Looking for the Wind in the Dust

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Principal collaborators:
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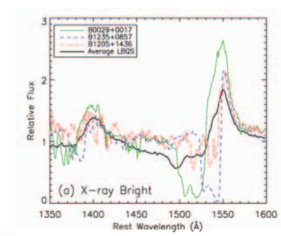
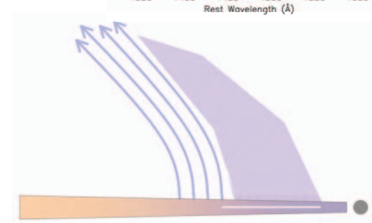
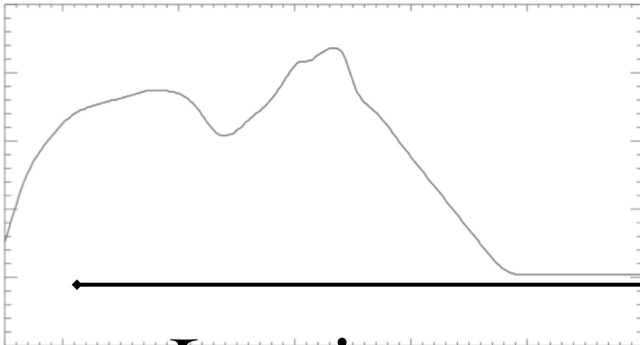




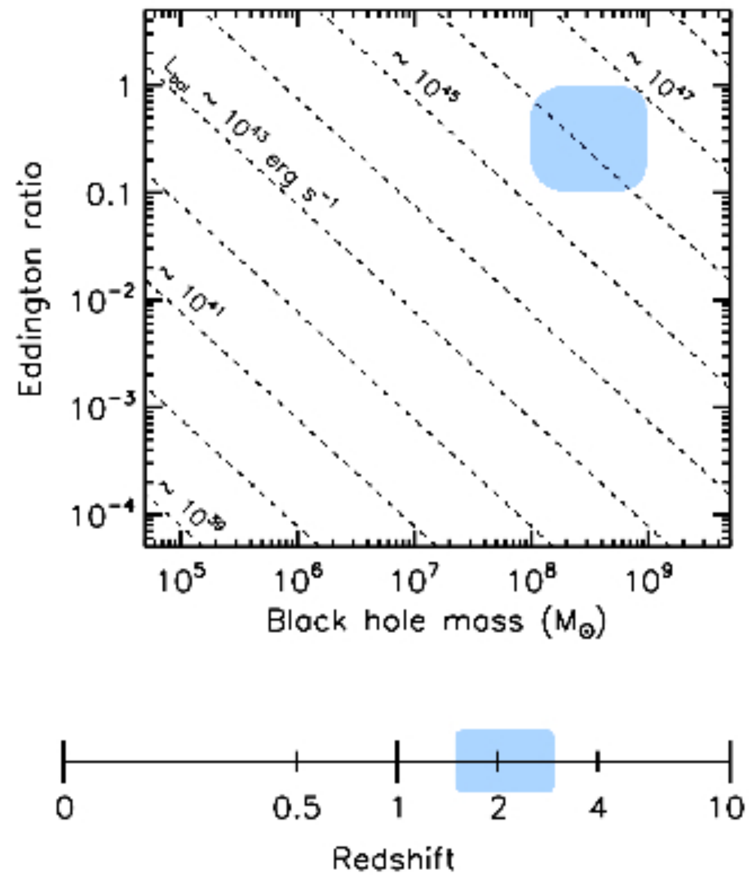
AGN Winds in Charleston ~ October 2011

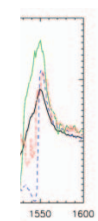


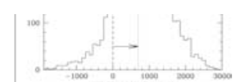
Focus

- Luminous quasars
  - big black holes
  - efficient accretion
    - high L/L_{Edd}
- z~2

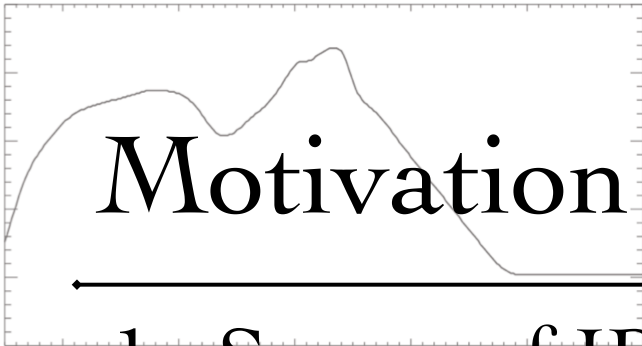
→ The systems where feedback in massive, cold gas-rich galaxies will happen.

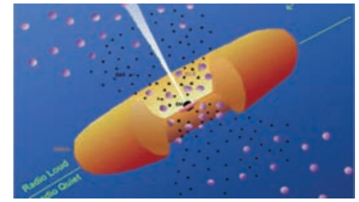




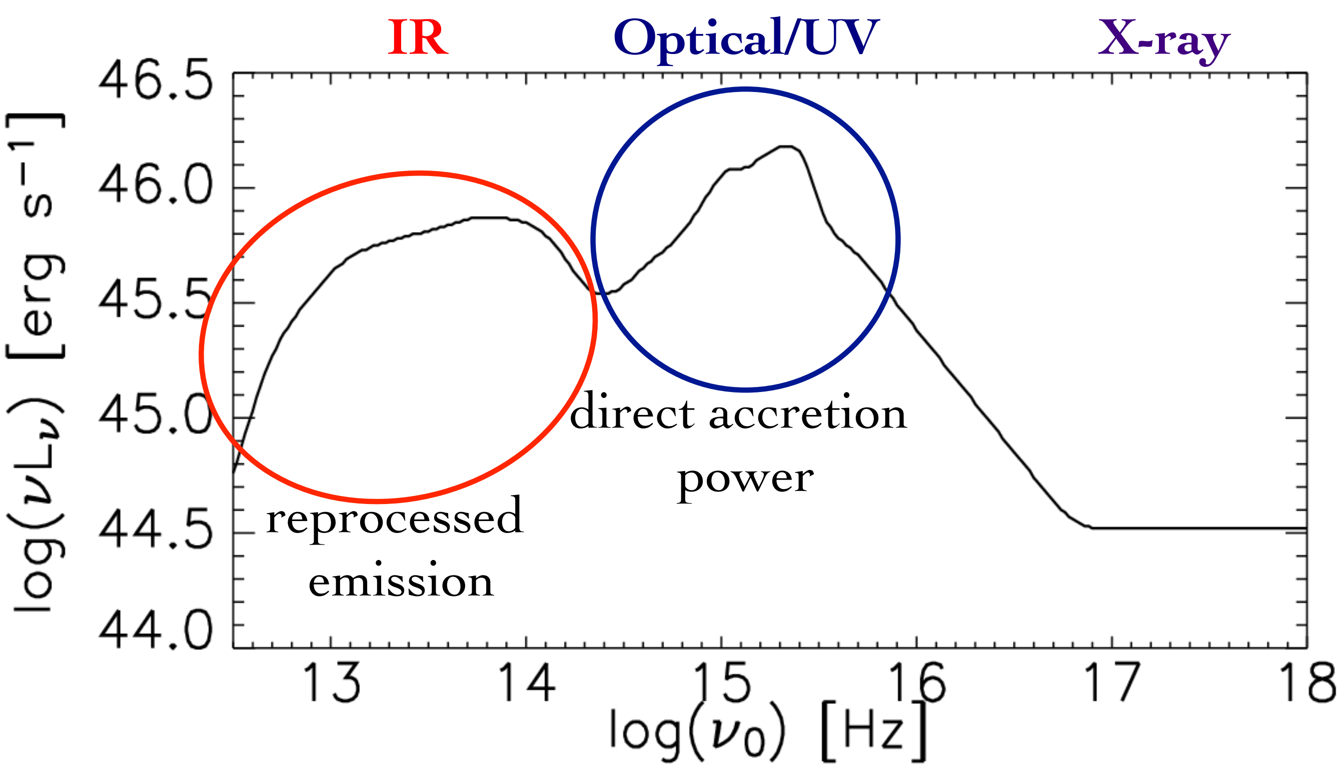


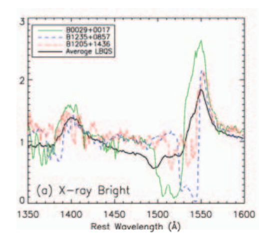
Motivation for the "torus"



