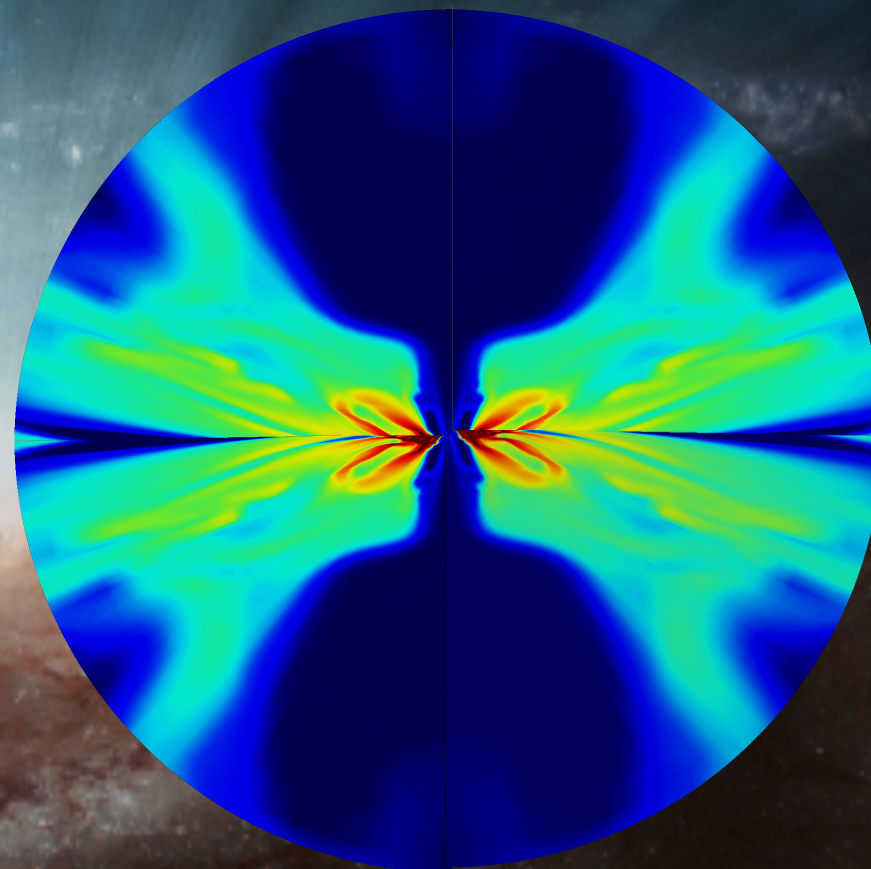
Georgia Winds
June 2017

TESTING QUASAR UNIFICATION

WITH RADIATIVE TRANSFER AND OBSERVATIONAL DATA



JAMES MATTHEWS

CHRISTIAN KNIGGE, NICK HIGGINBOTTOM, SAM MANGHAM (Southampton)

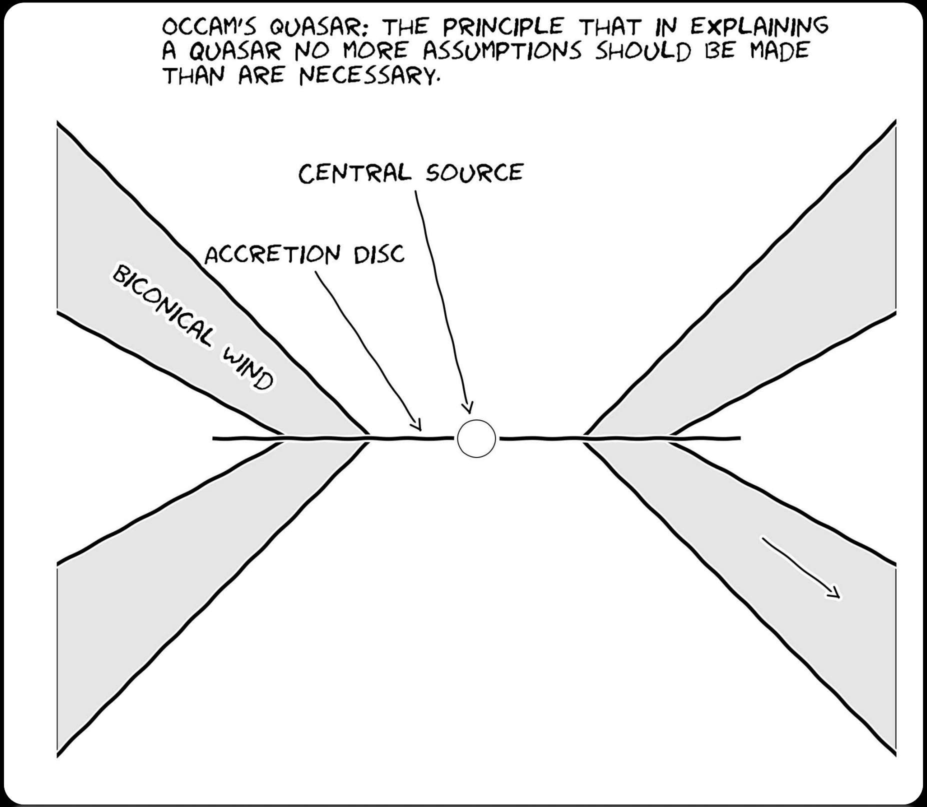
KNOX LONG (STScI, Eureka Scientific)

STUART SIM (Queen's Belfast)

UNIVERSITY OF OXFORD

OCCAM'S QUASAR

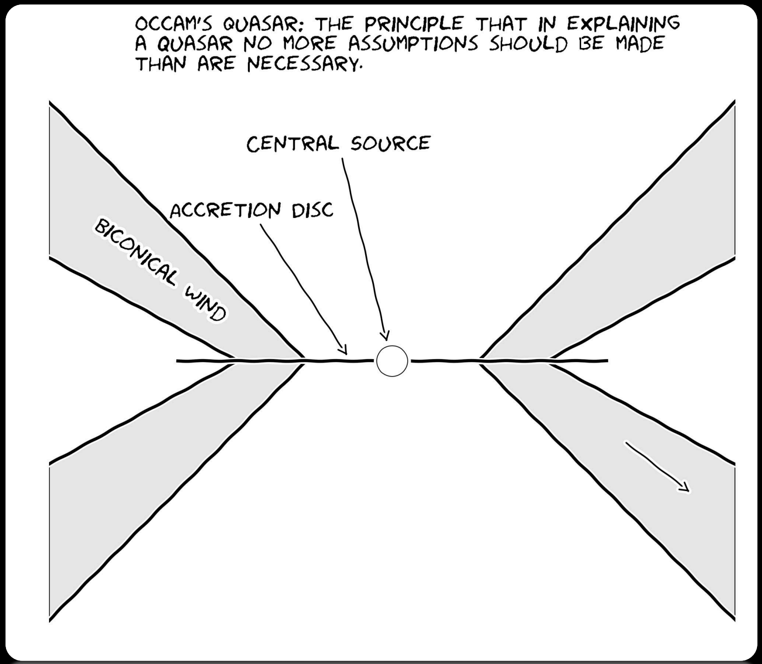
- Before we invoke clouds/additional components…
  - What's there already? Winds!



Emmering et al. 1992, Murray et al. 1995, de Kool & Begelman 1995, Elvis 2000.

TESTING THE PARADIGM

"Quantitative Hammer"



Tool: Monte Carlo Radiative Transfer (MCRT) with global ionization balance
Code: Python (named c. 1995)

Long & Knigge 2002
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Mangham et al., submitted

Radiative, Thermal and Ionization Equilibrium

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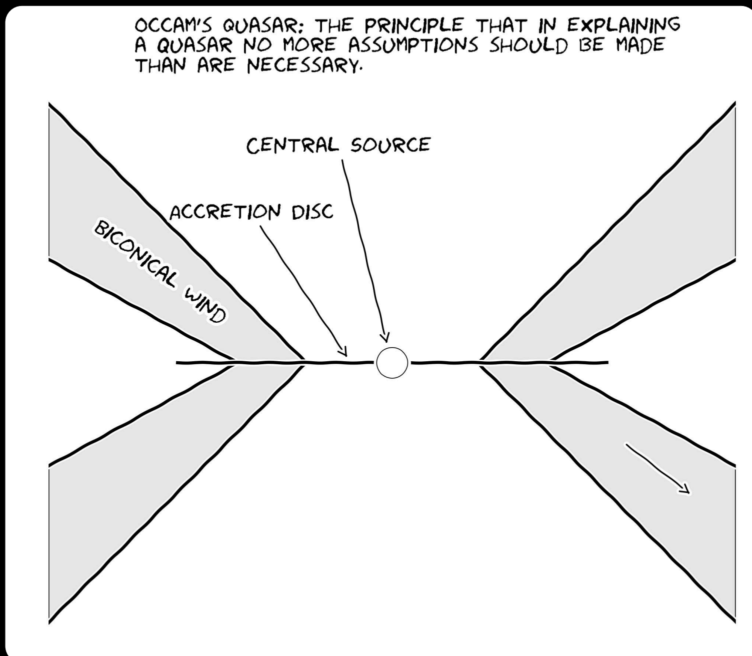

