Spectral Synthesis of Accretion Disk Winds in Active Galactic Nuclei

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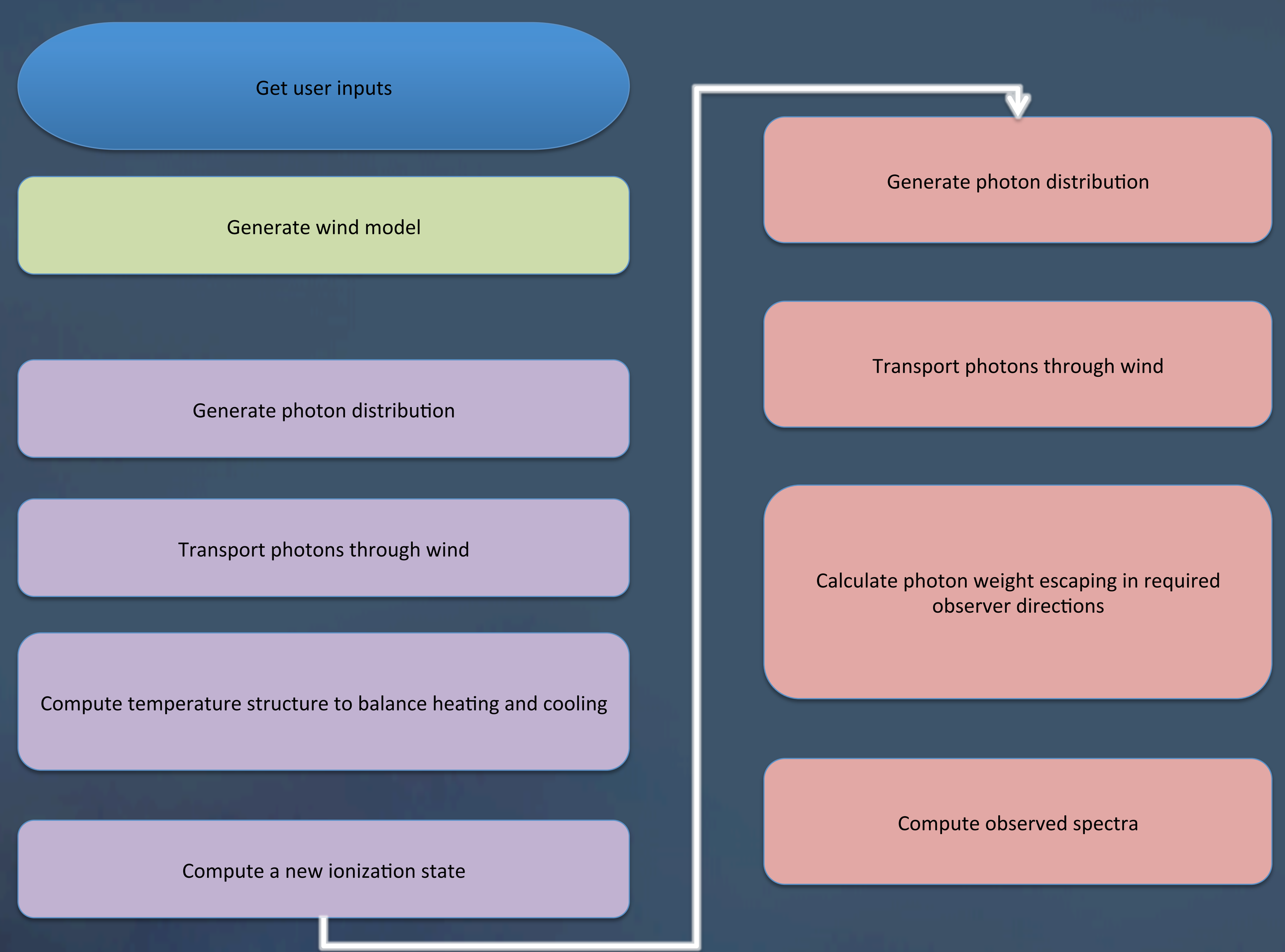
Abstract

