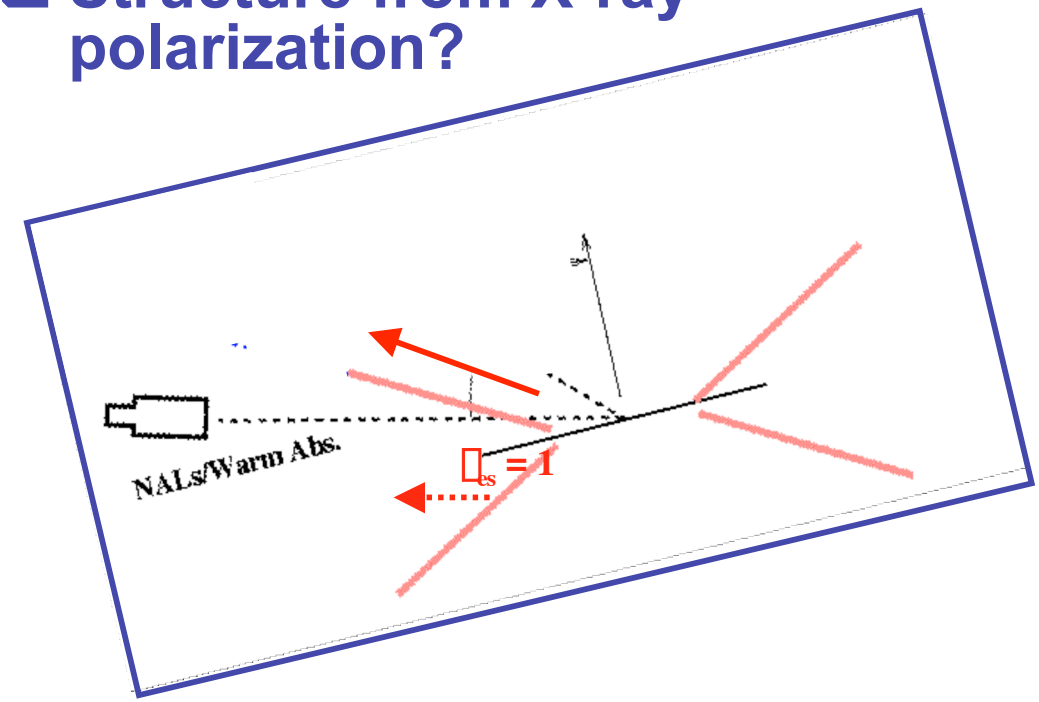
- **Radius of wind is unknown:**
  - **Torus?** ~few light-years
  - **Disk Wind?** **e.g. BELR** ~few light-weeks
- **Location fundamental to Wind physics**
- **Variability can decide**

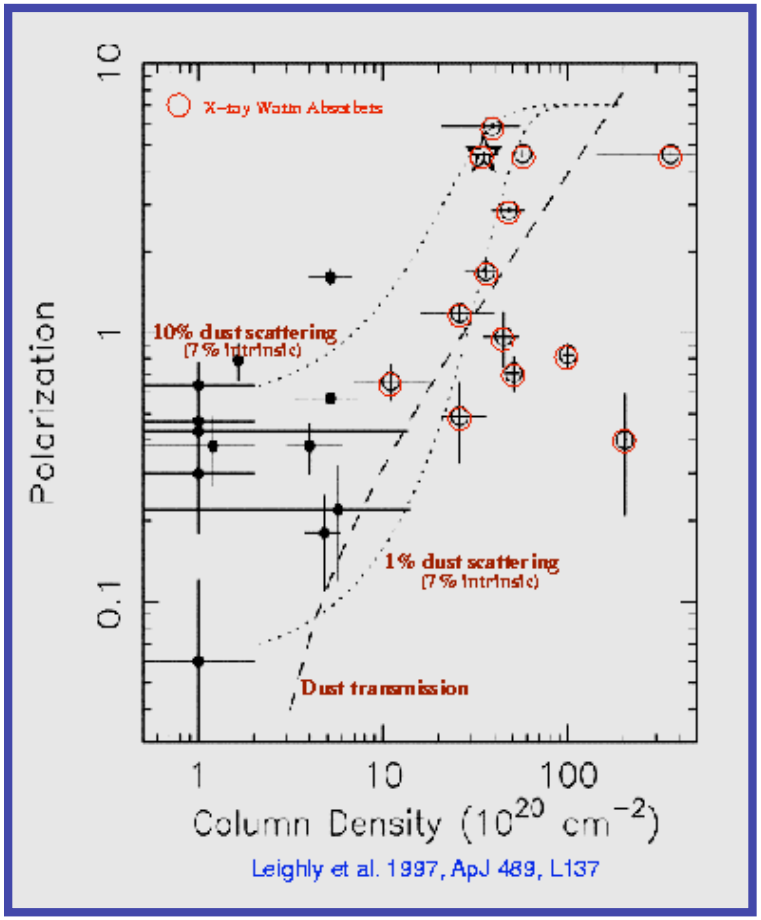
  Response time gives density
  + U gives R
- NGC 3783 R<6pc Krongold et al. ApJL, in press
  - *Chandra, XMM* monitoring will improve limits
  - *Constellation-X* excellent for locating quasar wind
- Higher resolution better: small mission, ***Pharos***

