UNIVERSITY OF Southampton

Modelling the Spectra of Quasars

Clumpy Winds and Unification

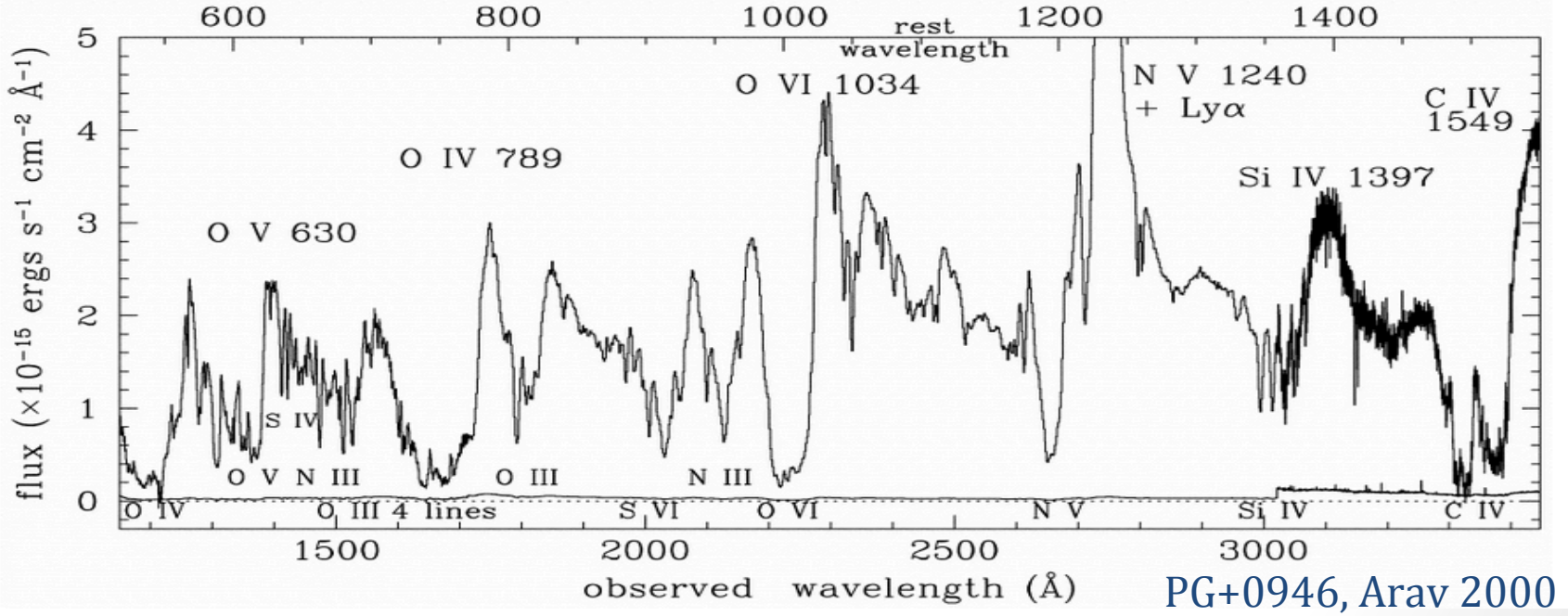
James Matthews

Christian Knigge, Nick Higginbottom, Knox Long,
Stuart Sim, Sam Mangham

TORUS 2015, Winchester
#torus2015

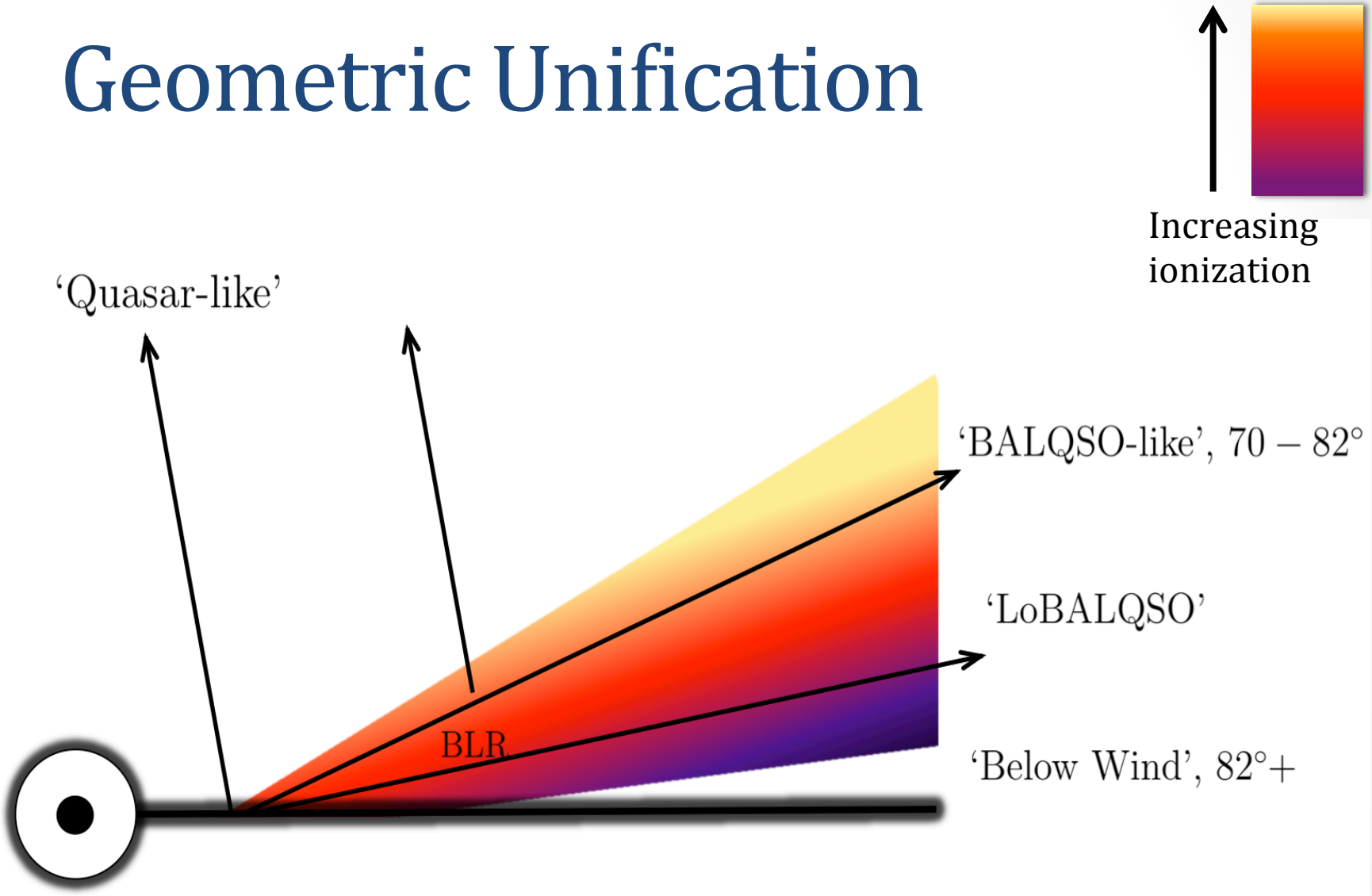
BALQSOs

- ~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 -> ***disc winds***
- Potentially 'line-driven'