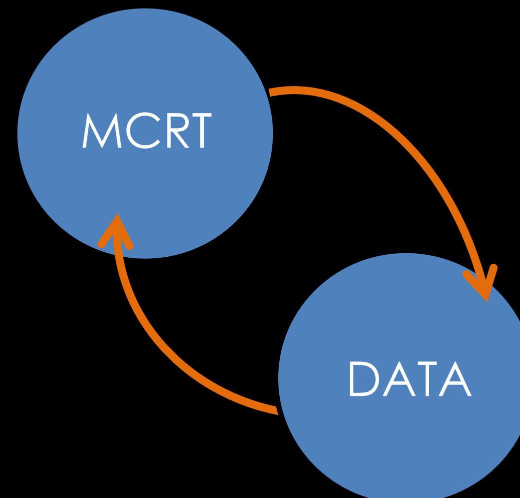

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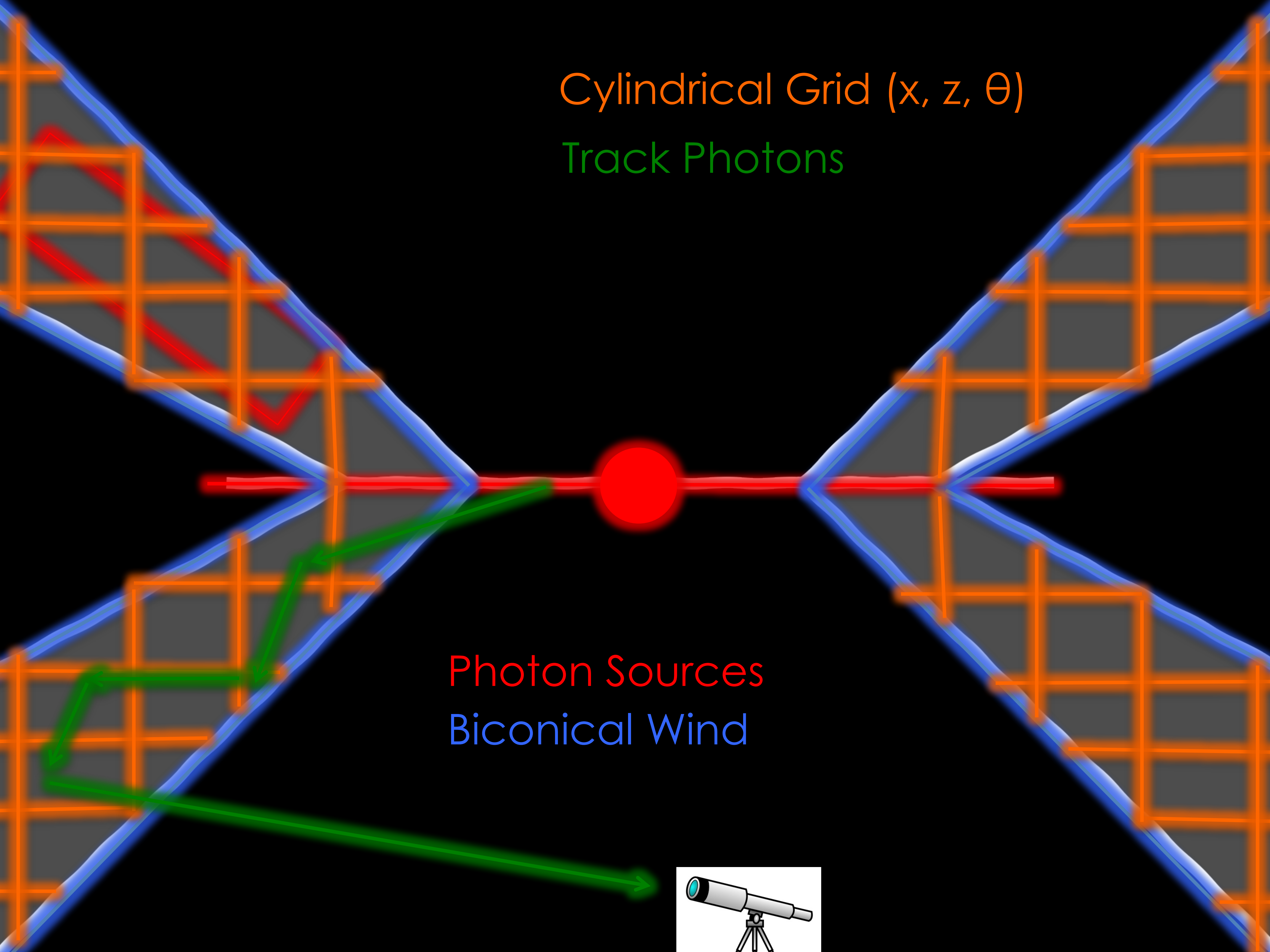
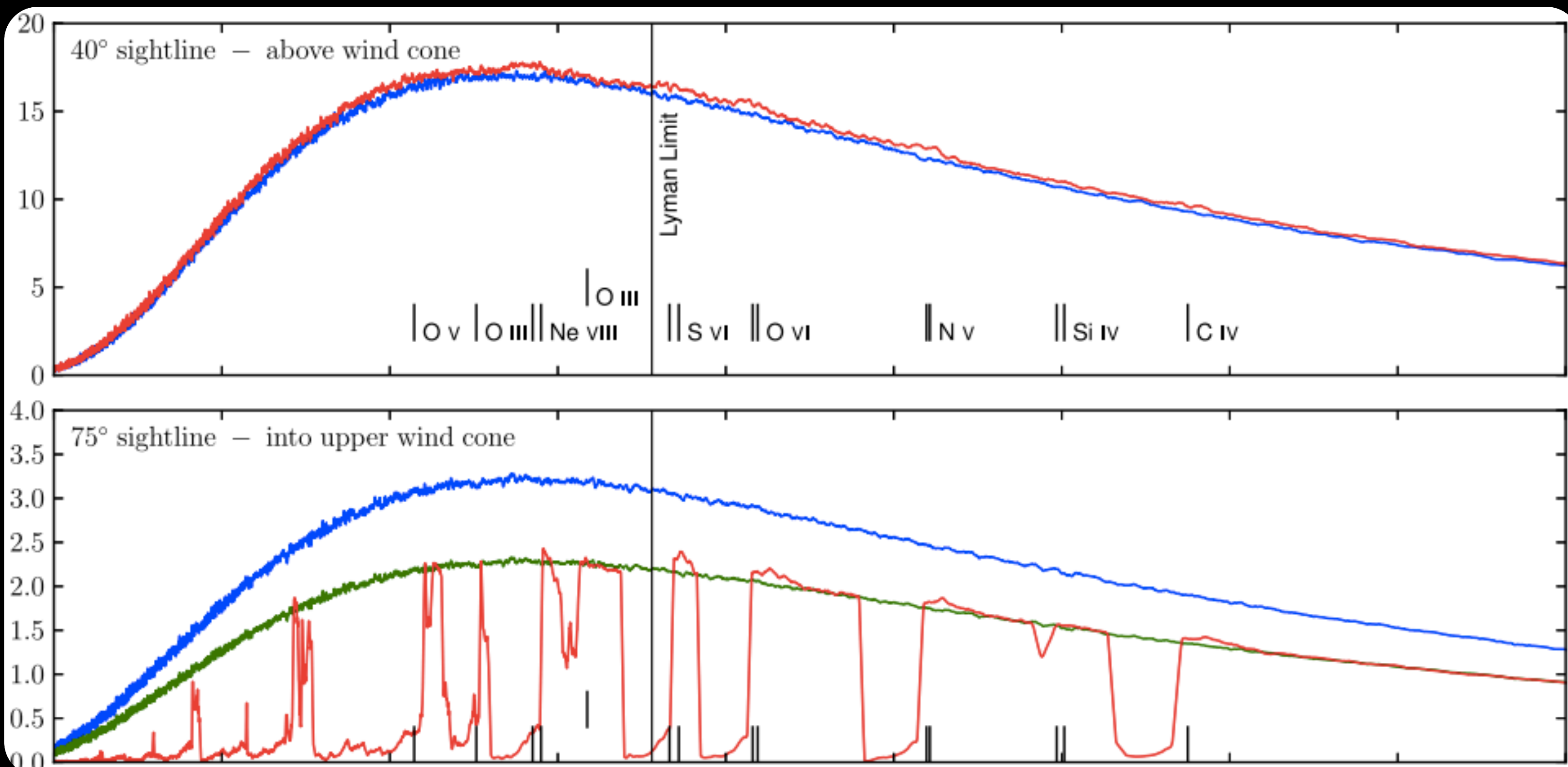

Cylindrical Grid (x, z, θ)
Track Photons
Photon Sources
Biconical Wind

BALQSO SPECTRA
(Higginbottom+ 2013)

Mass loss rate = accretion rate
10^9 BH mass

Two main issues:
- No emission lines at low inclinations
- Overly weak X-rays to prevent over-ionization



MICROCLUMPING

- Borrow a stellar winds technique: Microclumping
- Optically thin clumps i.e.

$$R_{clump} < 1/(\sigma n)$$

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

$$D=1/f$$

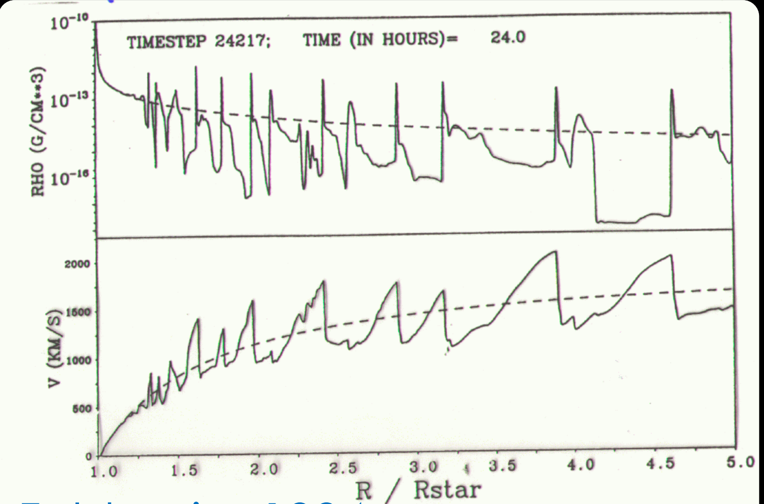
- Opacities and emissivities use enhanced density but reduced by f (volume/filling effect)

OPTICALLY THIN CLUMPS?

Is this at all justified?

- Some limits / literature:
  - ~10^{14} cm w/ Thomson & $n_e = 10^{10}$
  - 10^{11} cm – de Kool & Begelman (1995)
  - $N_H \sim 10^{17}$ – McCourt et al. (2016)
  - 'Quasar Rain' – Martin Elvis

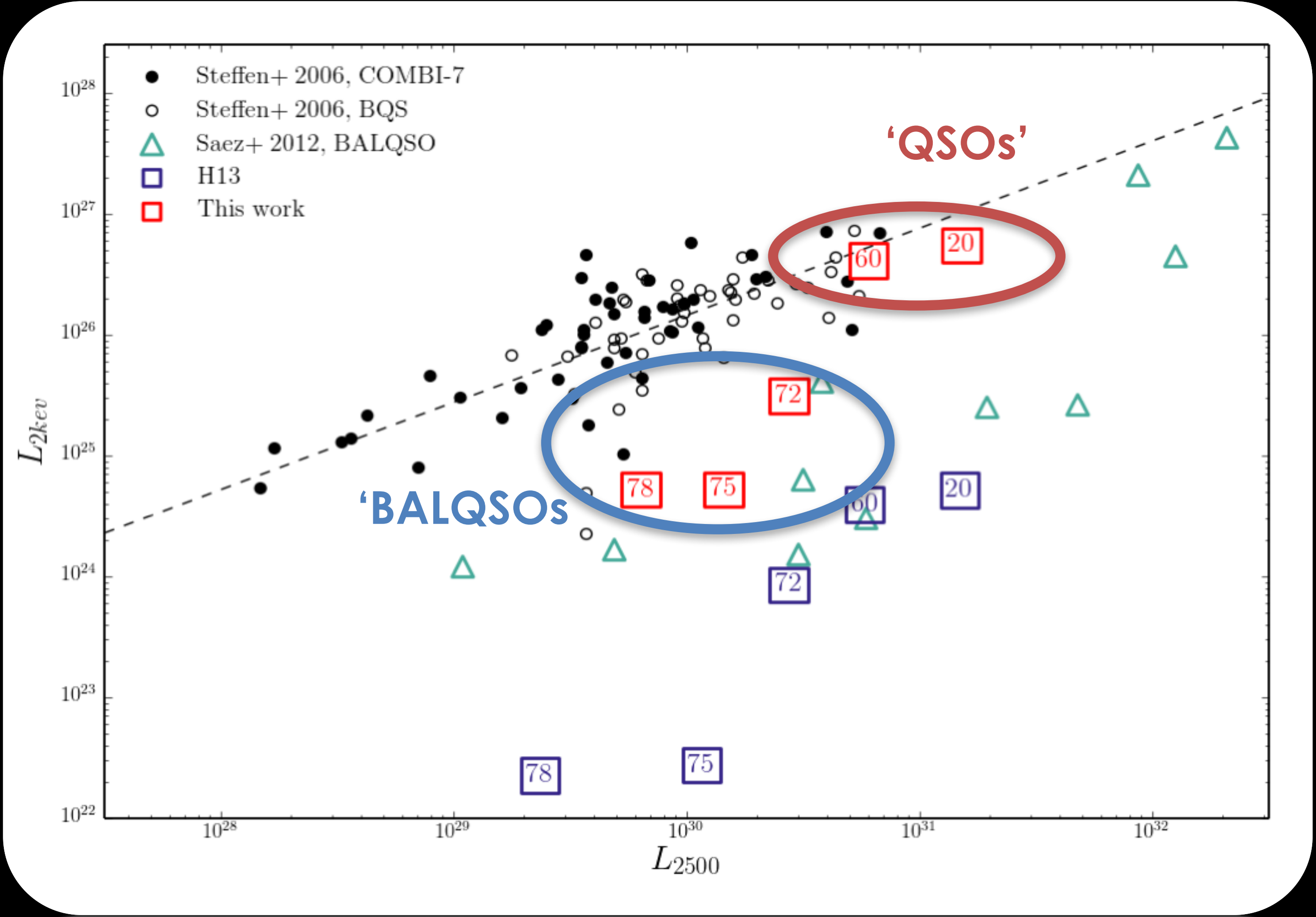
- Line Deshadowing Instability
  - Owocki, Lucy, Solomon, Feldmeier, Rybicki, Macgregor, O star community



Feldmeier 1994

Velocity perturbation causes increase in flux, increases line force -> instability.

X-RAY PROPERTIES: CLUMPY MODEL

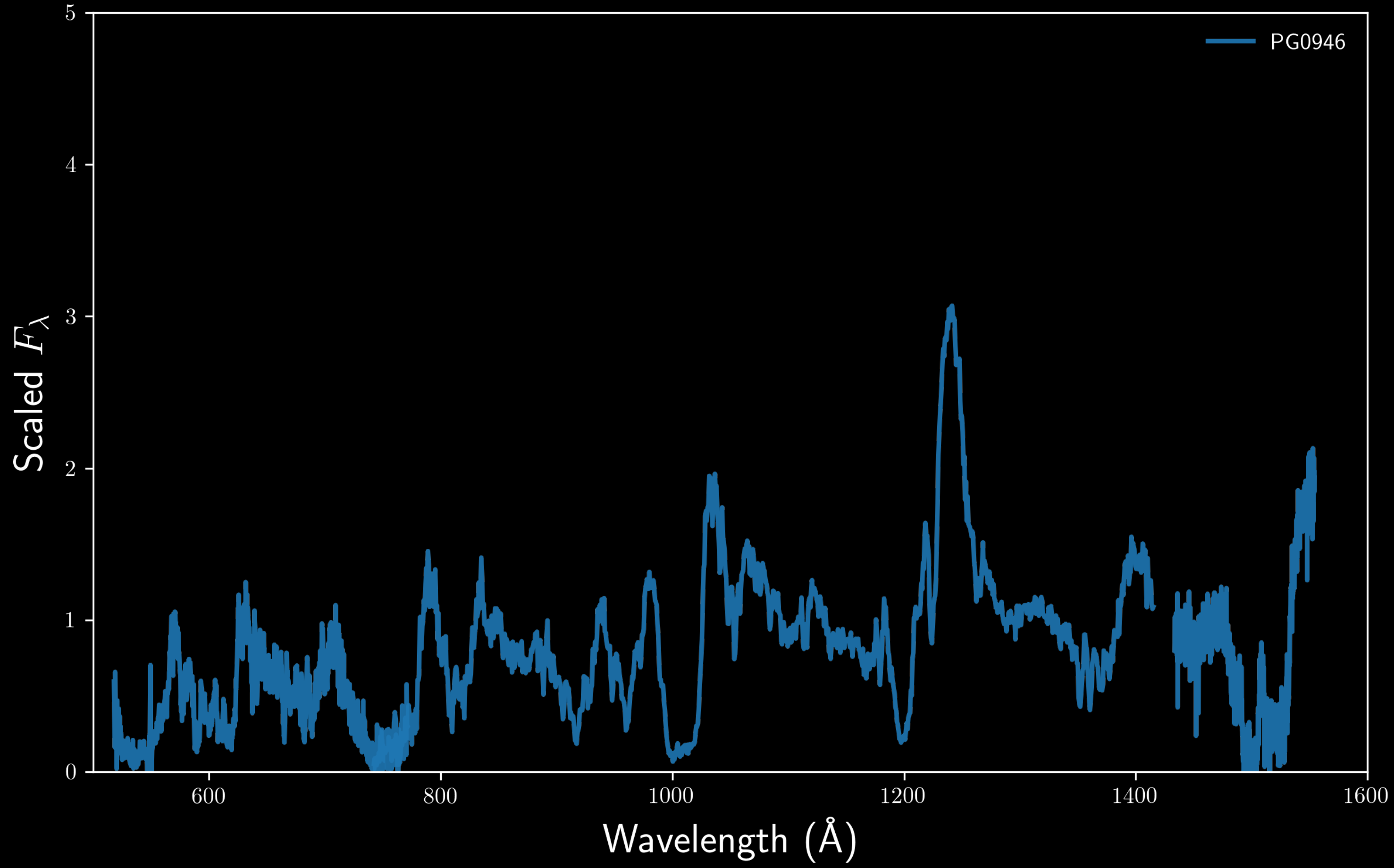


D = 100 (f = 0.01)
Isotropic X-ray source

Data: Saez+ 2012, Steffen+ 2006

PRODUCING BALs

(Matthews+ 2016)



