MODELING THE NUCLEAR DUST EMISSION REVERBERATION RESPONSE IN AGN

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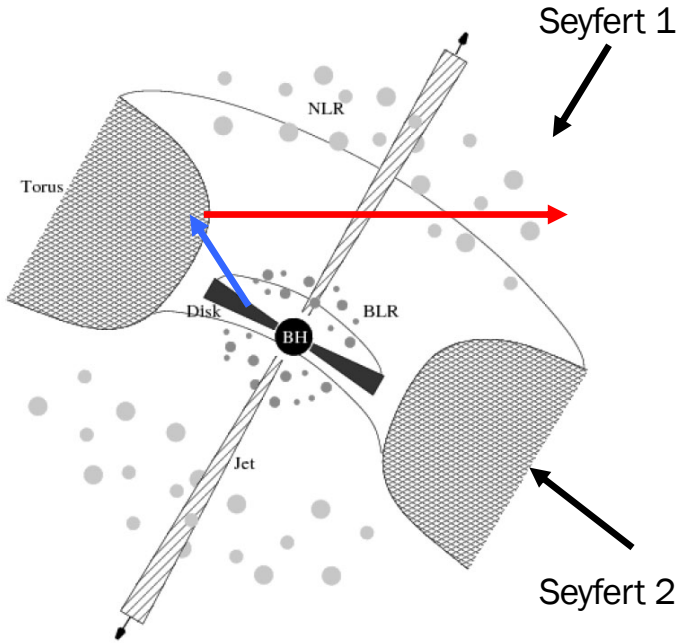
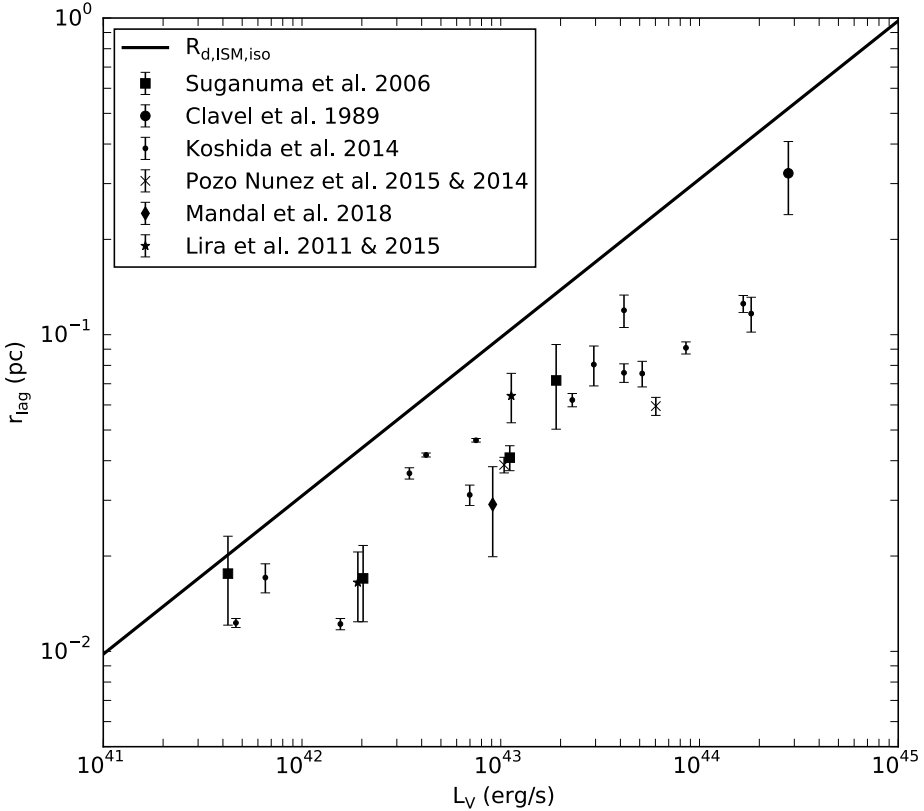
AGN Dust Reverberation Mapping

