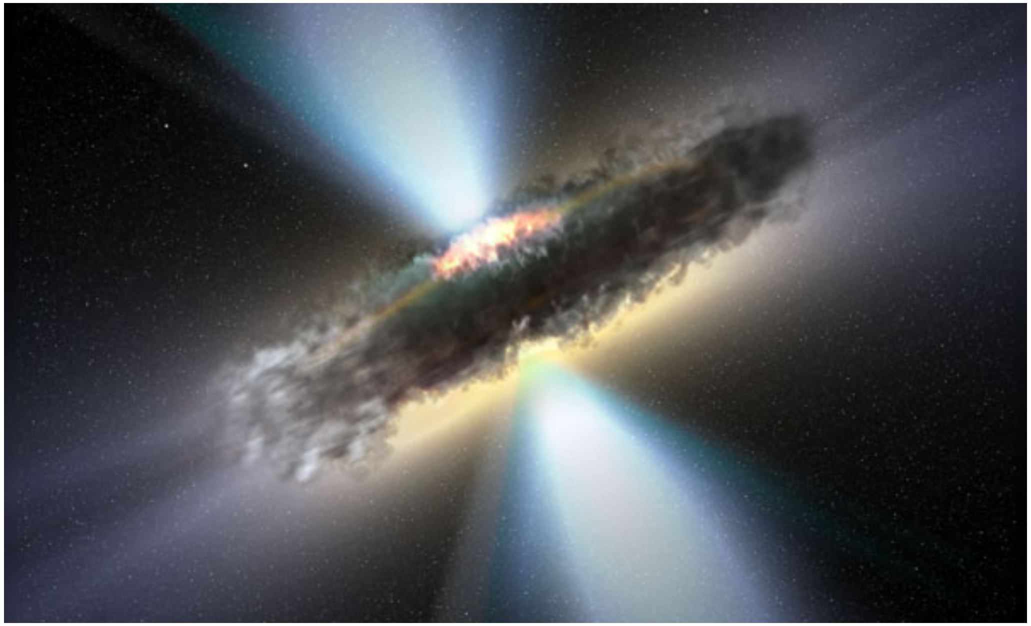


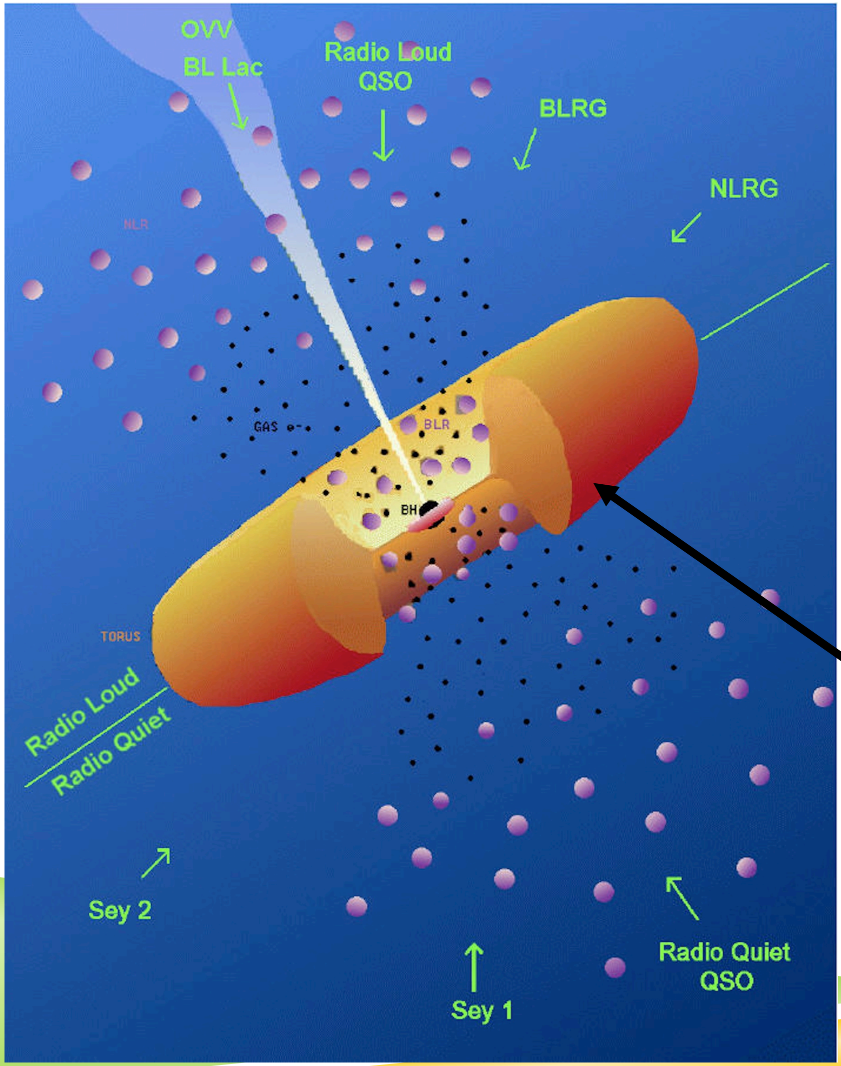
MODELING THE DUSTY TORUS REVERBERATION RESPONSE IN ACTIVE GALACTIC NUCLEI

Triana Almeyda

Rochester Institute of Technology

AST@RIT

AGN UNIFICATION MODEL



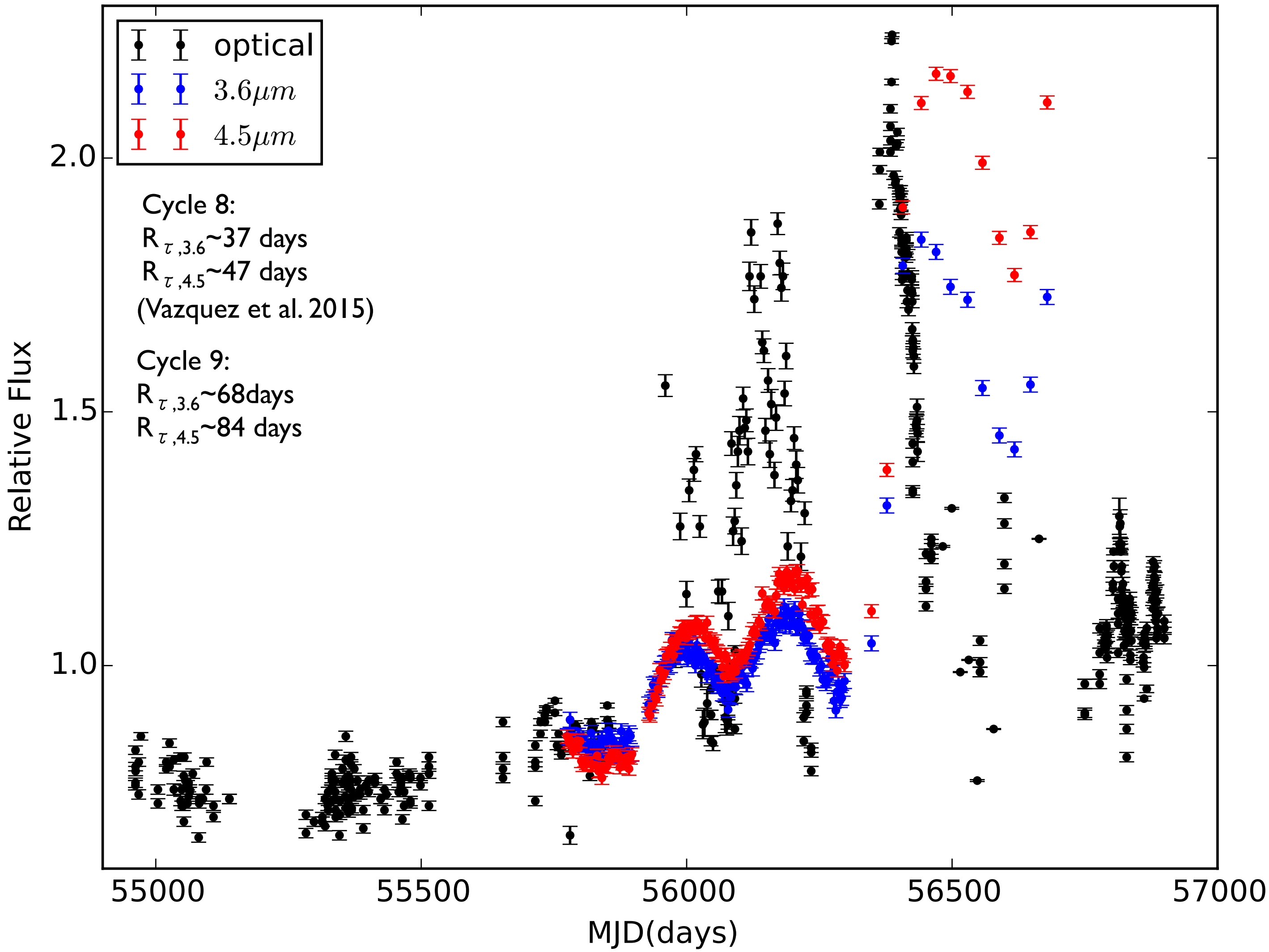
Dust in clumpy torus absorbs UV–visible radiation and re-emits in the IR

Credit: Urry & Padovani 1995

SPITZER AGN MONITORING CAMPAIGN