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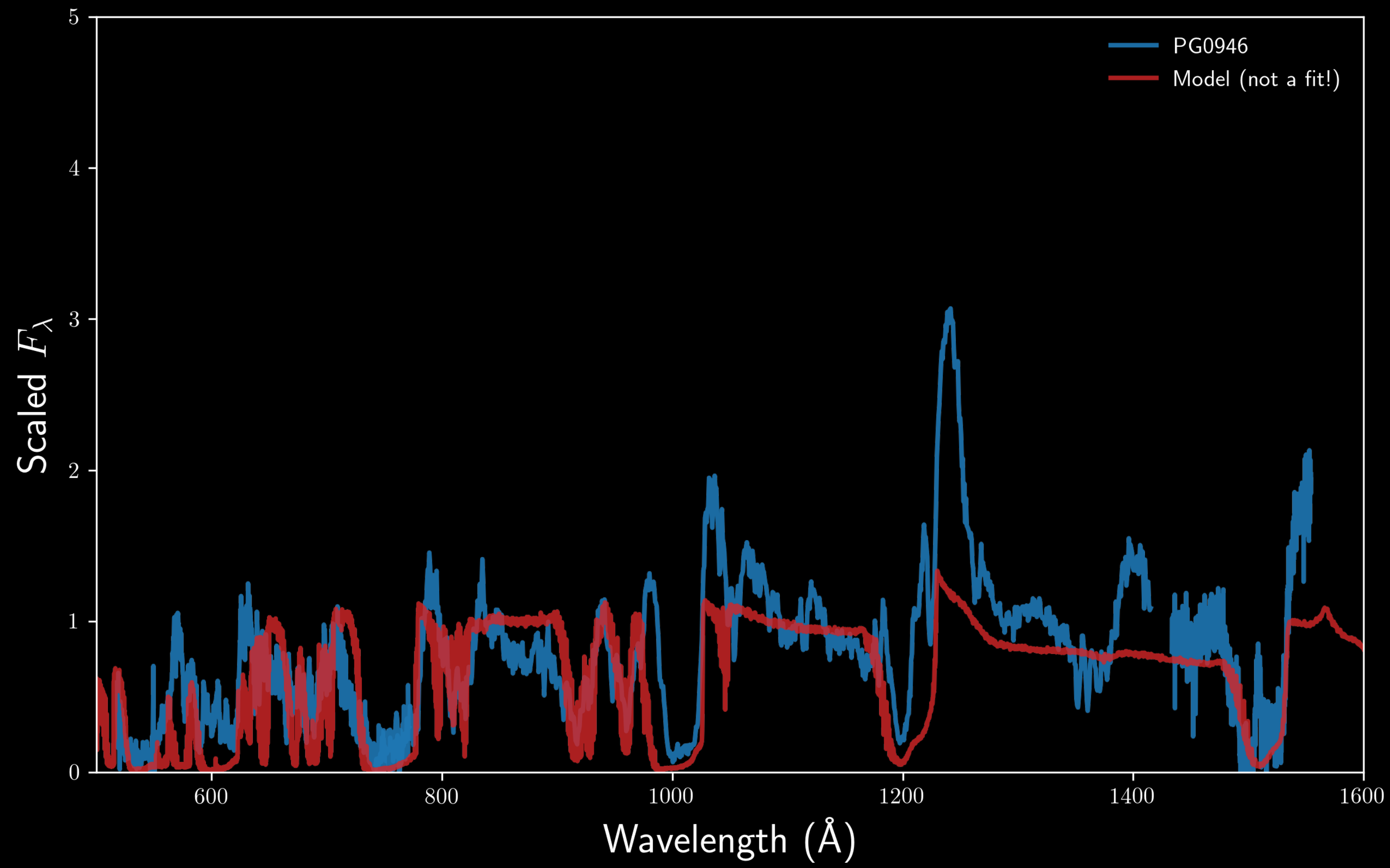

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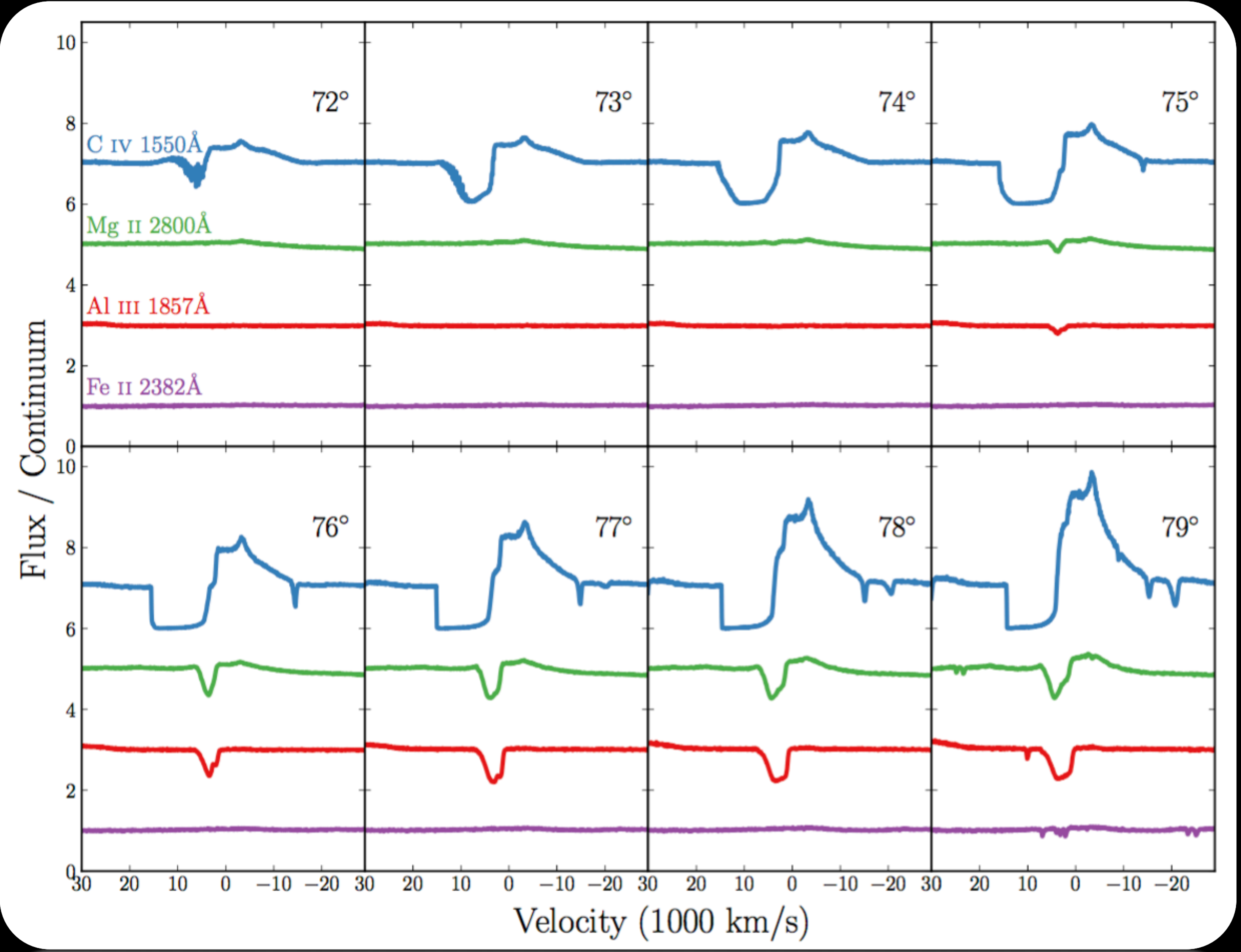
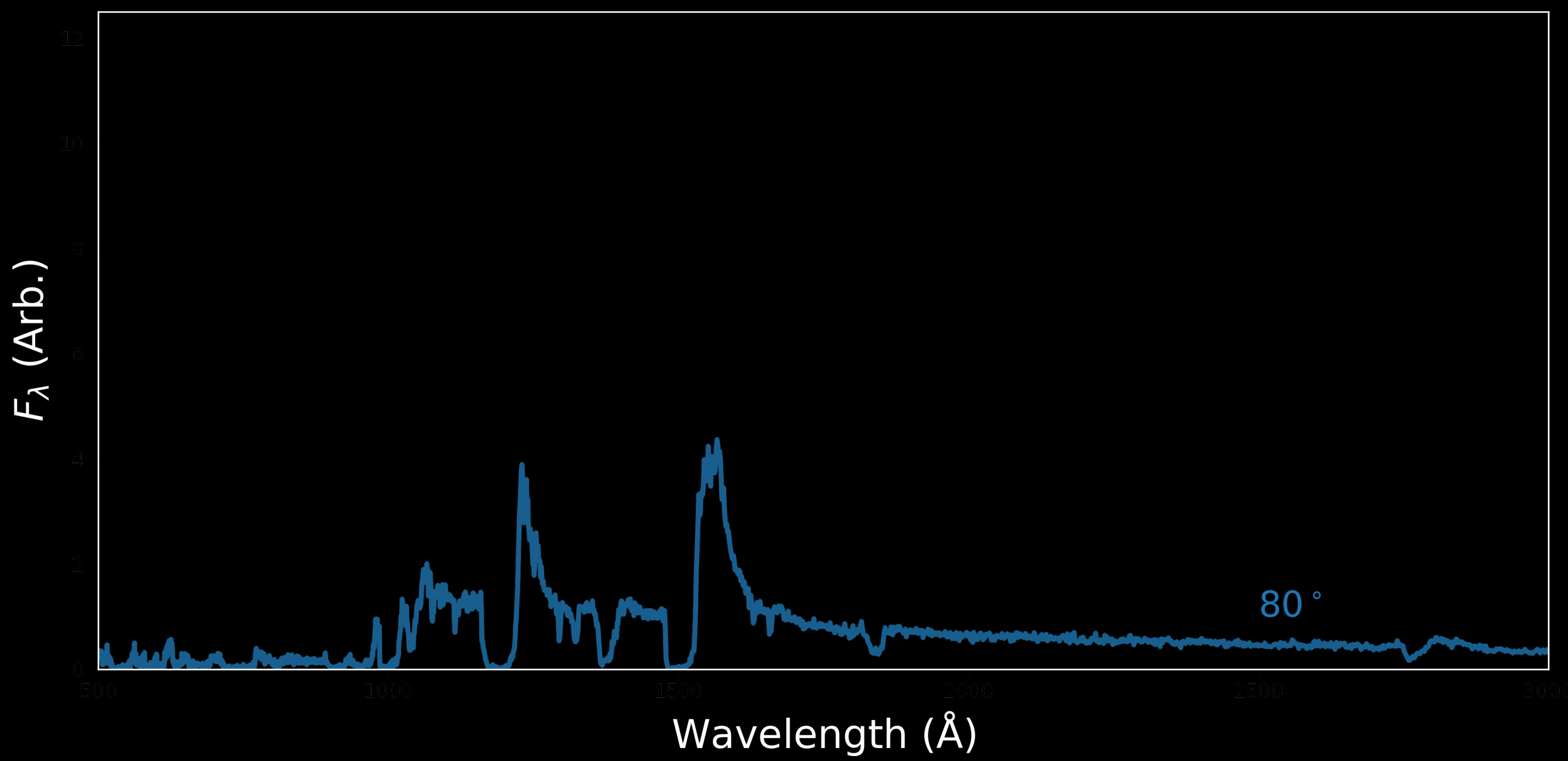
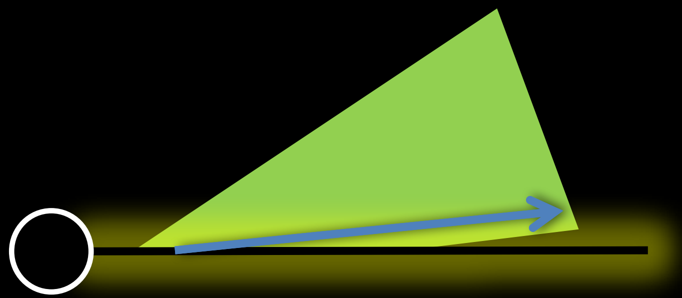