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



Credit: Middelberg & Bach 2008

Radius-Luminosity Relationship

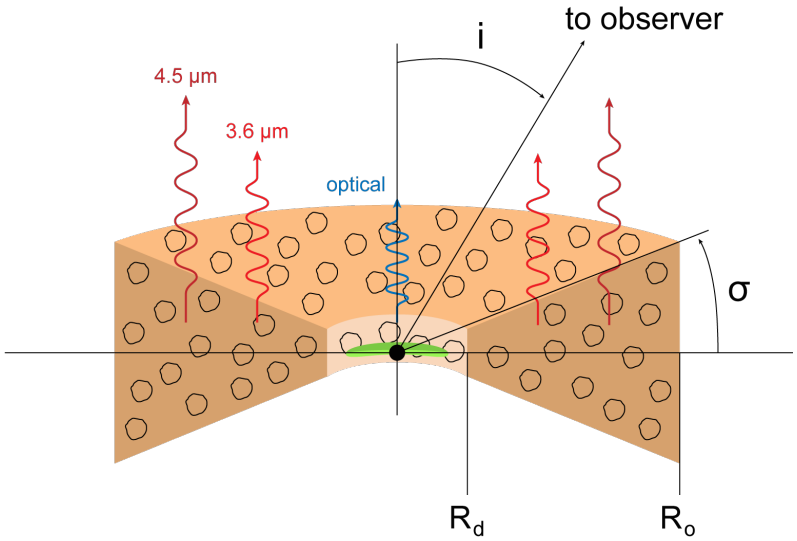


- Observed radii are ~2 time smaller than theoretical dust sublimation radius (e.g., Kishimoto et al. 2007, Vazquez et al. 2015)
  - *Hot graphite dust component (e.g., Mor et al. 2009, Mor & Netzer 2012)*
  - *Larger grain size (Kishimoto et al. 2007)*
  - *Anisotropic illumination of torus (Kawaguchi & Mori 2010, 2011)*

TORMAC: Torus Reverberation Mapping Code

- Model Features:
  - *Inner Radius set to Dust Sublimation Radius*
  - *Sharp or "fuzzy" boundary*
  - *Isotropic or anisotropic illumination, s*
  - *ISM dust composition*

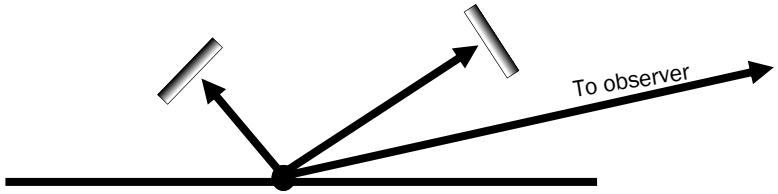
- Free Parameters:
  - *Spherical or disk, σ=0-90°*
  - *Inclination, i=0-90°*
  - *Radial distribution of clouds,* $\propto r^p$
  - *Radial depth, Y=R_o/R_d*
  - *Optical depth,* τ_V
  - *Volume filling factor,* Φ