- 12 Type 1 AGN monitored with Spitzer and optical ground based telescopes over 2.5 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

OBSERVED LIGHT CURVES: NGC 6418



RADIUS-LUMINOSITY RELATIONSHIPS

- R-L relationship

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

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

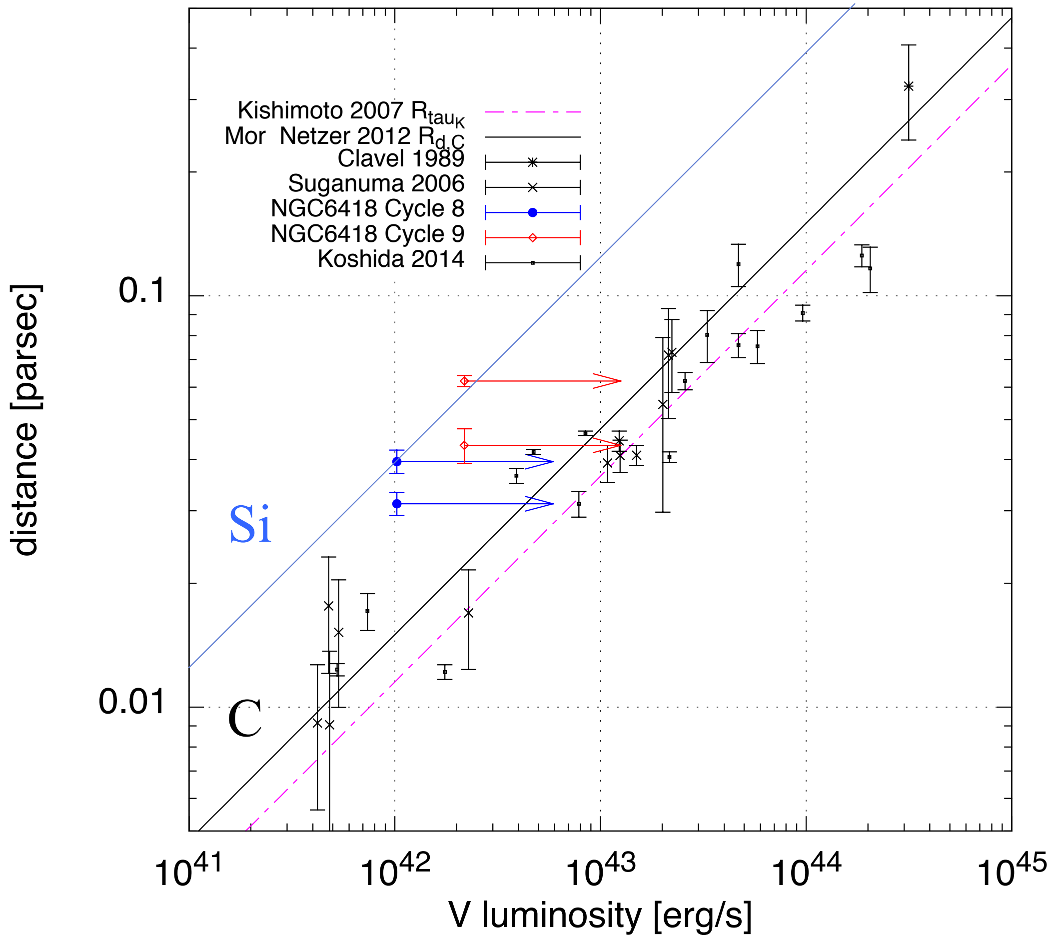
- Dust Sublimation radius

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

(Nenkova et al. 2008b, Barvainis 1987)