Winds Geometry from Polarization

Leighly et al. 1997 ApJ 489, L137

- Warm Absorber AGN more polarized in optical ~1% - ~5%
- Scattering off non-spherical distribution
- ➔Edge-on scattering structure
- **Structure from X-ray polarization?**





BALs in All Quasars

Ogle et al. 1999 ApJS, 125, 1; Ogle 1998 PhD thesis, CalTech

10% of quasars show BALs

***Old question*: Peculiar subset?**

***or* Normal, seen from special angle?**

BAL troughs are highly polarized

-> *flattened structure*

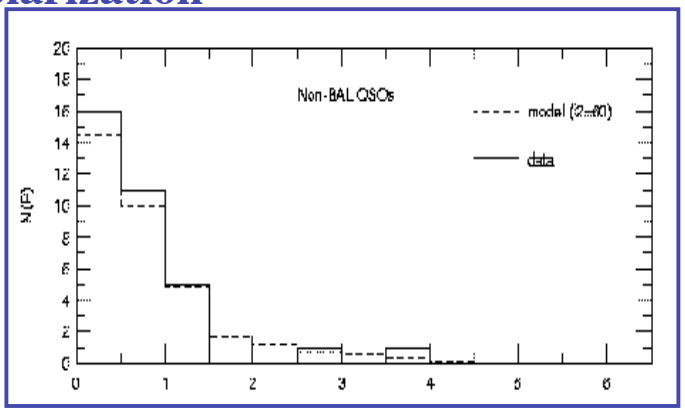
Scattering solves other BAL problems

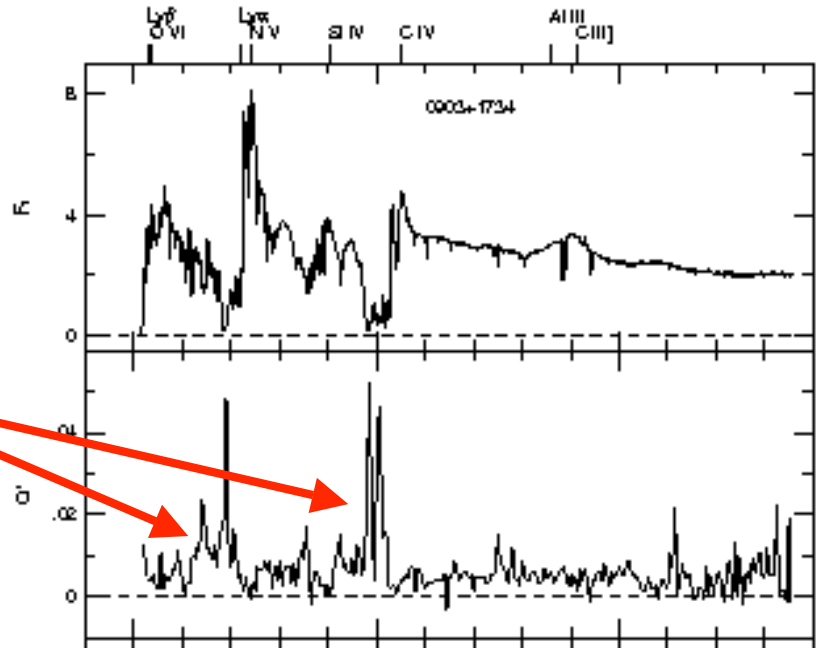
