UNIVERSITY OF Southampton

Modeling The Spectra of Quasars:
Clumpy Winds & X-ray Properties

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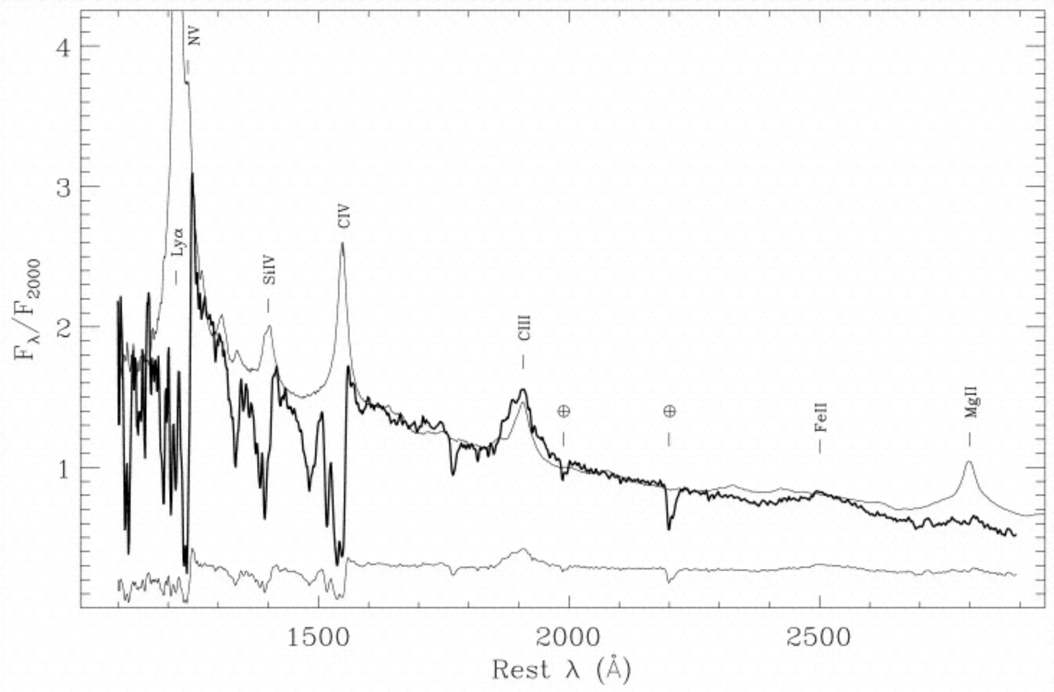
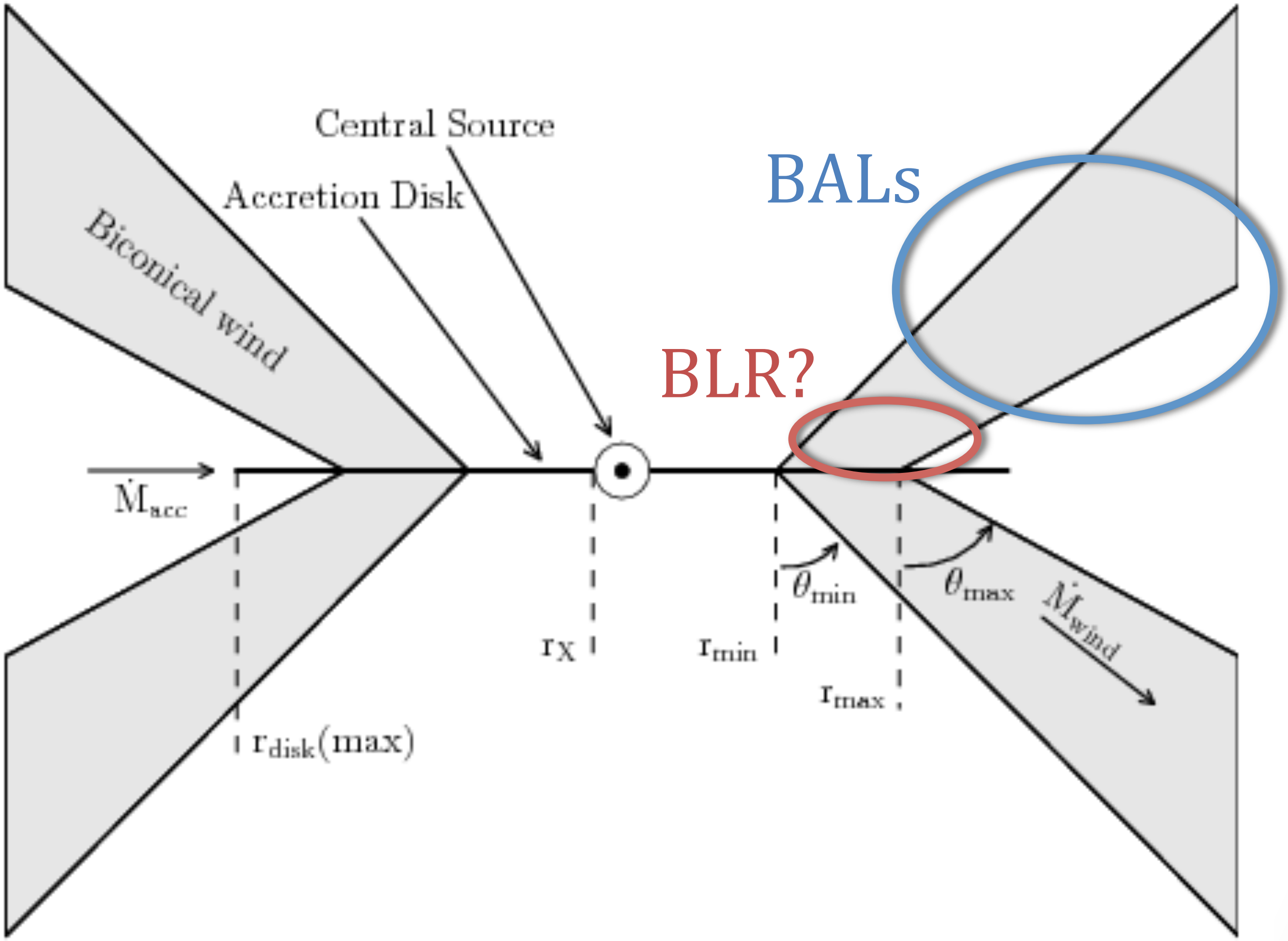
The Extremes of Black Hole Accretion, Madrid

BALQSOs

- ~20% of the QSO population (Knigge+ 2008, Allen+2011)
  - (depending on selection effects – we'll come back to this!)
- Blue-shifted Broad Absorption Line QSOs
- Smoking gun for outflowing material -> ***disk winds***
- Potentially 'line-driven'