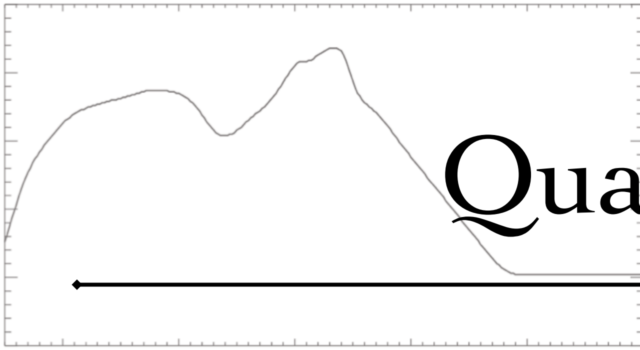


1. Source of IR emission
2. Obscuring structure

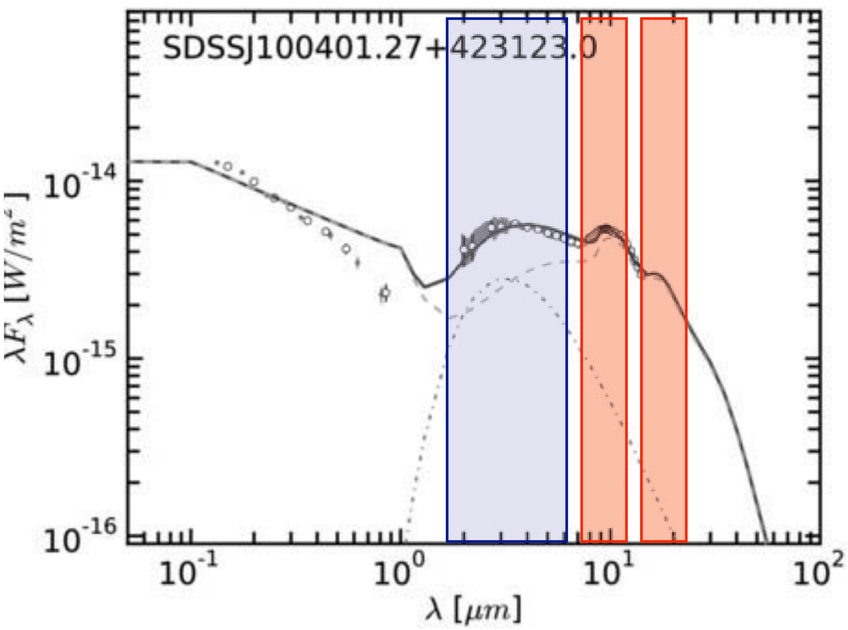




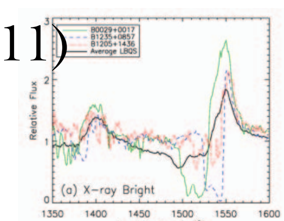
(SDSS composite from Richards et al. 2006)



Quasar IR spectra



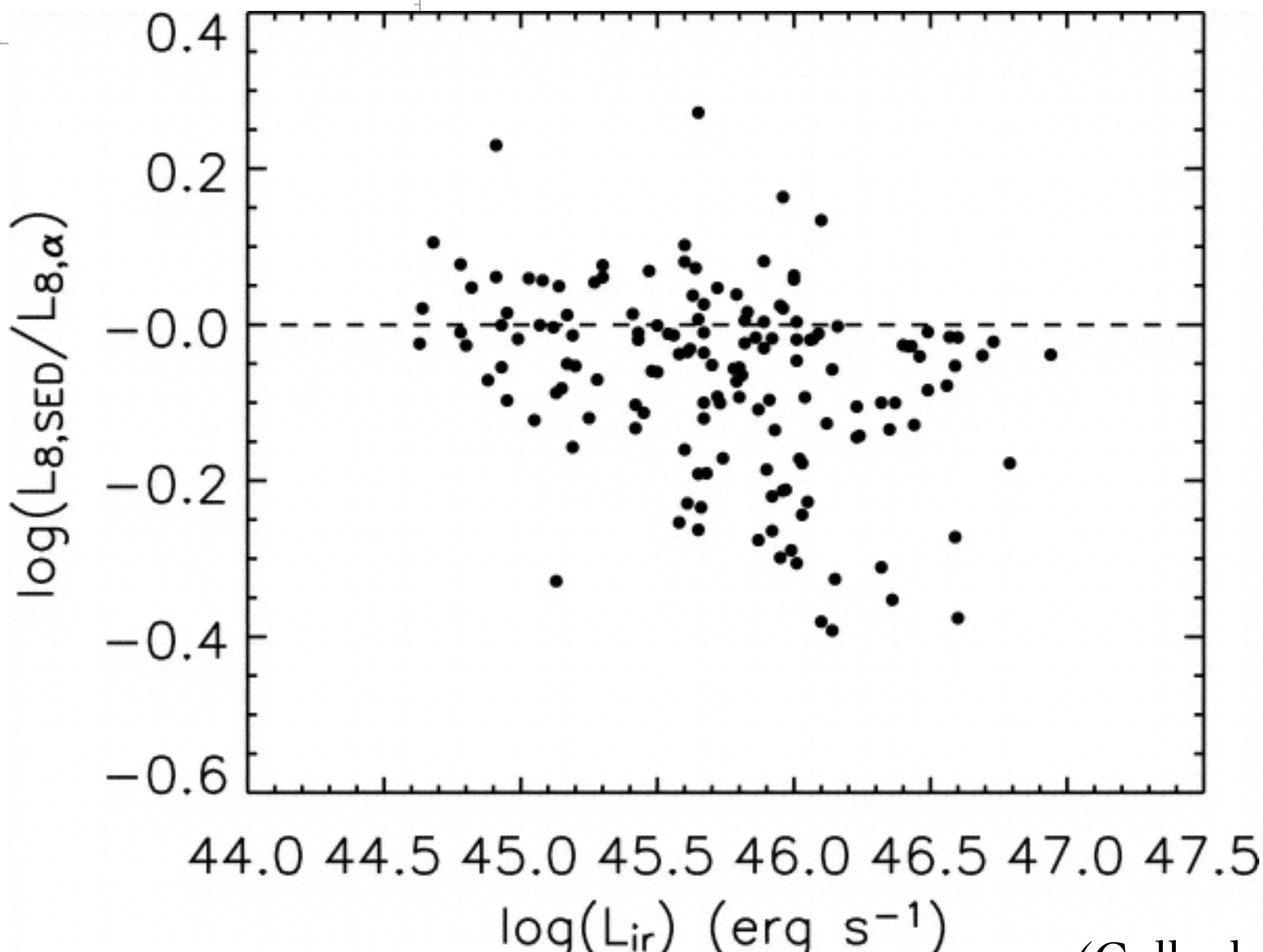
- **Prominent silicates**
- **3-5 µm "bump"** from hot dust (graphite)
  - T~1500 K blackbody (Barvainis 1987)
  - T_{BB}~1200 K (Deo et al. 2011)



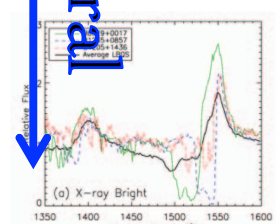
Static models can reproduce the silicate features, but not at the same time as the 3-5 µm bump.