ionization, abundances, N_H

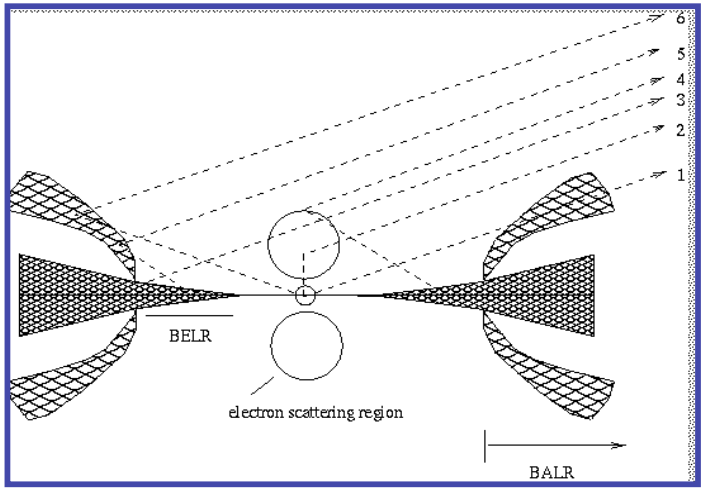
Thomson thick

-> narrow Fe-K, Compton hump

Bi-cone model *Predicts* non-BAL quasar polarization







Ogle, PhD thesis, 1998

Conical wind fits BALs

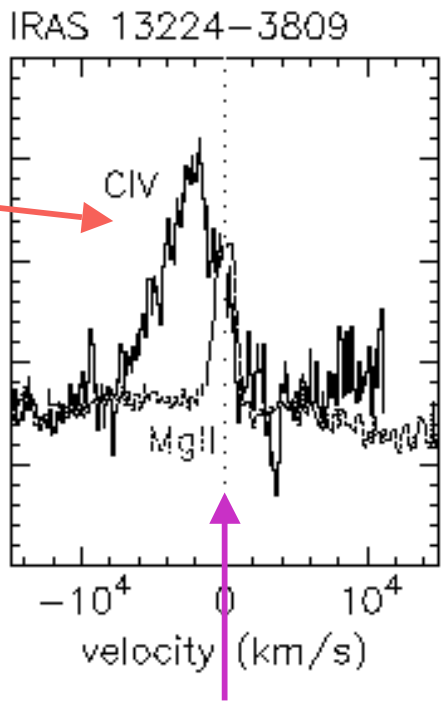
Emission lines: a wind only at some radii

Leighly & Moore 2004, ApJ, astro-ph/0402453

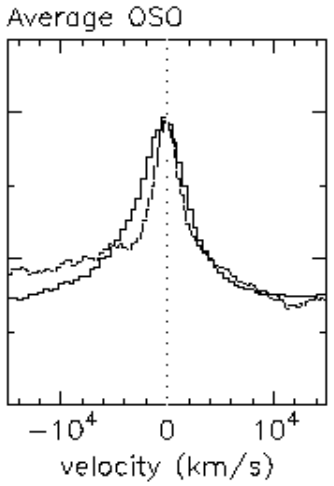
- Narrow Line Seyfert 1 galaxies (NLSy1s) show

broad, strongly blueshifted high ionization (CIV) lines

- disk wind
- redshifted lines hidden by disk
- Low ionization lines from outer disk c.f. Collin-Souffrin, Hameury & Joly,1988 A&A 205, 19