Nenkova et al. 2008a,b; Almeyda et al. 2017, submitted

Radiative Transfer Effects

- Cloud orientation

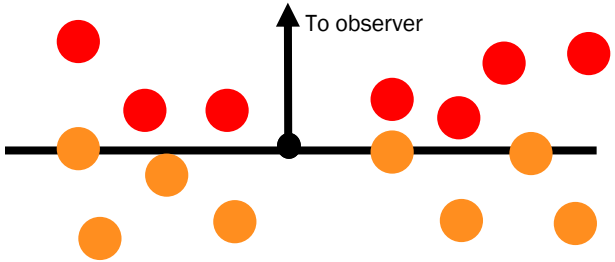


- Cloud shadowing

Shadowed clouds

Non-shadowed clouds

- Cloud occultation



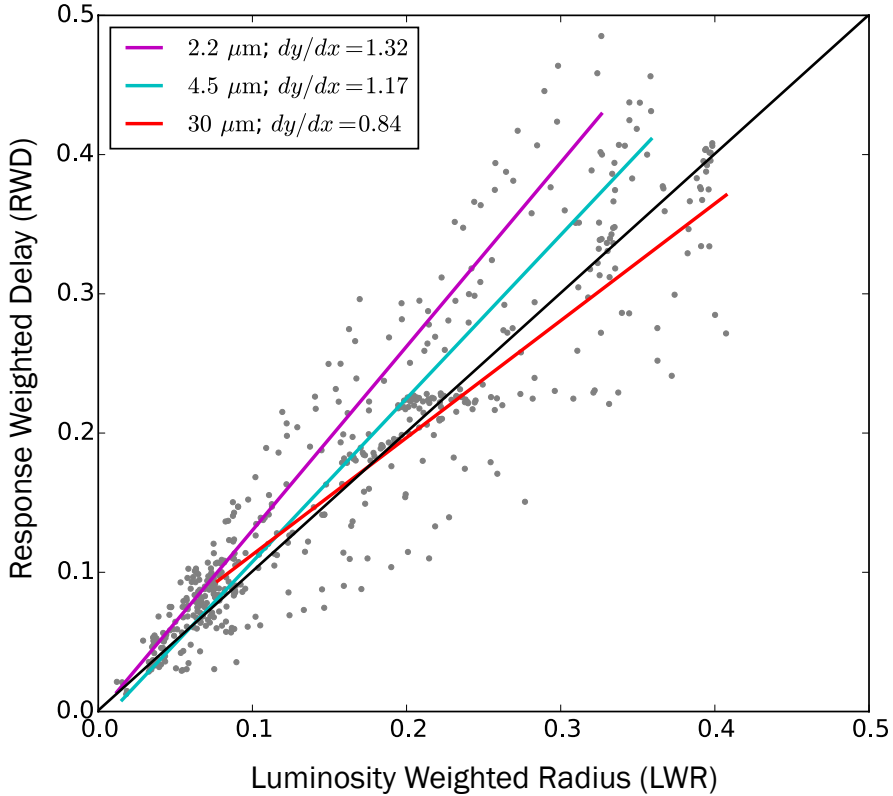
Occulted clouds

Non-occulted clouds

Descriptive Parameters

- Response Weighted Delay (RWD)
  - *Characteristic lag of transfer function*
- Torus Luminosity Weighted Radius (LWR)
  - *Effective radius of the torus*
- When torus is composed of isotropically emitting clouds, RWD=LWR
  - True for both sphere and disk

