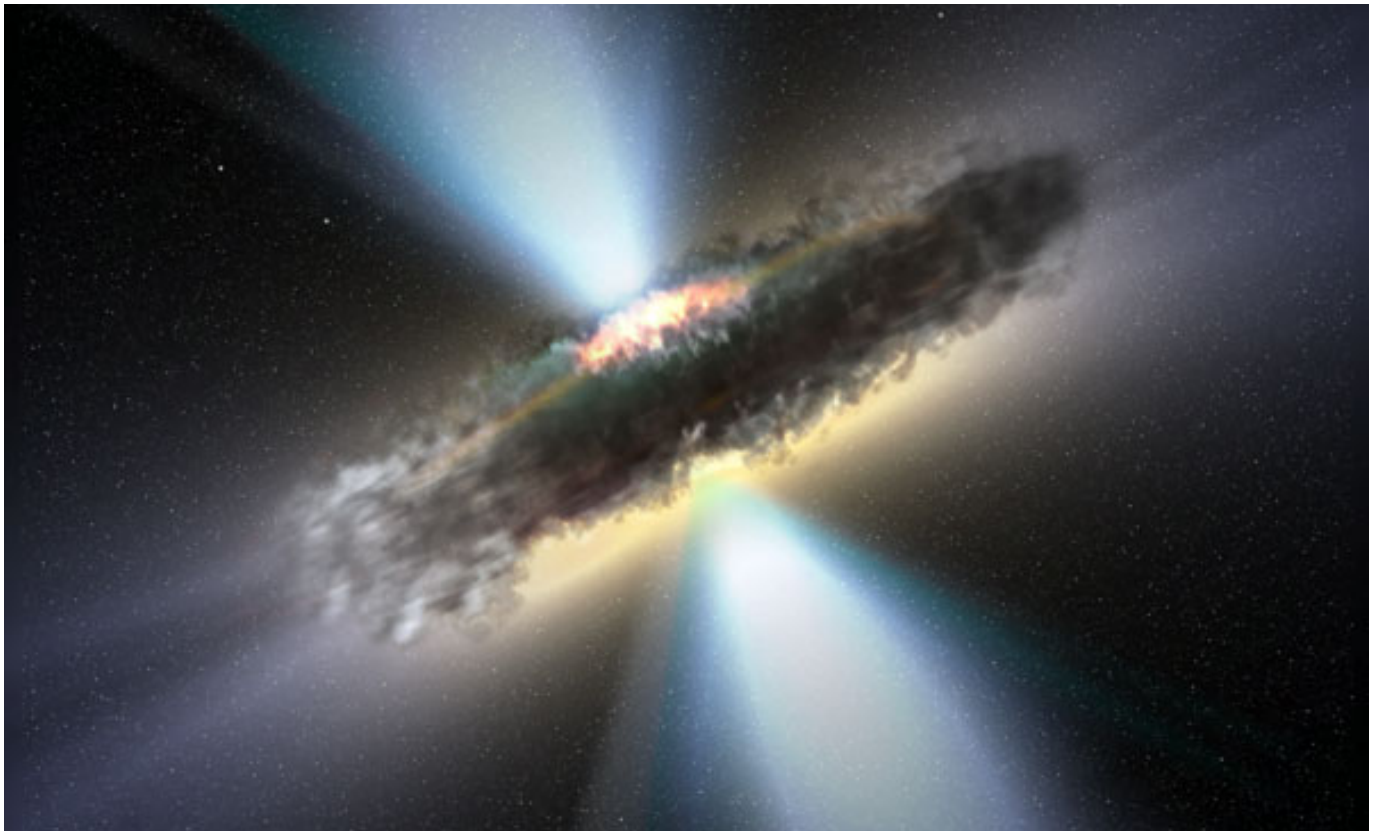
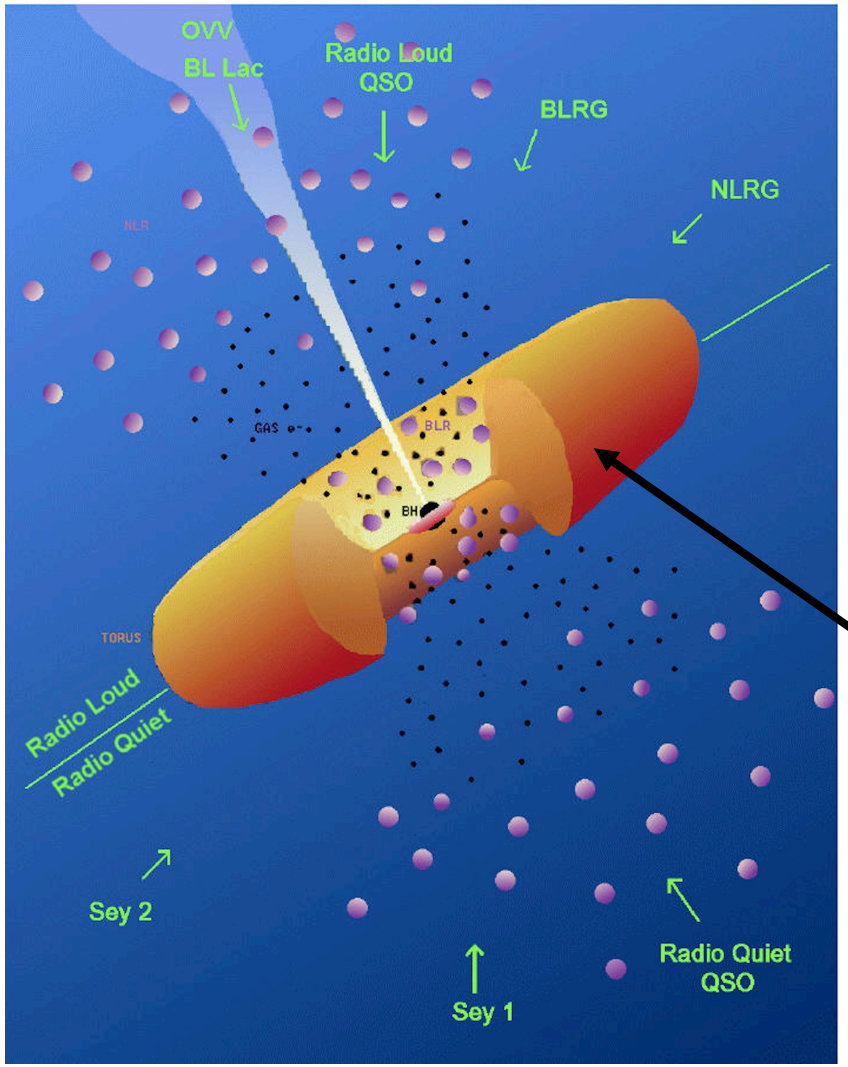


MODELING THE REVERBERATION RESPONSE OF THE DUSTY TORUS EMISSION OF NGC 6418

Triana Almeyda
Astrophysical Sciences and Technology
Rochester Institute of Technology