Outflows are central to our understanding of the connection between active galactic nuclei (AGN) and their host galaxies. In particular, a wind emanating from the accretion disk that fuels the supermassive black hole can provide the kinetic luminosity required for efficient AGN feedback, whilst also having a profound effect on the observational appearance of these systems. To test the effect of these outflows on the observational properties of AGN and QSOs, we have developed a Monte Carlo ionization and radiative transfer code. We have already used our code to demonstrate that a simple, physically motivated disk wind model can produce ultraviolet absorption lines that resemble those seen in broad absorption line quasars (BALQSOs). Recently, we have incorporated Lucy's 'macro-atom' into our code. This allows us to correctly model key spectral features, such as the Lyman-alpha and Balmer emission lines, and has already been successfully applied to a Cataclysmic Variable model. Here, we present the first results of simulations using this scheme, designed to to test disk-wind-based AGN unification scenarios. In particular, we address the question whether disk winds may be responsible for the broad emission lines seen in all Type I AGN/QSOs.

Radiative Transfer Code

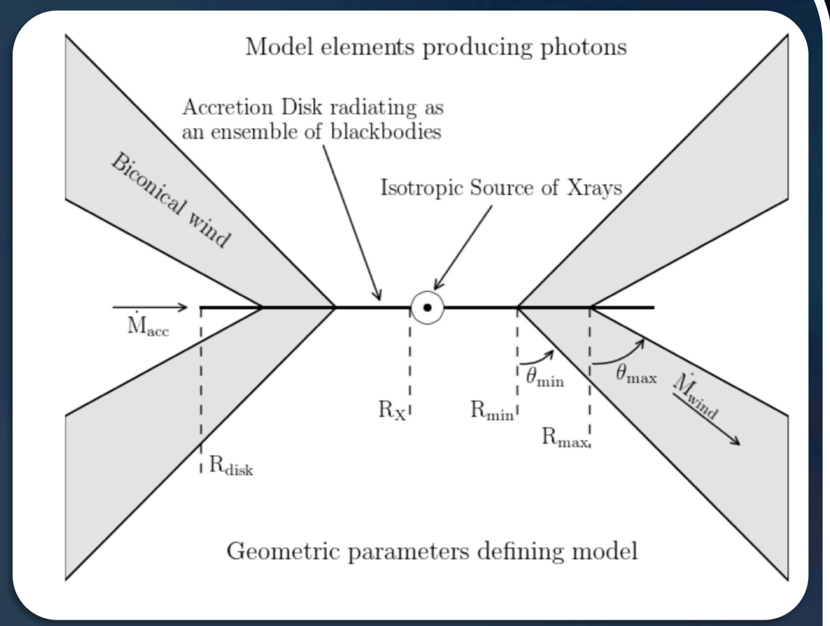
- We use a Monte Carlo Radiative Transfer Code, named PYTHON.
- Photons are produced by an accretion disk and central object
- Heating and cooling balance include Compton processes



- Different ionization options allow one to use either
- a modified Saha equation which models the spectrum in a cell
- Full solution of rate matrices for `macro atoms'