PG+0946, Arav 2000

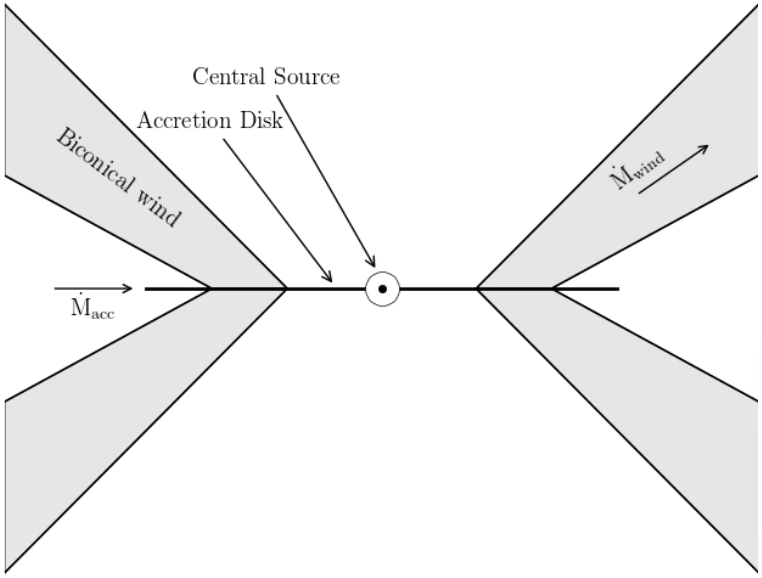
Geometric Unification



e.g. Elvis 2000, Murray et al. 1995, 1998

Testing The Paradigm

Quasar Radiative Transfer and Ionization Project

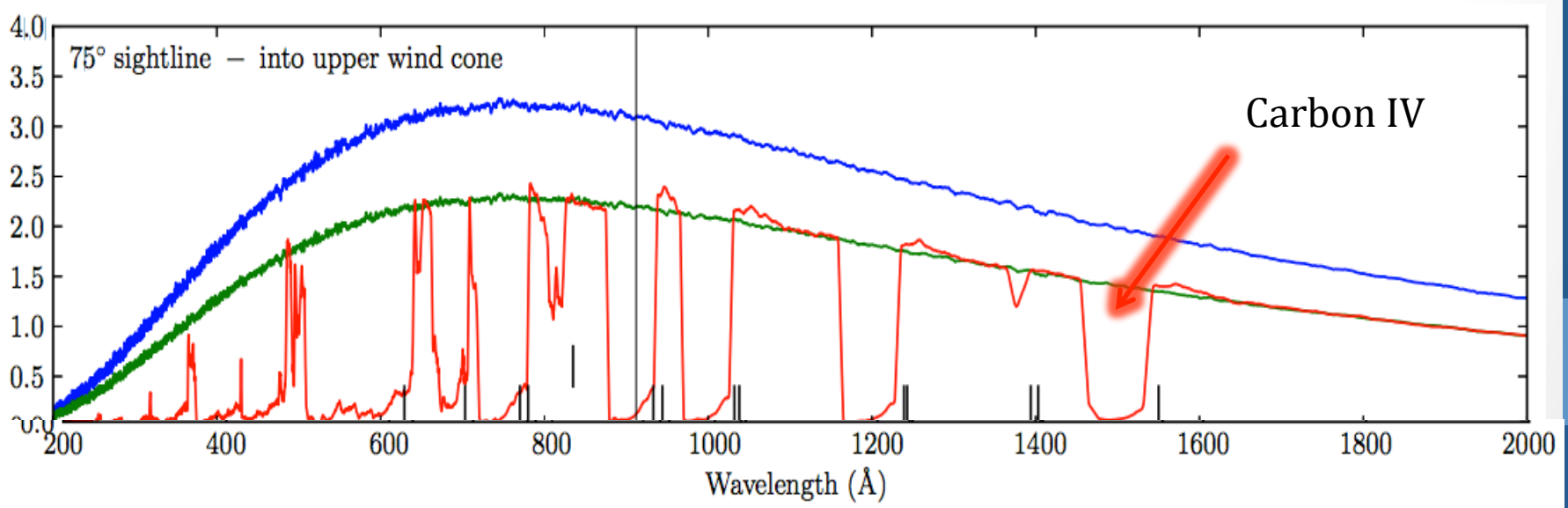


Tool: Monte Carlo Radiative Transfer (MCRT) + global ionization balance
(Long & Knigge 2002, Higginbottom et al. 2013, Matthews et al. 2015)

Over-ionization

