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

Create predefined wind geometry

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Transport photons through wind

Compute temperature and ionization structure

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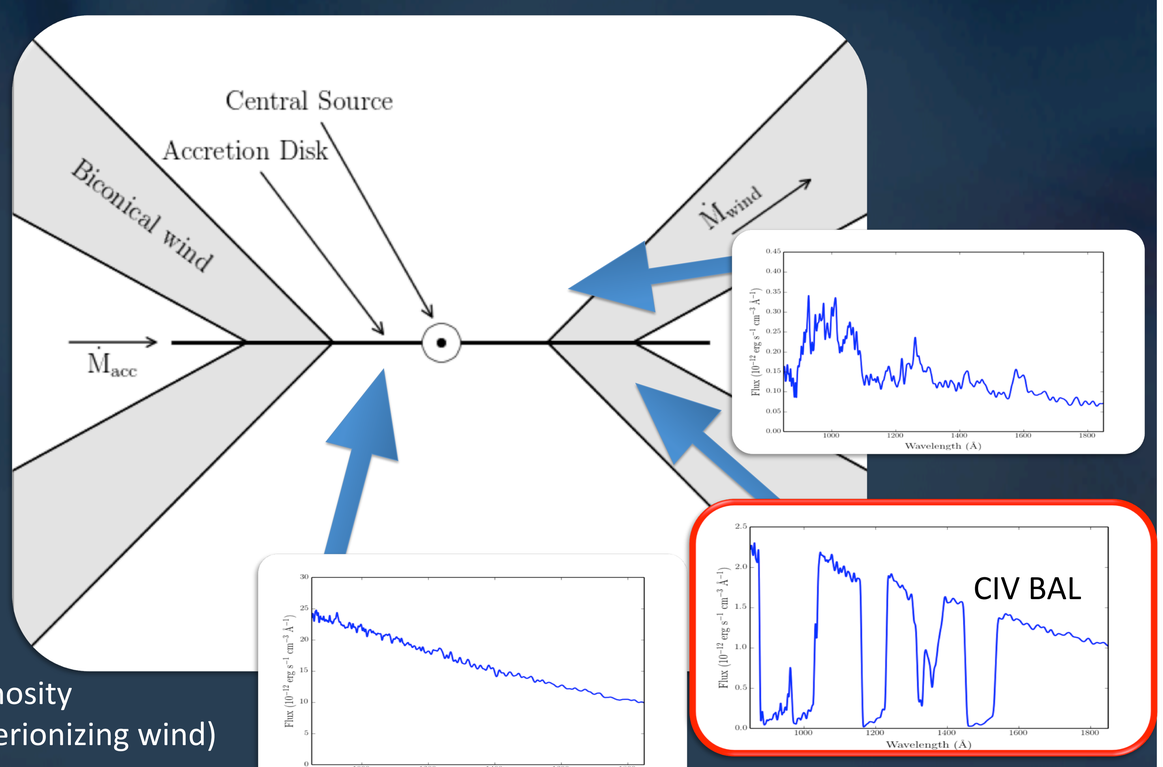
Compute observed spectra

Different ionization & excitation options:

- a modified Saha equation which models the spectrum in a cell
- Full solution of rate matrices for `macro atom' mode

A Benchmark Model for BALQSOs

- Higginbottom+ 2013 present a benchmark model
- **successfully reproduces blue shifted BAL troughs in e.g. CIV**
- 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:

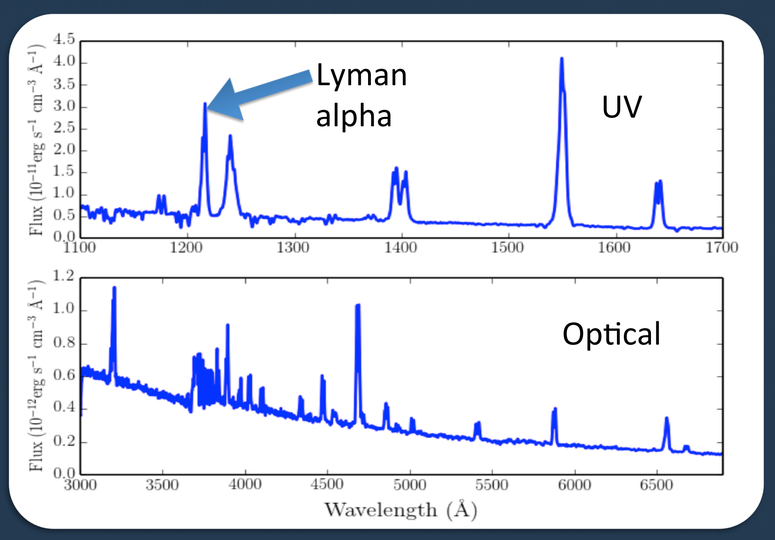
- The unabsorbed 2-10keV X-ray luminosity is too weak, at 1e43 erg/s (to avoid overionizing wind)
- The model fails to reproduce Lyman alpha emission
- The model fails to produce significant broad emission lines

Implications for AGN feedback

- Disk winds proposed as a possible AGN feedback mechanism- so-called 'Quasar-mode' feedback
- For a disk wind to be responsible for AGN feedback it must have an high enough energetically significant kinetic luminosity, defined as $L_k = \frac{1}{2} \dot{M}_W v^2$
- Di Matteo+ (2005) and Hopkins & Elvis (2010) require Lk/Lbol 0.005–0.05 for effective feedback
- We require the mass loss rate of the wind to be comparable to accretion rate, which gives **Lk/Lbol ≈ 0.25**
- **Consistent with idea that winds may be of sufficient kinetic power to influence the host galaxy**

Cataclysmic Variable Models

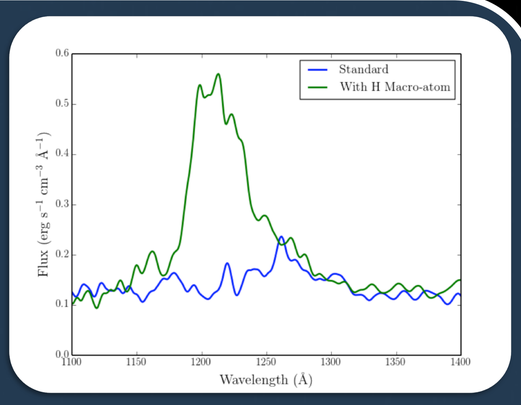
- 'Macro-Atoms': Line Transfer scheme developed by Lucy (2002,2003)
- NLTE solution without simplifying internal atomic transitions- good for recombination lines
- Using macro-atoms produces strong Balmer emission lines and enhances the Lyman alpha emission from the wind (Matthews+, in prep)



The Next Step

QSO Macro atom models

- Preliminary results suggest improved treatment of Hydrogen level populations produces more Lyman alpha emission (see right)

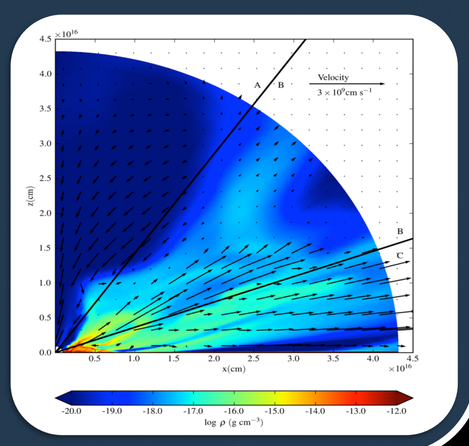


Parameter searches: Kinematics and Geometry

- 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 mass loss

Radiative-Hydro

- Higginbottom+ 2014 treats the Proga & Kallman 2004 model with our radiative transfer code (see density map, right)
- We find the wind is overionized and would not exist in that *particular* state
- Future plan to couple our code with ZEUS for radiative-hydro



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