AGN Unification Model



Dust in clumpy torus absorbs UV–visible radiation and re-emits in the IR

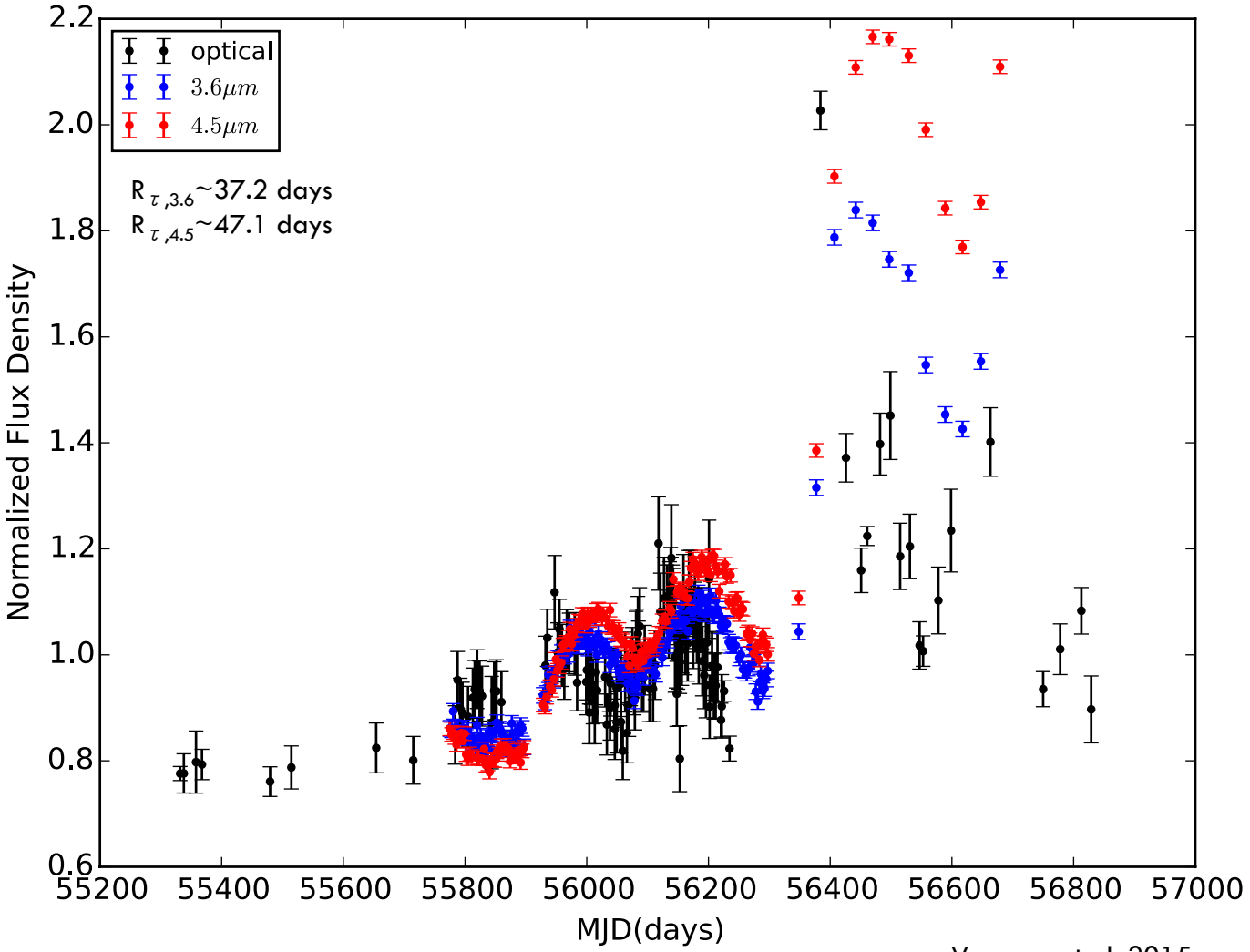
Credit: Urry & Padovani 1995

Spitzer AGN Monitoring Campaign

- 12 Type 1 AGN monitored with Spitzer and optical ground based telescopes over 2 years
  - $z<0.4$
- Infrared
  - Spitzer Space Telescope
    - Channel 1 and Channel 2 (3.6 and 4.5 microns respectively)
    - 3 day cadence during Cycle 8, 30 day cadence Cycle 9
- Optical
  - Liverpool Telescope
  - Southwestern University Telescope
  - Faulkes Telescope North
  - Catalina Sky Survey

See Robinson et al. poster for more information!

Observed Light Curves: NGC 6418



Vazquez et al. 2015

Radius-Luminosity Relationships

- R-L relationship

$$\tau \sim \frac{R}{c}$$

$$R \propto L^{1/2}$$

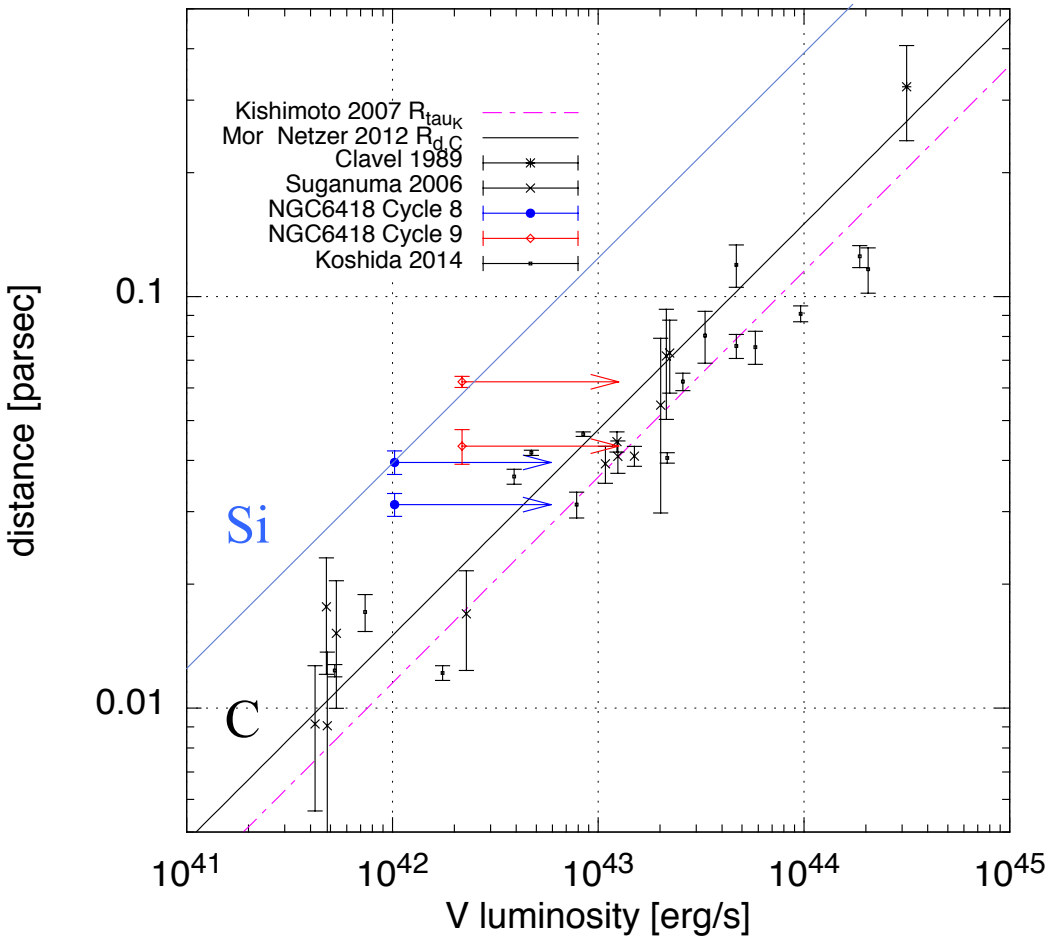
- Dust Sublimation radius

$$R_d \approx 0.4 \left(\frac{L}{10^{45} erg^{-1}} \right)^{0.5} \left(\frac{1500K}{T_{sub}} \right)^{2.6} pc$$