[Higginbottom poster, A5]

- Higginbottom et al. 2013 presented a model with strong BALs in the synthetic spectra
- However: LX too low by ~100x
  - "Over-ionization problem"
- No broad emission lines produced at low inclinations



Clumping

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

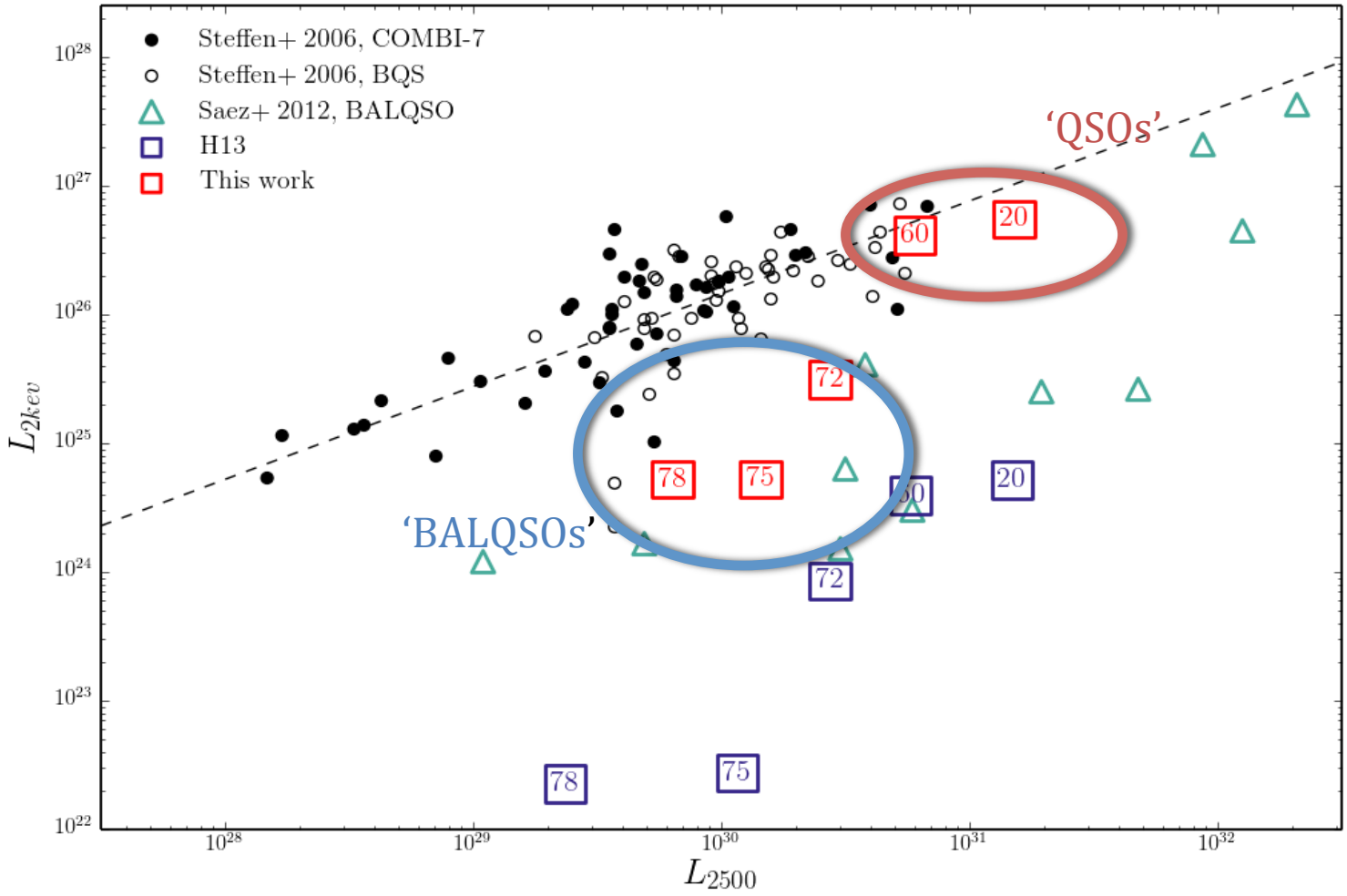
$$R_{clump} << 1/(\sigma n)$$ (~ 10^{14}cm w/ Thomson, $n_e = 10^{10}$)