(Deo et al. 2011)

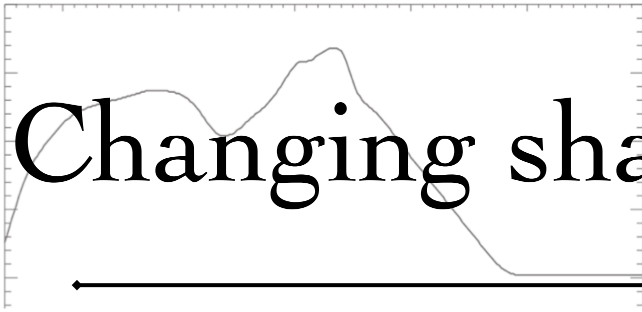
3-5 μm bump strength increases with luminosity



increasing spectral curvature

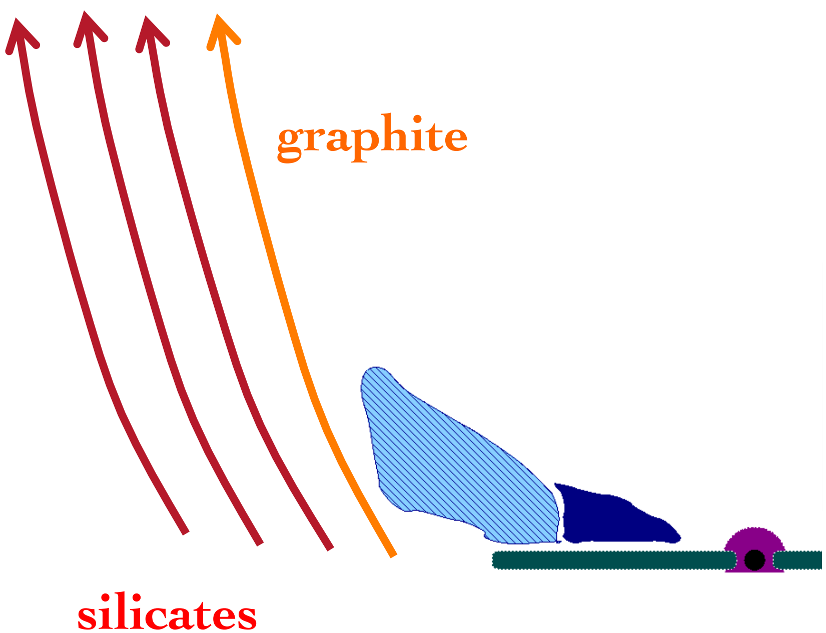


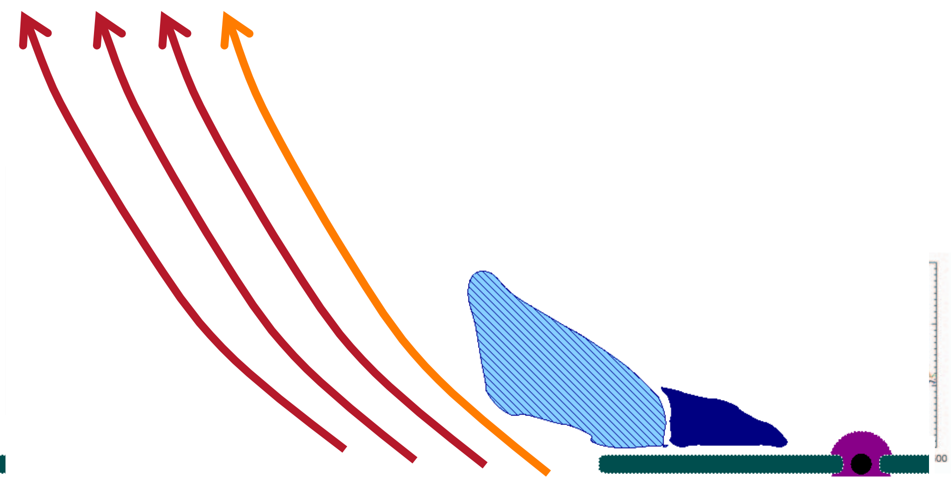
(Gallagher et al. 2007)

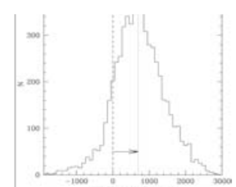


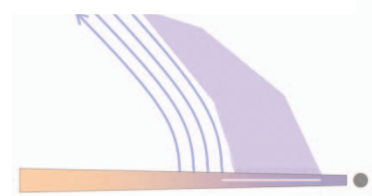
Changing shape of a dusty outflow?

Less Luminous | **More Luminous**



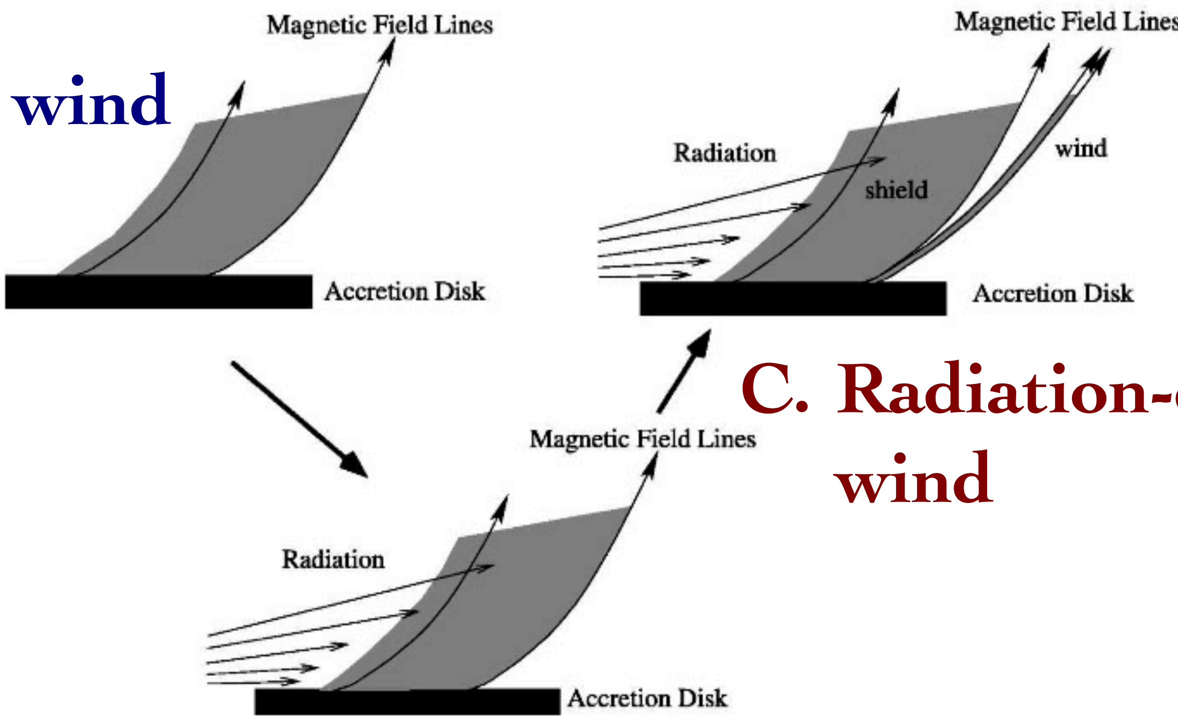




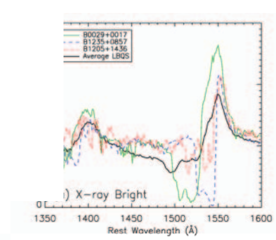


Modeling the torus as a dusty wind

A. MHD wind

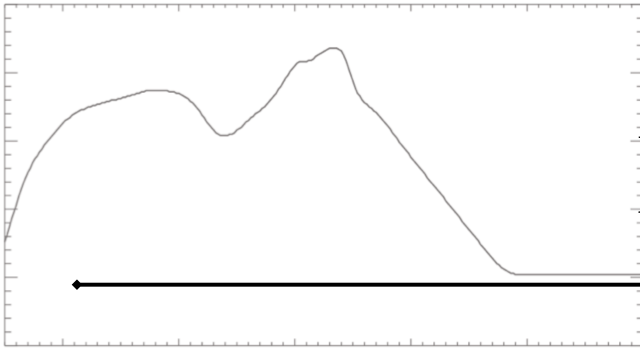


C. Radiation-driven wind



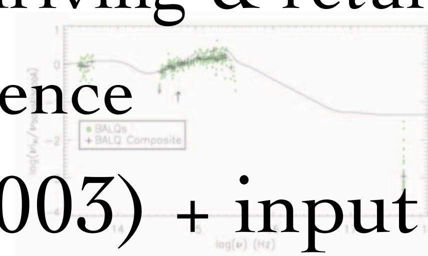
B. Add radiation pressure from dust

(add in dust continuum opacity to Everett 2005)