RWD vs LWR

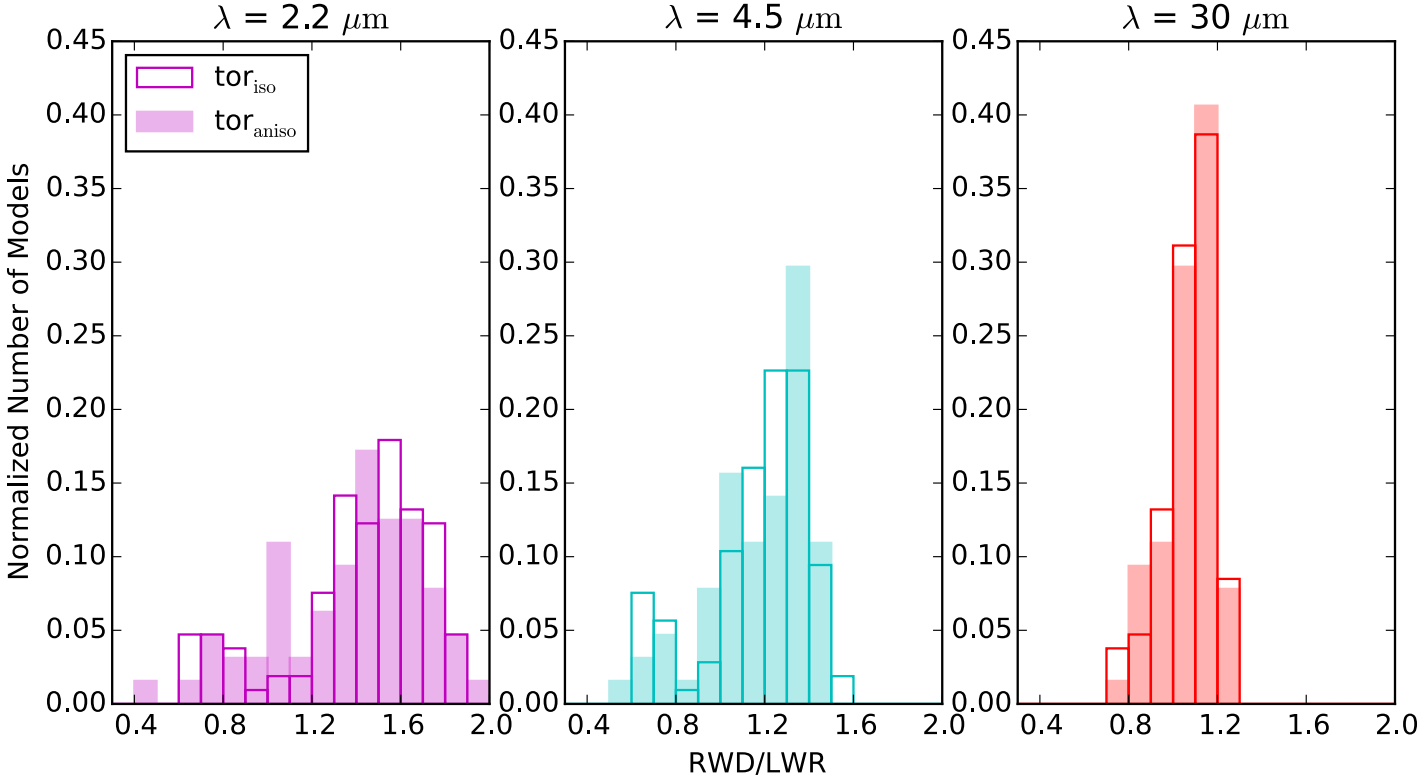


- Model Parameters:
  - $\propto r^{p}$; p=-2–4
  - $Y=R_o/R_d$ =2-50
  - i=0-90°
  - σ =15-60°
  - s=0.01-1
  - τ_V =5-100
  - Φ =0.0001-0.1