- 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)

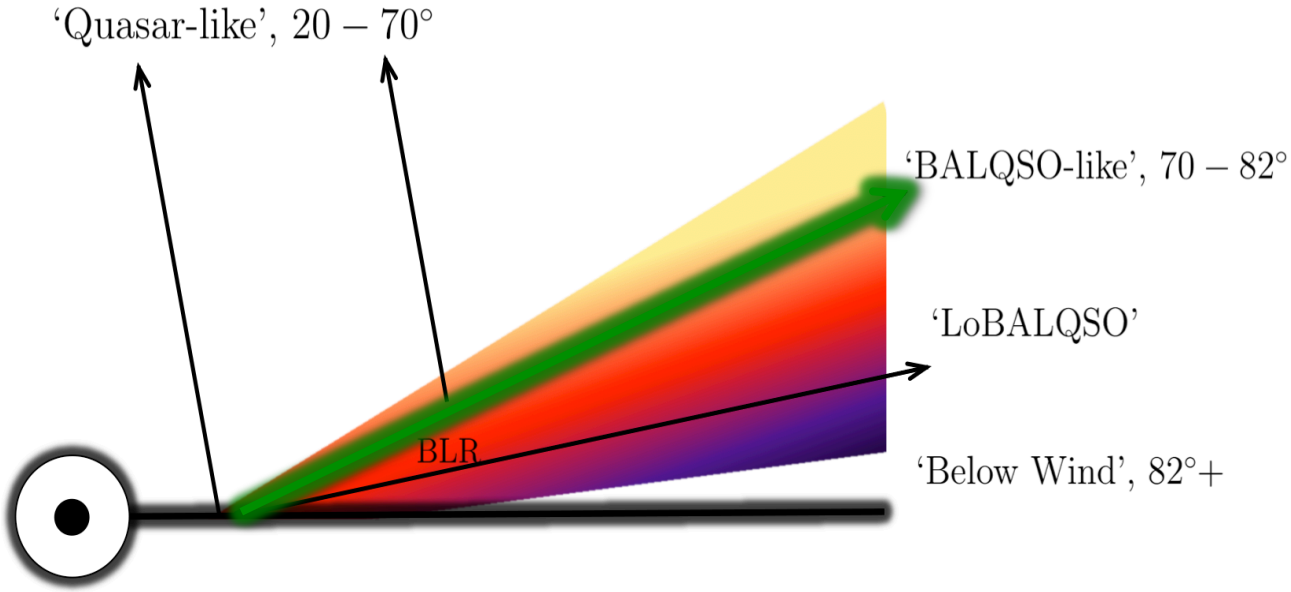
X-ray Properties: Clumpy Model

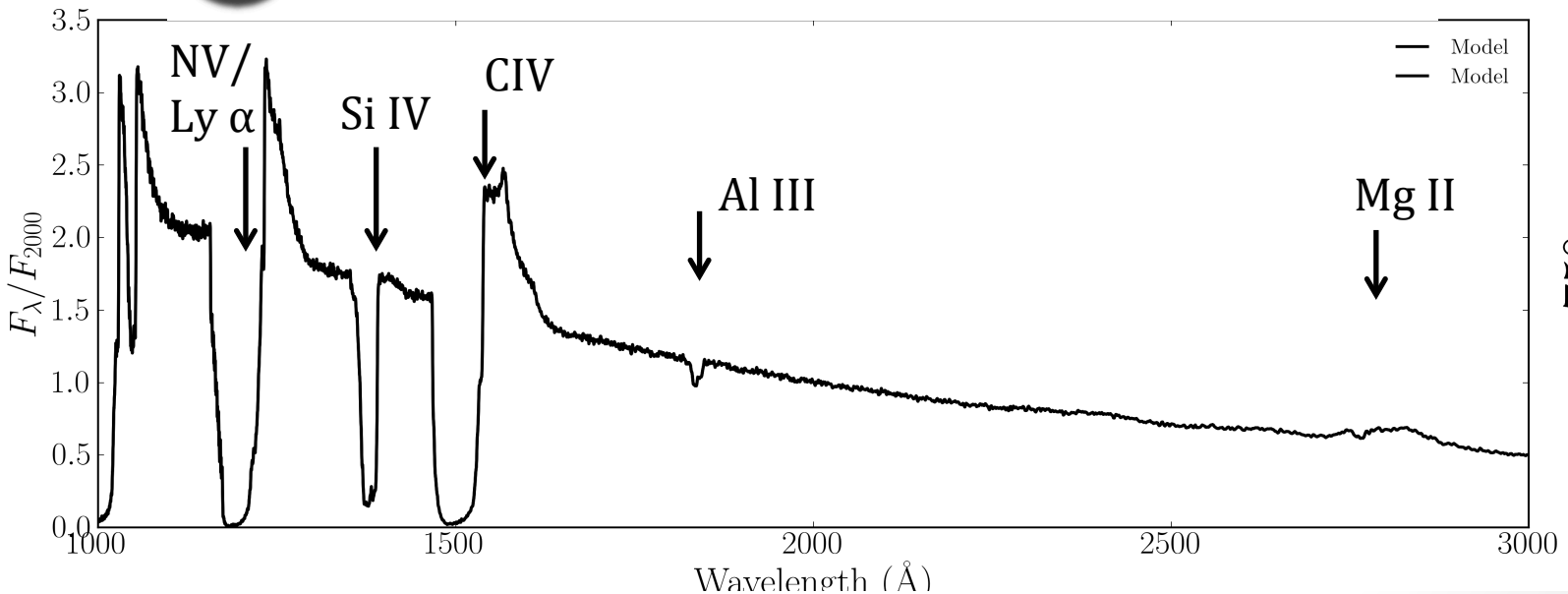


D = 100 (f = 0.01)
Isotropic X-ray source

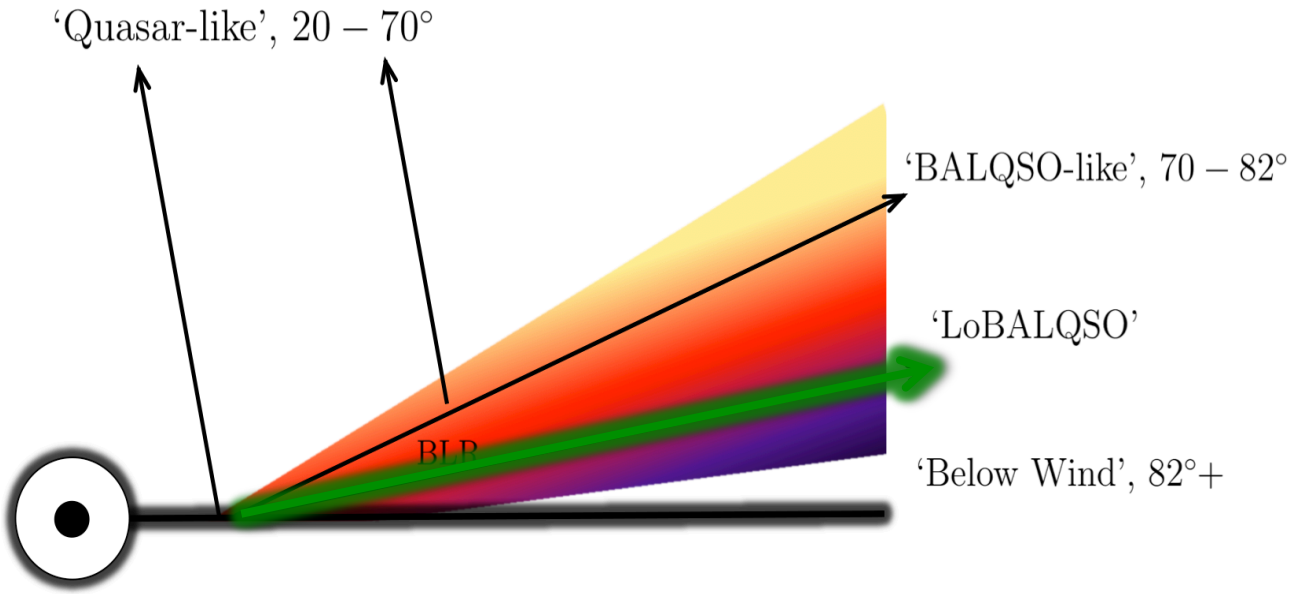
Data: Saez+ 2012, Steffen+ 2006

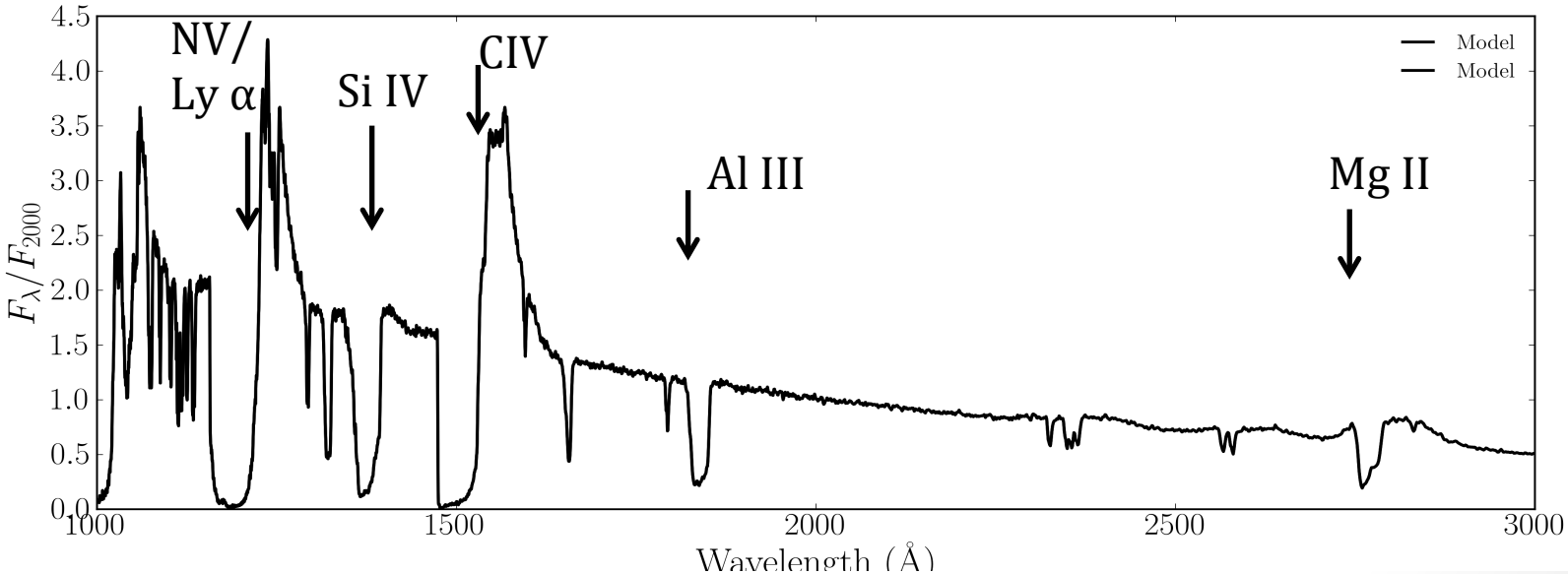
Synthetic Spectra