- $R_d \sim 2R_{observed}$

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



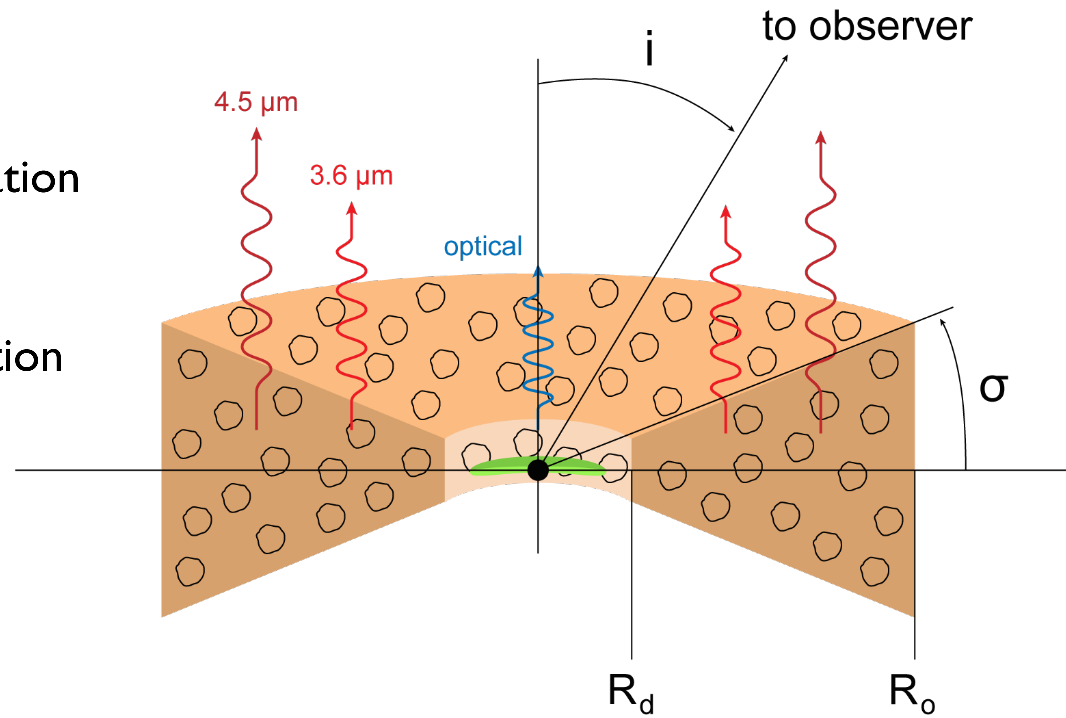
adapted from Vazquez et al. 2015

TORMAC: A TORUS REVERBERATION MAPPING CODE

- Set up 3D ensemble of clouds
- Given the input UV/optical light curve, calculate the emission of a given cloud at a single observer time step
- Sum the emission from every cloud
- Repeat steps 2-3 for every observer time step
- Produce IR light curve

TORUS GEOMETRY AND STRUCTURE

- Model Features:
  - Set up 3D ensemble of clouds
  - Inner Radius set to Dust Sublimation Radius
  - Sharp or "fuzzy" boundary
  - Isotropic or anisotropic illumination
  - ISM dust composition



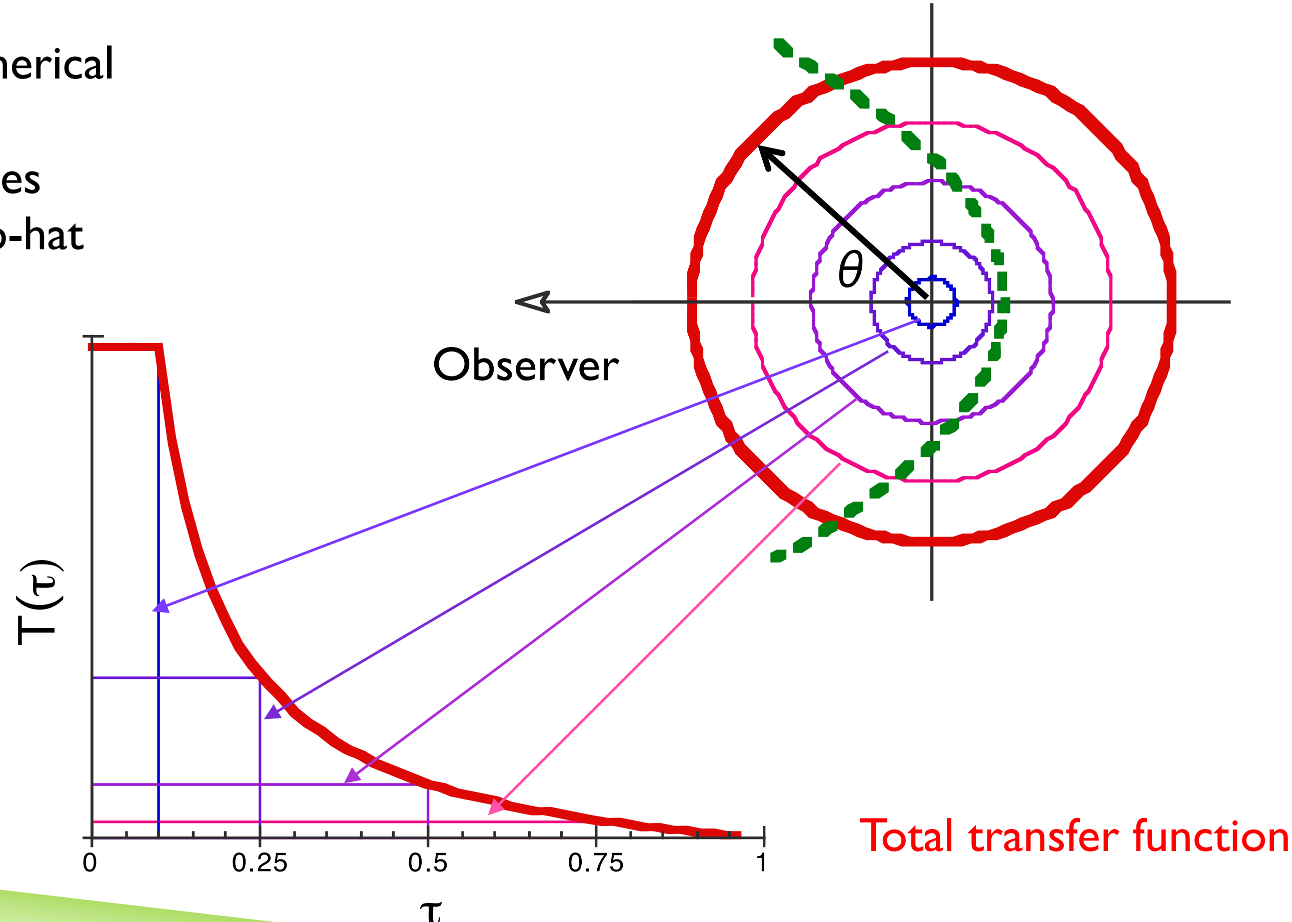
- Free Parameters:
  - Spherical or disk, σ =0-90°
  - Inclination, i=0-90°
  - Radial distribution of clouds, $\propto r^q$
  - Radial depth, $Y=R_o/R_d$