SYNTHETIC SPECTRA





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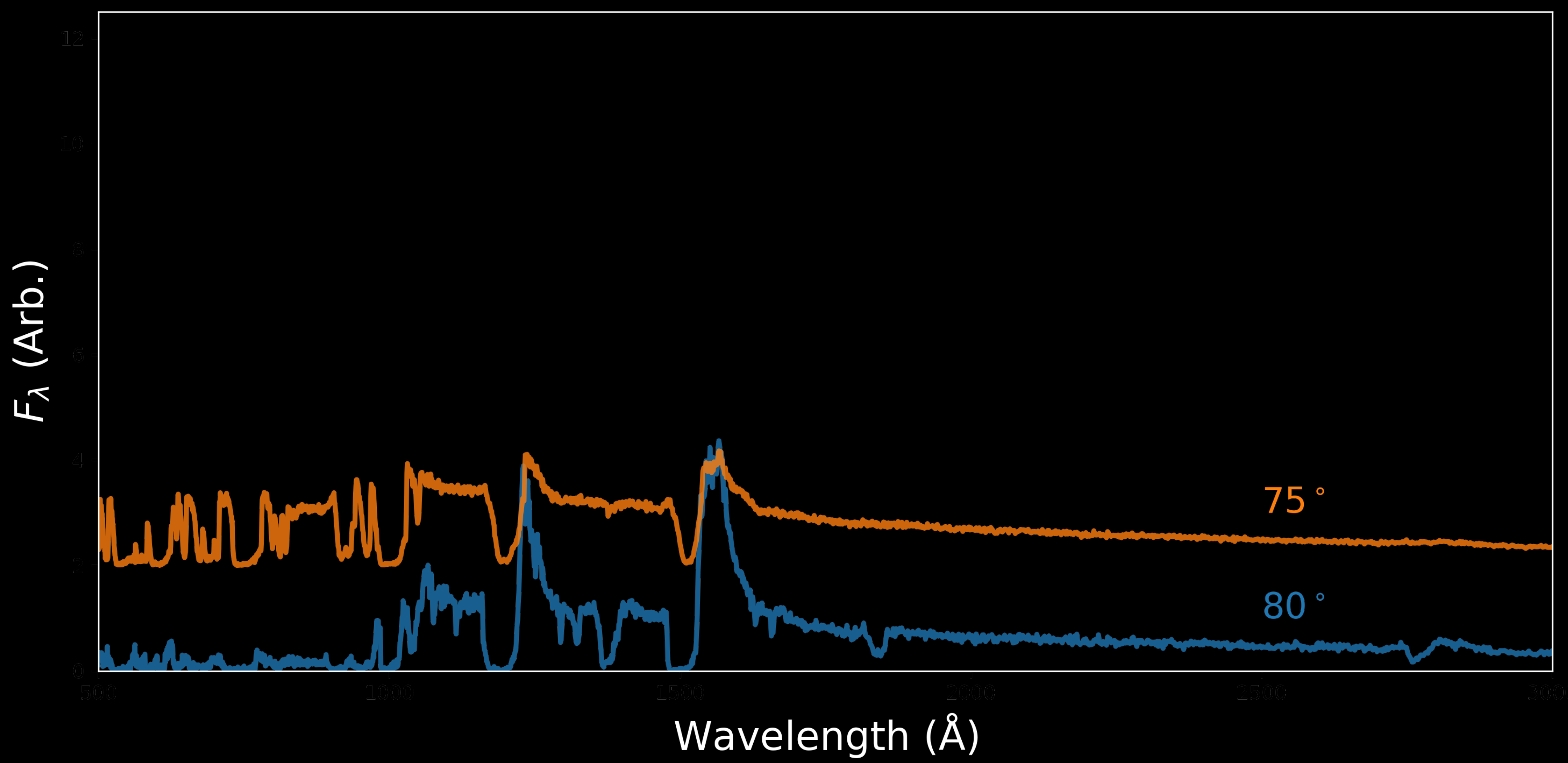

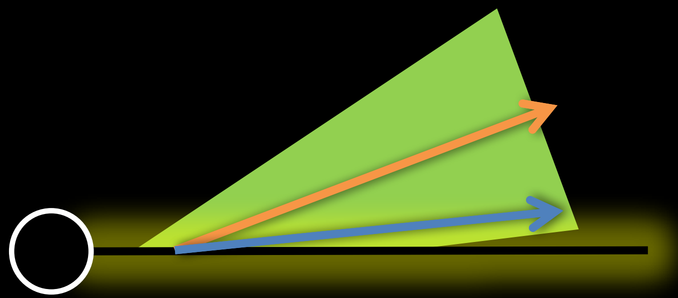

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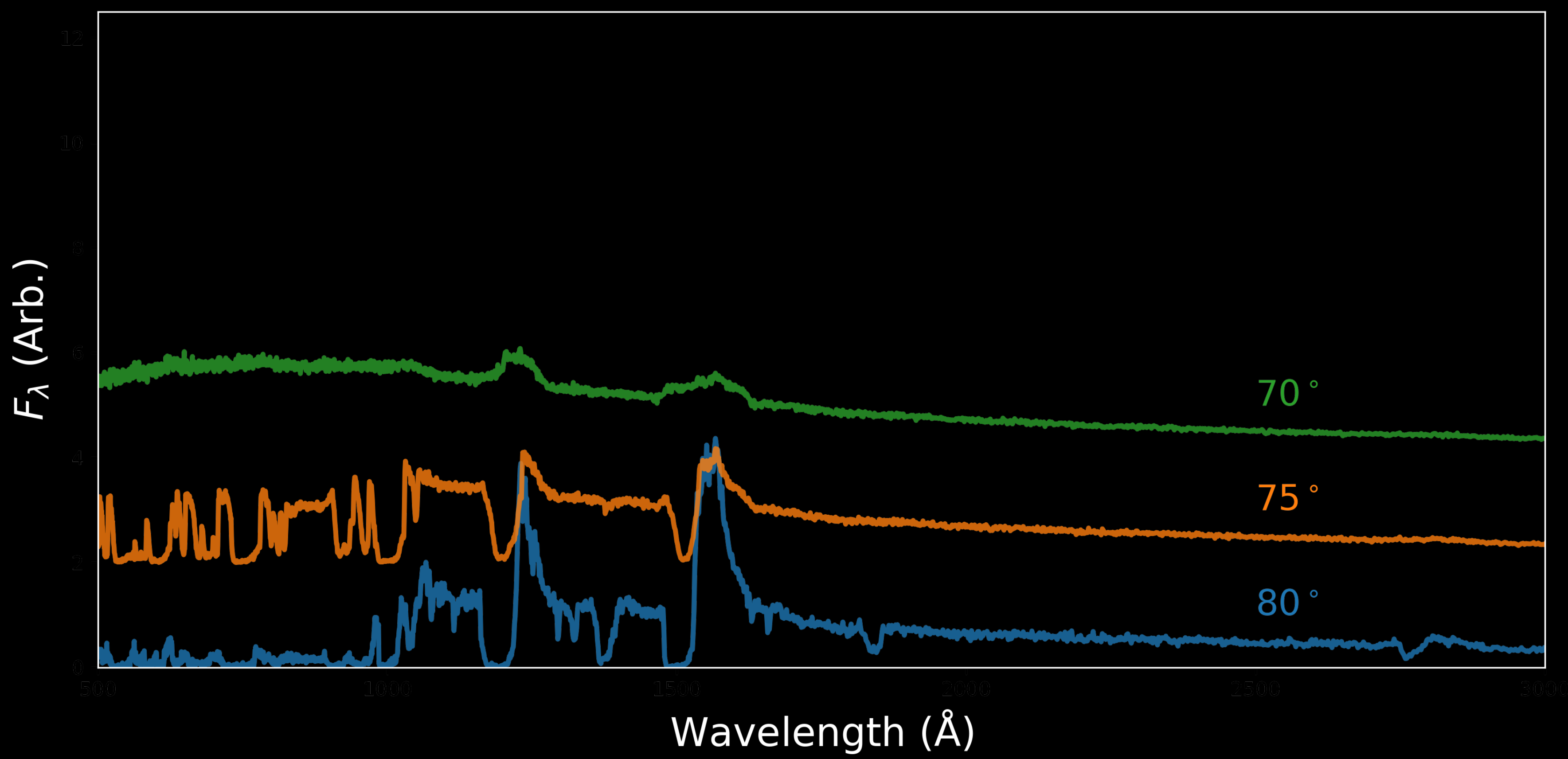

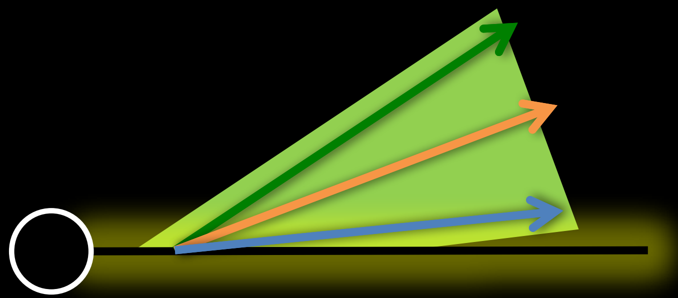

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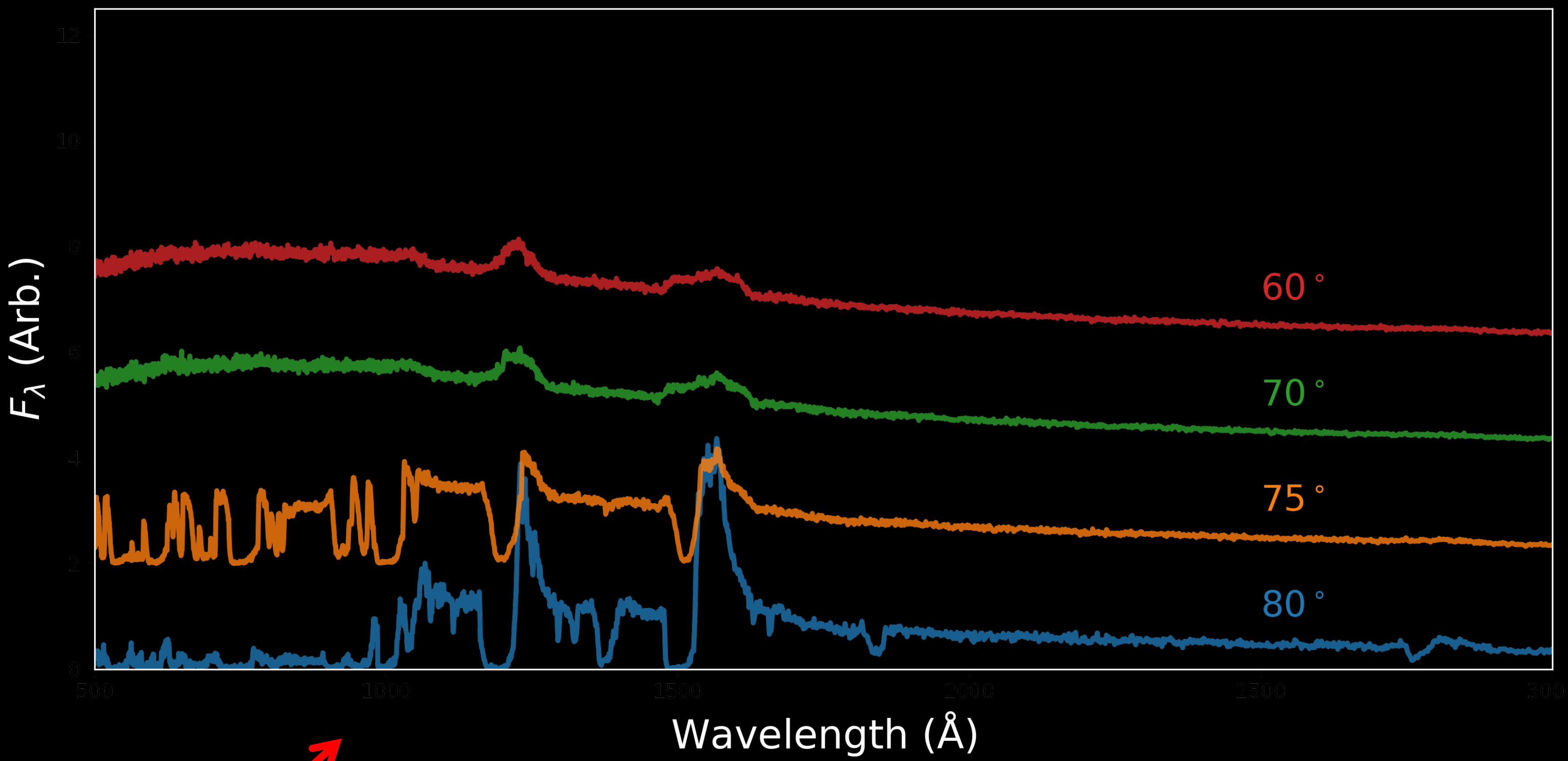