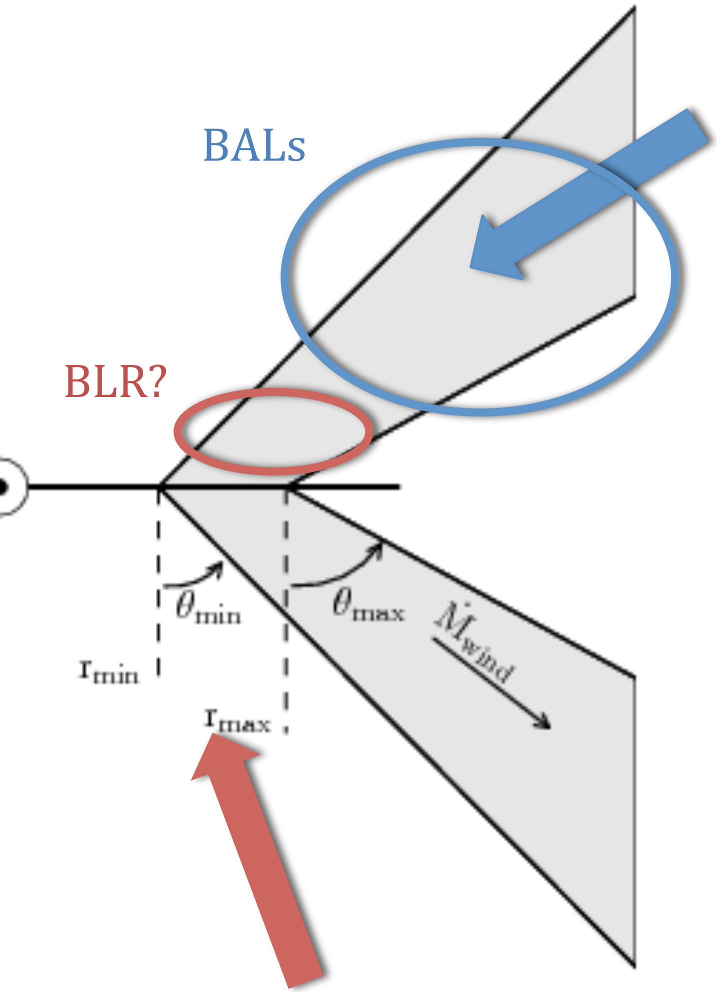


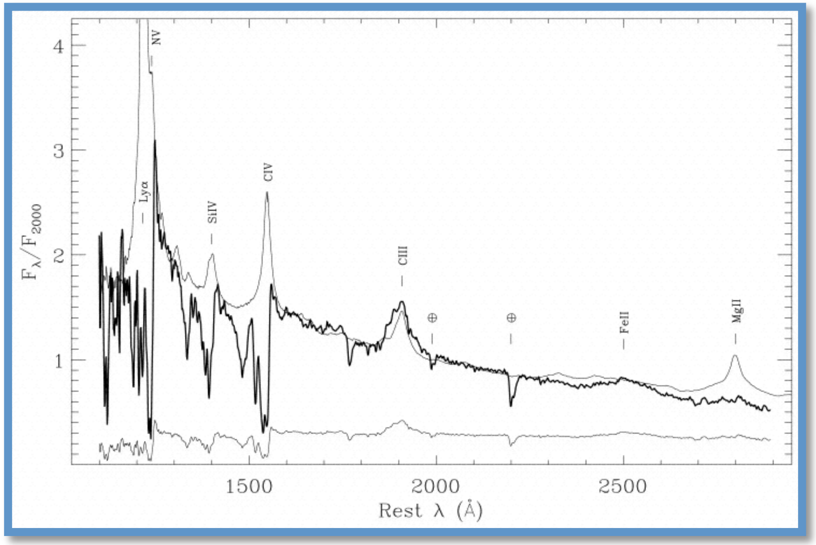
Geometric Unification

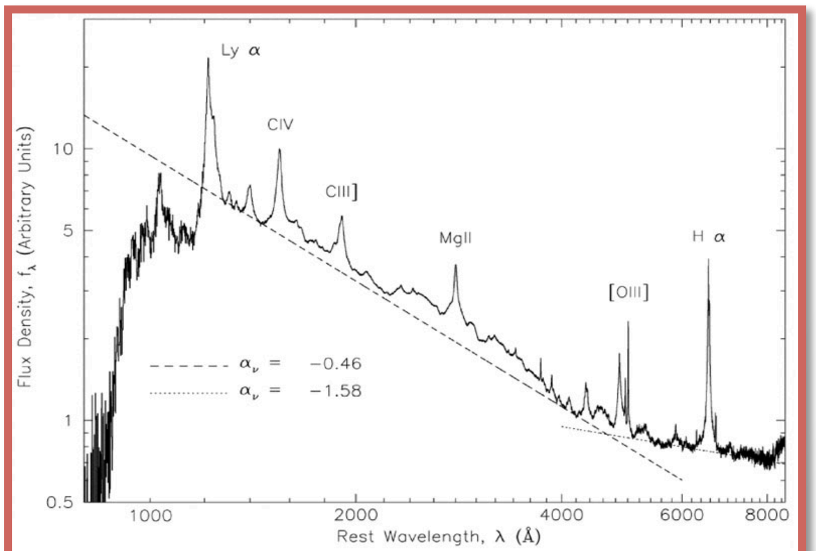


e.g. Elvis 2000, Murray+ 1995, 1998

Geometric Unification







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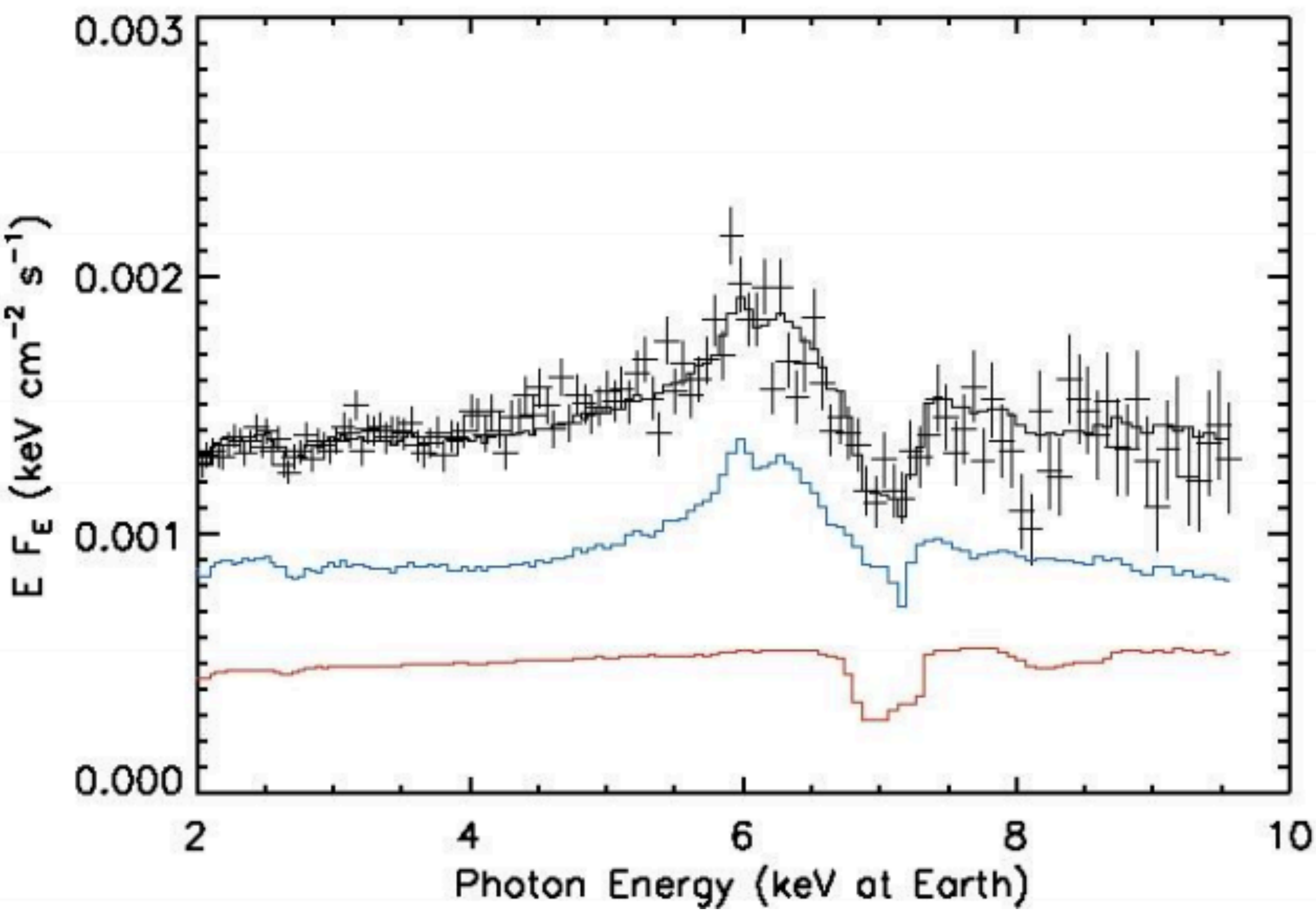

Data

Model

See Sim+ 2008, 2010

Unified Model Checklist

- ☐ BAL resonance line profiles (high i)