Nenkova et al. 2008a,b

TRANSFER FUNCTION

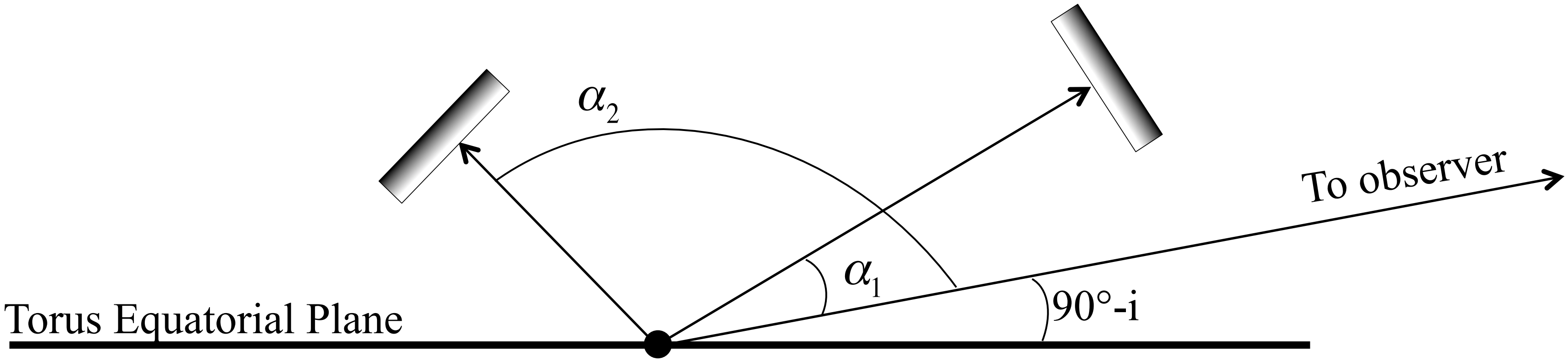
Consider thick spherical shell as series of concentric thin ones whose TF's are top-hat functions