Low ionization
MgII



See: Gaskell 1982

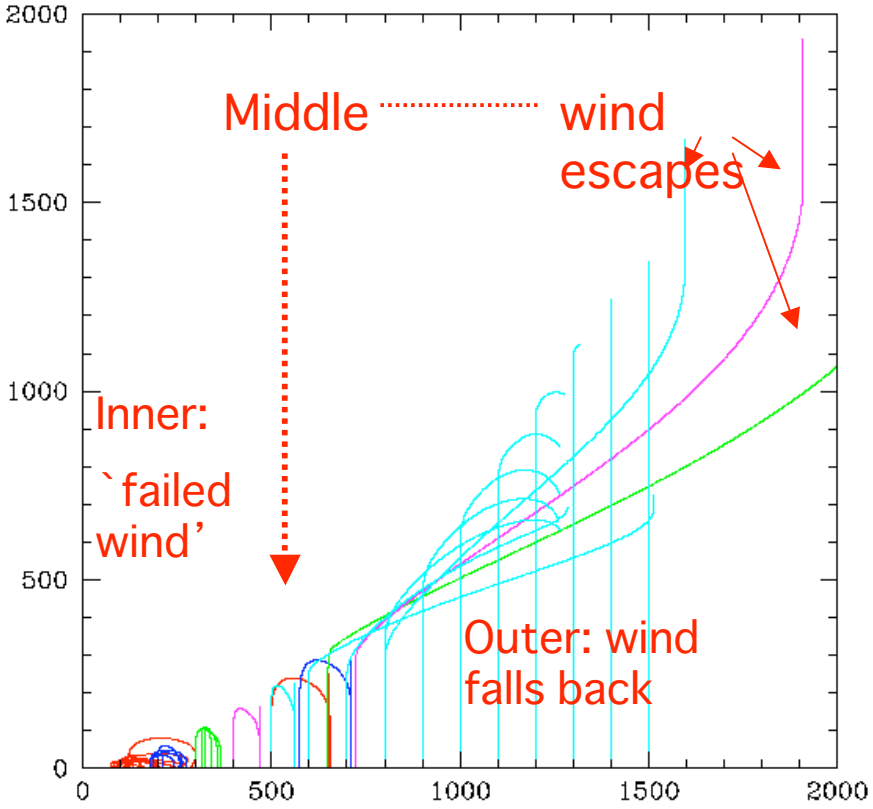
Wilkes 1984

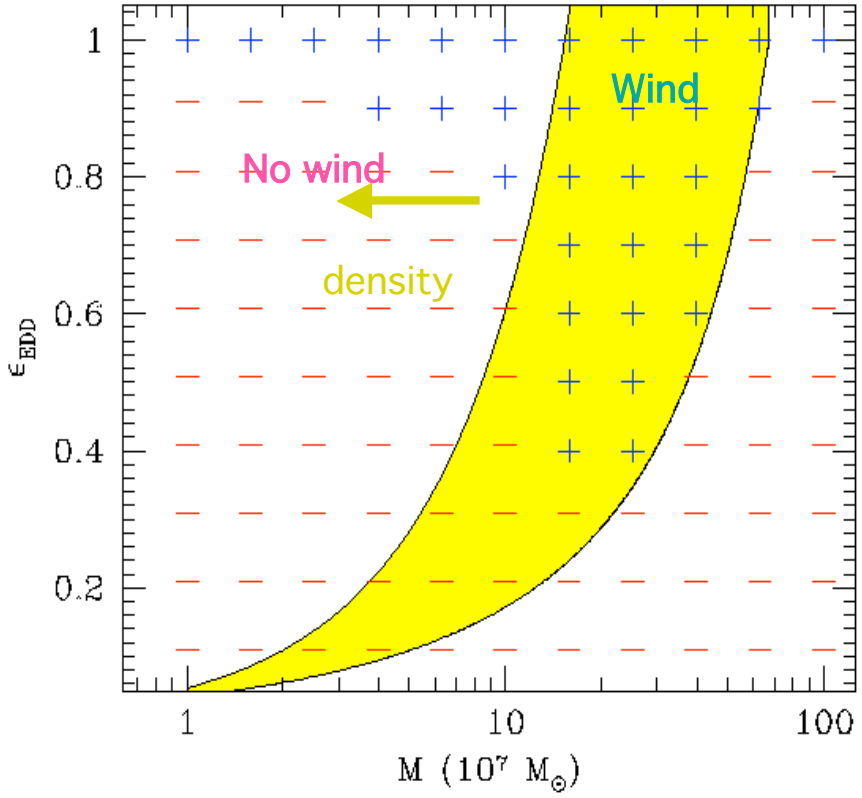
Does Wind radius & strength produce eigenvector 1?

Line Driven Winds: Why is the wind thin?