(Nenkova et al. 2008b, Barvainis 1987)

- $R_d \sim 2R_{observed}$

(Kishimoto et al. 2007, Vazquez et al. 2015)



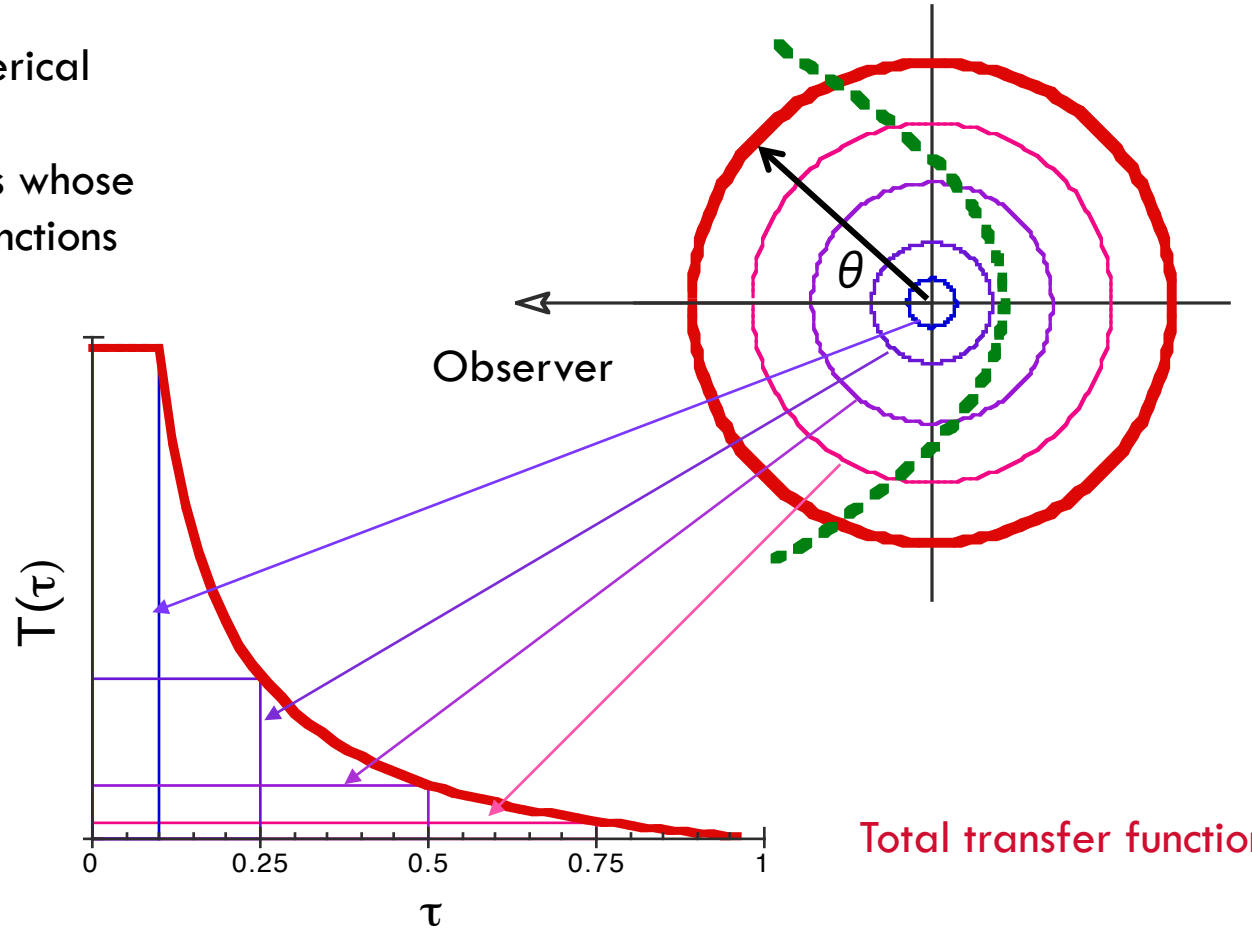
adapted from Vazquez et al. 2015

Motivation of Research

- Develop computer simulation of time dependent response of torus IR emission to variations in AGN UV/optical continuum
  - Identify the key parameters that effect the response within the clumpy torus paradigm
  - Help interpret observed lags and extract structural information about torus from data obtained through Spitzer Campaign

Transfer Function

Consider thick spherical shell as series of concentric thin ones whose TF's are top-hat functions