  - *Sharp and fuzzy*

0.4LWR<RWD<1.8LWR

Almeyda et al, submitted

RWD vs LWR



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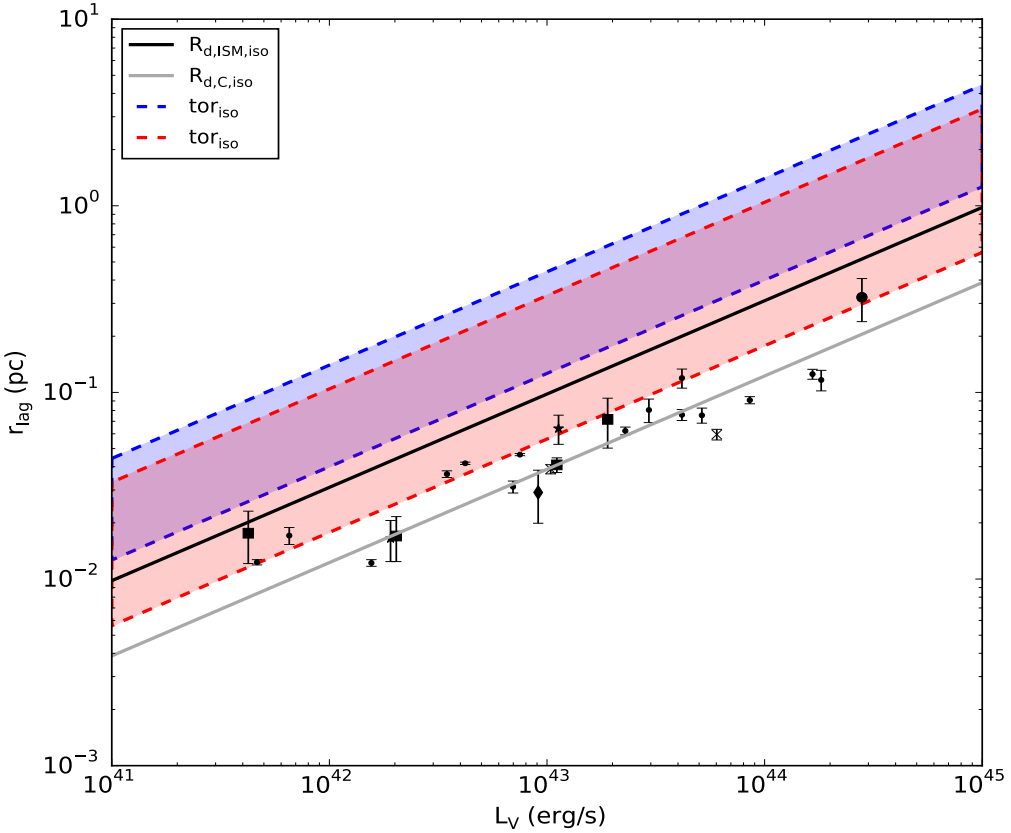
Radius-Luminosity Relationship