- ☐ Realistic X-ray properties
- ☐ Broad emission lines (low i)
- ☐ Good comparison to composite spectra

Testing The Paradigm

Quasar Radiative Transfer and Ionization Project

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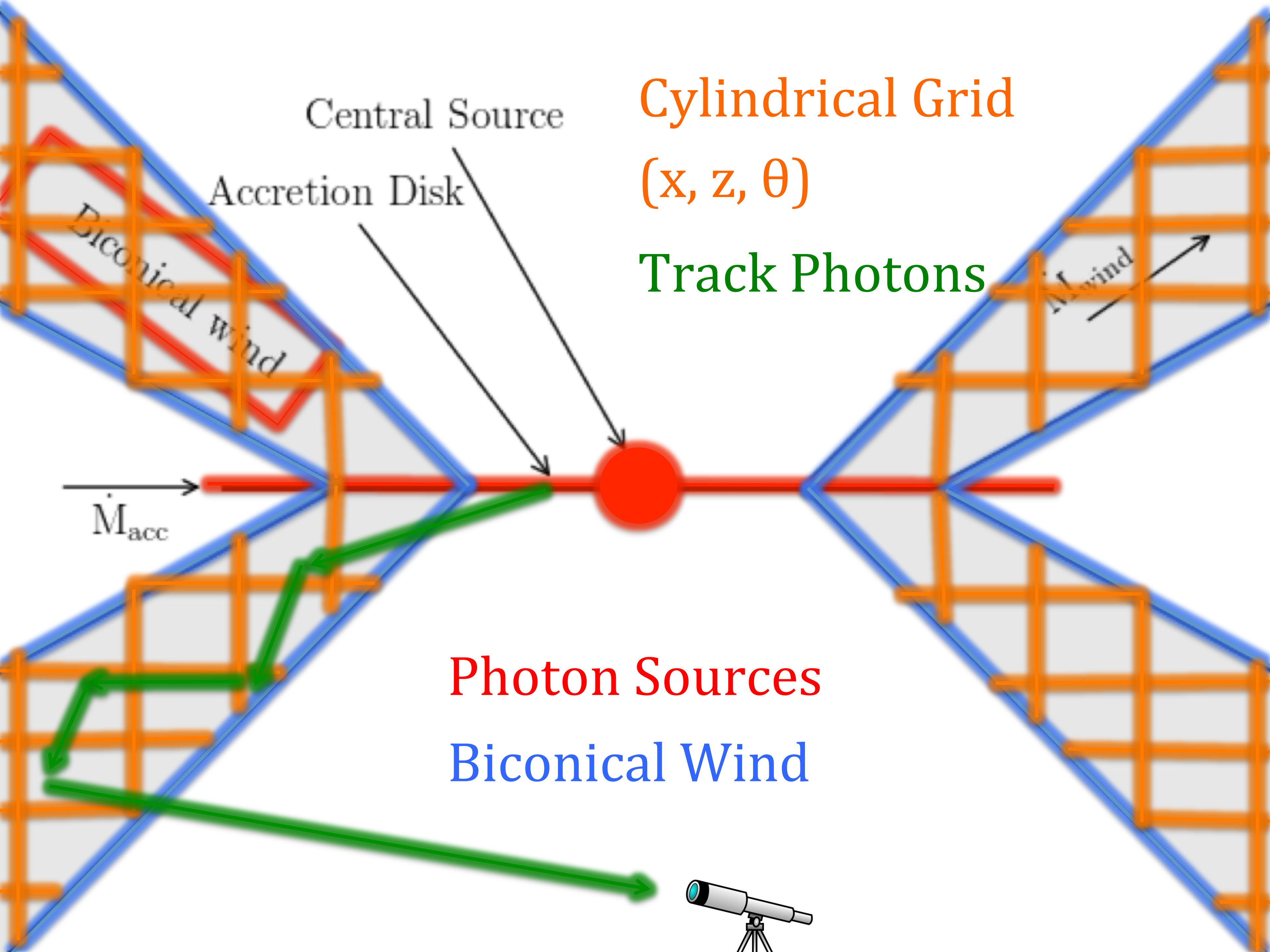
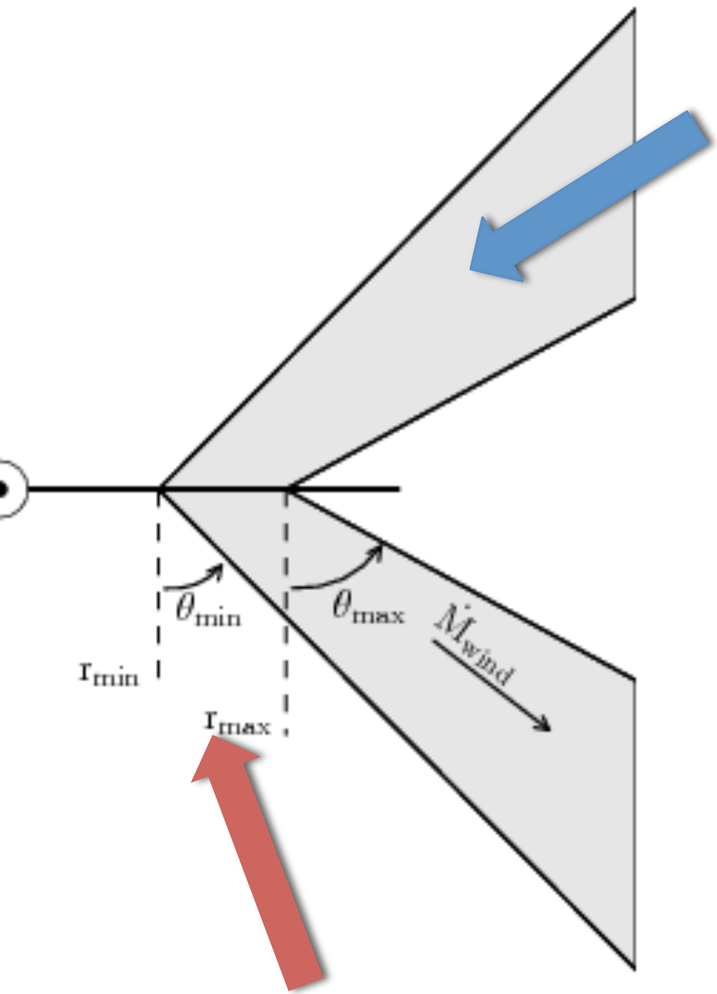
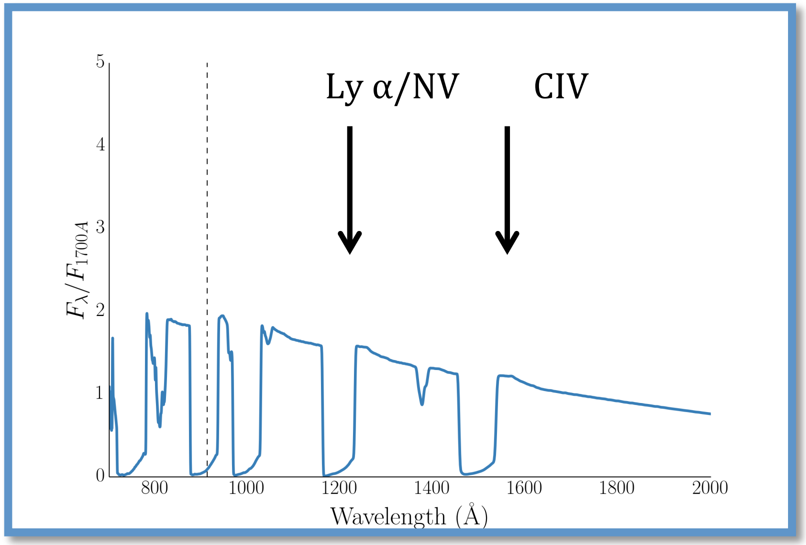
Tool: Monte Carlo Radiative Transfer (MCRT) w/ global ionization balance