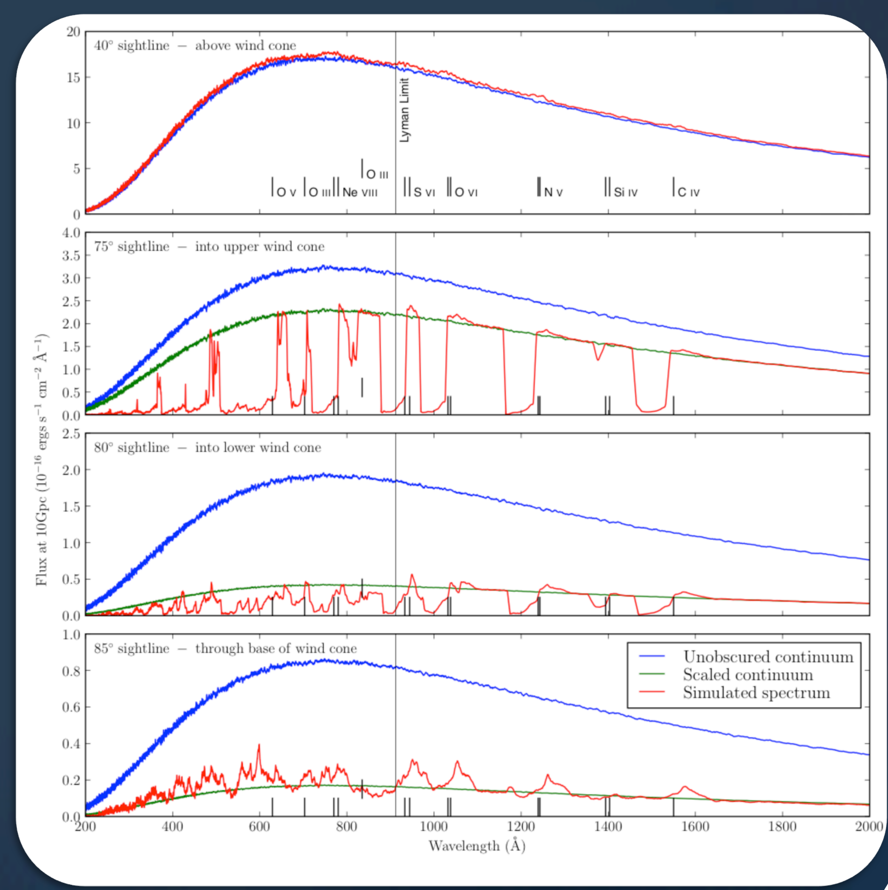
A Benchmark Model for BALQSOs

- Higginbottom+ 2013 present a benchmark model, which successfully reproduces blue shifted BAL troughs in species such as CIV *(see model spectra, right)*.
- This is the first time this has been done in a spectral synthesis code using a self-consistently calculated wind structure



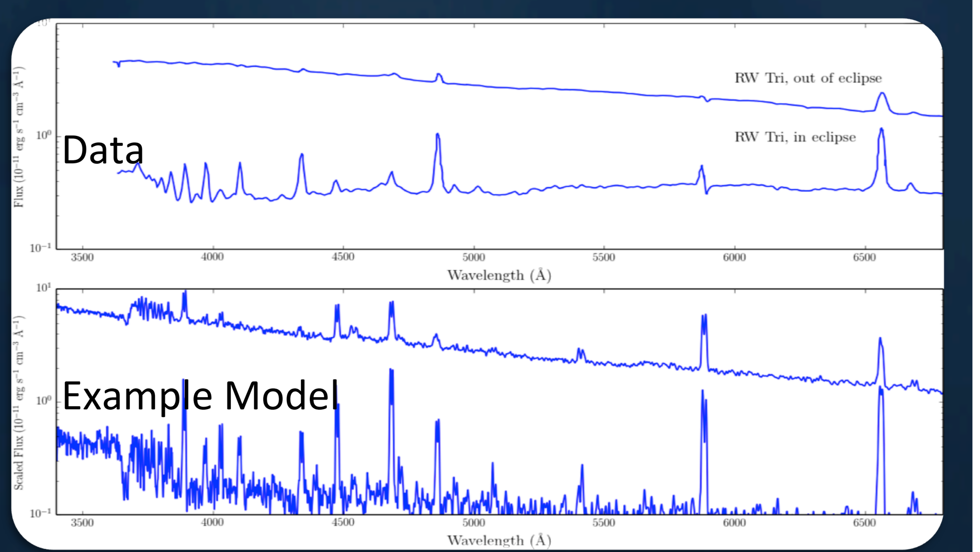
The model has a number of unsolved problems:

- The unabsorbed 2-10keV X-ray luminosity is too weak, at only 1e43 erg/s
- The model fails to reproduce Lyman alpha emission
- The model fails to produce significant broad emission lines



