

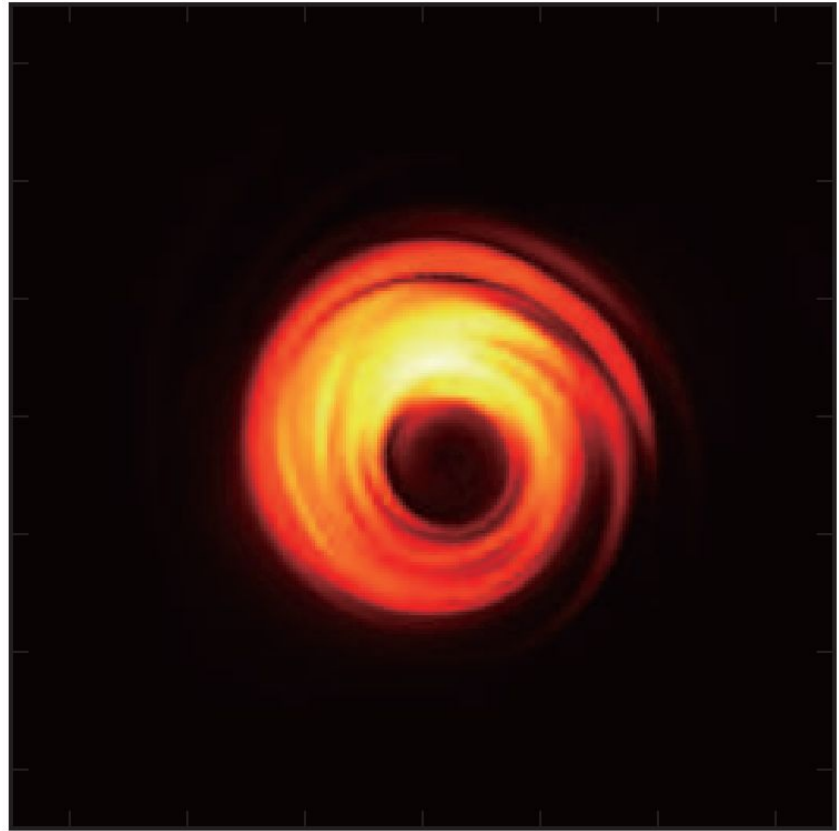
# Reverberation Mapping of AGN Accretion Disks