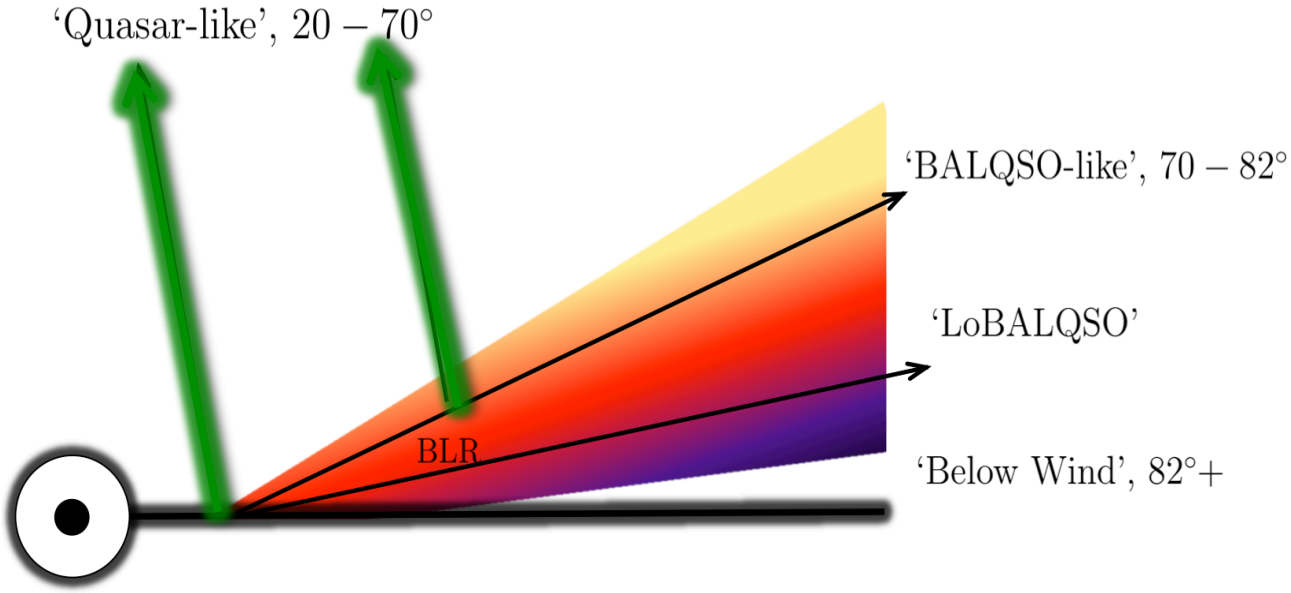


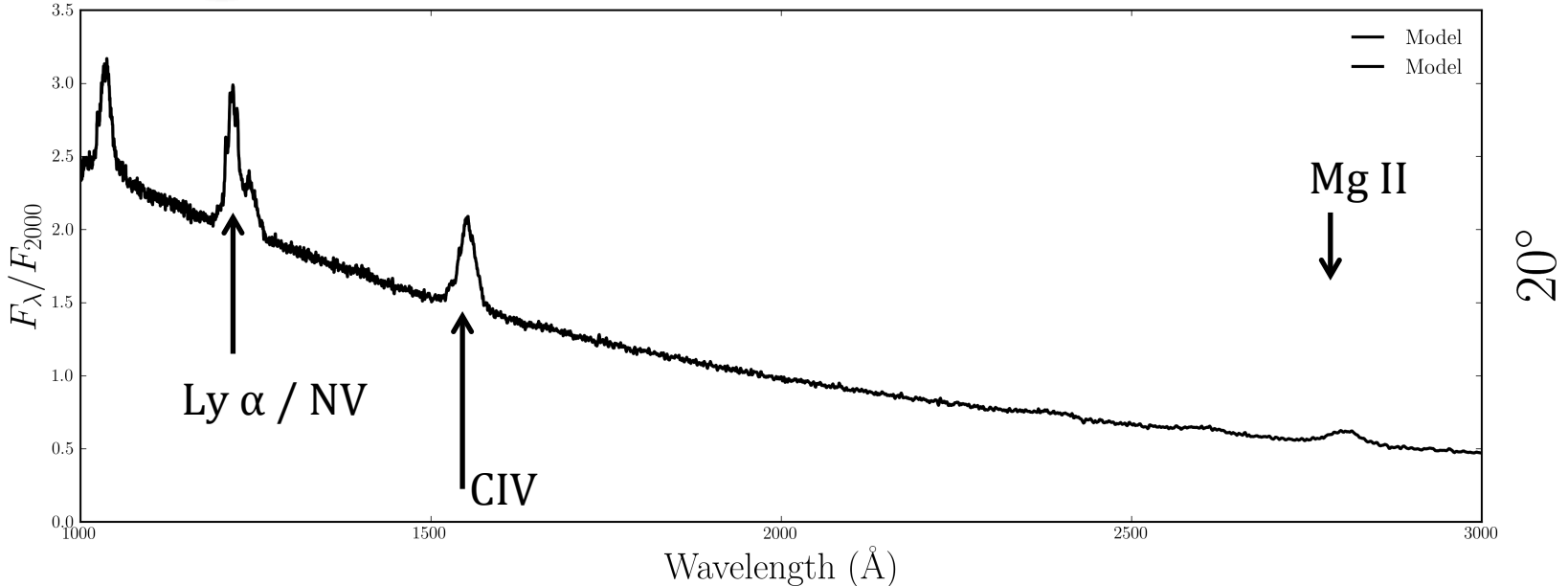
Synthetic Spectra

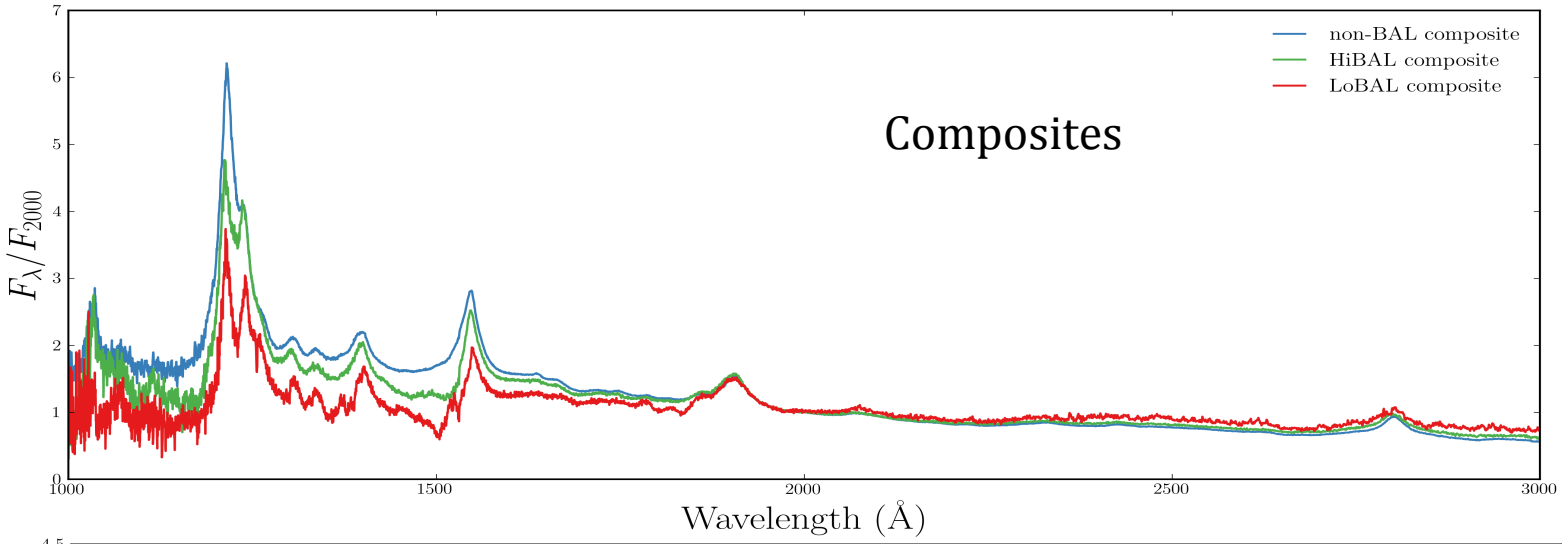


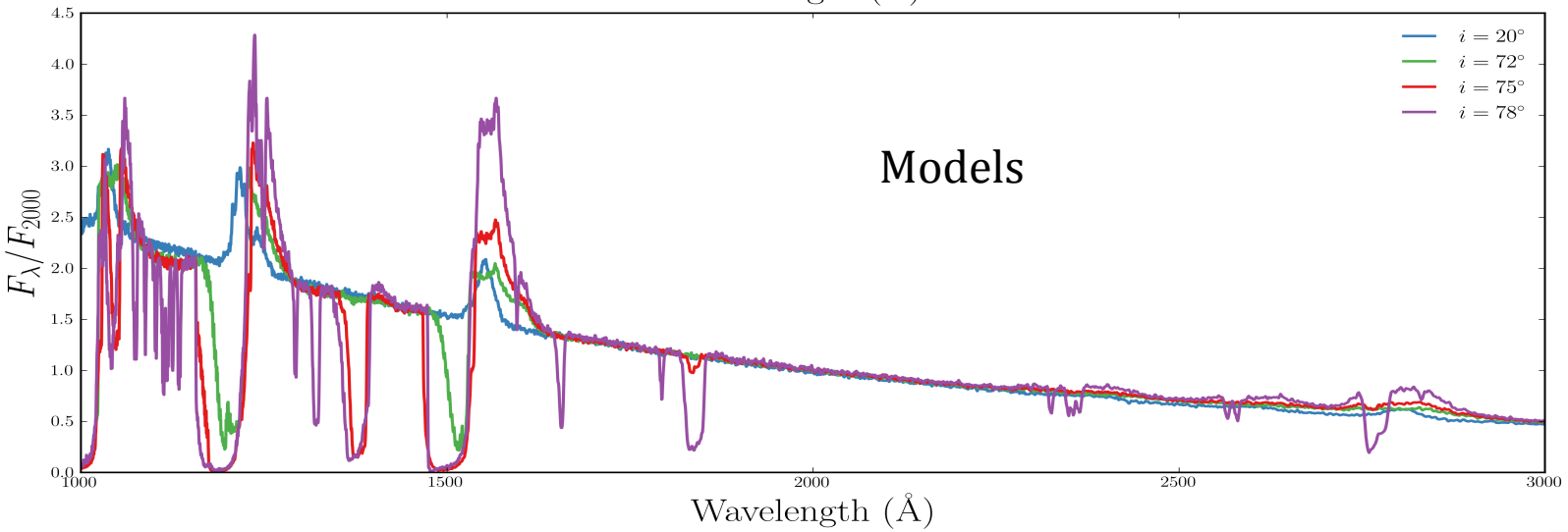


Synthetic Spectra









Quasars and BALQSOs have remarkably similar emission line properties (Weymann et al. 1991, Reichard et al. 2003).

Our models don't.

It is *impossible* to reproduce uniform line properties in quasars and BAL quasars *unless* the continuum and lines have the same angular distribution of emission.

(Matthews et al. 2015b, in prep)

(In a geometrical picture)

Not unique to wind models for the BLR!

Possible solutions:

- QSO accretion disks emit more or less isotropically (!)
- All Quasars viewed from narrow angle range?
- The line emitting region emits anisotropically in the same way as the disc
  - not expected from theory of line emission from a disc
    (Horne & Marsh 1985, Murray & Chiang 1996)
  - could predict $f_{BAL} \sim 1$!

Summary

- With clumping, X-ray properties now agree well with data.
- BALQSO winds can produce strong BELs
- The accepted BALQSO geometry may need rethinking
  - Equatorial wind, 20% covering factor? Perhaps not.
- **The angular distribution of emission is crucial** and poses challenges to the disc wind unification model *(Matthews et al. 2015b, in prep)*

"The outflow is crucially important in shaping the spectrum of a quasar- whichever way you look at it!"

(Matthews et al. 2015a, in prep)