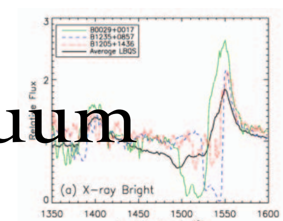


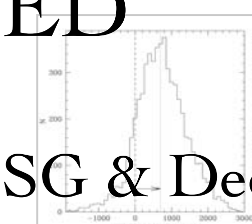
Procedure

1. Start with MHD wind to calculate density and velocity as a function of height
   a. Use Cloudy to simulate photo-ionization and determine opacities
   b. Calculate radiation driving & return to 1.
   c. Iterate until convergence



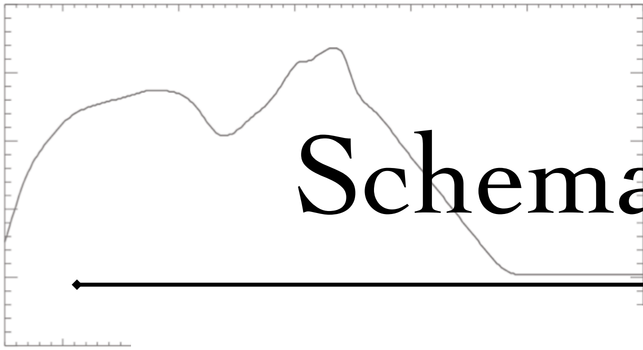
2. Use MC3D (Wolf 2003) + input continuum & wind model to predict IR SED

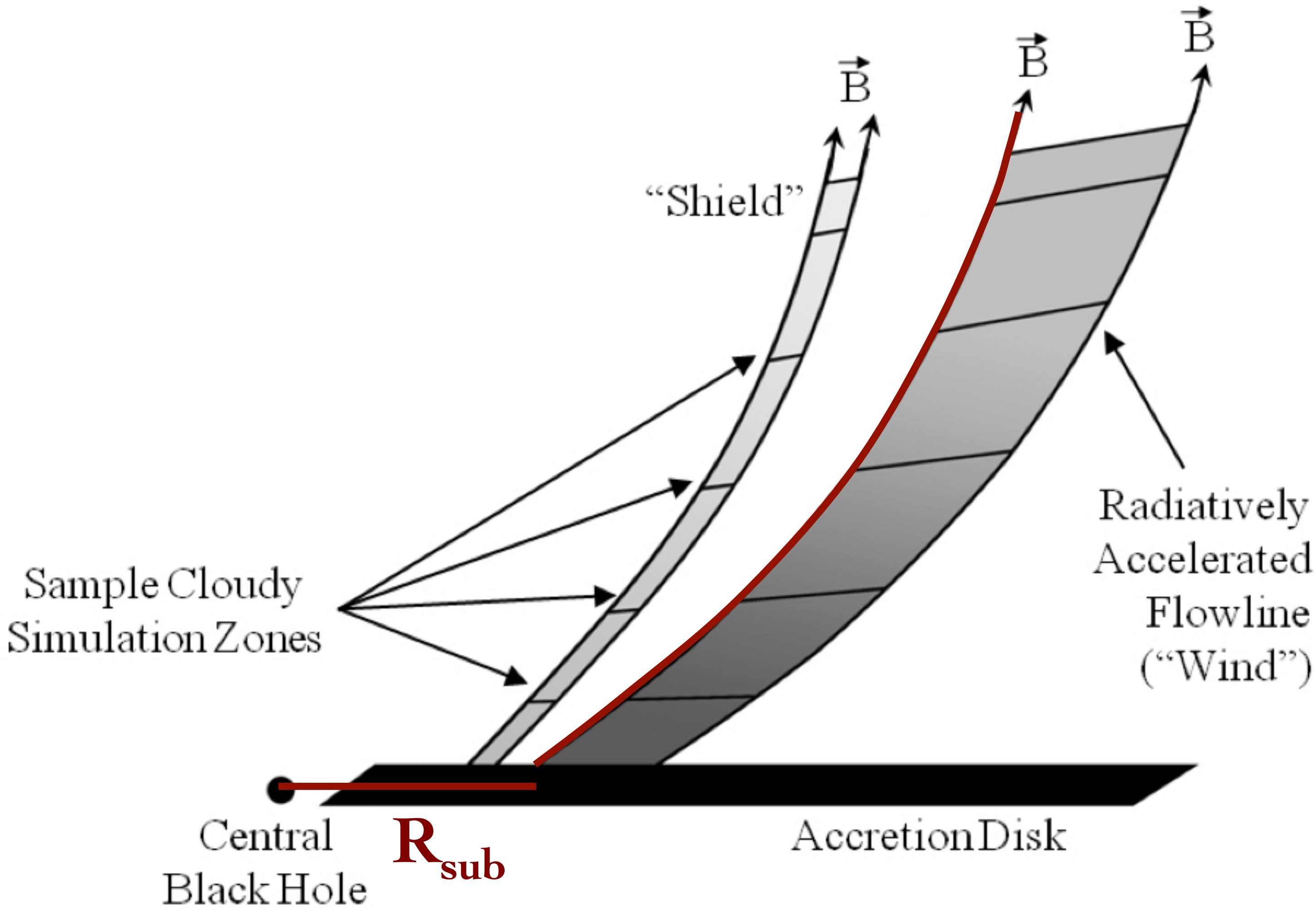


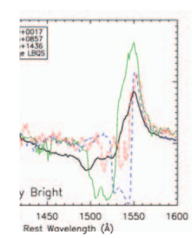


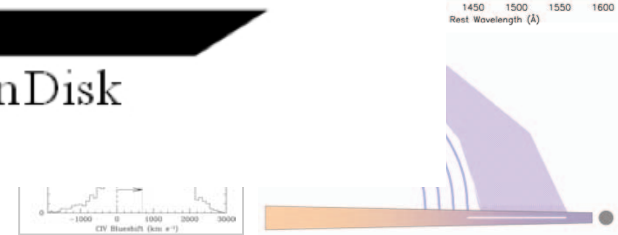
(Keating, Everett, SG & Deo, submitted)