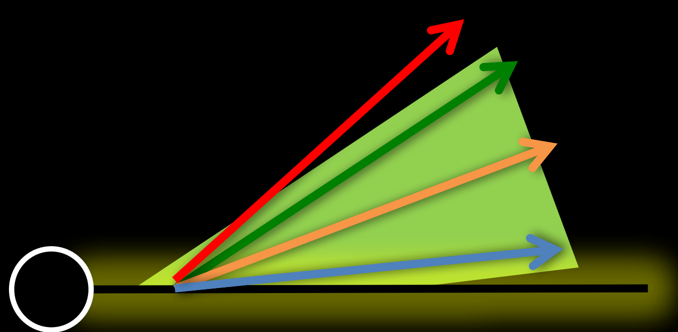

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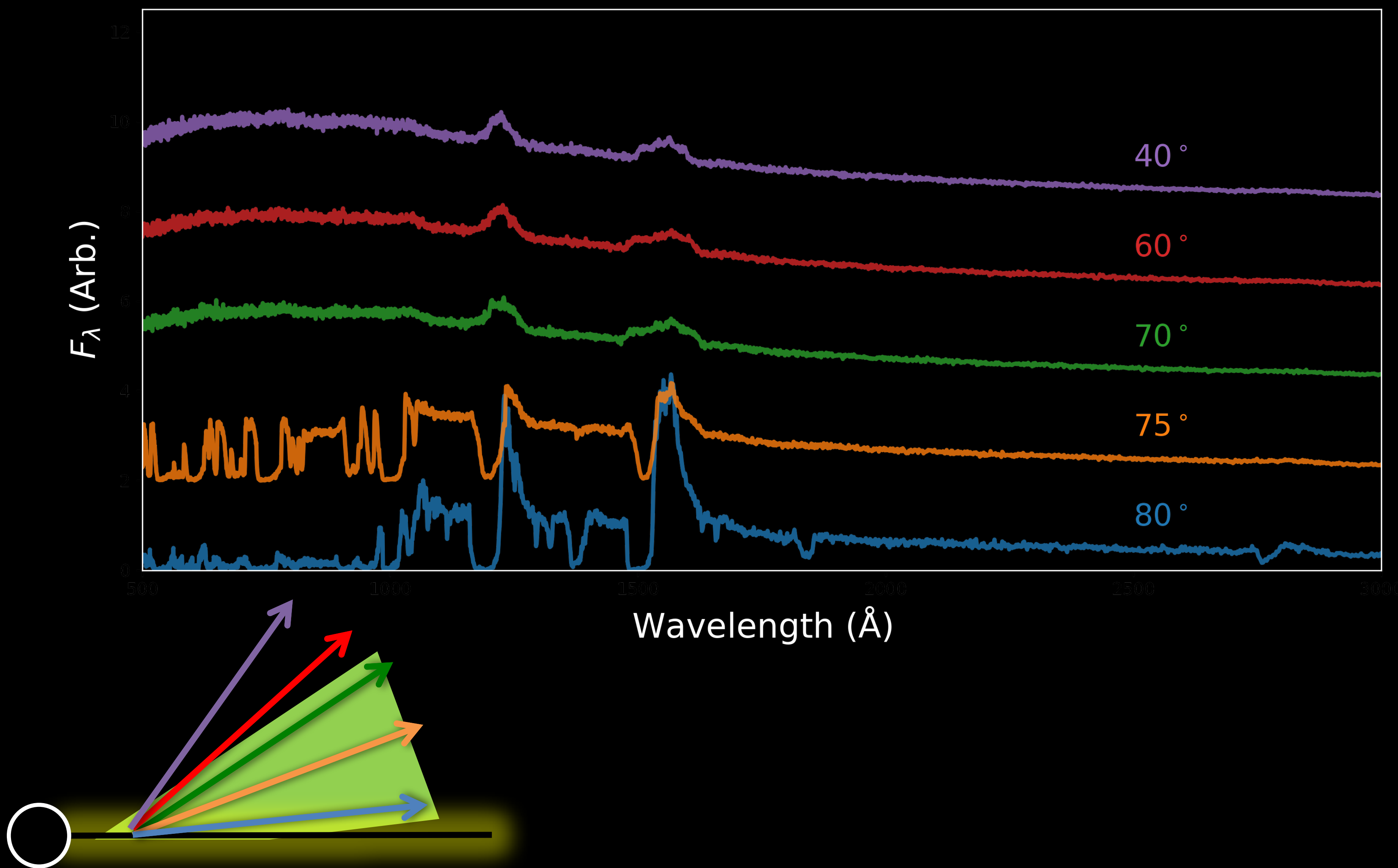

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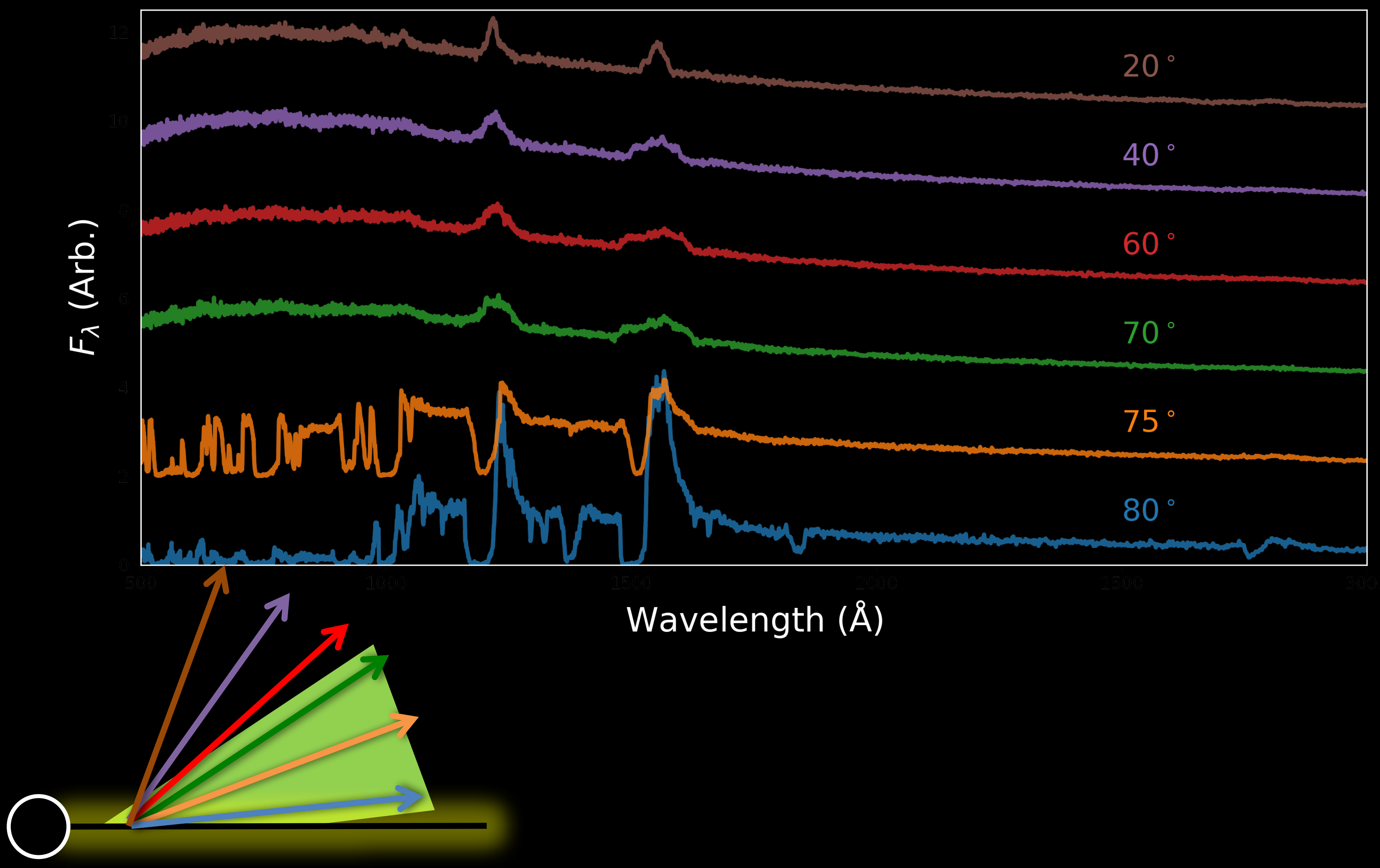

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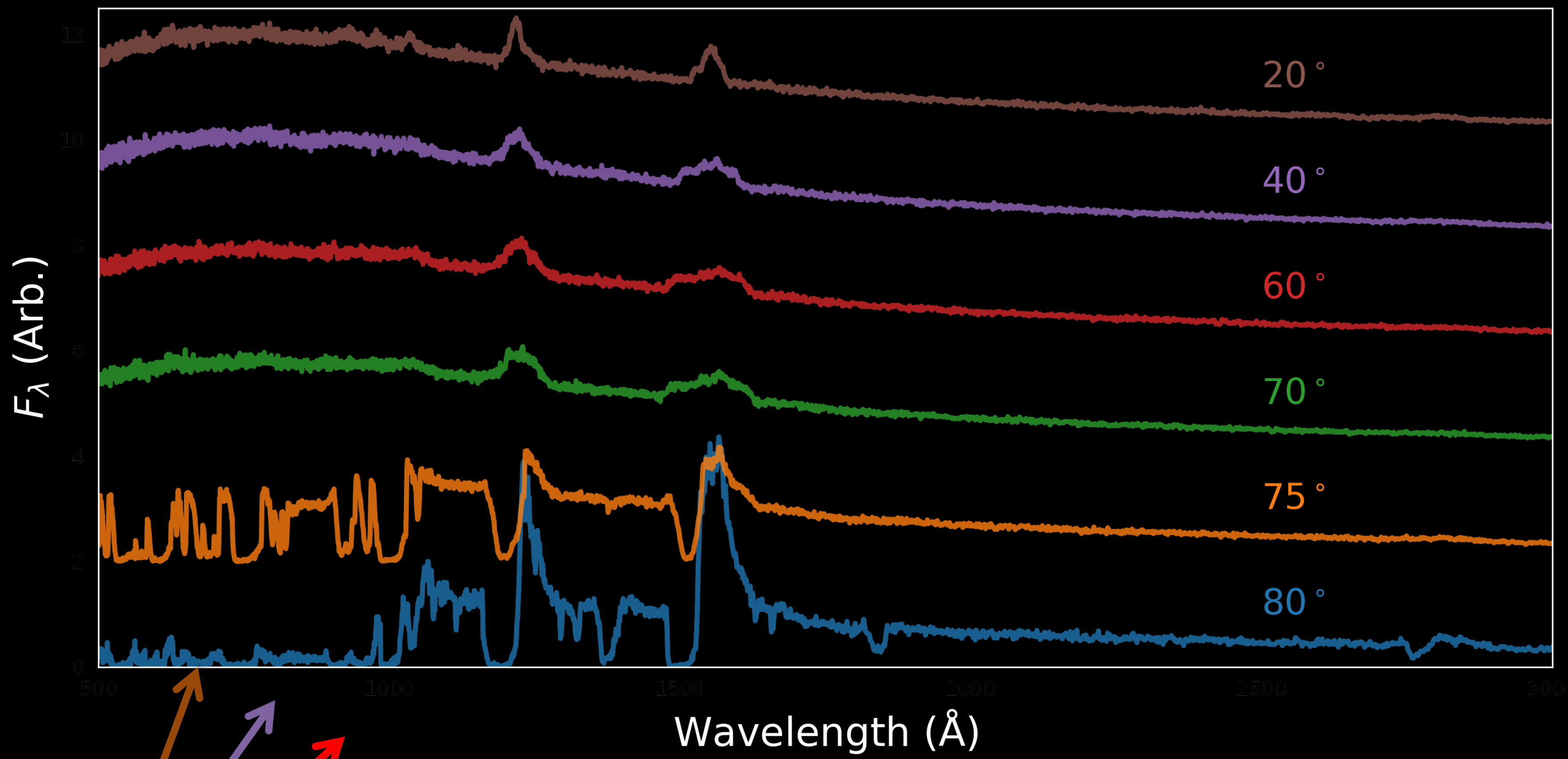
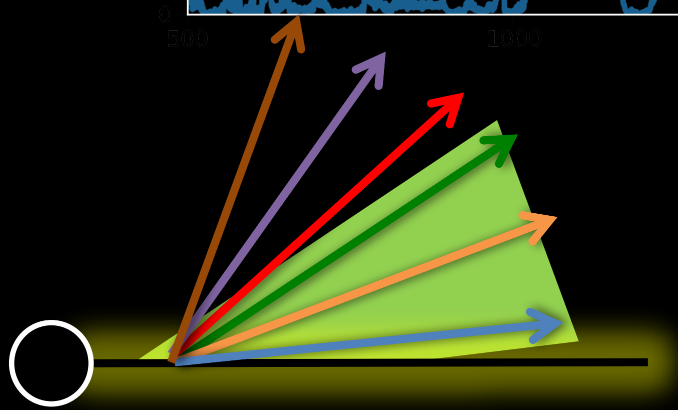


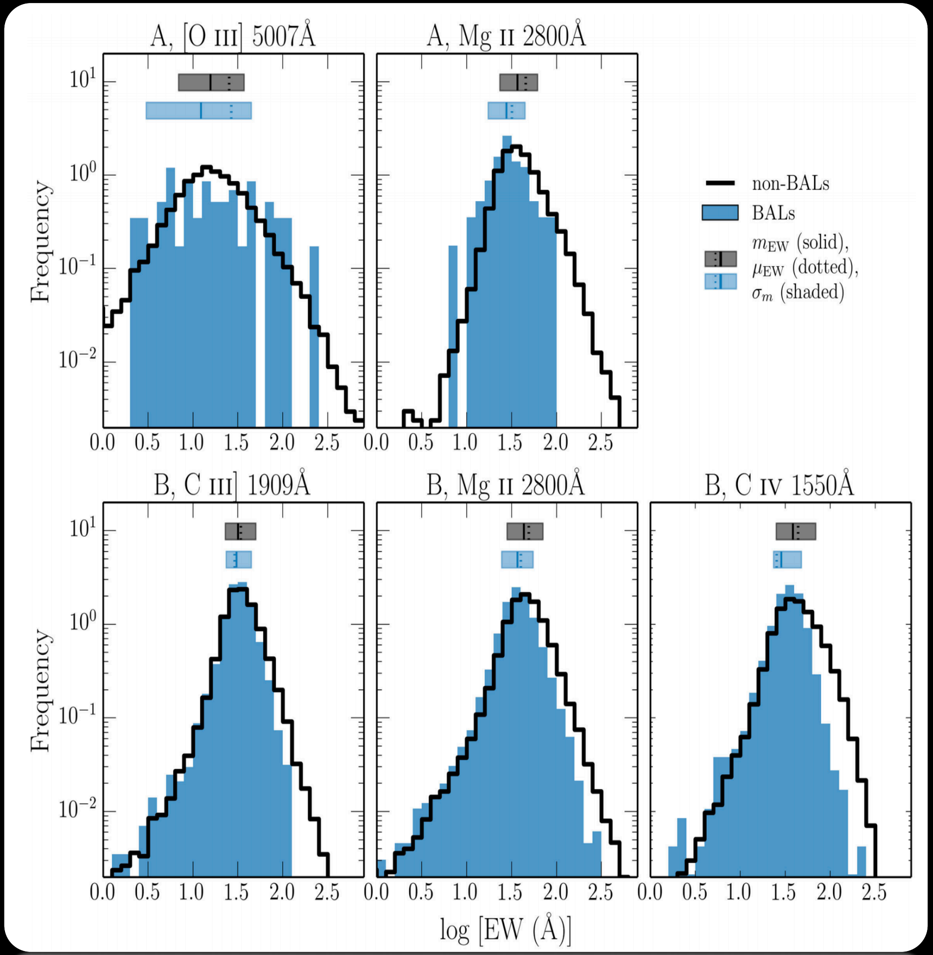


$$EW = EW_0/\epsilon(\theta)$$

$\epsilon(\theta) = \cos\theta$ for foreshortening

EQUIVALENT WIDTH DISTRIBUTIONS IN SDSS

- The emission line EW distributions in BAL and non-BAL quasars are remarkably similar
- ***Inconsistent with equatorial wind + foreshortened disk***
- *Cannot* be easily explained by:
  - GR effects
  - Line anisotropy
  - Obscuration