$$\tau = \frac{r}{c}\left(1 - \cos\theta\right)$$

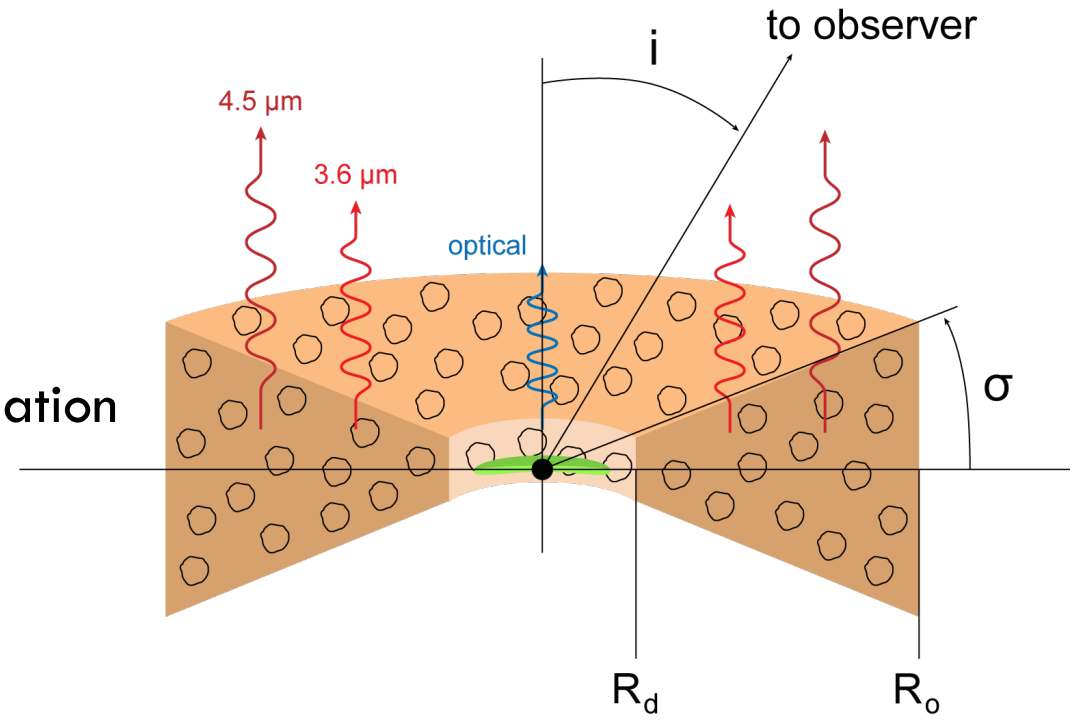
Total transfer function

Credit: Andrew Robinson

Torus Geometry and Structure

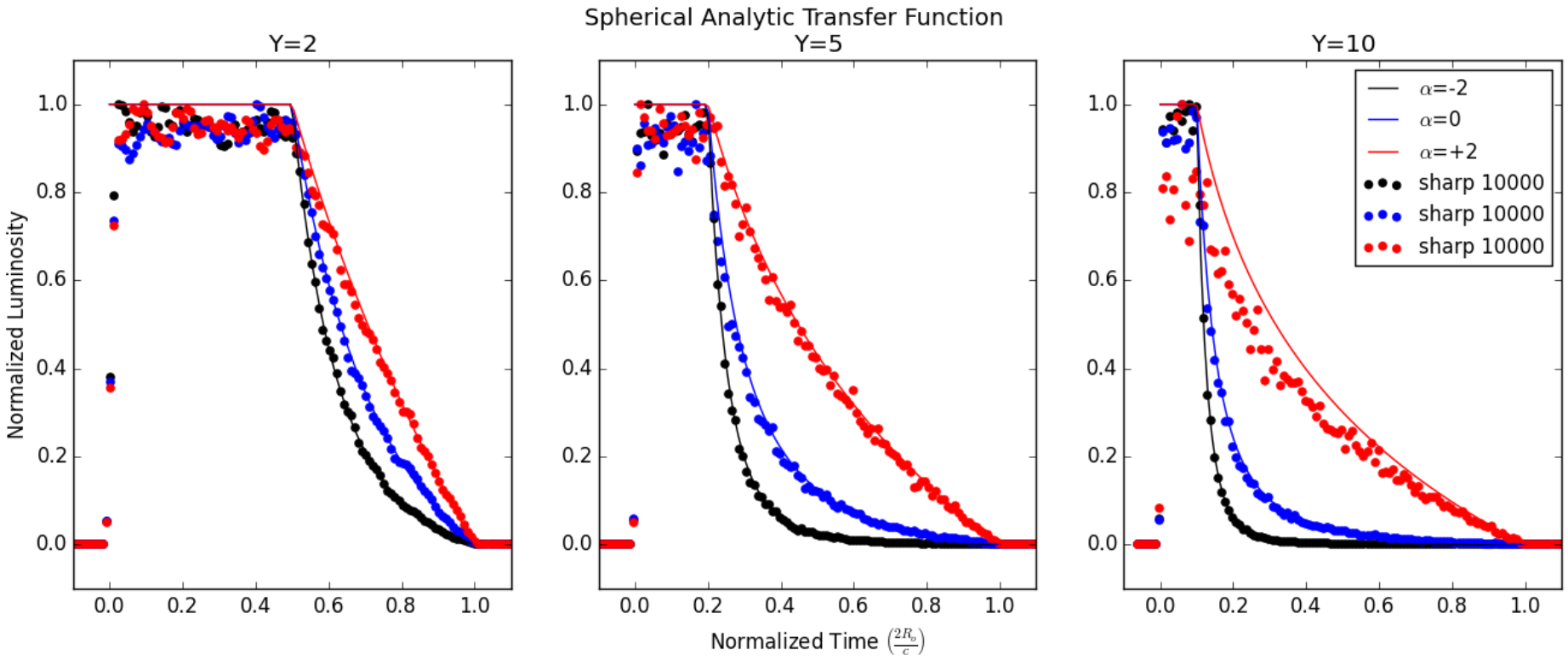
- Each cloud has same size
- Inner Radius set to Dust Sublimation Radius
- ISM dust composition
- Sharp or "fuzzy" boundary
- Isotropic or anisotropic illumination

- Free Parameters:
  - Spherical or disk, σ =0-90°
  - Inclination, i=0-90°
  - Radial distribution of clouds, $\propto r^{\alpha}$
  - Radial depth, $Y=R_o/R_d$