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The Ohio State University

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David Starkey, Keith Horne

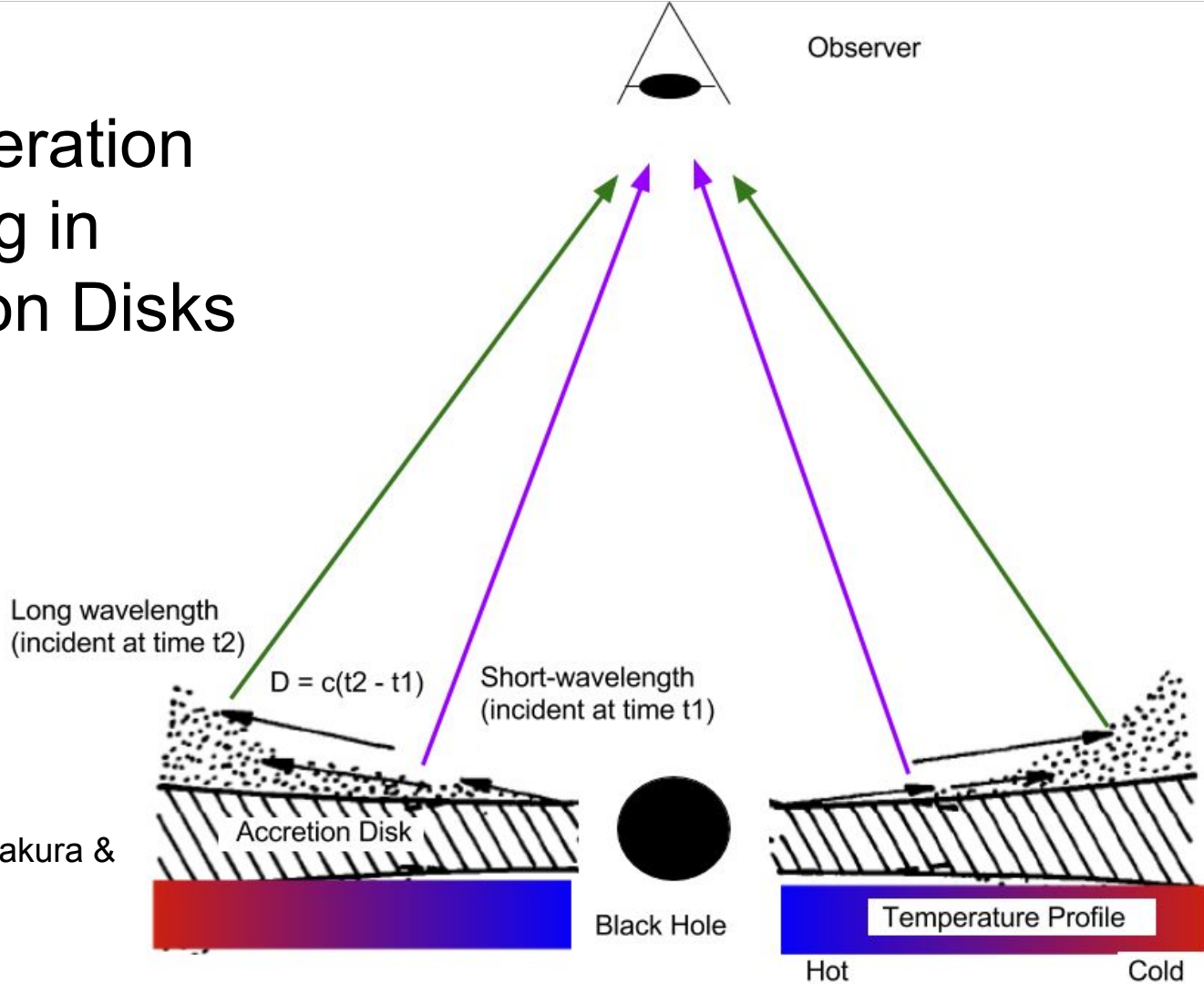
# The Accretion Disk

- Fundamental for AGN physics
- So far, unresolved
  - (EHT)
- Indirect methods



Akiyama et al. 2015

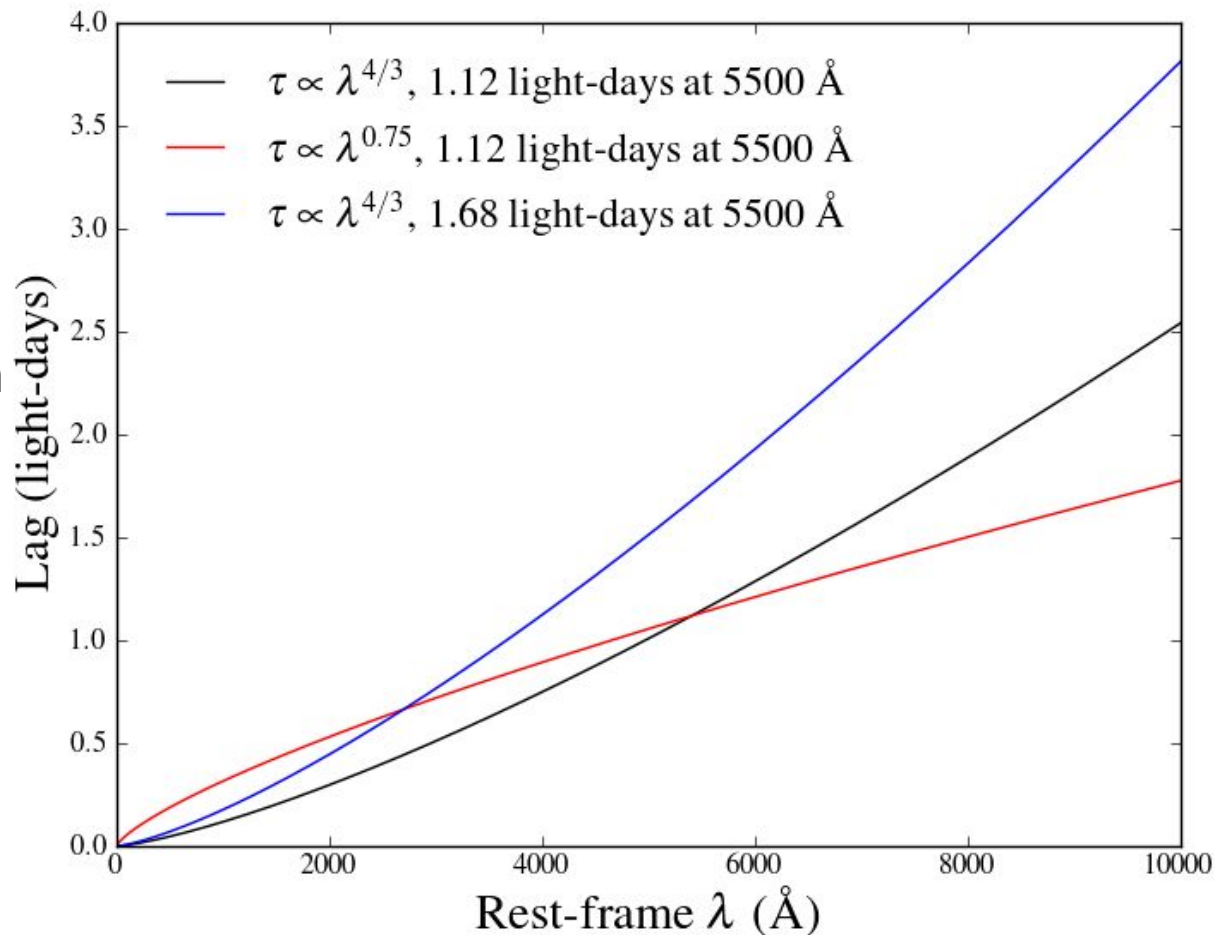
# Reverberation Mapping in Accretion Disks