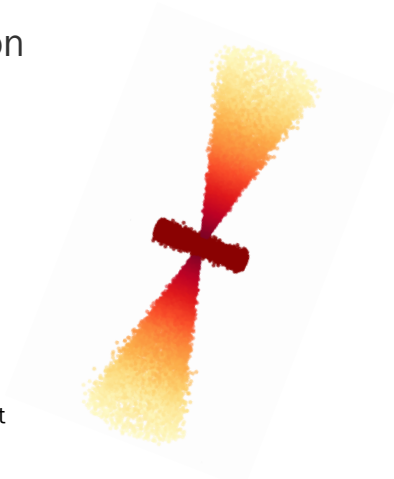
Suganuma et al. 2006
Clavel et al. 1989
Koshida et al. 2014
Pozo Nunez et al. 2015 & 2014
Mandal et al. 2018
Lira et al. 2011 & 2015

Almeyda et al, submitted

Current Capabilities

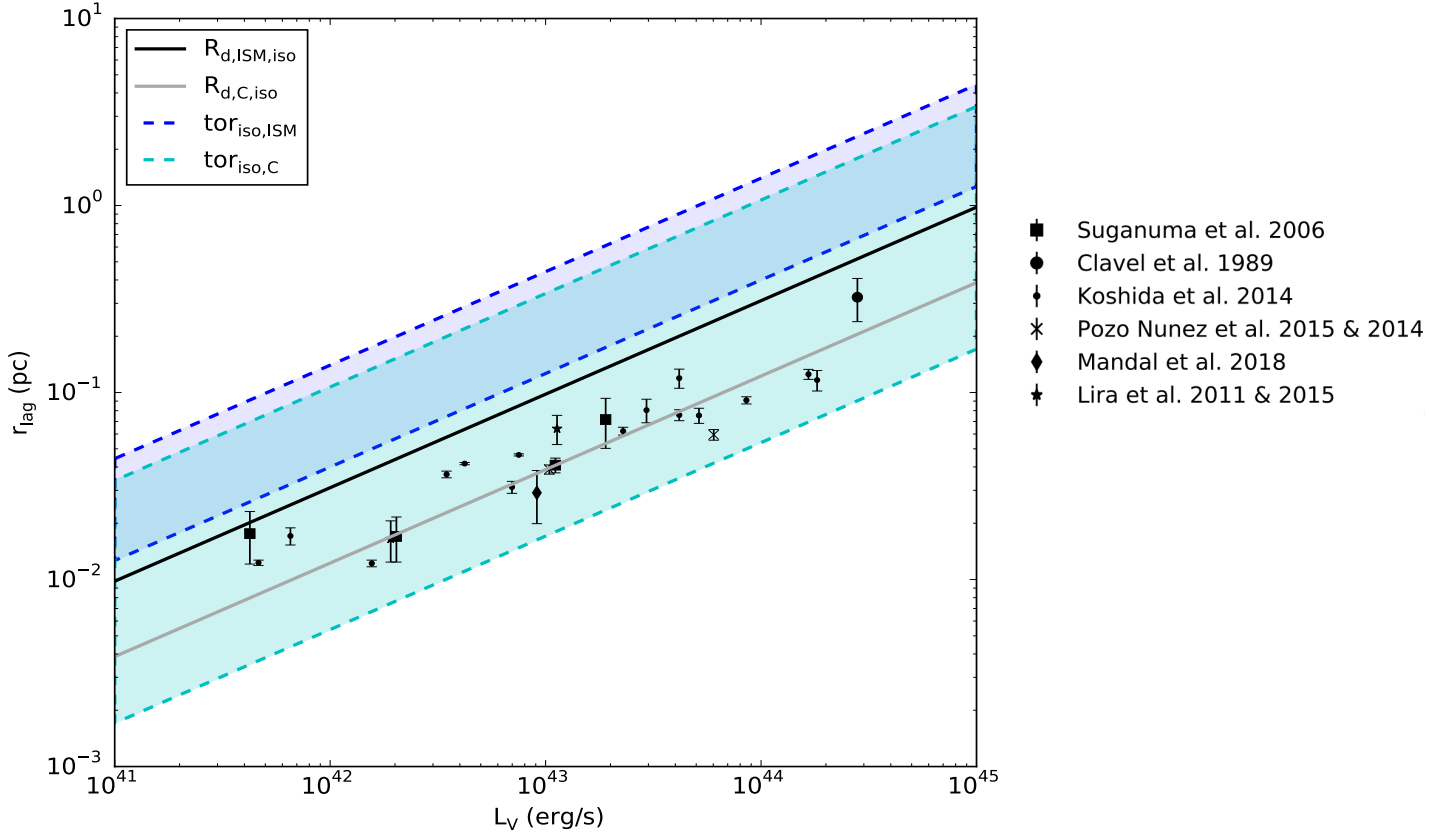