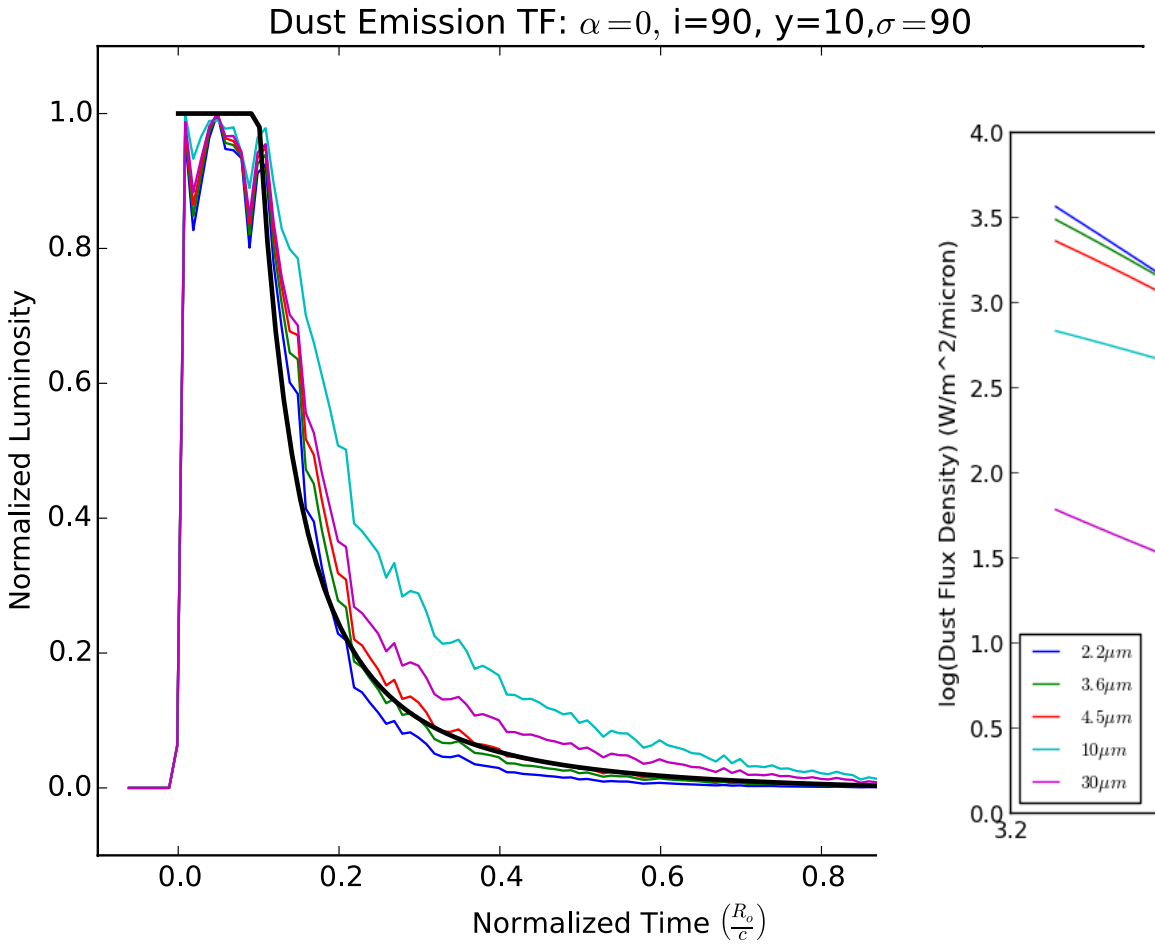


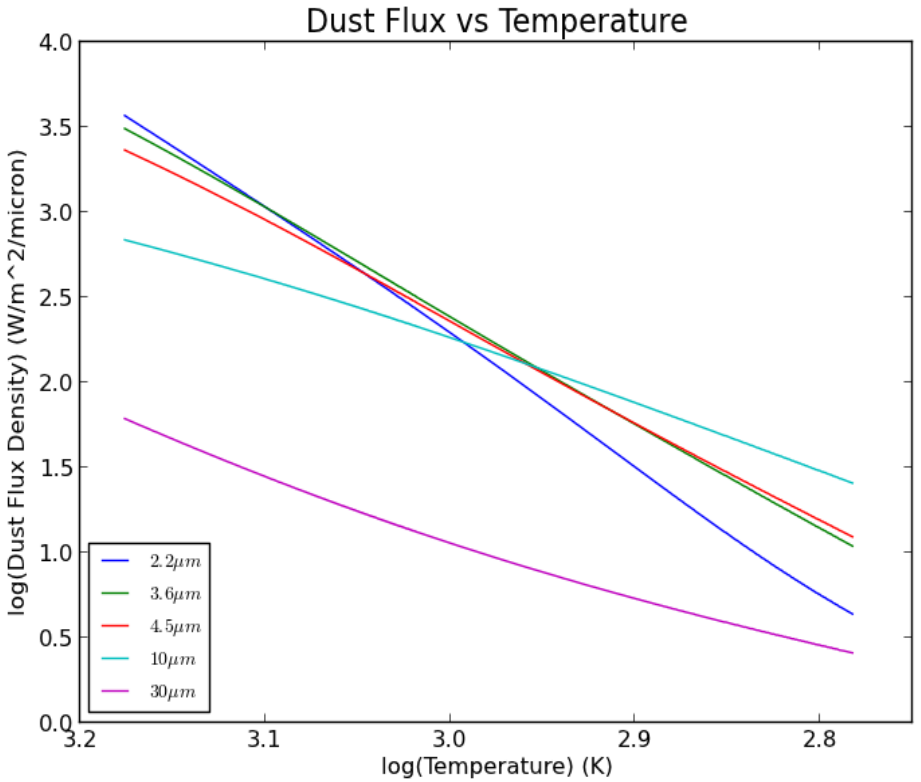
Nenkova et al. 2008a,b

Spherical Shell Transfer Function



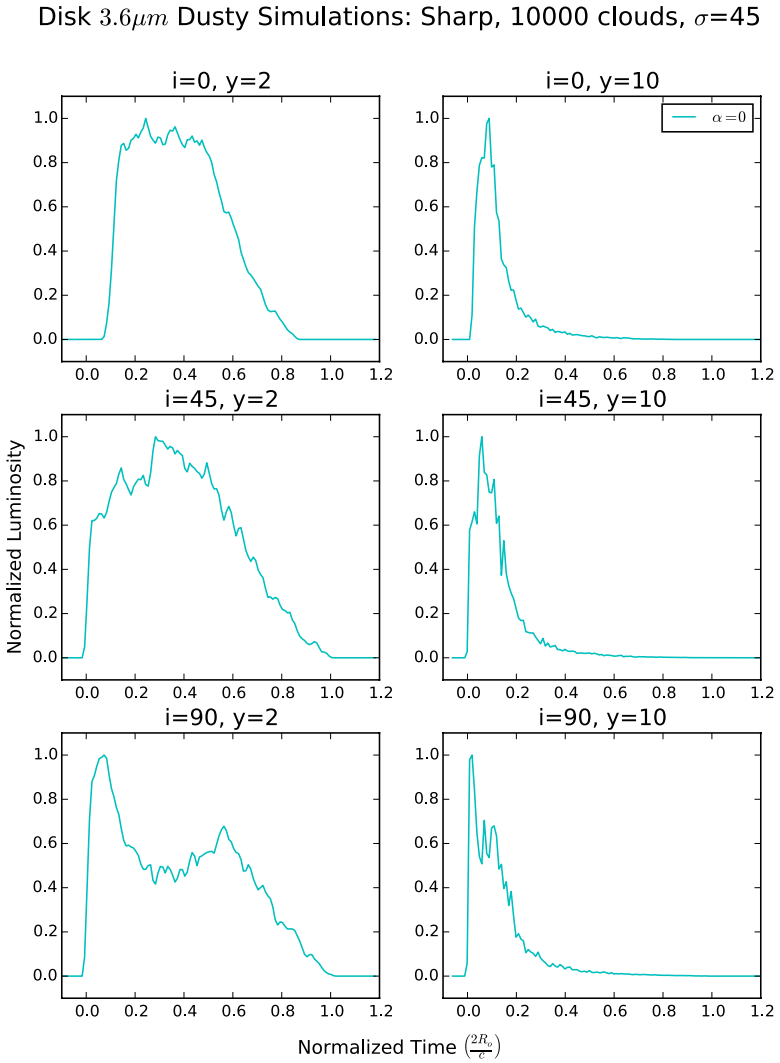
Dust Emission at Selected Wavelengths



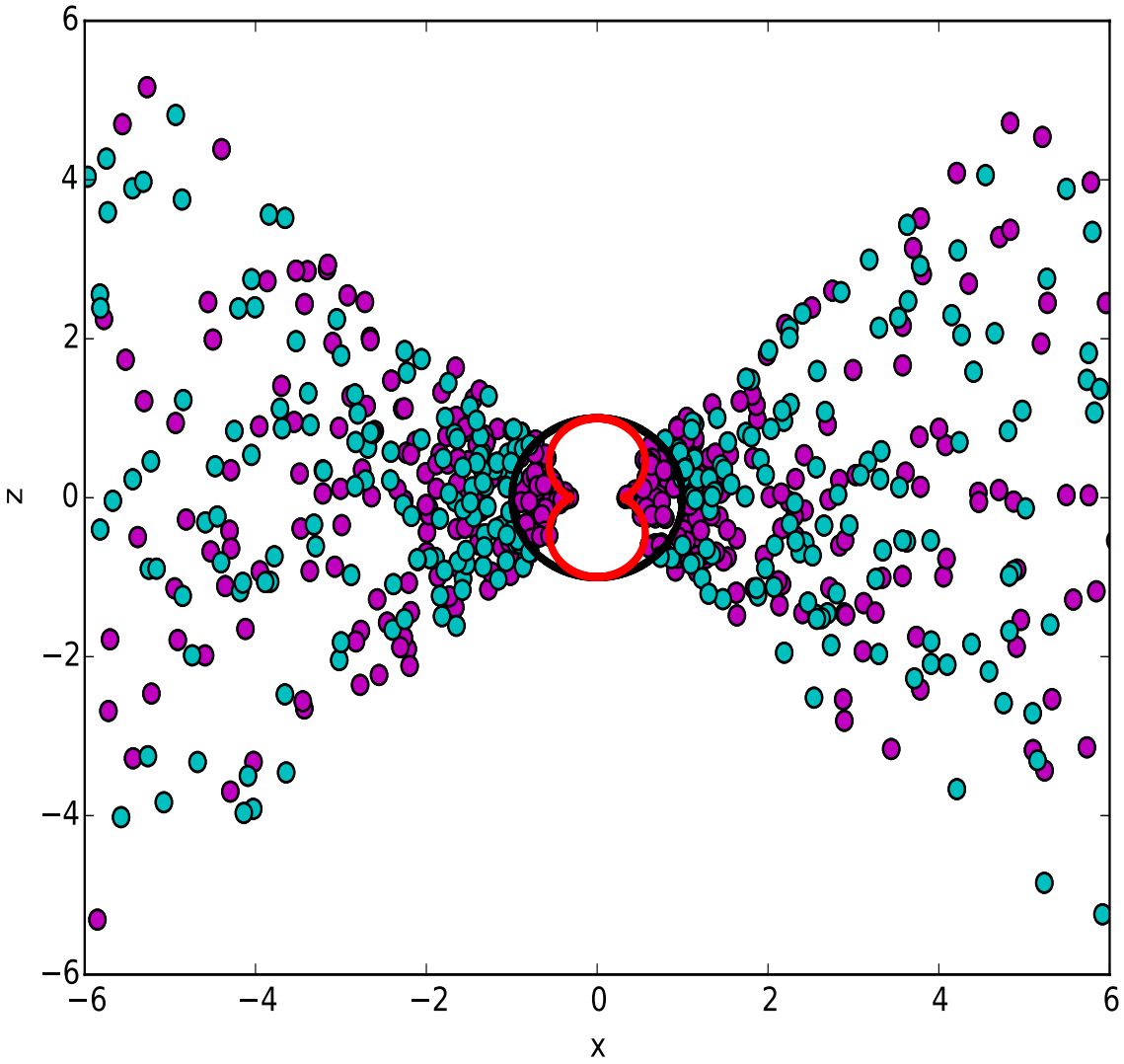


Dust emission for standard ISM composition calculated