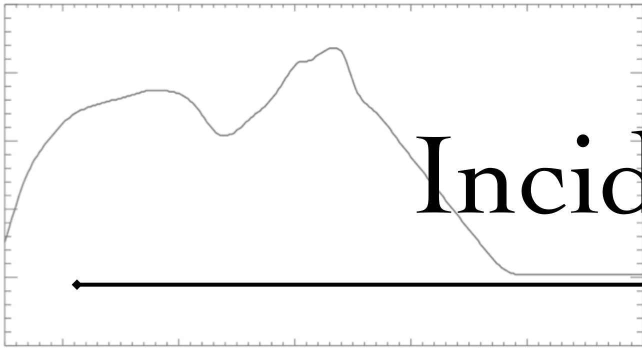
Schematic of dusty wind



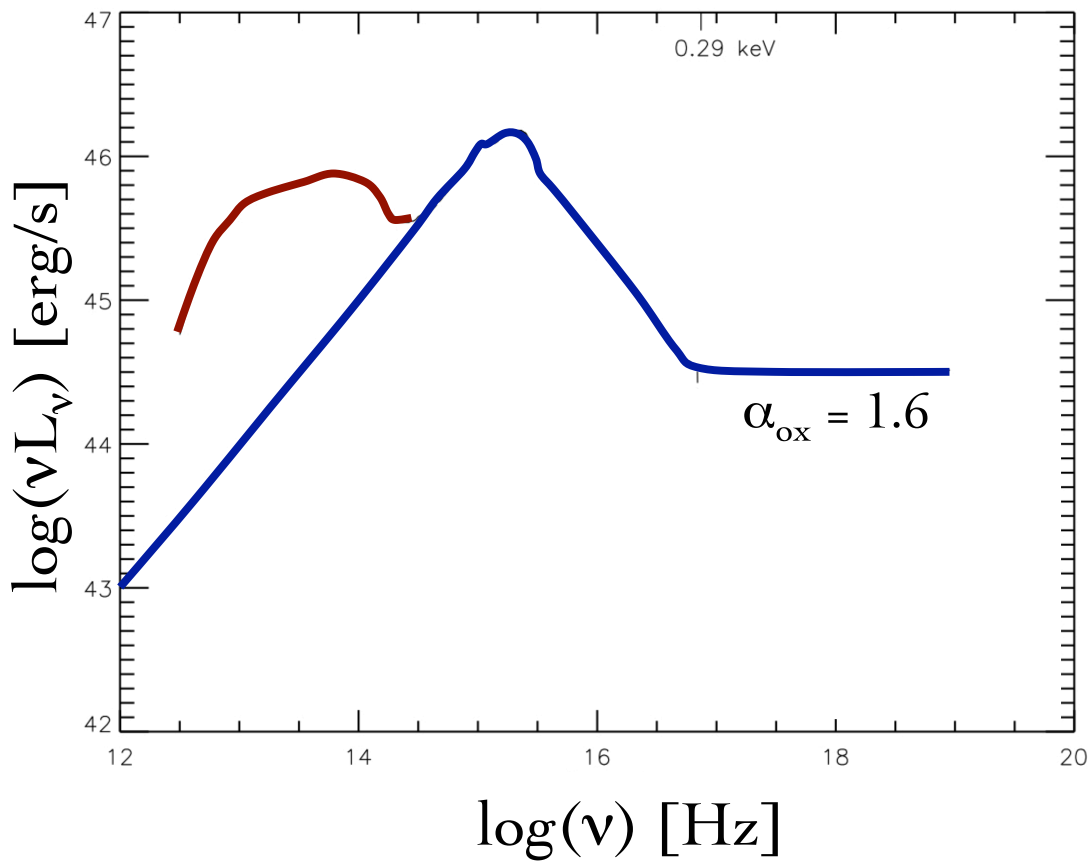


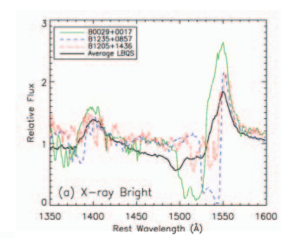


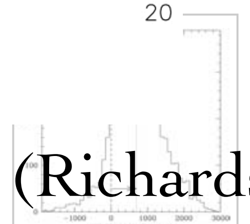




Incident continuum



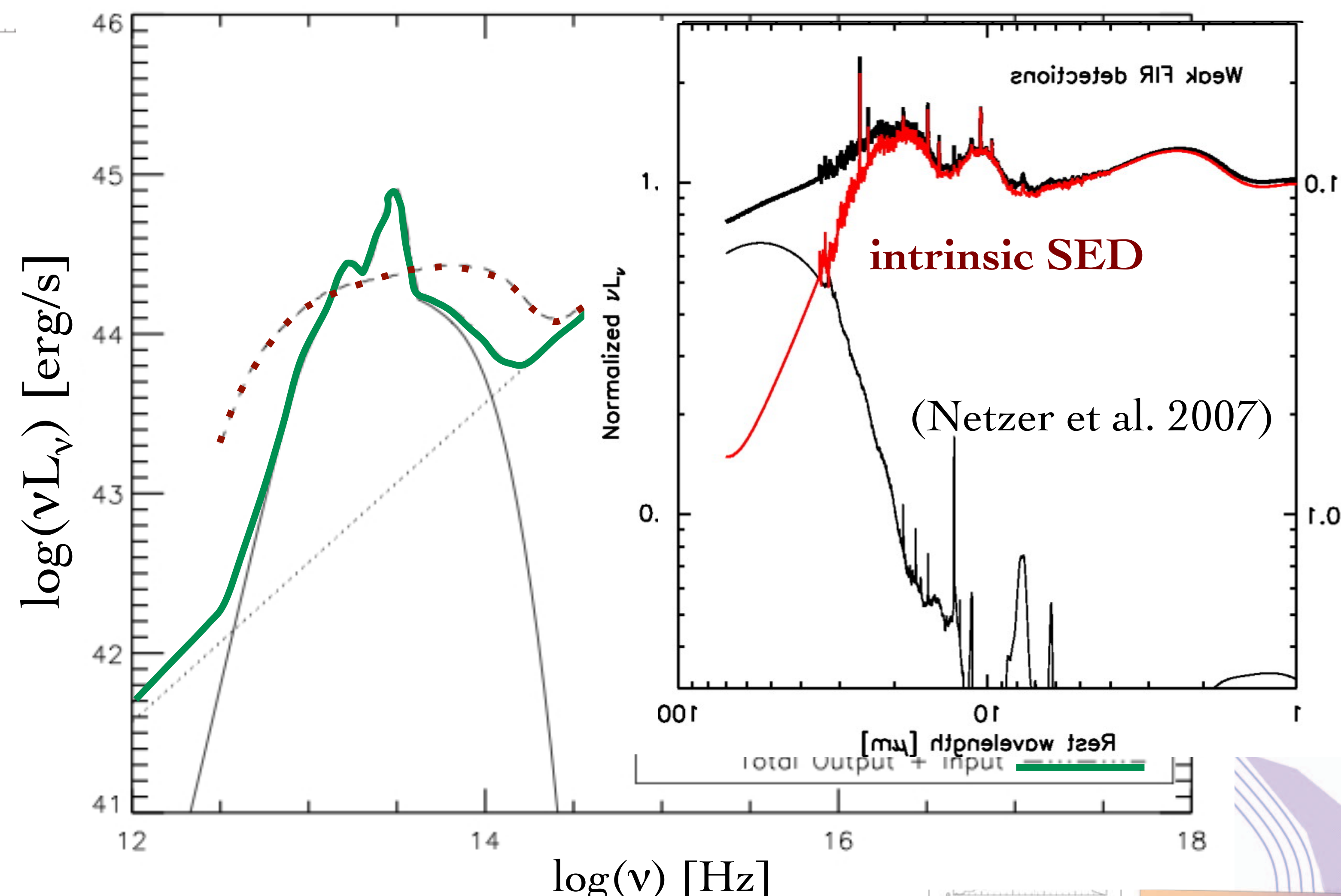




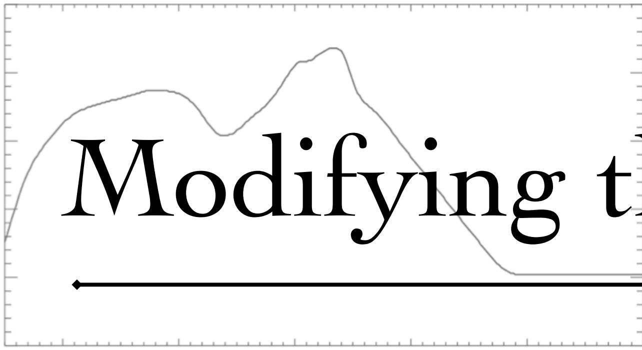
(Richards et al. 2006)