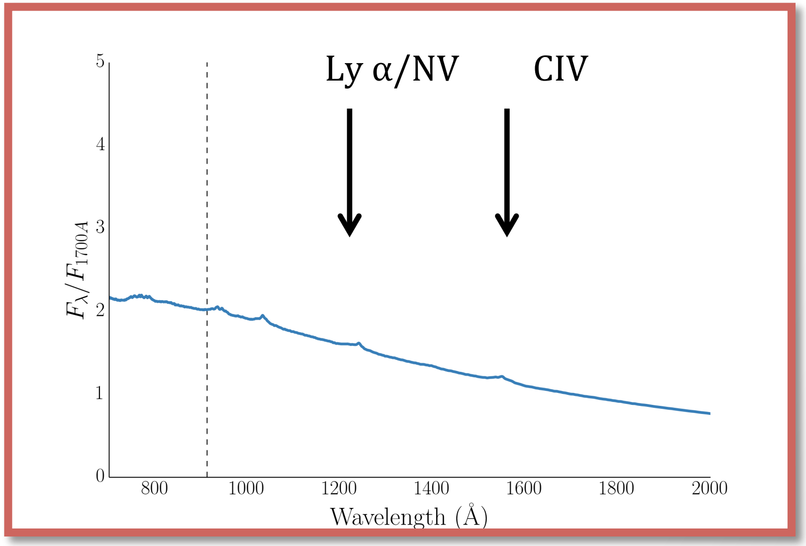

Cylindrical Grid
(x, z, θ)
Track Photons
Central Source
Accretion Disk
Biconical wind
Ṁacc
Ṁwind
Photon Sources
Biconical Wind