using DUSTY radiative transfer code (Ivezic & Elitzur 1997, Ivezic, Z., Nenkova, M. & Elitzur, M., 1999).

Isotropically Illuminated Disk



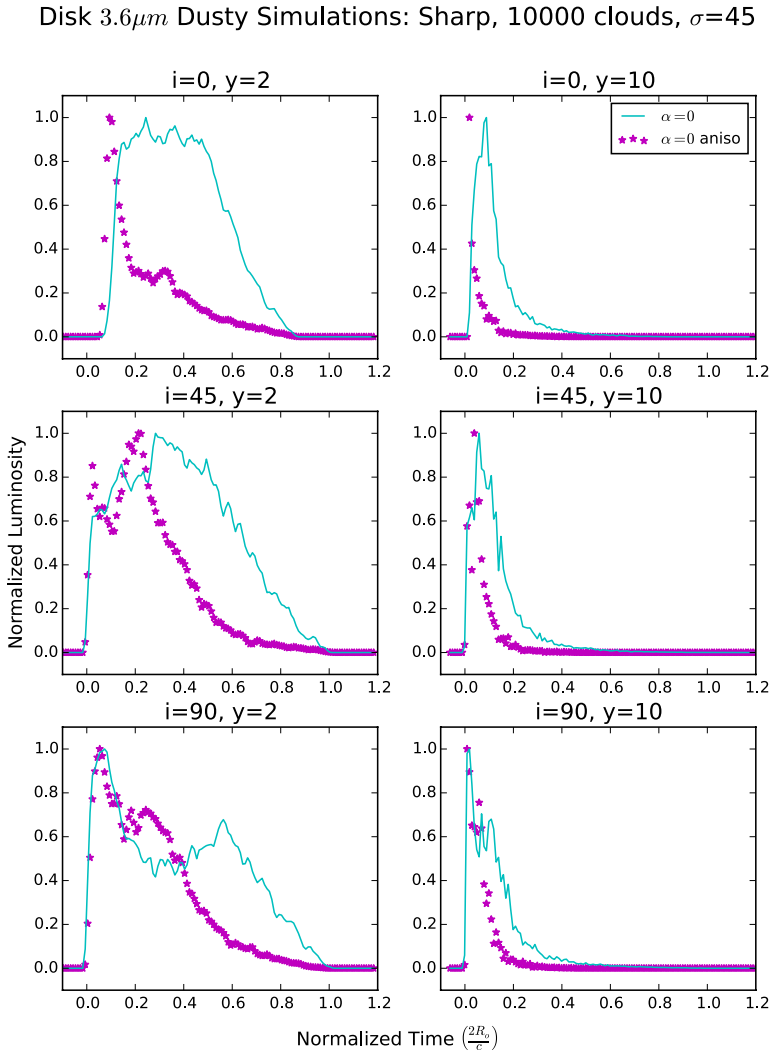
Isotropic vs Anisotropic Illumination



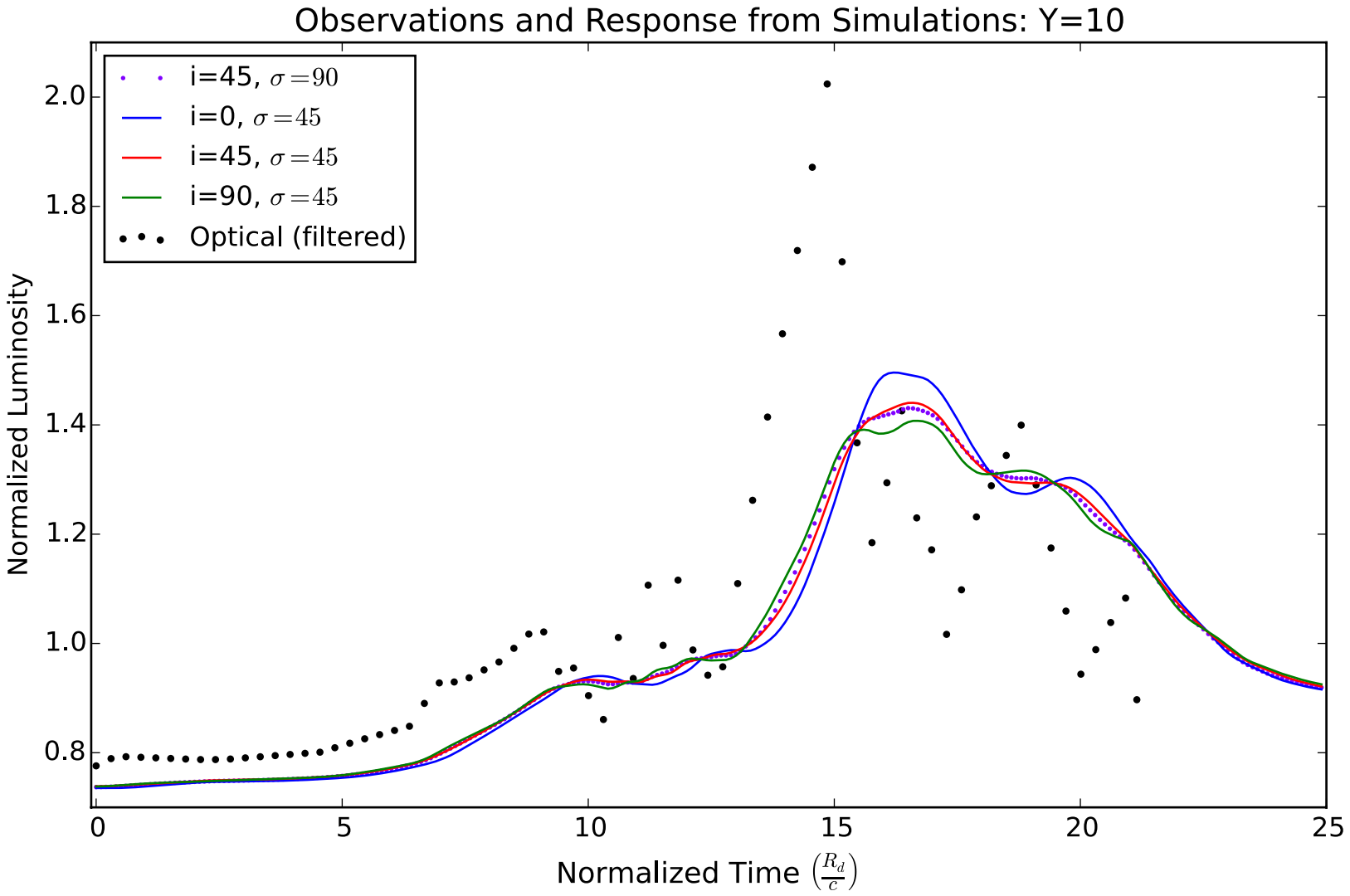
$$F \propto \frac{1}{3}\cos\theta(1+2\cos\theta)$$