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



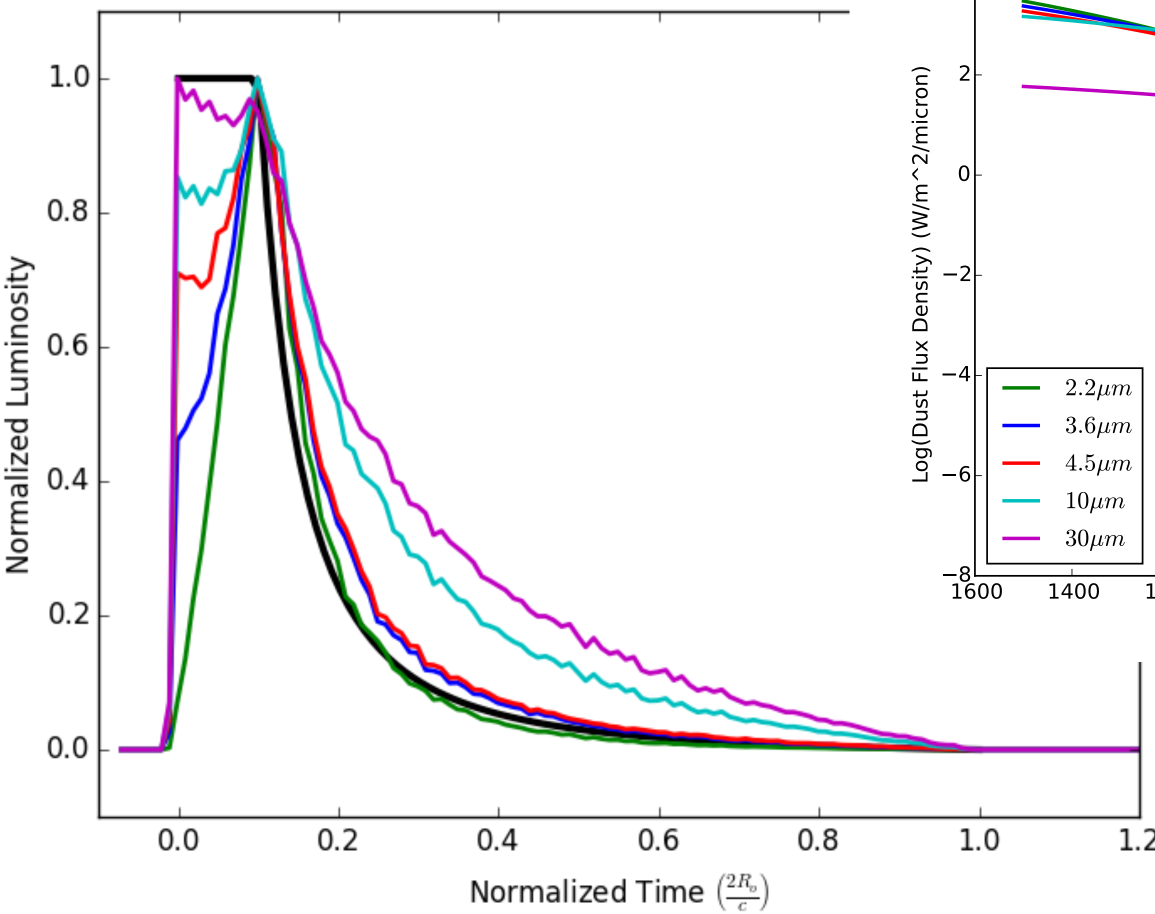
Credit: Andrew Robinson

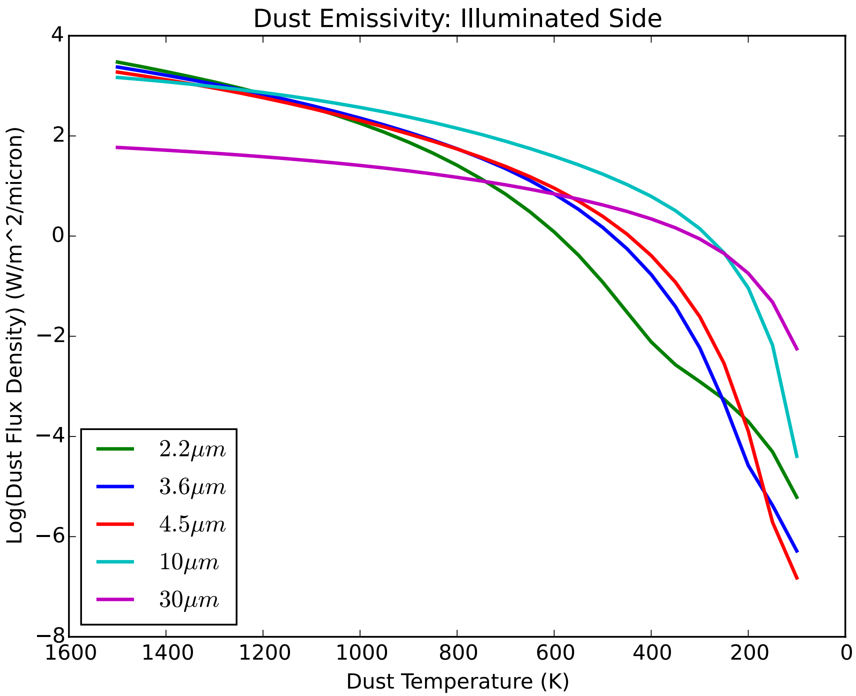
DUST SLAB ORIENTATION



DUST EMISSION AT SELECTED WAVELENGTHS

Response functions for a spherical shell cloud ensemble





Dust emissivity for an individual cloud

Dust emission assuming standard ISM composition calculated using DUSTY radiative transfer code (Ivezic & Elitzur 1997, Ivezic, Z., Nenkova, M. & Elitzur, M., 1999, Nikutta, R. private communication).

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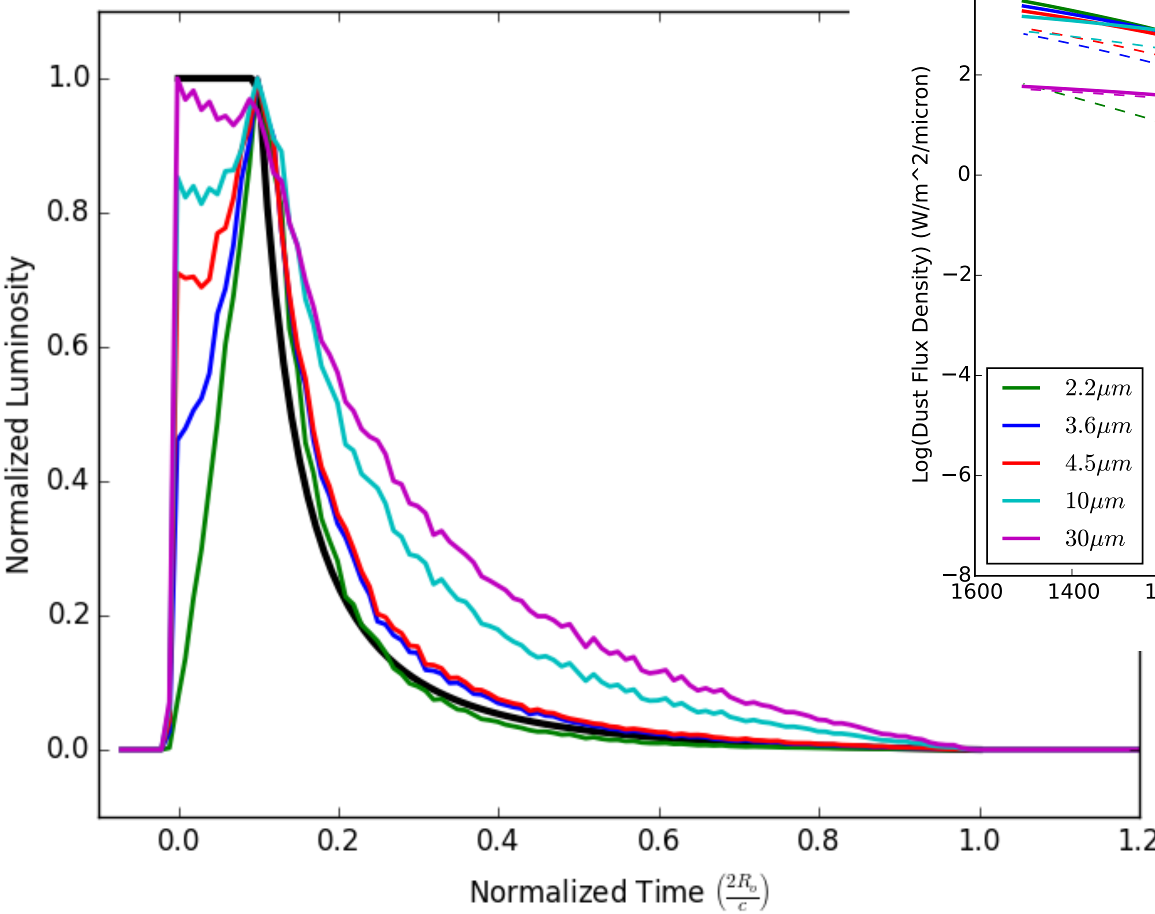