Benchmark BALQSO model

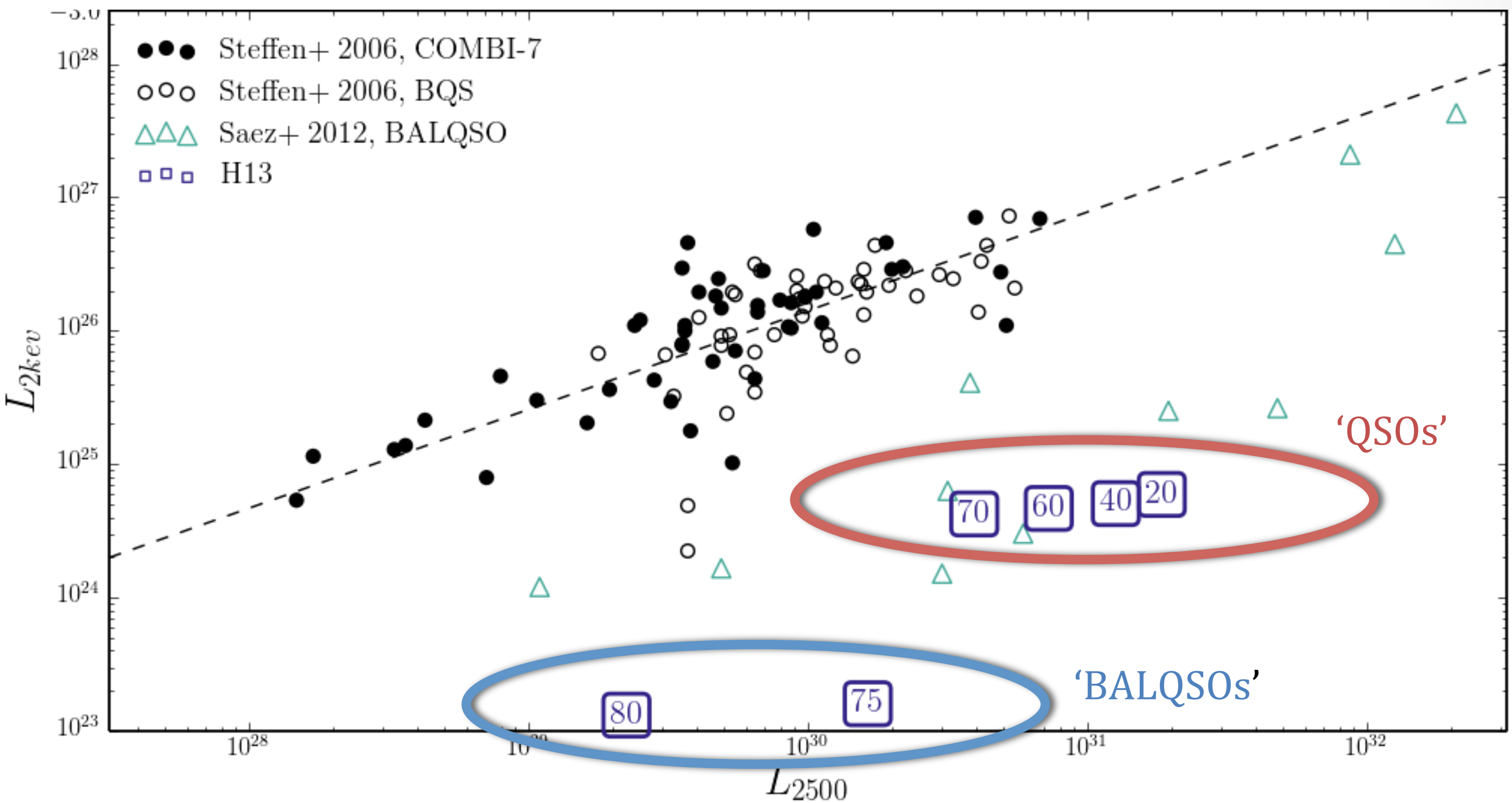
Higginbottom+2013 (H13)







X-ray Properties: H13



Data: Saez+ 2012, Steffen+ 2006

Unified Model Checklist, H13

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Clumping

- *Predicted* by theory
- *Required* in O-star winds (AGN variability?)
- 'Microclumping' assumes optically thin clumps i.e.

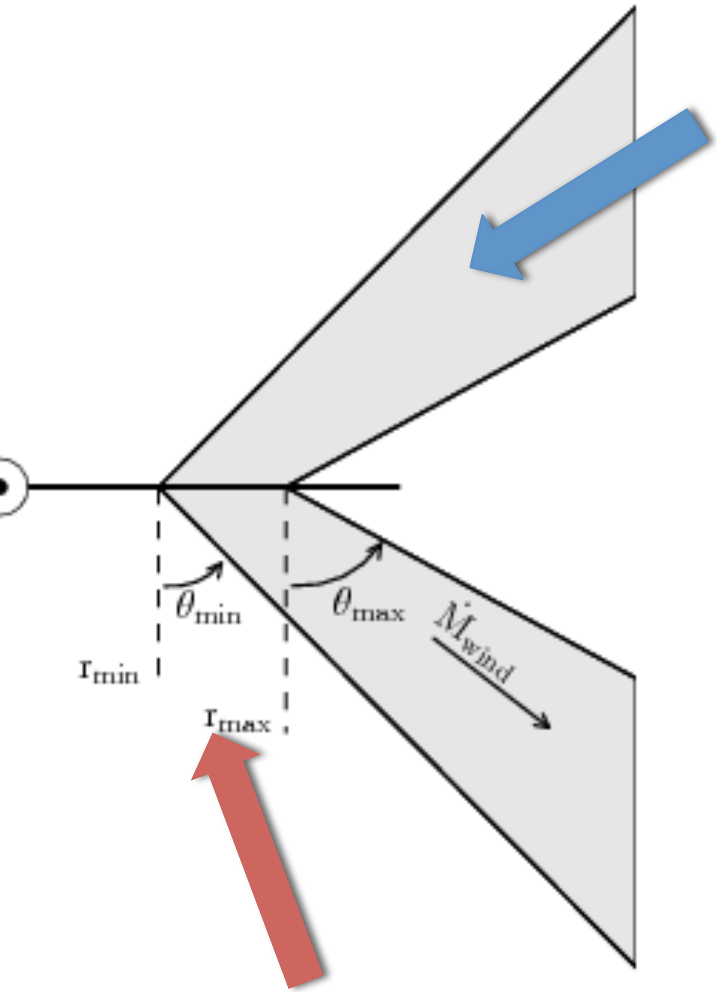
$$R_{clump} << 1/(\sigma n)$$ (~ 10^{14}cm w/ Thomson, $n_e = 10^{10}$)

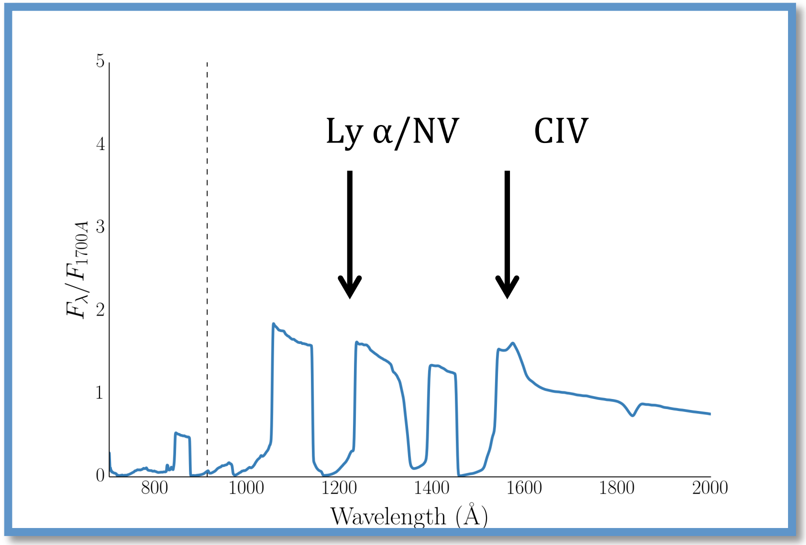
- Introduce a fill factor f, which produces a density enhancement D