- TORMAC compatible with any radiative transfer grid/database

- “hot dust” component
  - *Gradient in composition of clouds from Carbon-dominated to full ISM composition*
    - *http://cat3d.sungrazer.org/
- Polar dust distribution



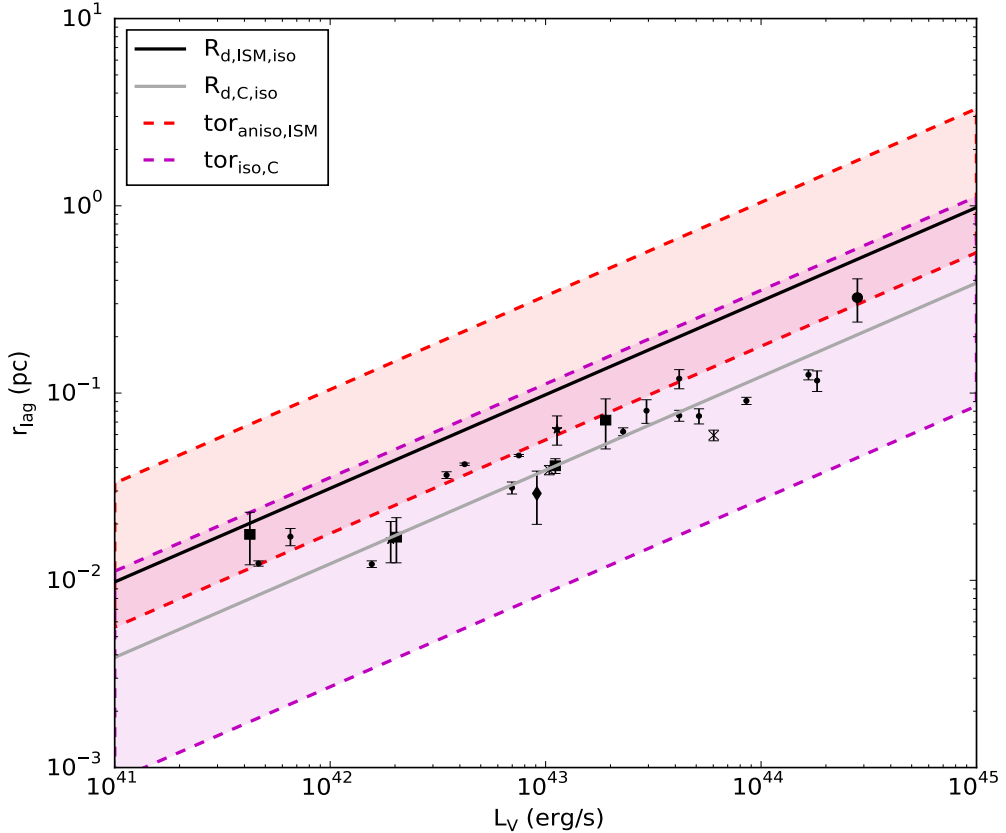
Credit: N. Ikonnikova, UoS undergraduate student