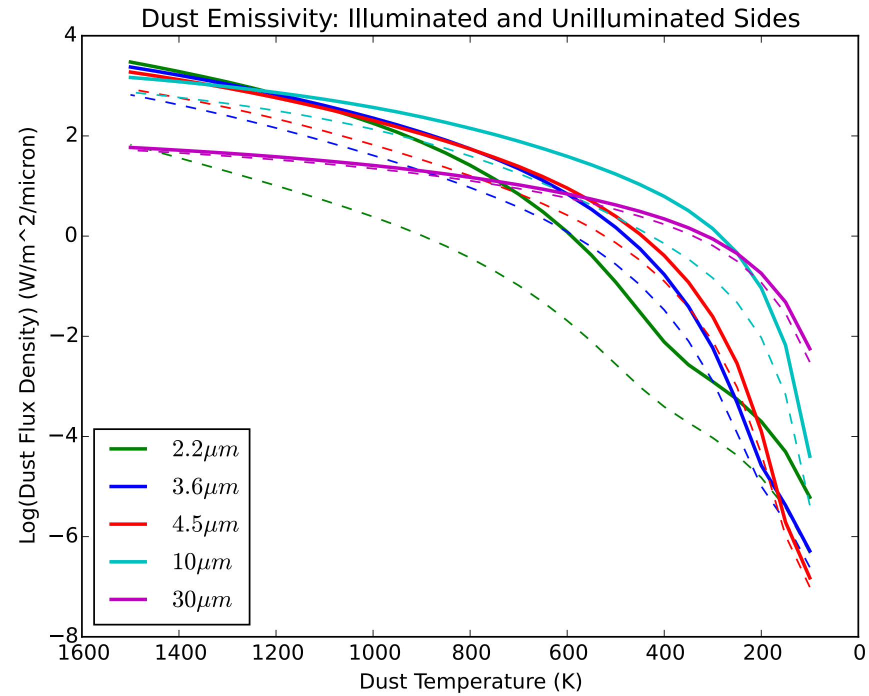

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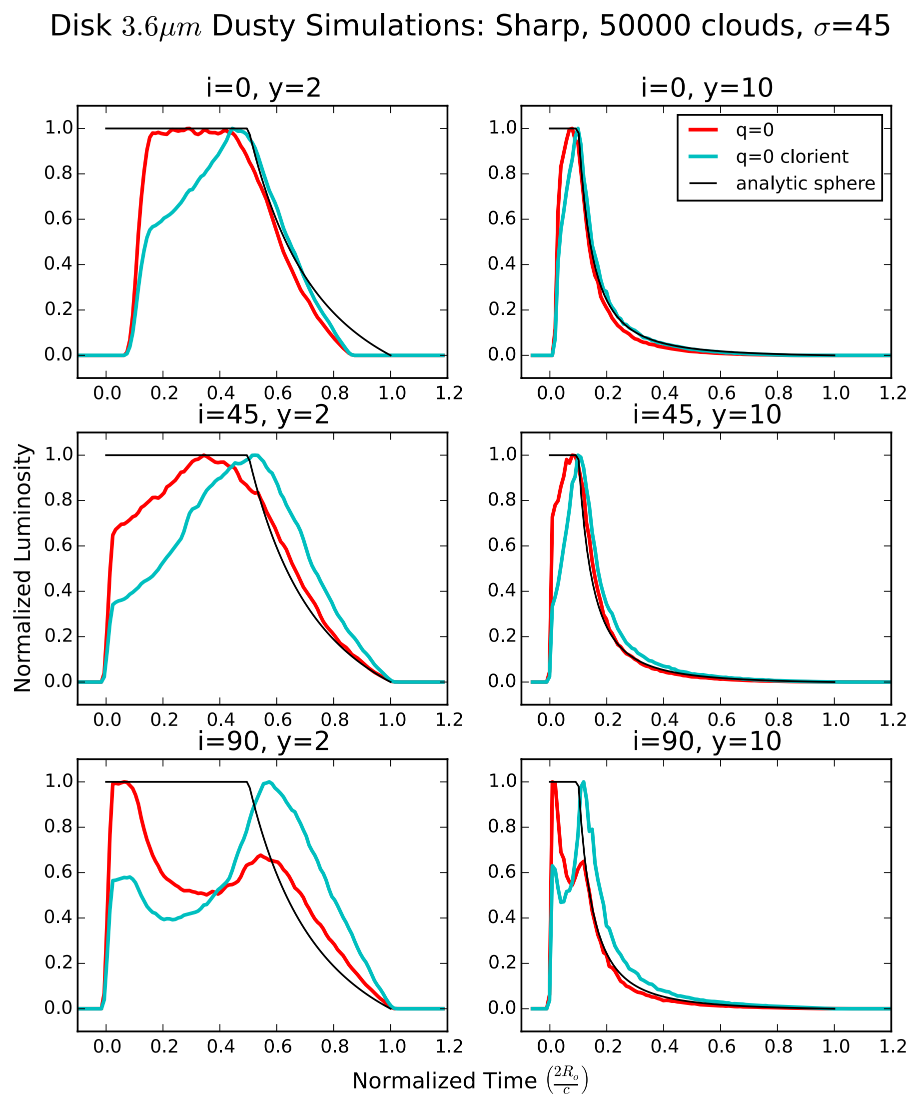
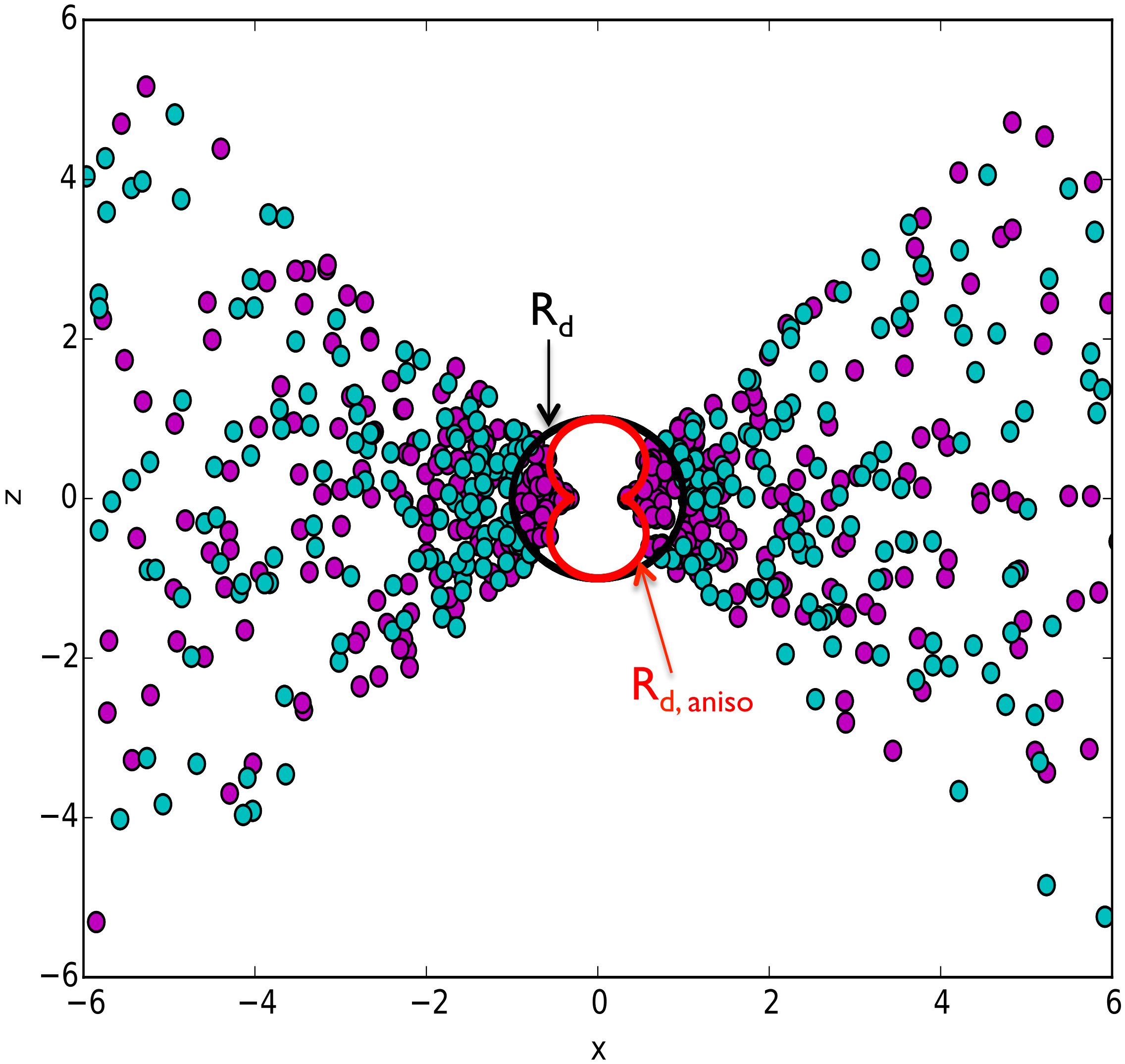
EFFECTS OF CLOUD ORIENTATION