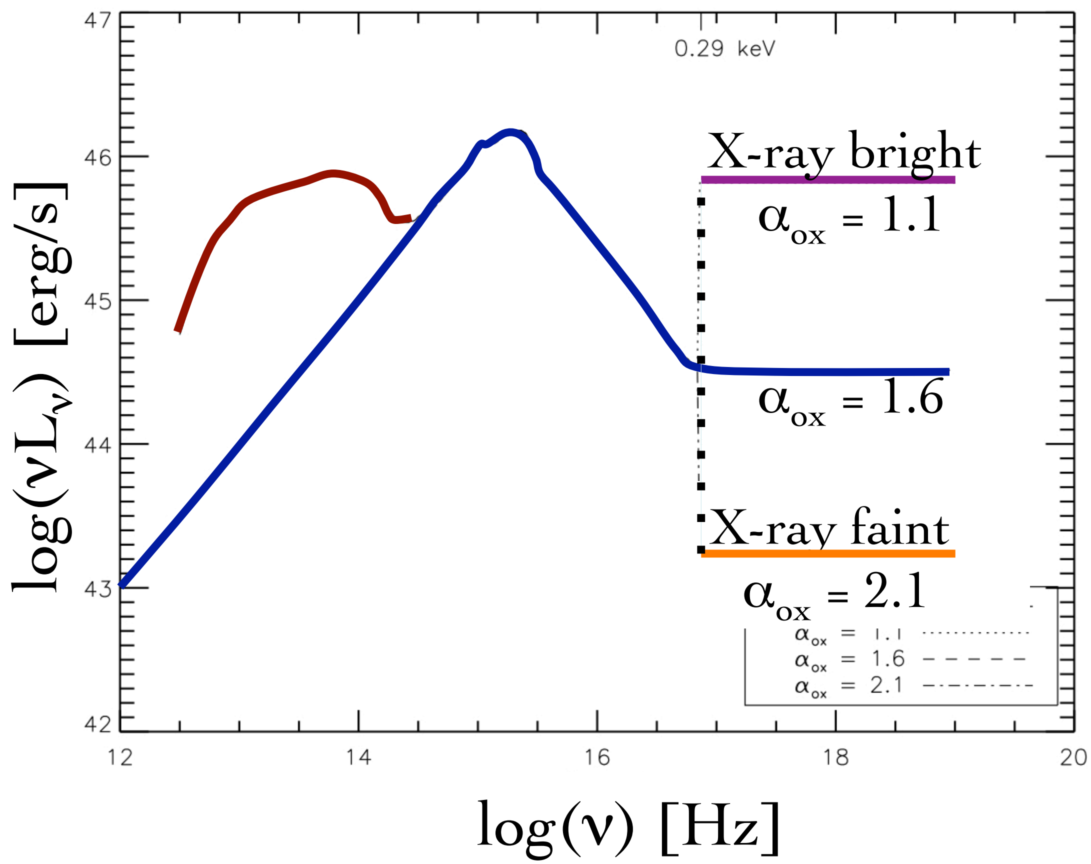
Output SED of the fiducial model

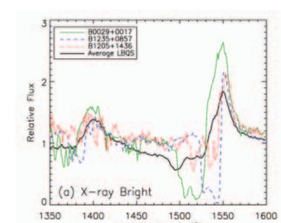
$N_{H,base}=10^{25}$ cm^{-2}; $L/L_{Edd}=0.1$; $M_{BH}=10^{8}\ M_{o}$; $\alpha_{ox} = 1.6$