(Kawaguchi & Mori, 2010, Netzer 1987)

Isotropic vs Anisotropic Illumination

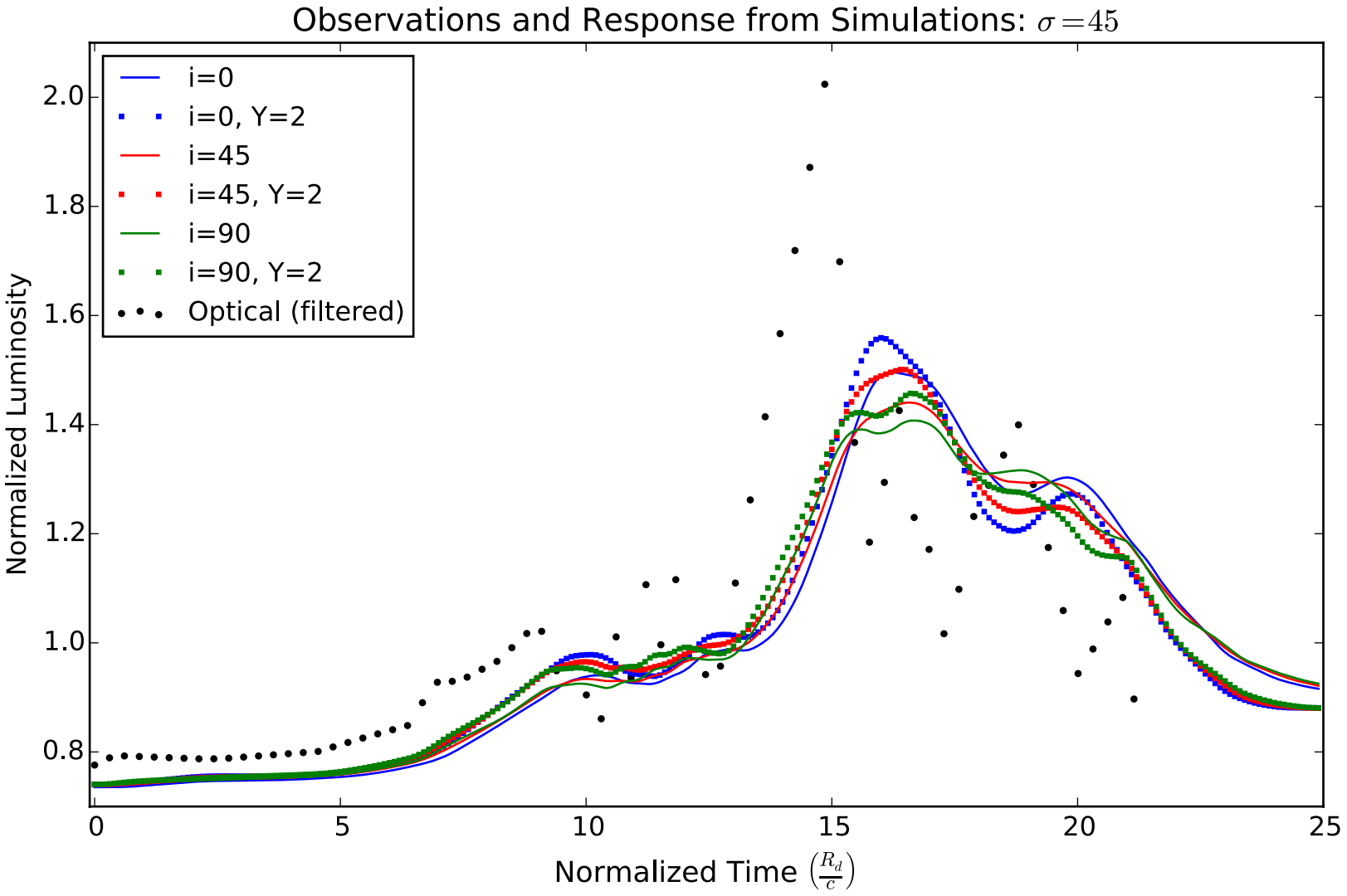


NGC 6418



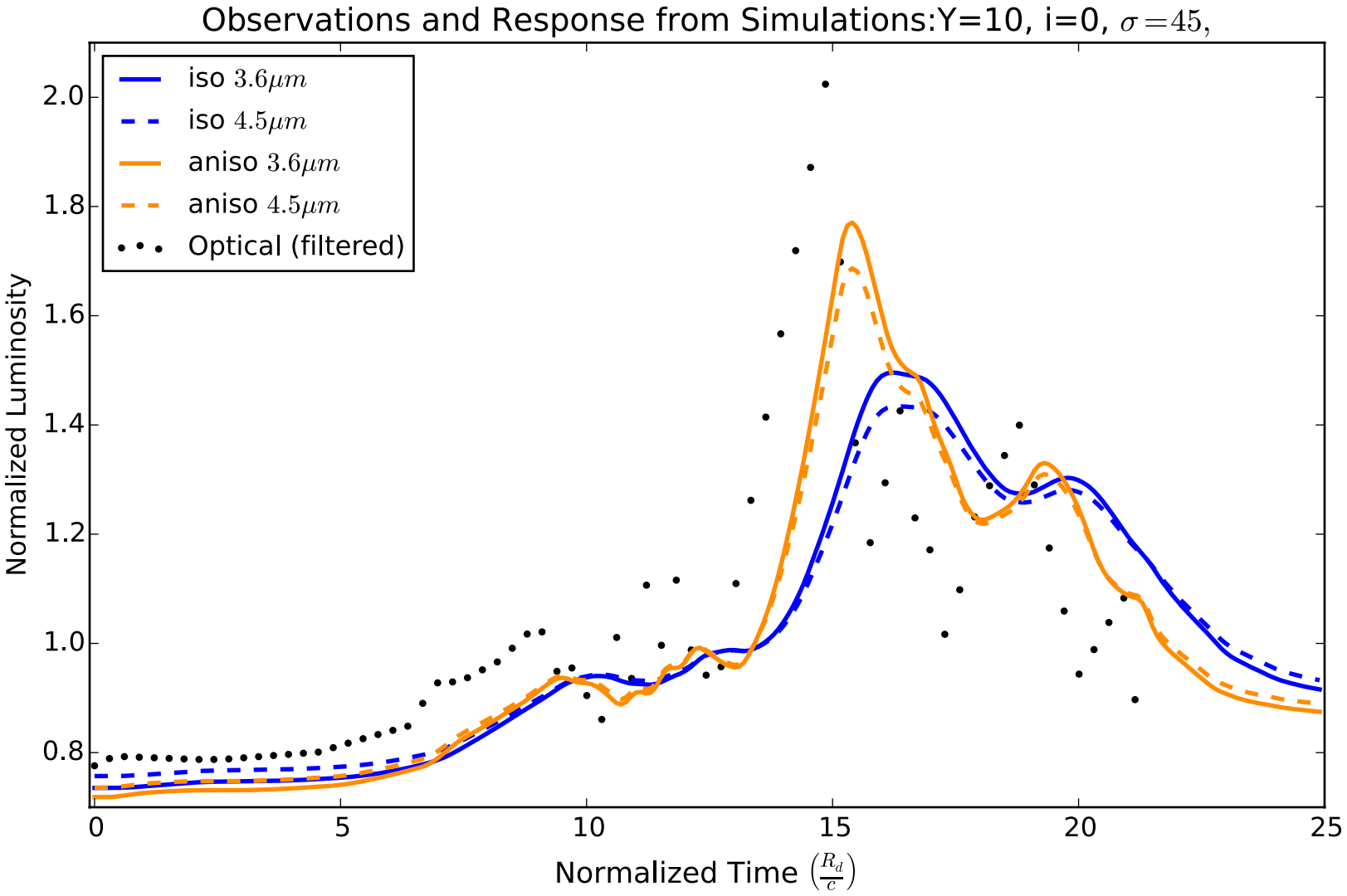
Optical input light curve plotted with the 3.6 micron response for a cloud distribution of large (Y=10) radial depth showing the effects of inclination and angular width.

NGC 6418



Optical input light curve plotted with the 3.6 micron response for a thick disk cloud distribution showing the effects of inclination and radial depth.

NGC 6418

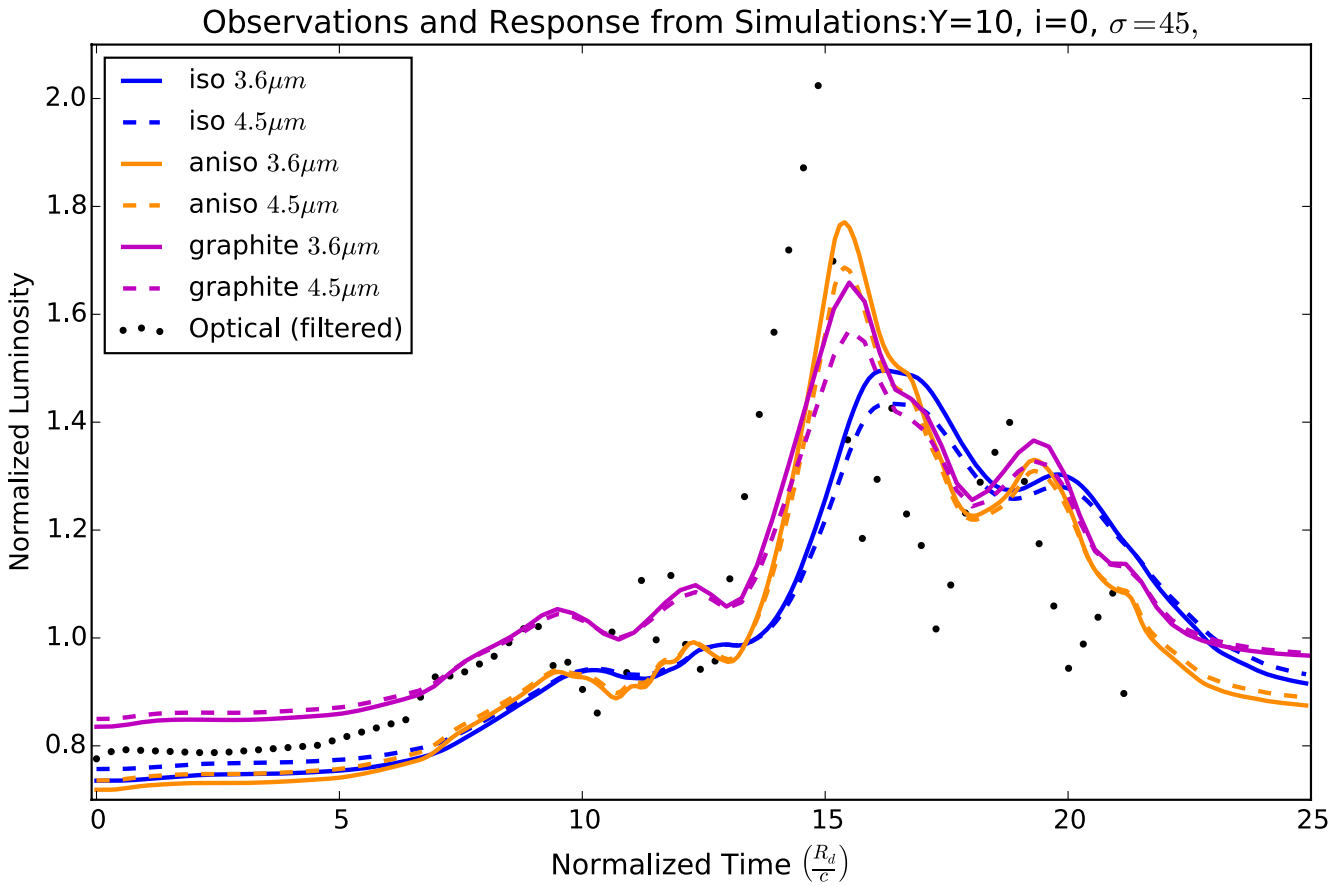


Optical input light curve plotted with the 3.6 and 4.5 micron response for a large thick disk cloud distribution showing the effects of isotropic and anisotropic illumination.

Summary

- Preliminary Response Simulations of NGC 6418
  - Smaller inclinations yield larger variations in amplitude and longer response times
  - An inclined (i=45) thick disk is nearly indistinguishable from a spherical distribution
  - Larger radial depth (Y) yields smaller variations in amplitude and larger response time
  - Anisotropic illumination yields shorter response times and larger variations in amplitude
  - Response at 3.6 and 4.5 microns are very similar, with smaller amplitude for 4.5 micron

Graphite Example



Optical input light curve plotted with the 3.6 and 4.5 micron response for a large thick disk cloud distribution showing the effects of isotropic illumination for both ISM and pure graphite grains and anisotropic illumination for ISM grains.