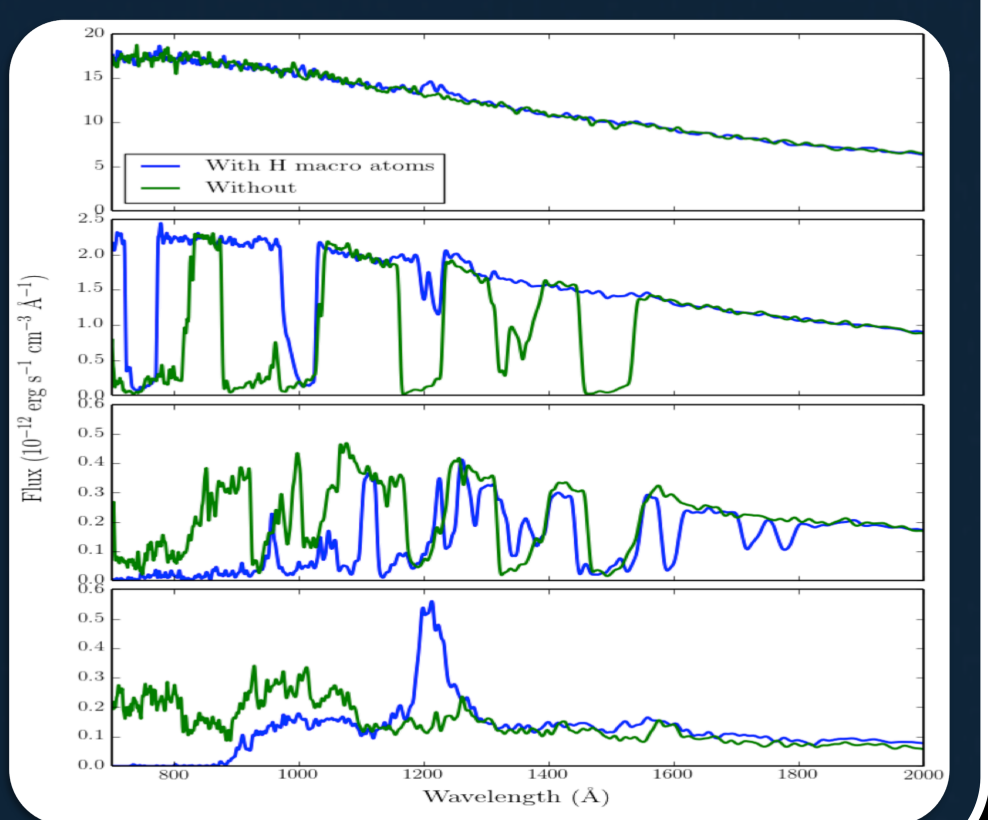
CV models with Macro-Atoms

- Line Transfer scheme developed by Lucy (2002,2003)
- NLTE solution without simplifying internal atomic transitions- good for recombination
- Our CV model produces strong Balmer emission



QSO models with Macro-Atoms

- The additional line cooling changes the ionization state due to a more efficient 'shield'
- Need to improve the treatment of the base of the wind. Cool areas lead to unusual Fe II absorption features
- Strong Lyman alpha emission at certain angles
- Changes in the Lyman edge absorption
- Work ongoing…



Implications for AGN feedback

- Disk winds have been proposed as a possible AGN feedback mechanism, used to limit the growth of black holes – the so-called 'Quasar-mode' of feedback
- The minimum requirement for a disk wind to be responsible for AGN feedback is that it has a high enough kinetic luminosity, defined as

$$L_k = \frac{1}{2} \dot{M}_W v^2$$

to be energetically significant.

- Di Matteo, Springel & Hernquist 2005 and Hopkins & Elvis (2010) require Lk/Lbol 0.005–0.05 for effective feedback – sufficient to establish M-σ relation, for example.
- We require the mass loss rate of the wind to be comparabel to that through the disk
- The parameters of our model give Lk/Lbol ≈ 0.25, suggesting that winds with these mass loss rates may be of sufficient kinetic power to influence the host galaxy

The Next Step

- Parameter searches
  - Can a similar model produce BELs with modest kinematic changes?
  - Can a model with a more realistic X-ray luminosity produce BAL features?
- Clumping: Is it required? Density fluctuations could lower the ionization parameter and boost the emission measure without changing the mass loss rate
- Decelerating winds: As a wind impacts on the ISM in the host galaxy, it will slow down. This decelerating region could in fact be responsible for emission lines
  - Understanding this interface is clearly also important for AGN feedback

References

Higginbottom et al. 2013
Higginbottom et al. 2014
Matthews et al., in prep
Lucy 2002, 2003
Di Matteo, Springel & Hernquist 2005
Hopkins & Elvis 2010