- Details in Matthews+ 2017

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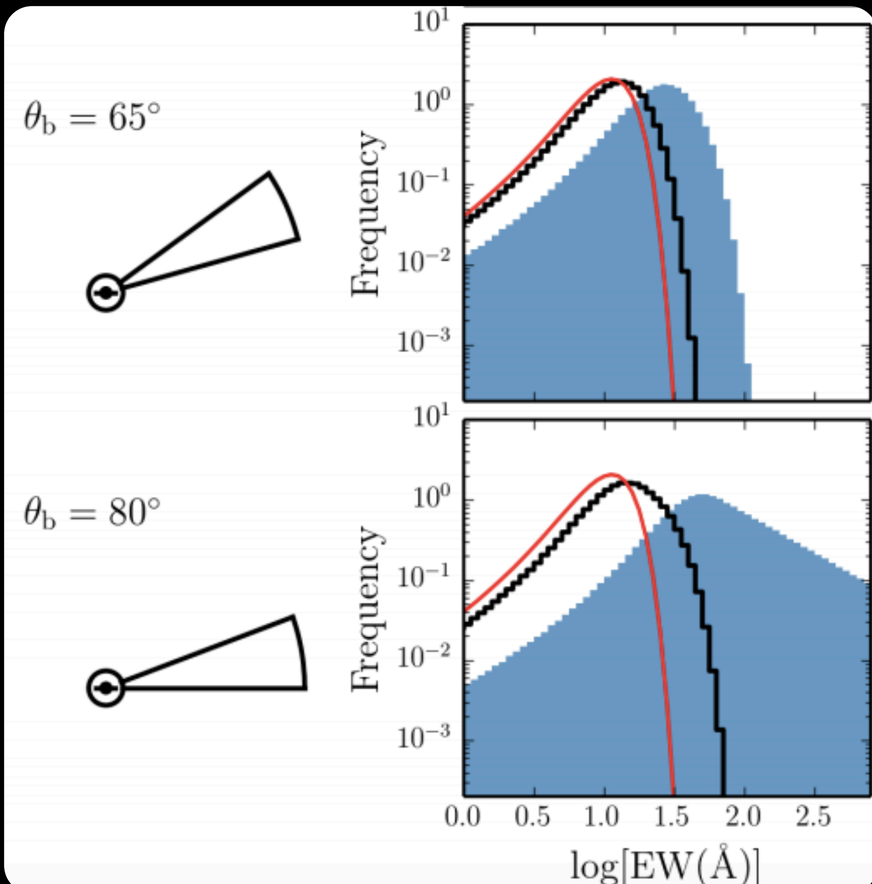

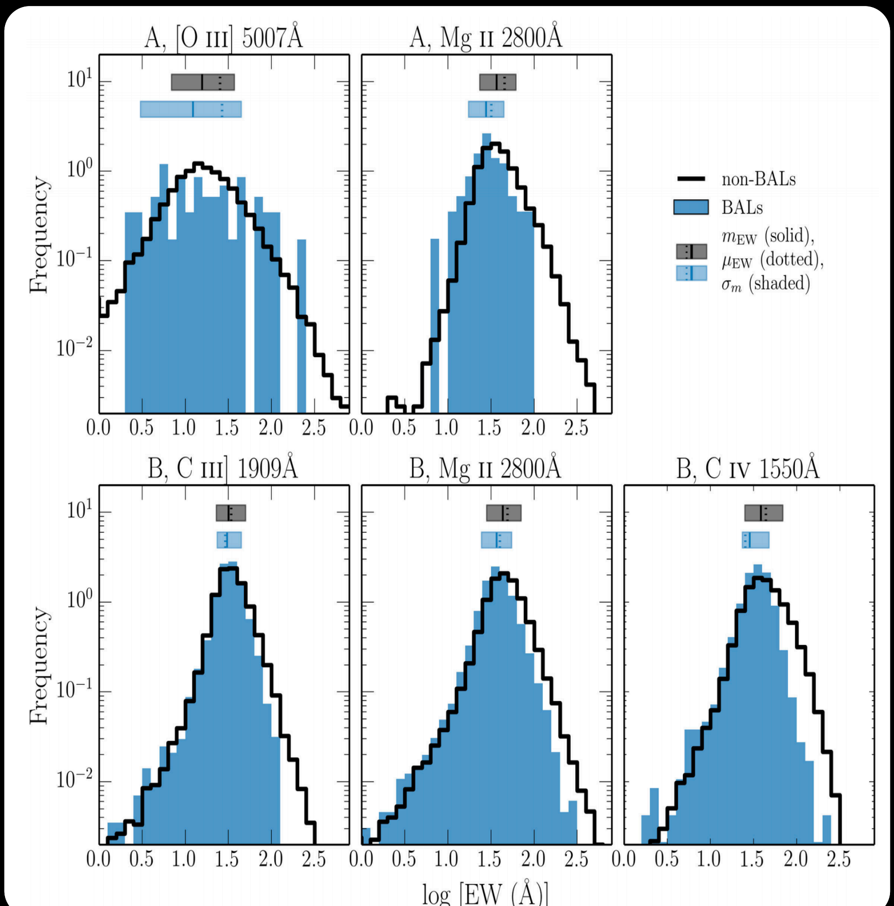

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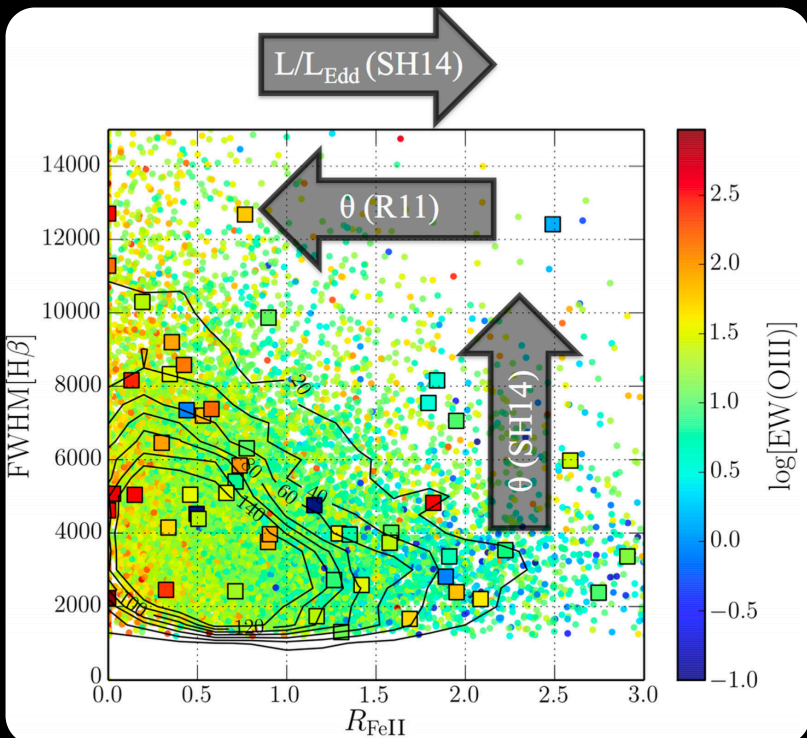
EQUIVALENT WIDTH DISTRIBUTIONS IN SDSS

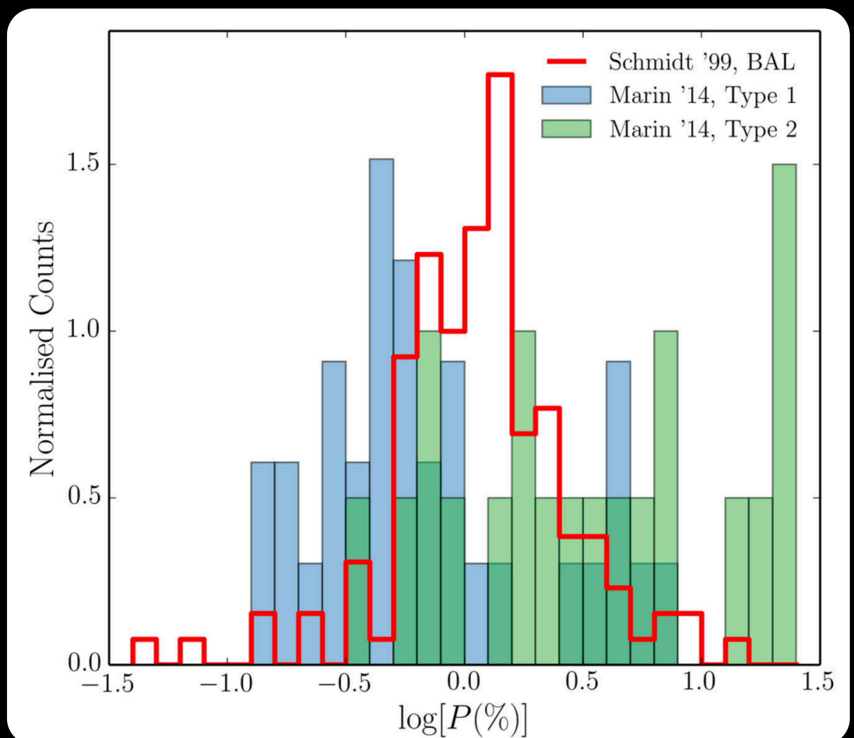
Clues from elsewhere?

Eigenvector I



No preferred inclination?

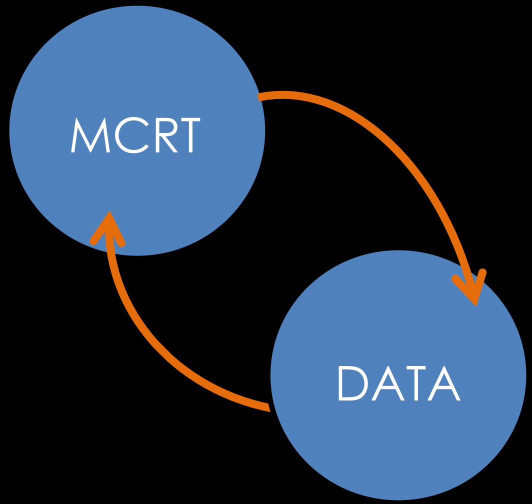
Polarisation



Intermediate inclinations?

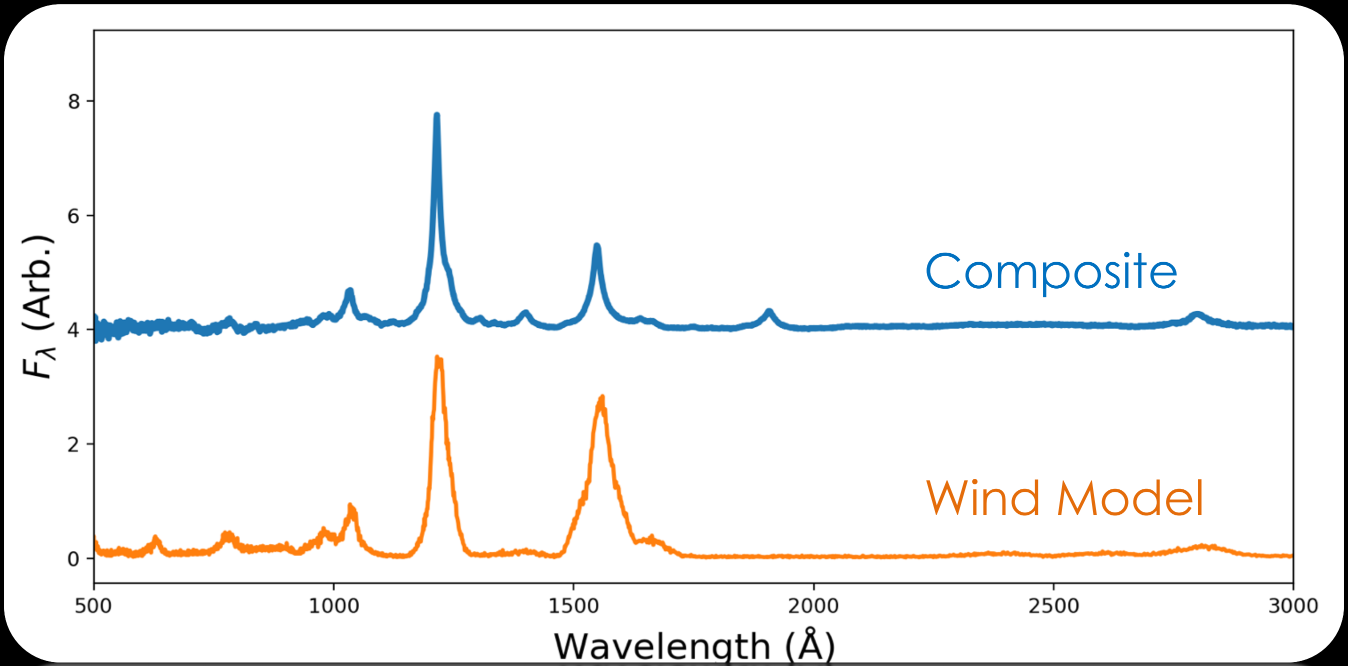
EQUIVALENT WIDTH DISTRIBUTIONS IN SDSS

- SOLUTIONS:
  - A: Discs are roughly isotropic
    - Plenty of problems with disc models, e.g. the "disc-size problem"
  - B: BALQ outflows aren't equatorial
    - Many models so far predict or use equatorial geometries
    - Polarisation? Systematic differences in BALs. Modelling needed.
  - C: Geometric unification doesn't work