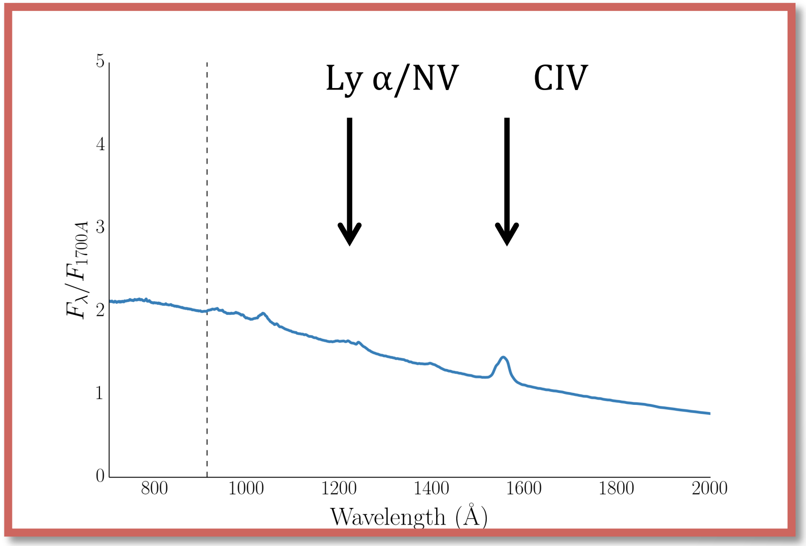
$$D=1/f$$

- **Consequences:**
  - ρ^2 processes should ***increase*** by a factor D
  - Ionization will ***decrease*** (less ionizing photons per atom)

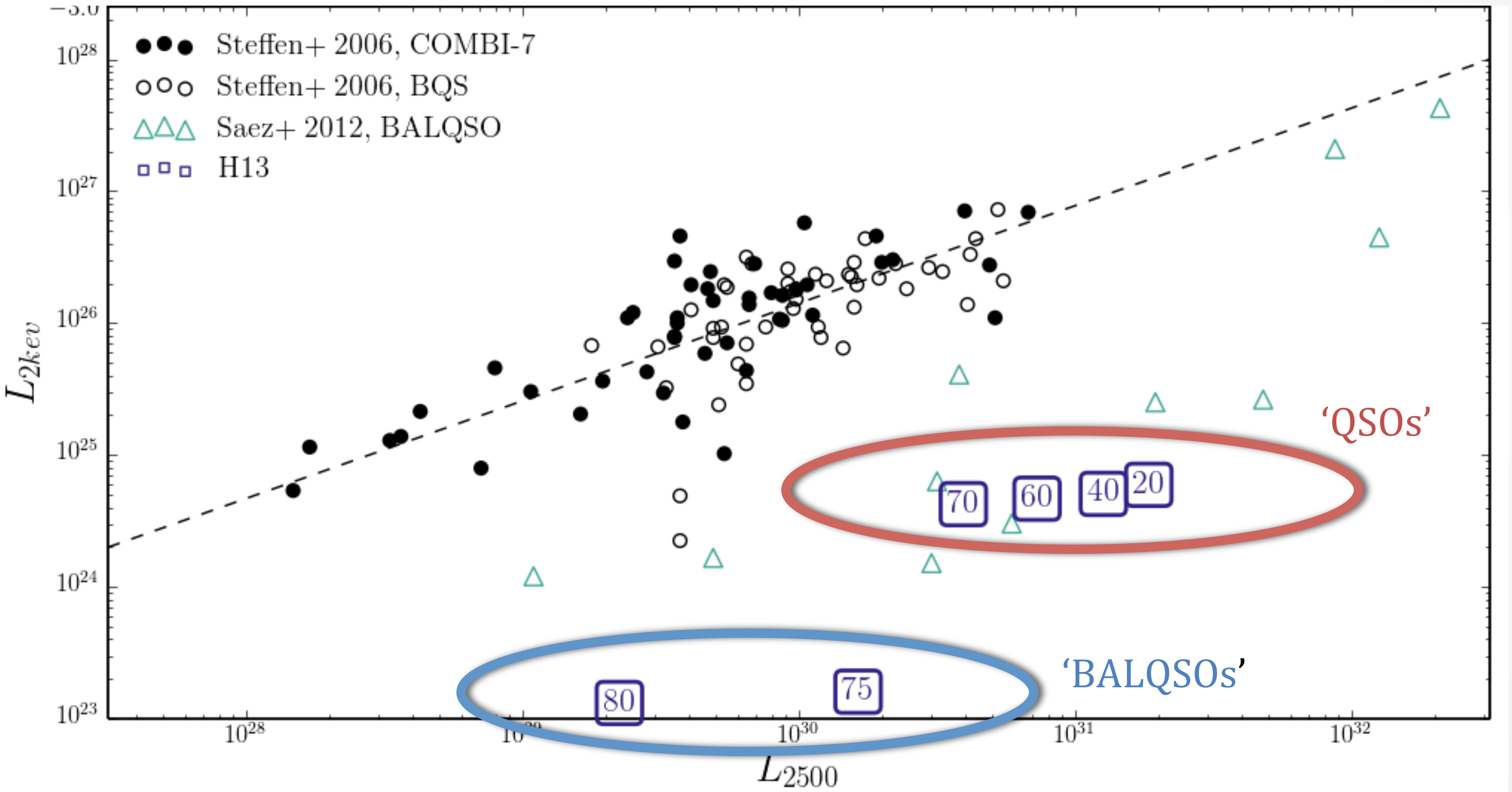
New model ($f = 0.01$, L_X x 100)