Risaliti & Elvis 2004, ApJ submitted

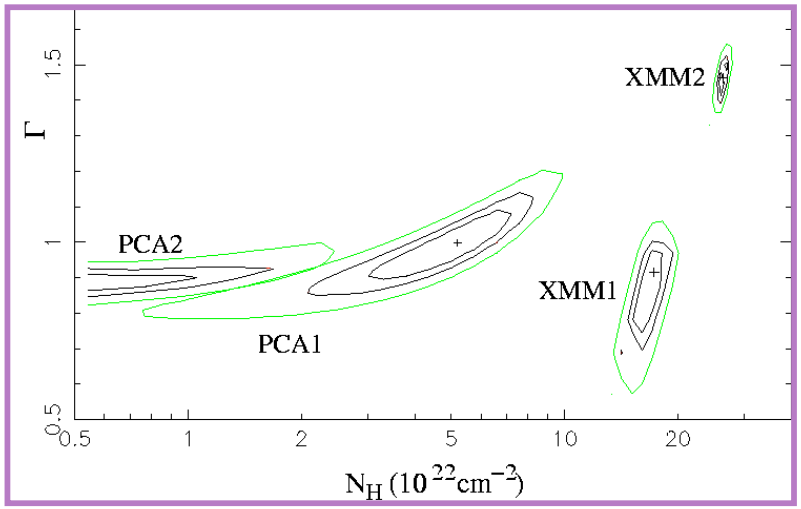
3 Zones: Inner, Middle, Outer

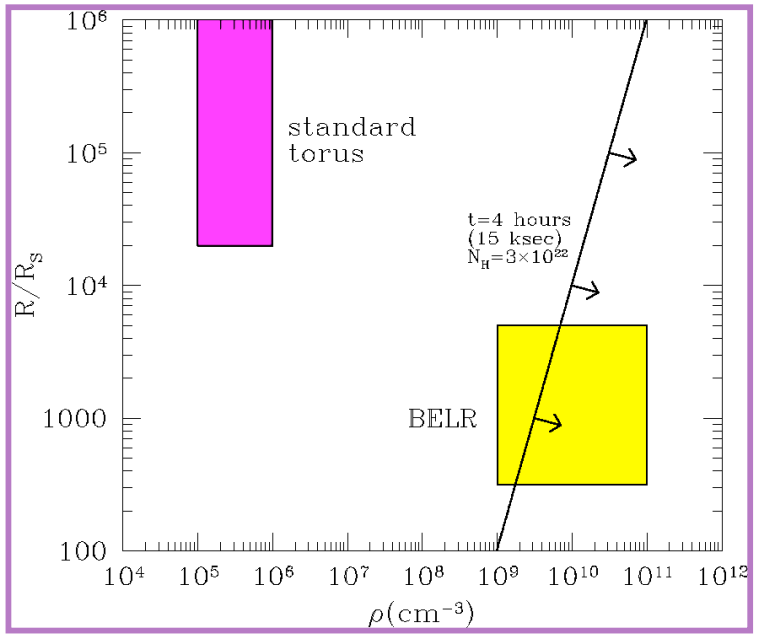


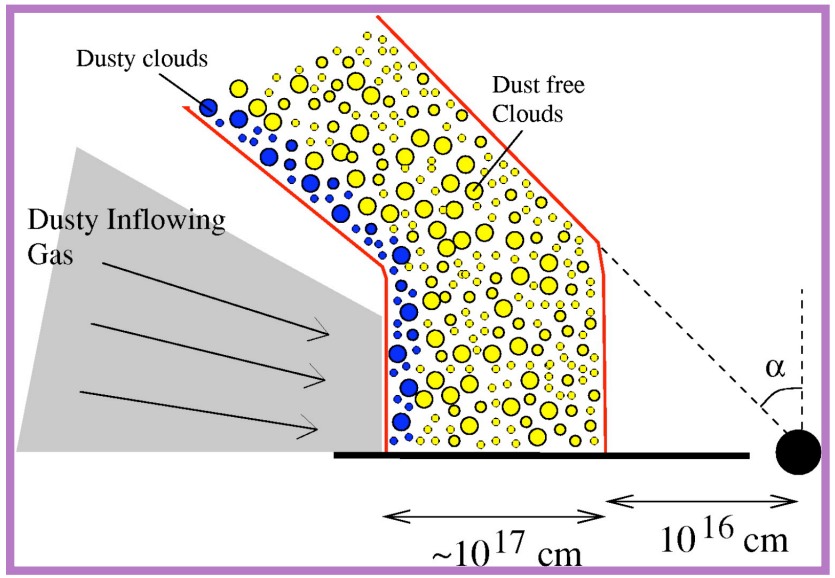


The Torus is the Wind

- Large N_H changes in 4 hours
  - NGC4388, NGC4151, NGC1365
    - ✓ *See Risaliti talk*
- Small absorber: BELR scale







- Still topologically a torus
- But ***dynamic***

Quasar Winds

- Winds give a paradigm for thinking about AGNs
- Missing 4th element of quasars
- 2-3 phase photo-ionized medium
- Wind radius, strength->eigenvector 1
- The Wind is the Torus
- Use to diagnose inner accretion disk
- Effect on IGM, host ISM
- R~5000 spectra & variability

  -> wind origin, abundances, dynamics

- Polarimetry will determine structure