IONIZATION STRUCTURE

- Illuminating a BALQ outflow with a Shakura-Sunyaev disk naturally produces a BLR spectrum!
  - All you have to do is get the right balance between emergent continuum and BLR contribution
  - Geometry is CRUCIAL



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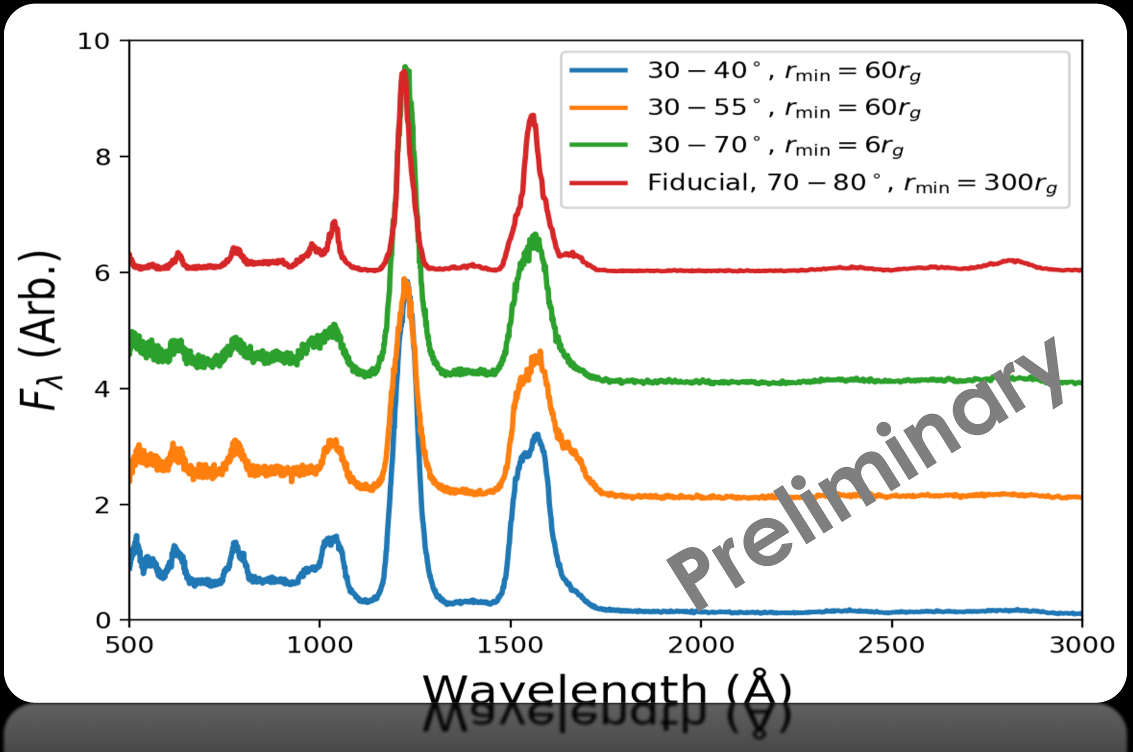

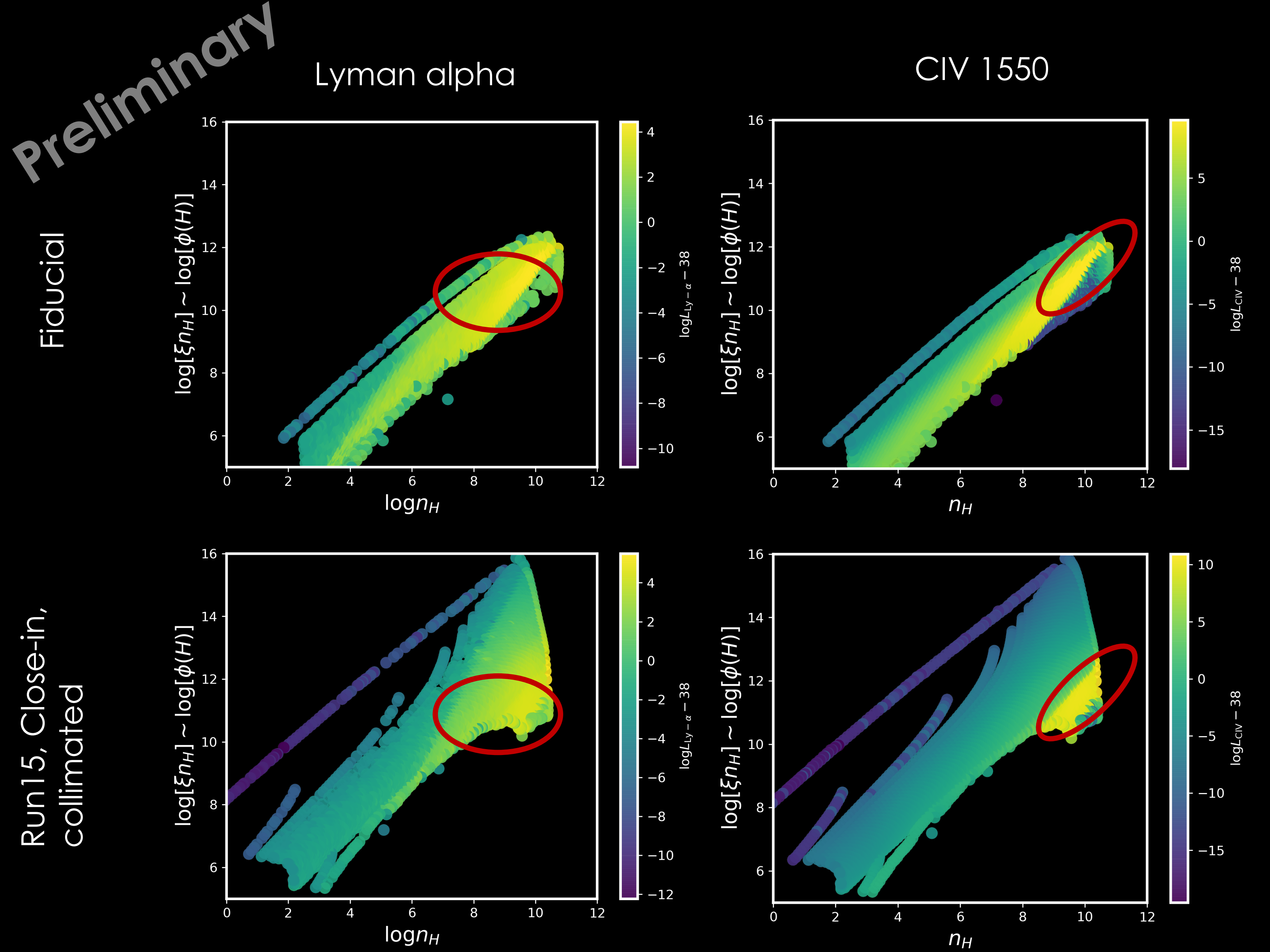

Preliminary
Lyman alpha
CIV 1550
Fiducial
Run15, Close-in, collimated
log[ξn_H] ~ log[φ(H)]
logn_H
n_H
logL_Ly−α − 38
logL_CIV − 38

WINDS AS BLRS?

Winds natural possess many of the benefits of LOC models.

…with one key advantage:

Winds definitely exist.

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Reprocessing efficiency + observed continuum + intercepted flux
Atomic physics + disc physics + disc physics & wind geometry

SUMMARY

- Clumpy [line-driven?] disc winds…
  - …naturally produce BALs, BELs and the range of observed ionization states
  - …are fundamentally different to LOC and optically thick cloud models
  - …explain observed X-ray weakness in BALQs

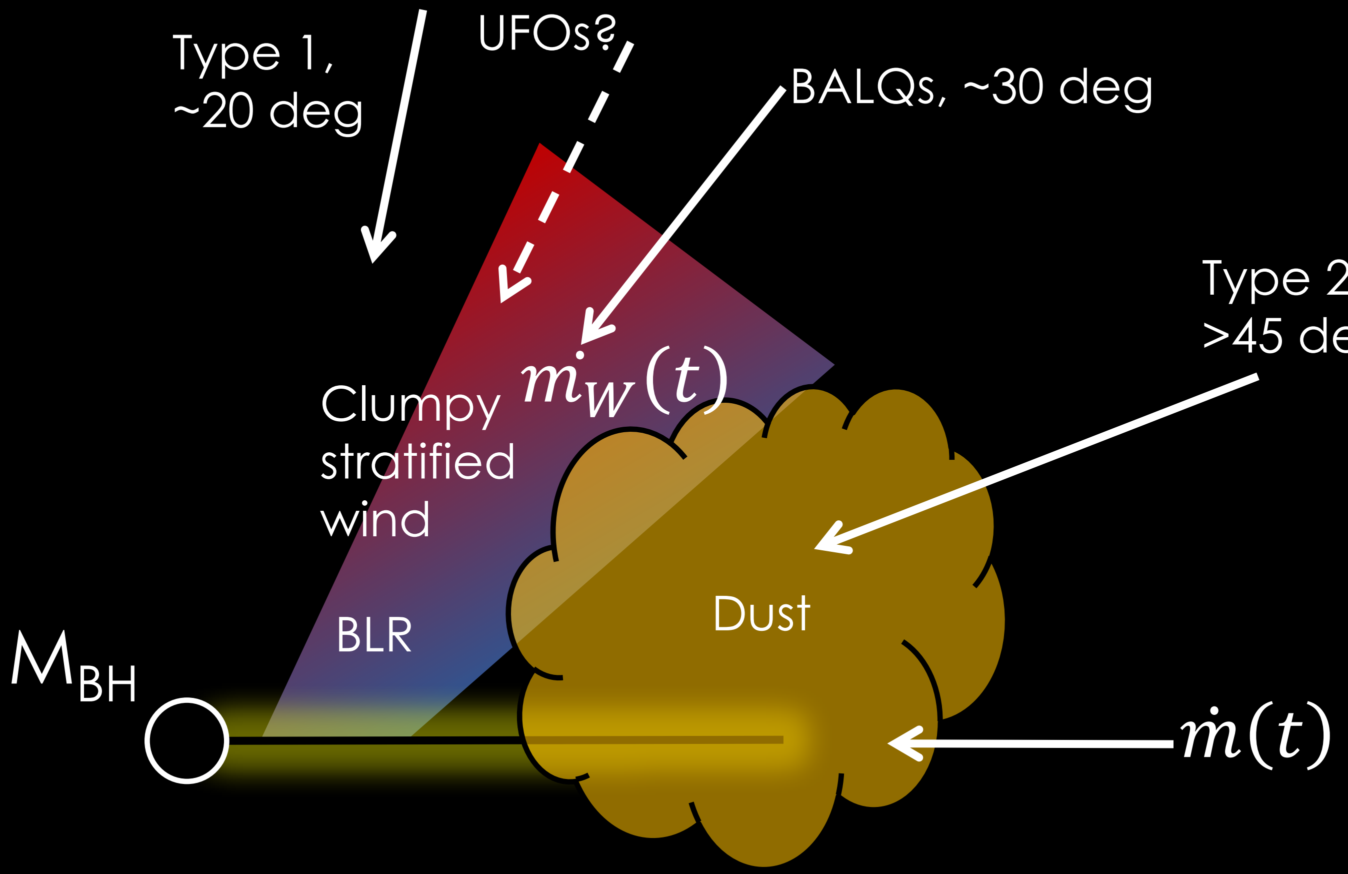
- Quasar emission line EW distributions are inconsistent with an equatorial BAL outflow rising from an optically thick accretion disc
  - Something's gotta give.