X-ray Properties: H13



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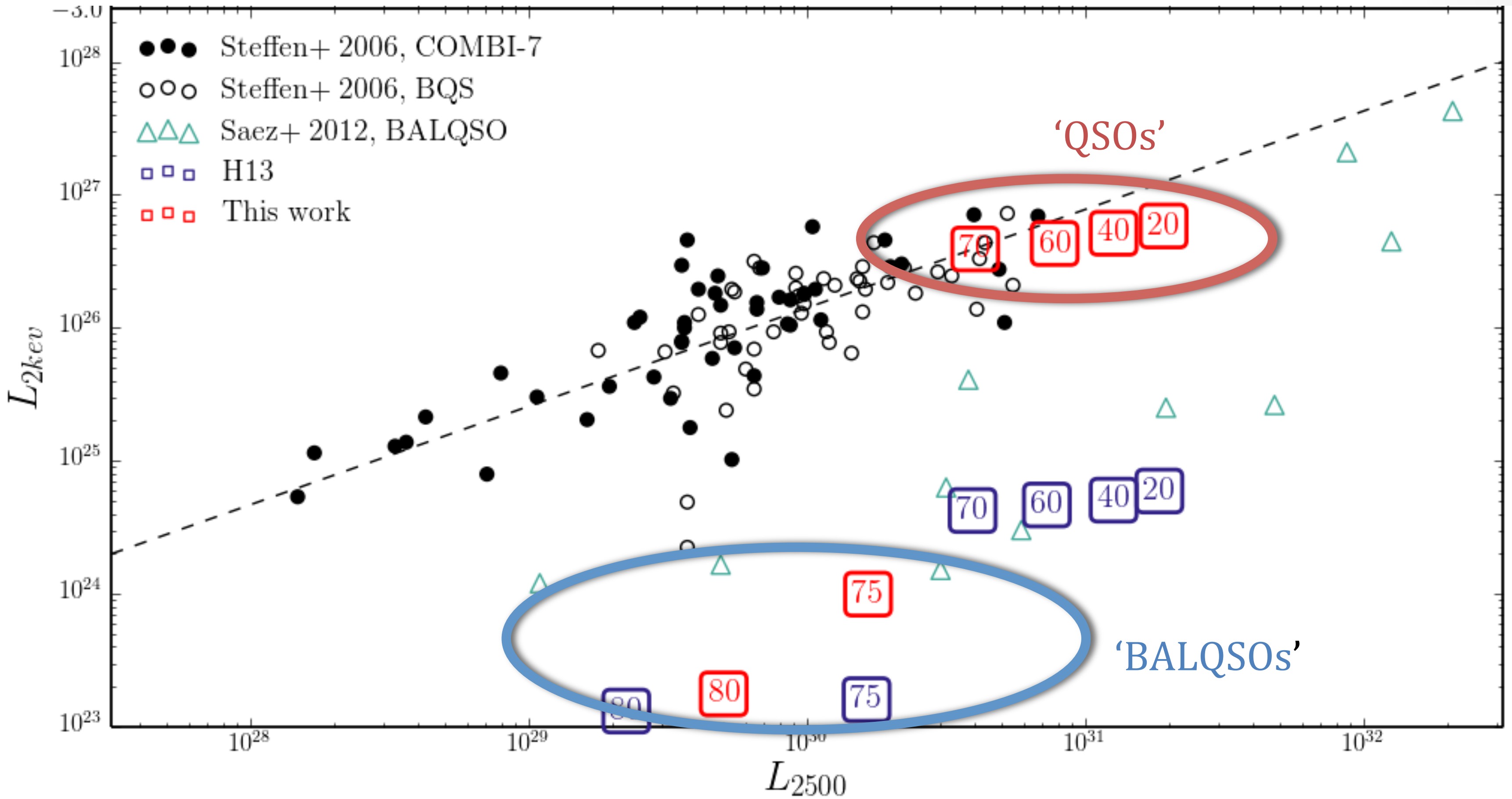
X-ray Properties: New Model

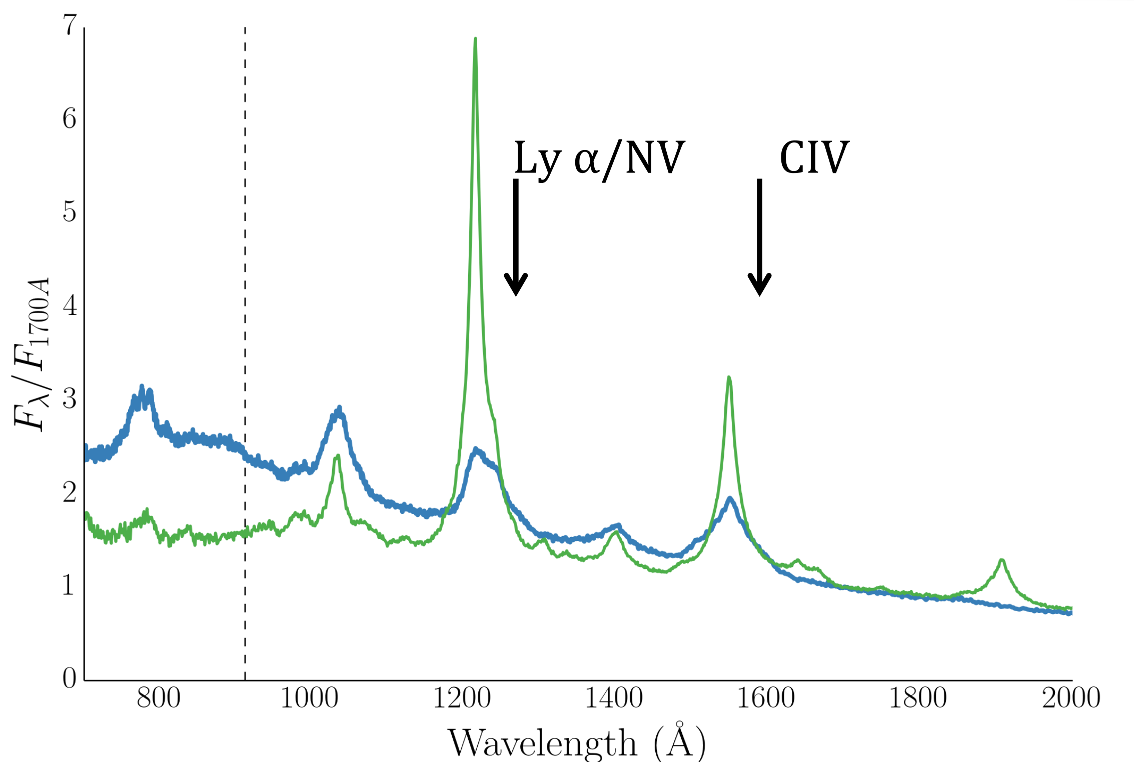


Data: Saez+ 2012, Steffen+ 2006

Producing BELs

Must reprocess (relatively) more flux and make it emerge in lines at low inclinations. How?