ISOTROPIC VS ANISOTROPIC ILLUMINATION



Dust sublimation radius:

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

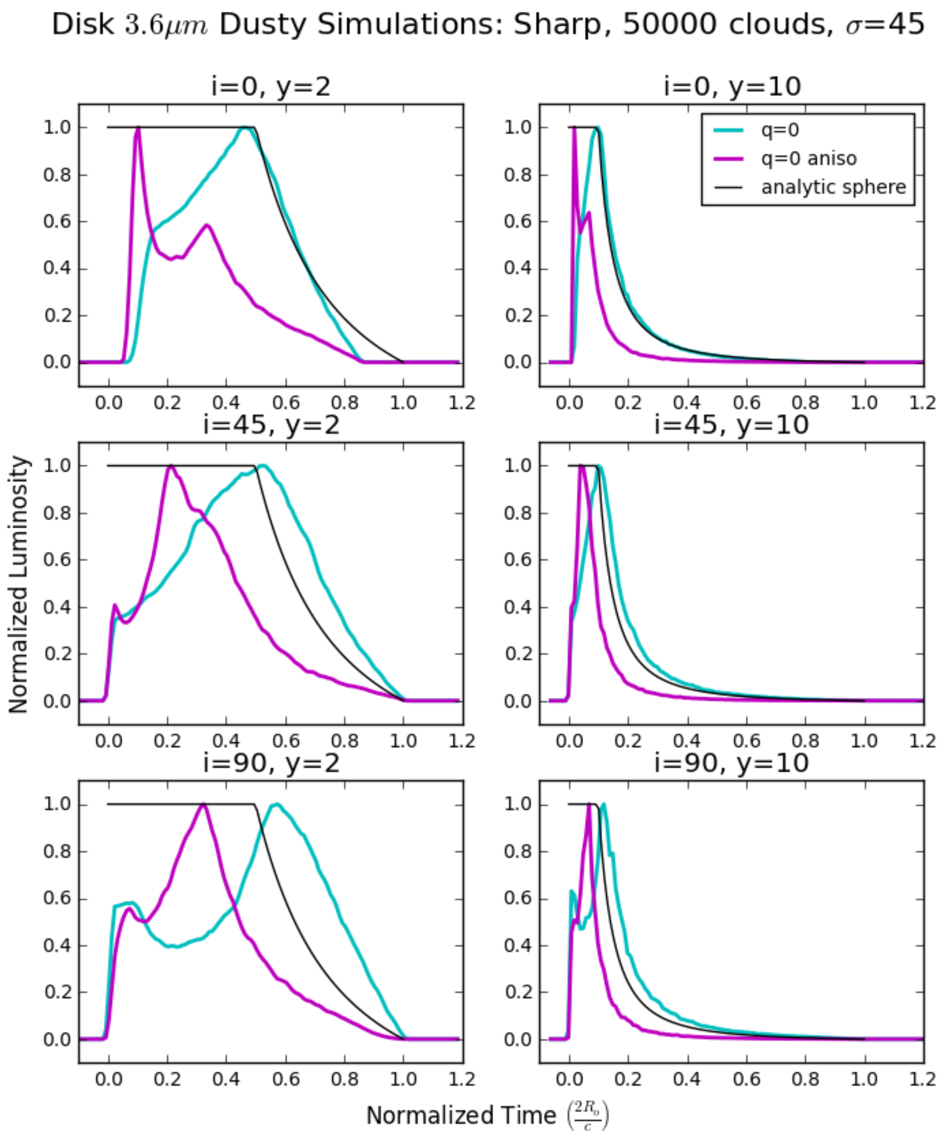
(Nenkova et al, 2008a,b)