R-L Relationship with Carbon grains



Almeyda et al, in prep

R-L Relationship with Carbon grains



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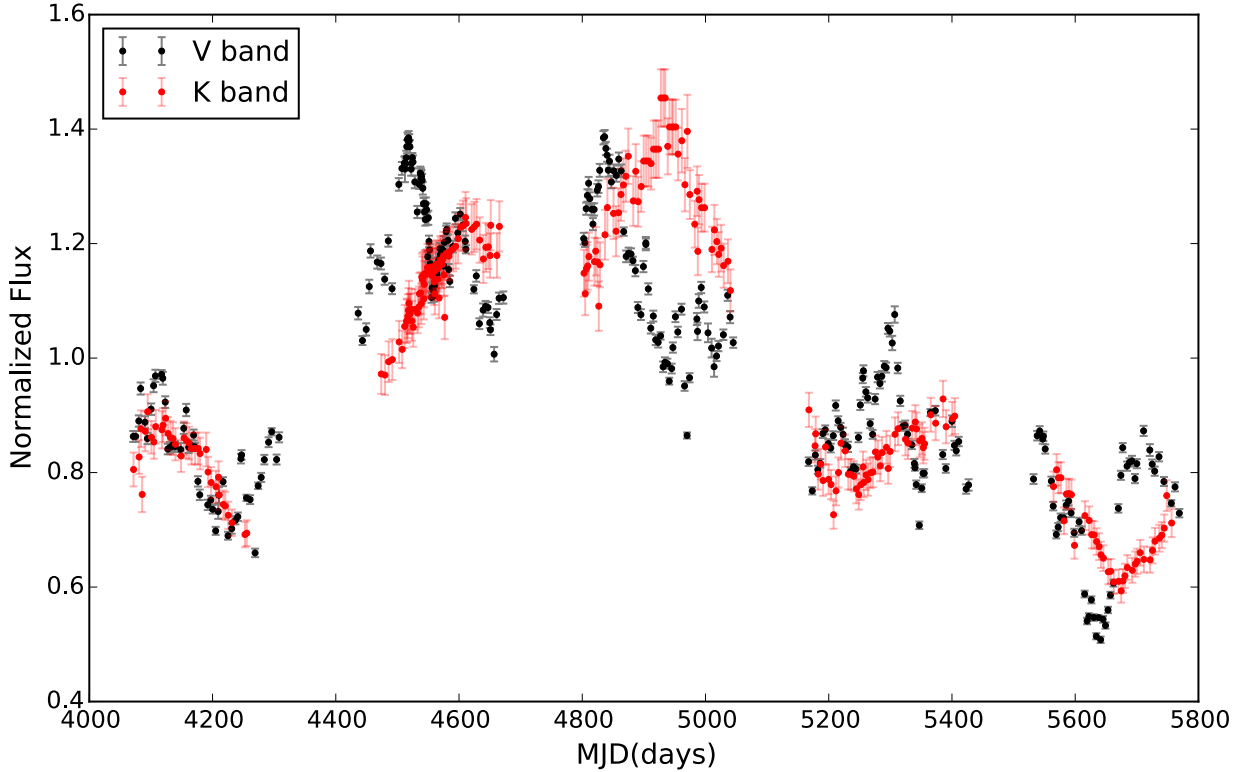
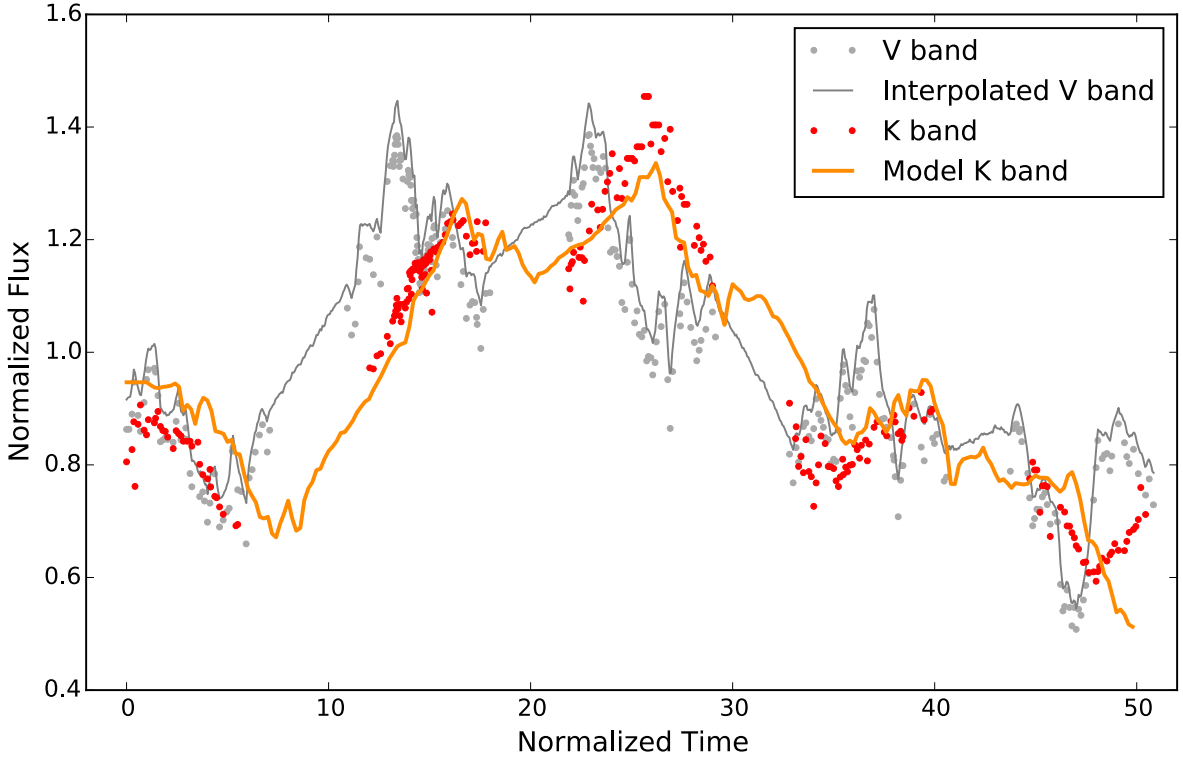
NGC 3783



Light curves courtesy of Paulina Lira

NGC 3783: Models



Summary

- Multiwavelength dust emission response for cloud ensemble using radiative transfer models
- Simulate IR response LC given any driving LC
- Incorporates anisotropic illumination, global opacity effects
- Need hot graphite dust component to match observations
- 0.4LWR<RWD<2LWR