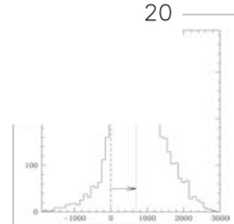


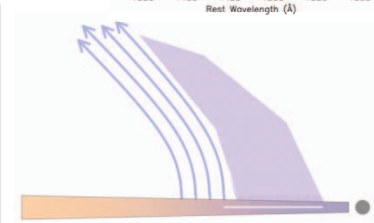
Modifying the incident continuum



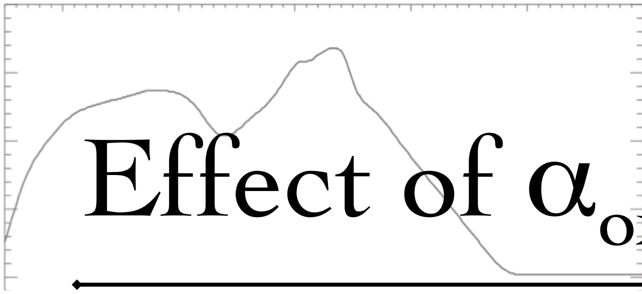


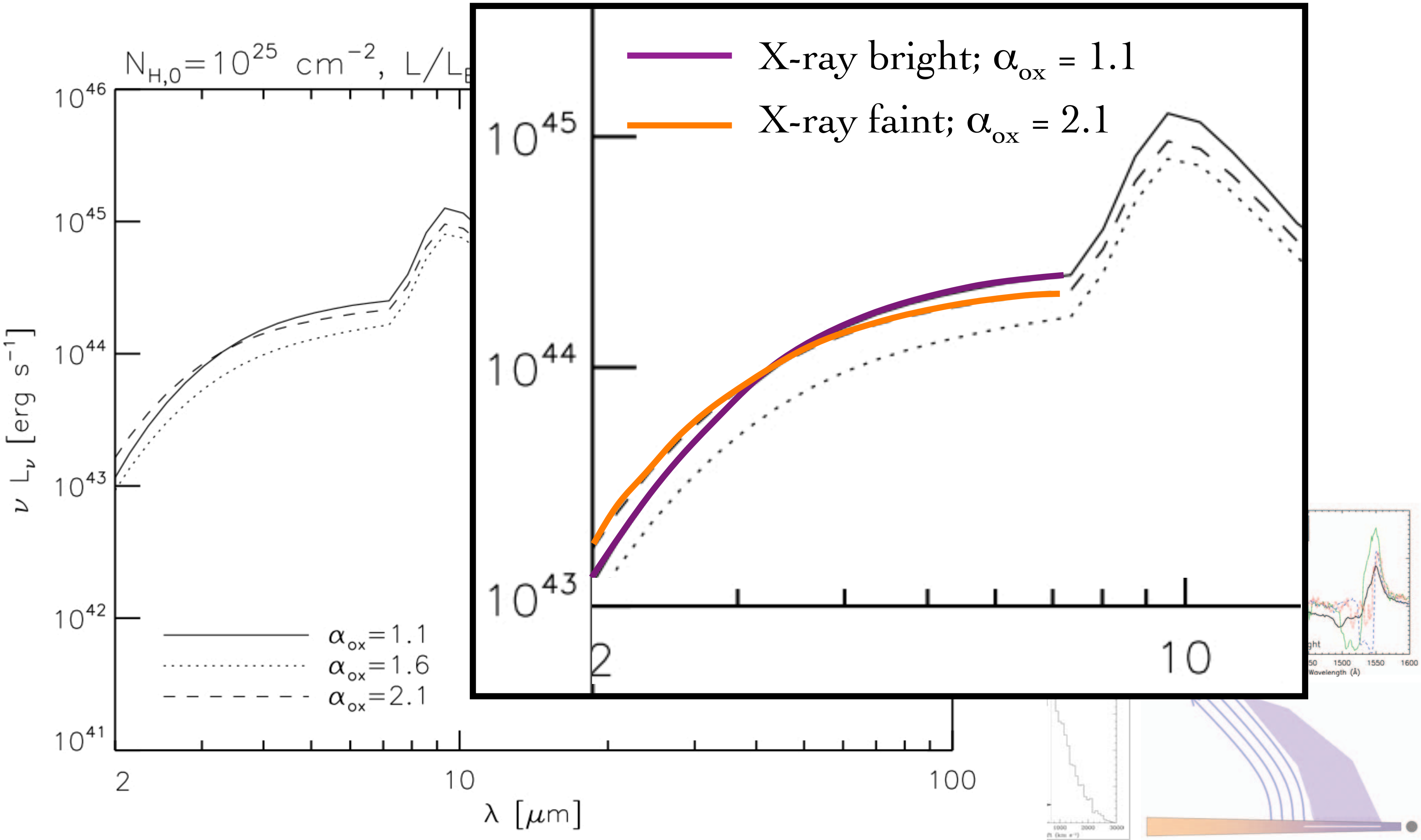




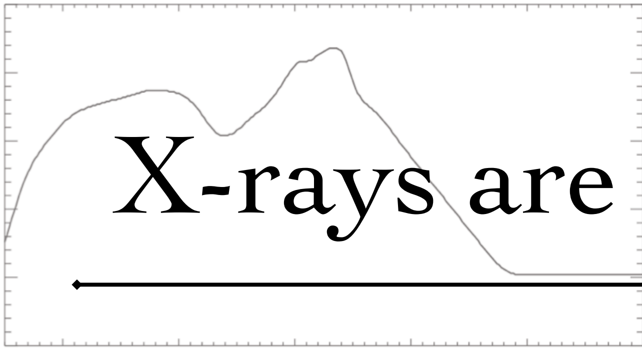


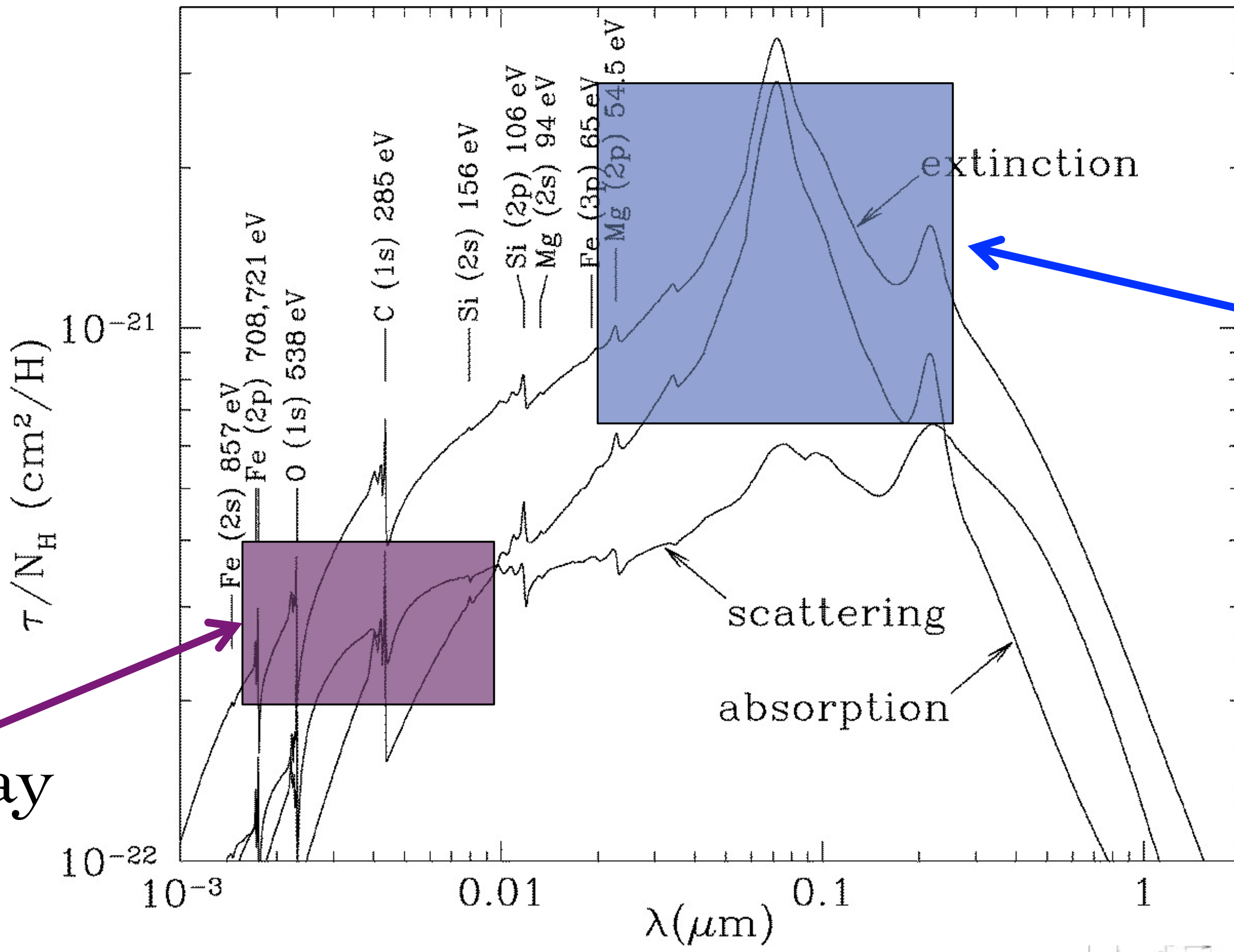
Effect of α_{ox} on the near-IR SED





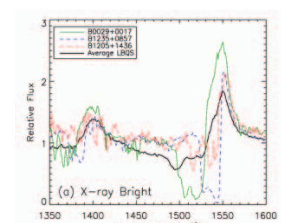
X-rays are more likely to scatter



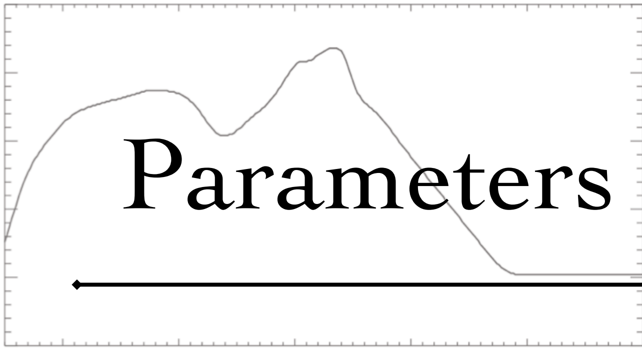


absorption dominates in the UV

X-ray



(Draine 2003)



Parameters of interest from models

- Terminal outflow velocity of dusty wind:

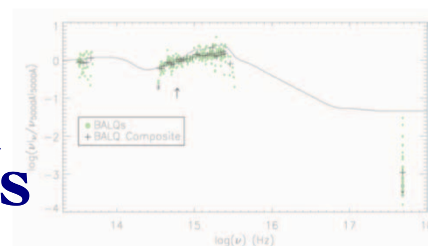
  1900 – 8000 km/s

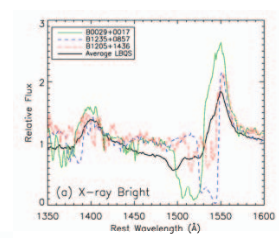
- Mass-outflow rate:

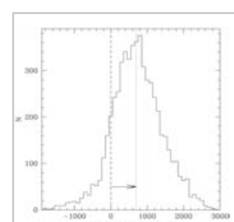
  1 – 4 M_{Sun}/yr

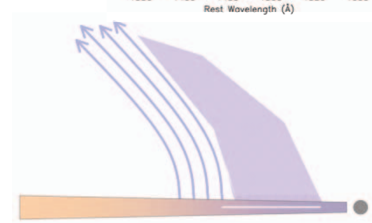
- Kinetic luminosity:

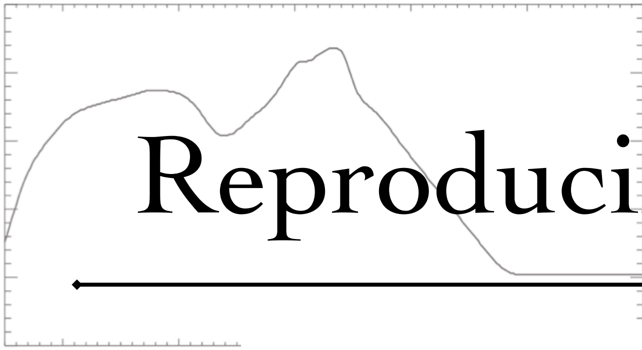
  10^{42} – $10^{43.8}$ erg/s



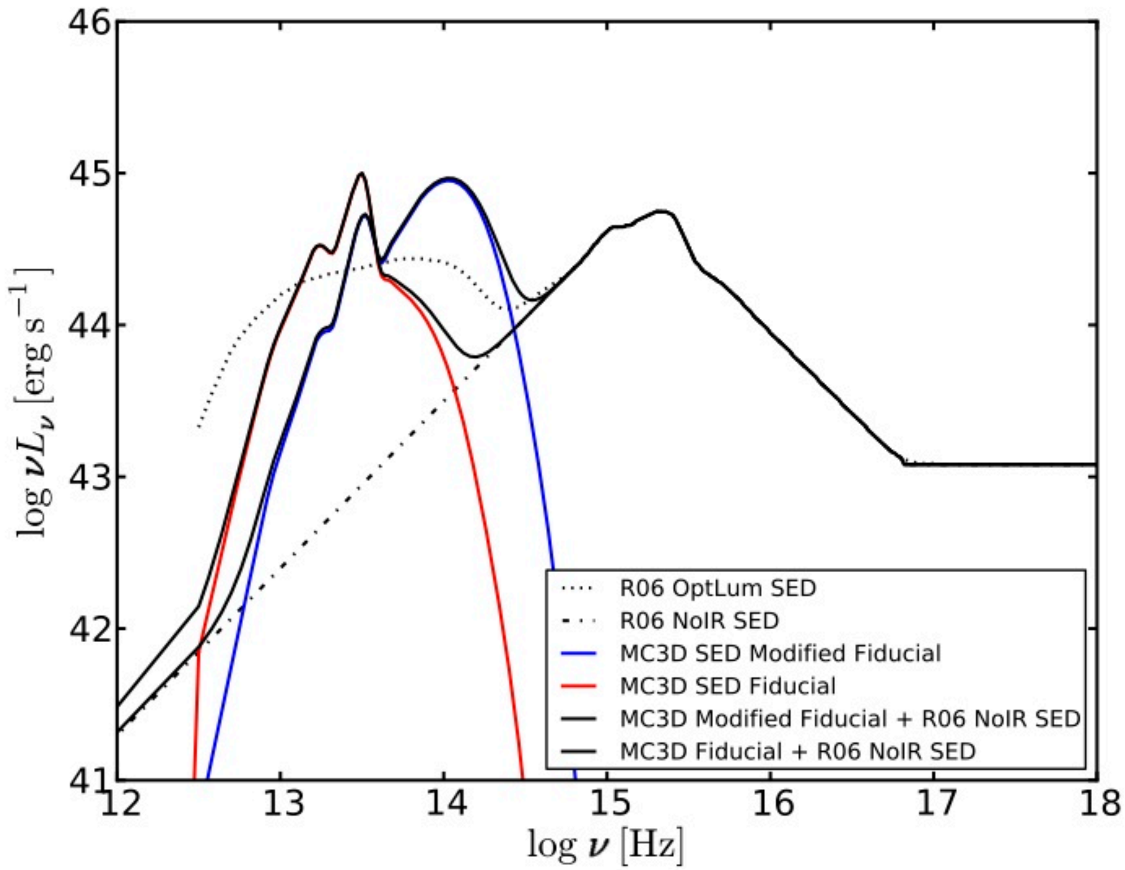


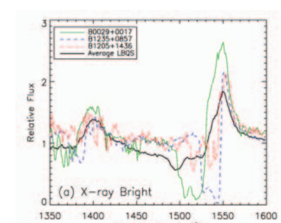


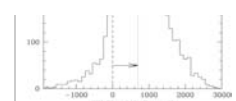


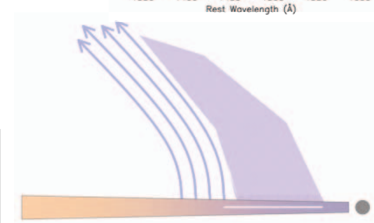


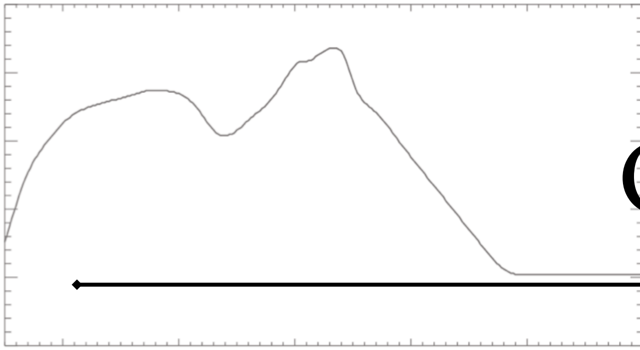
Reproducing the 3–5 μm bump





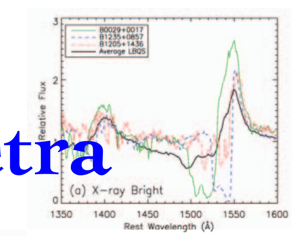




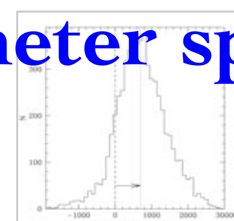


Conclusions

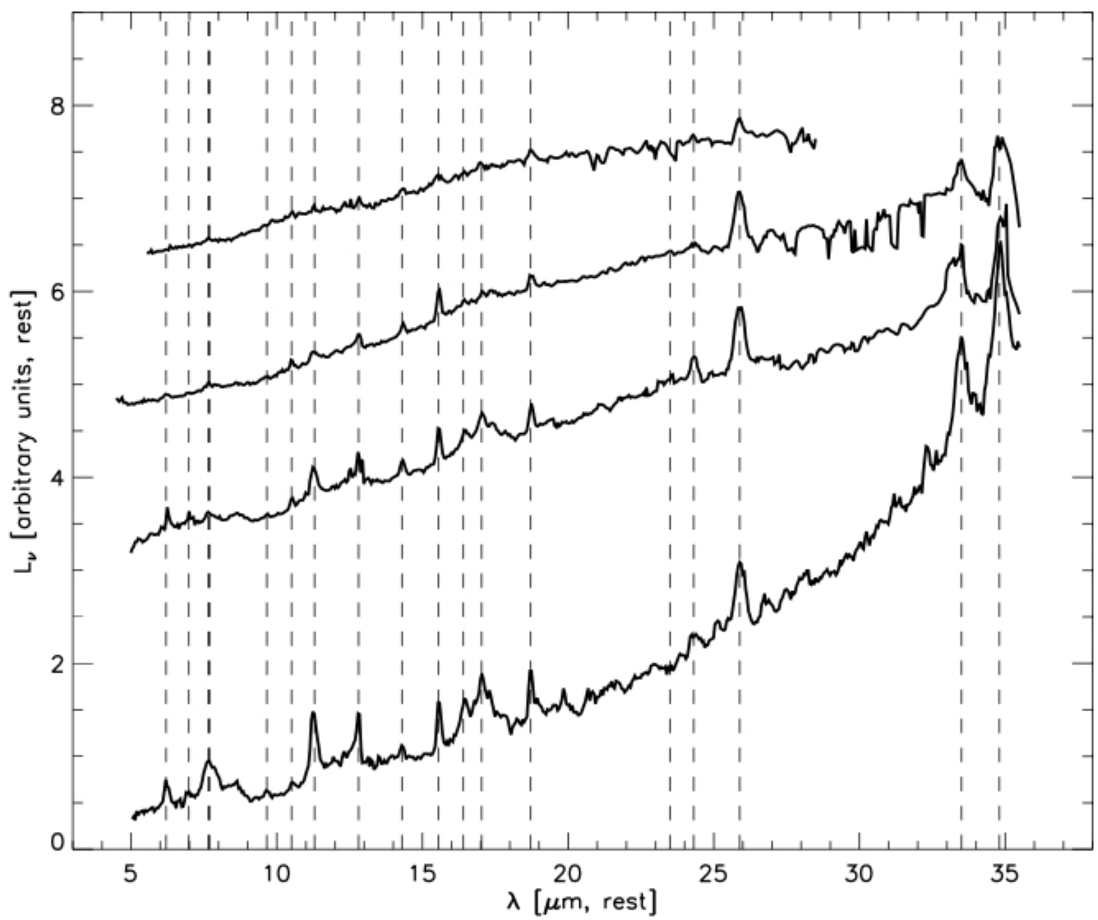
1. A dusty wind can reproduce the power & shape of the mid-IR hump of the composite SED.
2. The 3-5 micron bump may be a diagnostic of dusty winds, and offer constraints on the incident SED.



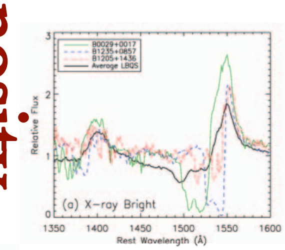
Goal: To use the details of mid-IR spectra to constrain the model parameter space.



Systematic changes in mid-IR spectra



increasing luminosity



(Spitzer IRS composites; Hill et al. POSTER)