- **Disc winds *can* successfully unify quasars.**
  - **But that doesn't mean they *do*.**

- *References:*
  - *Matthews et al. 2016, MNRAS, 458, 293, Matthews et al. 2017, MNRAS, 467, 2571*
  - *Sam Mangham's talk, Mangham et al. (submitted)*
  - *BLR + unification -> Matthews et al. (in prep.)*

ADDITIONAL SLIDES

MY PREFERRED PICTURE



- Open questions [discussion: Matthews+ 2017]:
  - *Explaining polarisation and radio properties*
  - *Reconciling with hydro outflow models*
  - *Comparing to reverberation results for the BLR*
  - *Understanding the disc continuum*

See e.g. talk by Martin Elvis

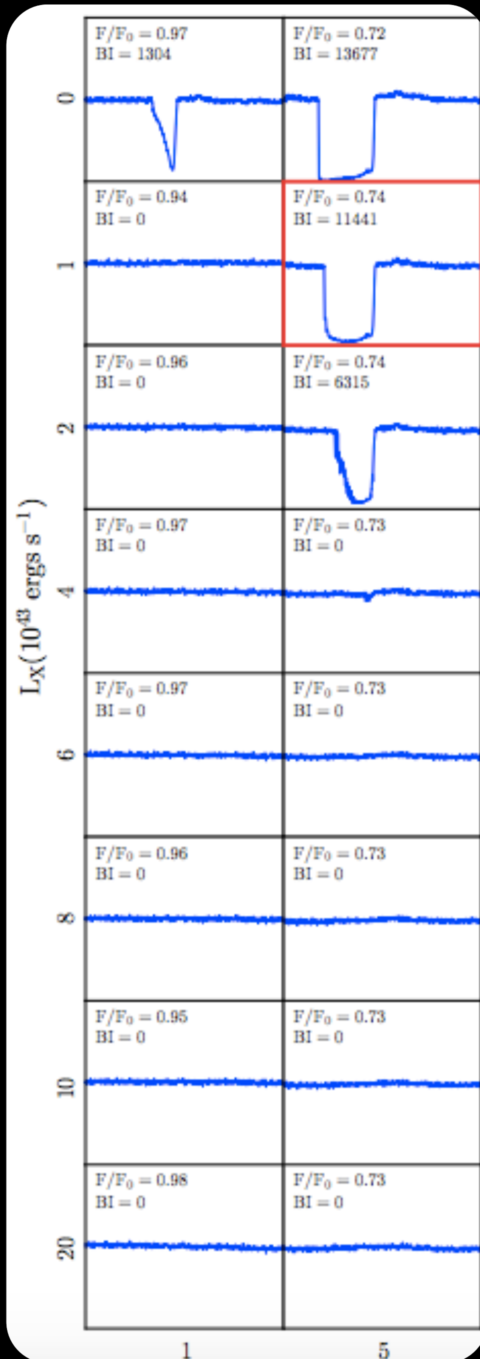
OVERIONIZATION PROBLEM

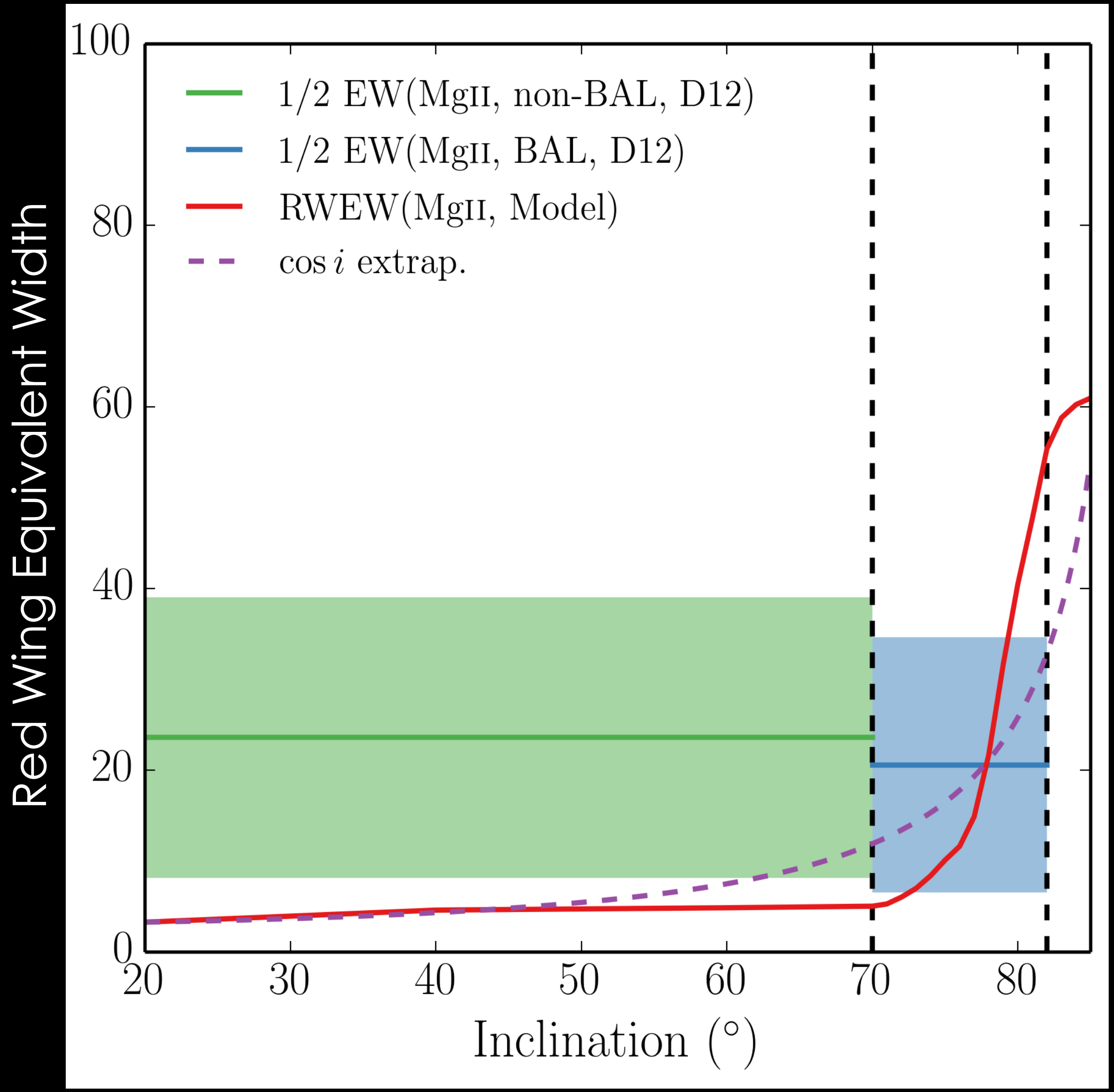
- Photoionization models tend to find over-ionization is a big issue
  - Prevents line formation
  - Prevents line-driving

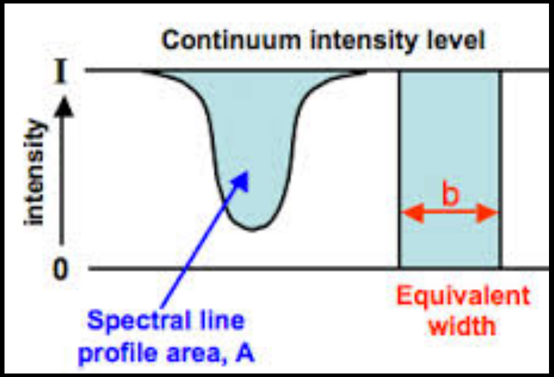
- Proposed solutions
  - Shielding
  - Clumping
  - Radius

- See e.g. Murray+ 1995, Proga+ 1998, Higginbottom+ 2013, 2014, Hamann 2013

Increasing X-rays, decreasing Balnicity



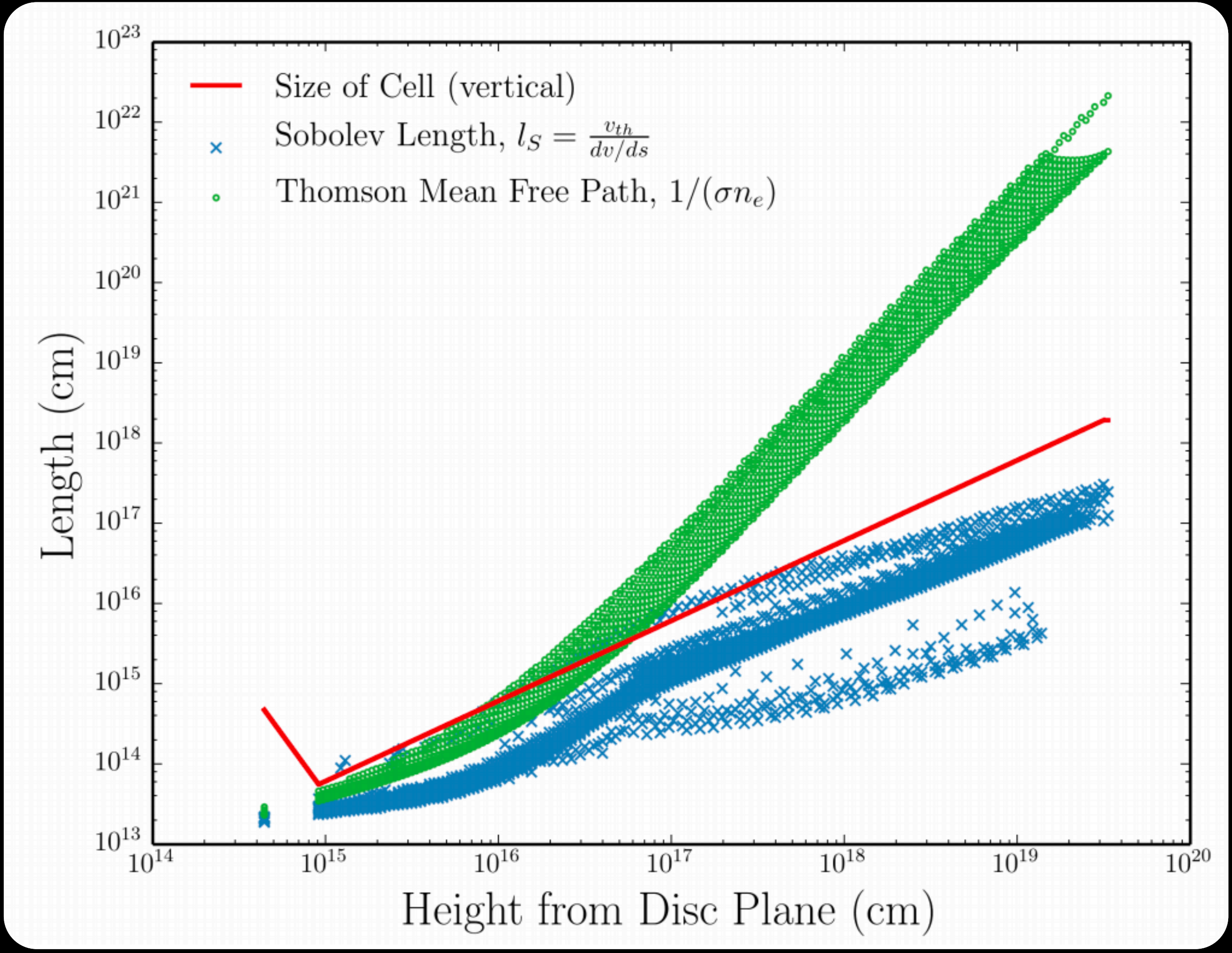




Quasars and BALQSOs have remarkably similar emission line properties (Weymann et al. 1991, Reichard et al. 2003).

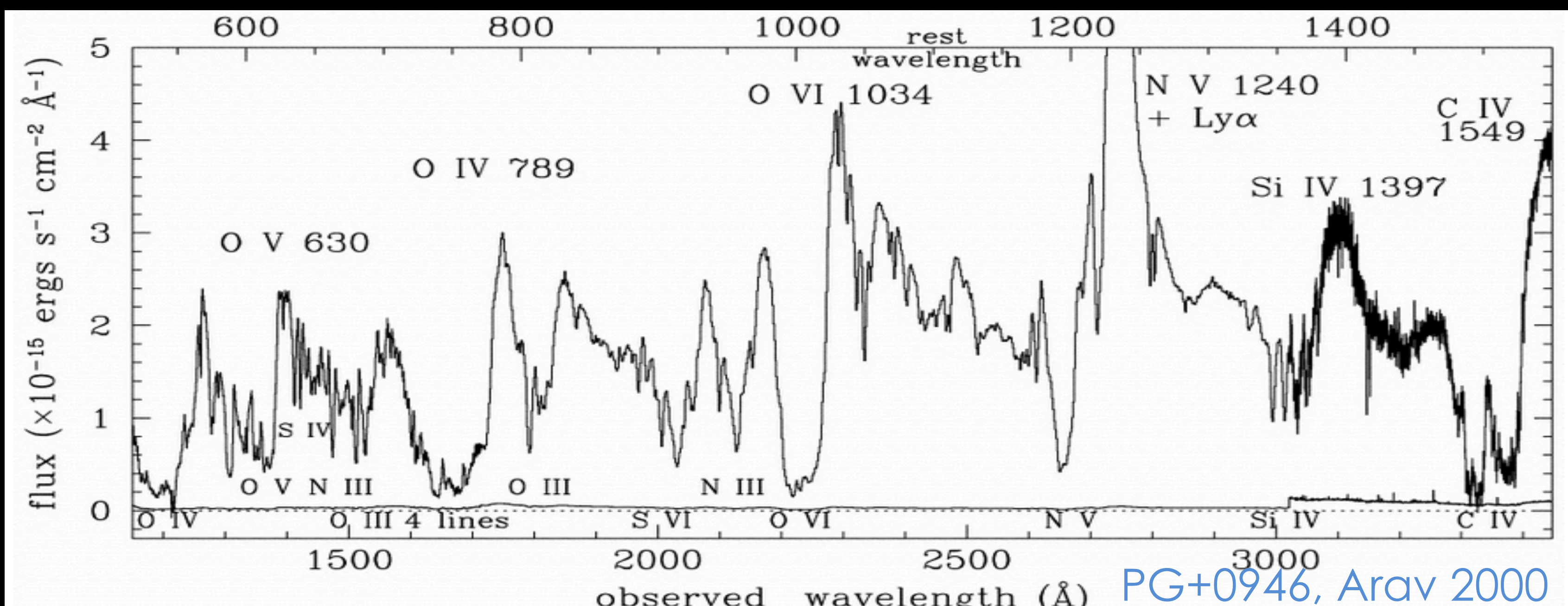
Our models don't.

LENGTH SCALES



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