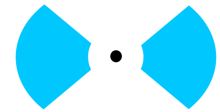
Anisotropic Correction:

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

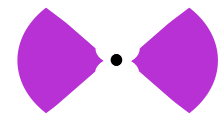
(Kawaguchi & Mori, 2010, Netzer 1987)

ISOTROPIC VS ANISOTROPIC ILLUMINATION



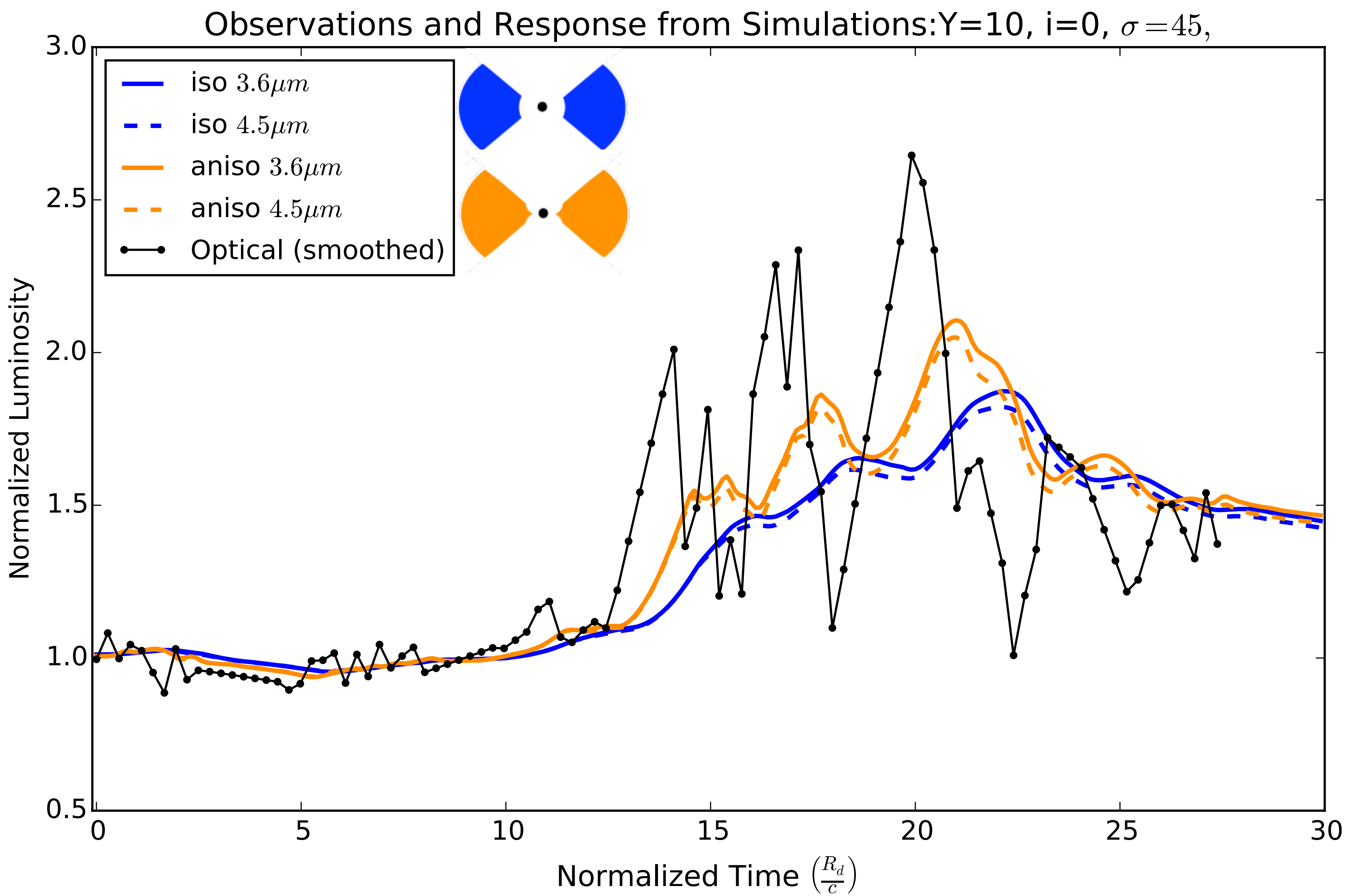


isotropic



anisotropic

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

- Approximate TF Results
  - Smaller inclinations result in slightly larger lags
  - Switch in peak emission in inclined cloud orientation cases
  - Sharper features and shorter response durations in anisotropic cases

- Response light curves (based on NGC 6418)
  - Shorter response times result from anisotropic illumination
  - Larger variations amplitude anisotropic illumination

- Future Work
  - Explore effects of:
    - dust composition, cloud optical depth, dust sublimation treatment
  - Estimate parameter probability distribution using MCMC fits to observed light curves

SPHERICAL SHELL TRANSFER FUNCTION