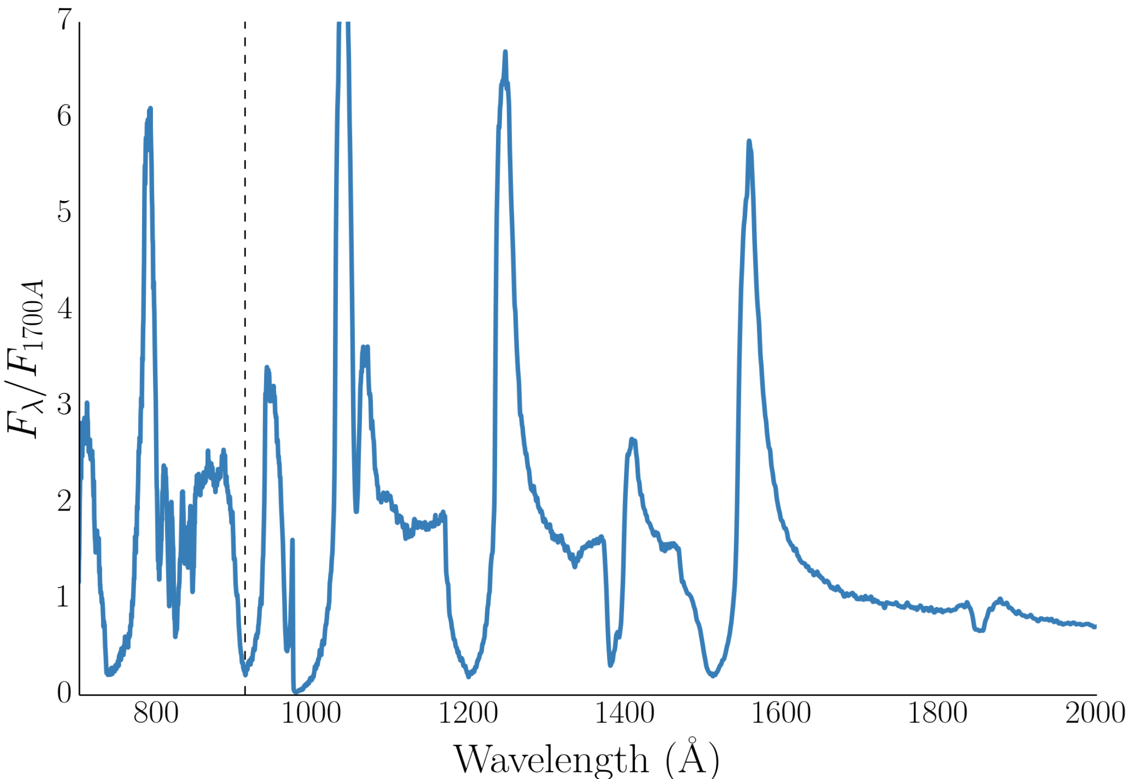
- Cover UV bright portion of disk
- Larger covering factors / emission regions



Producing BELs

- BAL angles: higher line/continuum
- Due to foreshortening, limb darkening, attenuation
- Intrinsic fraction: 63%-> naïve prediction observed: 5%!

Could BALQSOs *dominate* the intrinsic QSO population!?



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- ✔ BAL resonance line profiles (high i)
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- ✗ Good comparison to composite spectra
- ✗ Correct BAL fraction

"TO DO" list!

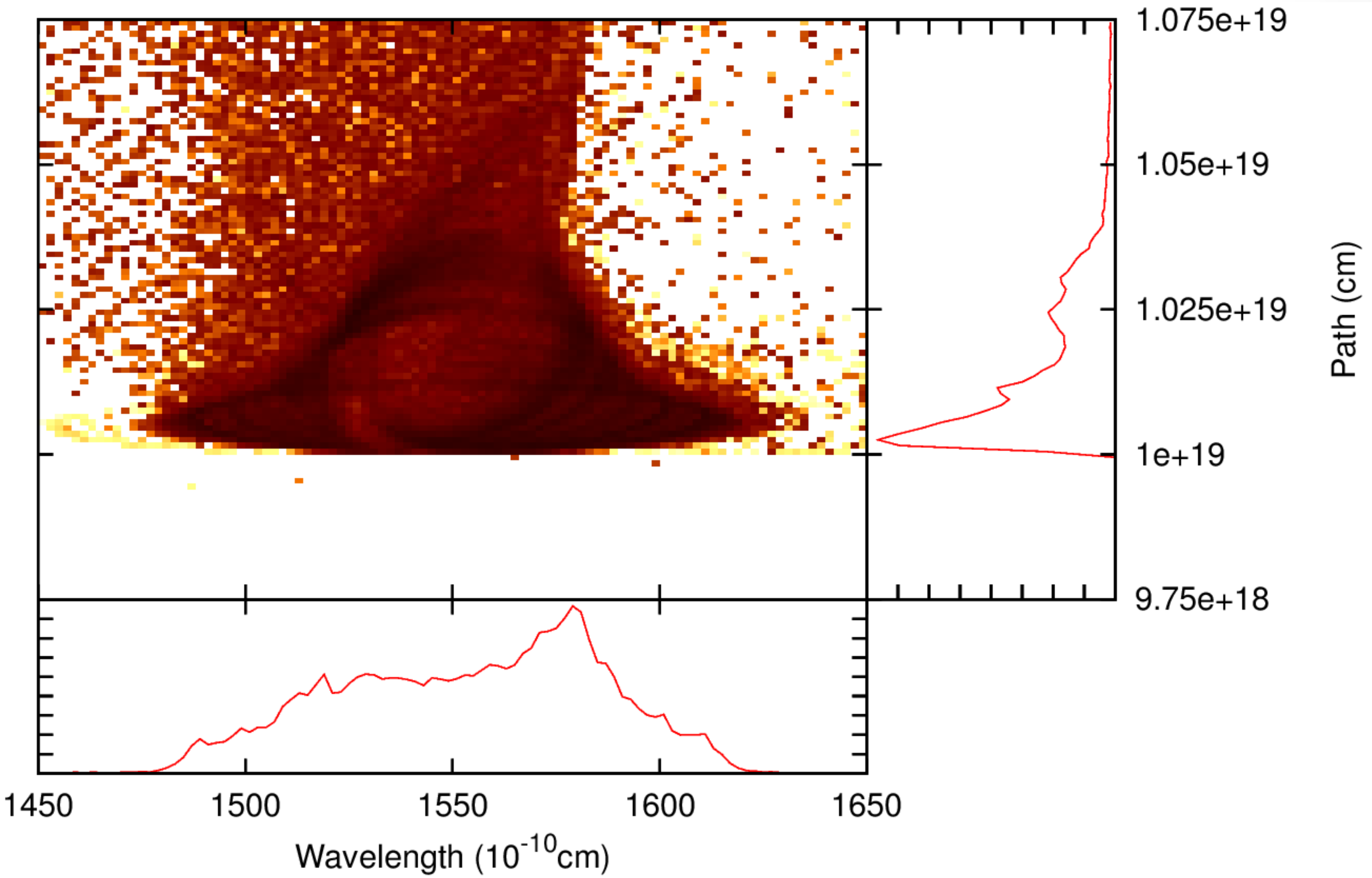
Summary

- With clumping, X-ray properties now agree well with data.
  - Clumping may not be the solution- but you need *something* to prevent over-ionization
- BALQSO winds can produce BELs - not yet at right EW
  - higher mass loss? modified disk prescription? (Laor & Davis 2014, Capellupo+ 2015)
- The ‘accepted’ BALQSO geometry may need rethinking
  - Equatorial, 10-20% covering factor? Perhaps not!
- Must explore M_{BH} & L/L_{edd} space

Outflows may be crucially important in shaping the spectra of QSOs at all angles (Matthews+, in prep)

More observational constraints needed: Geometric and Multi-wavelength.

Reverberation with MCRT



Mangham+, in prep