Adapted from Shakura & Sunyaev 1973

# RM in Accretion Disks

- $T \propto R^{-3/4} \rightarrow R \propto \lambda^{4/3}$
- $R \propto (\dot{M})^{1/3}$
- Measure lag vs. wavelength
  - Temperature profile
  - Size of the disk

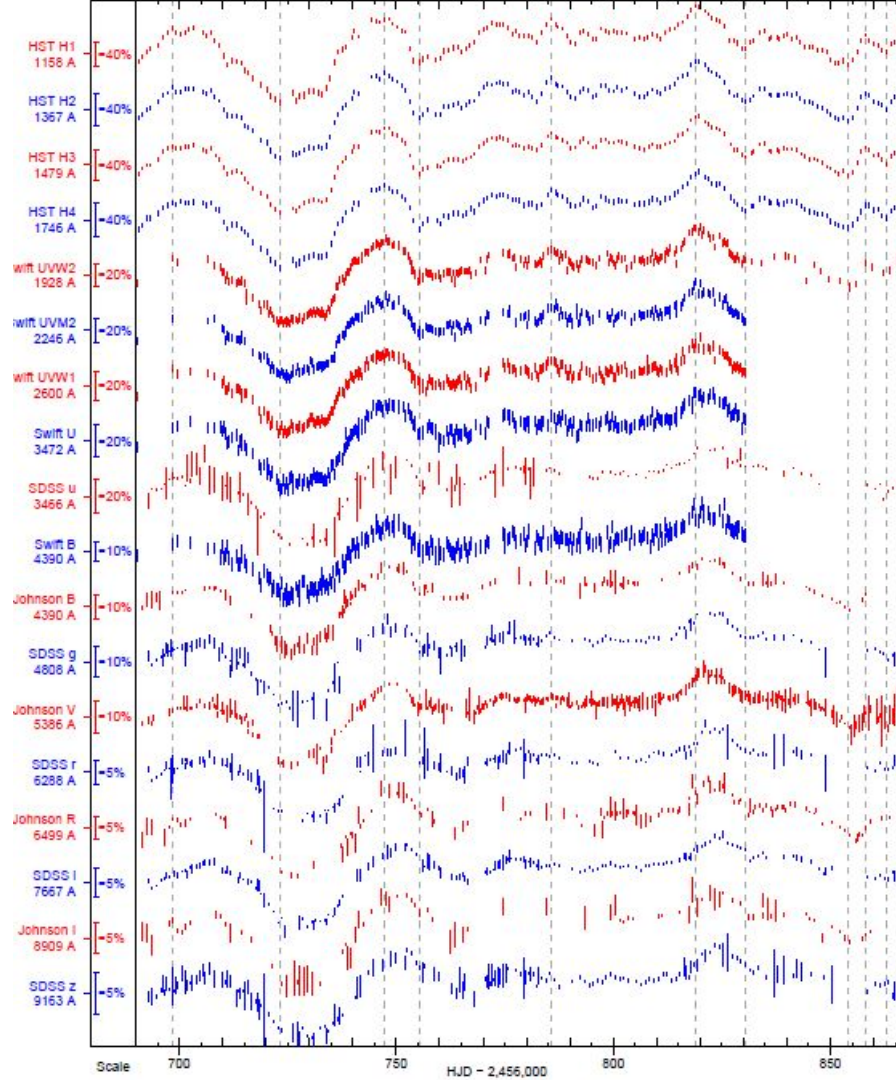


# AGN STORM

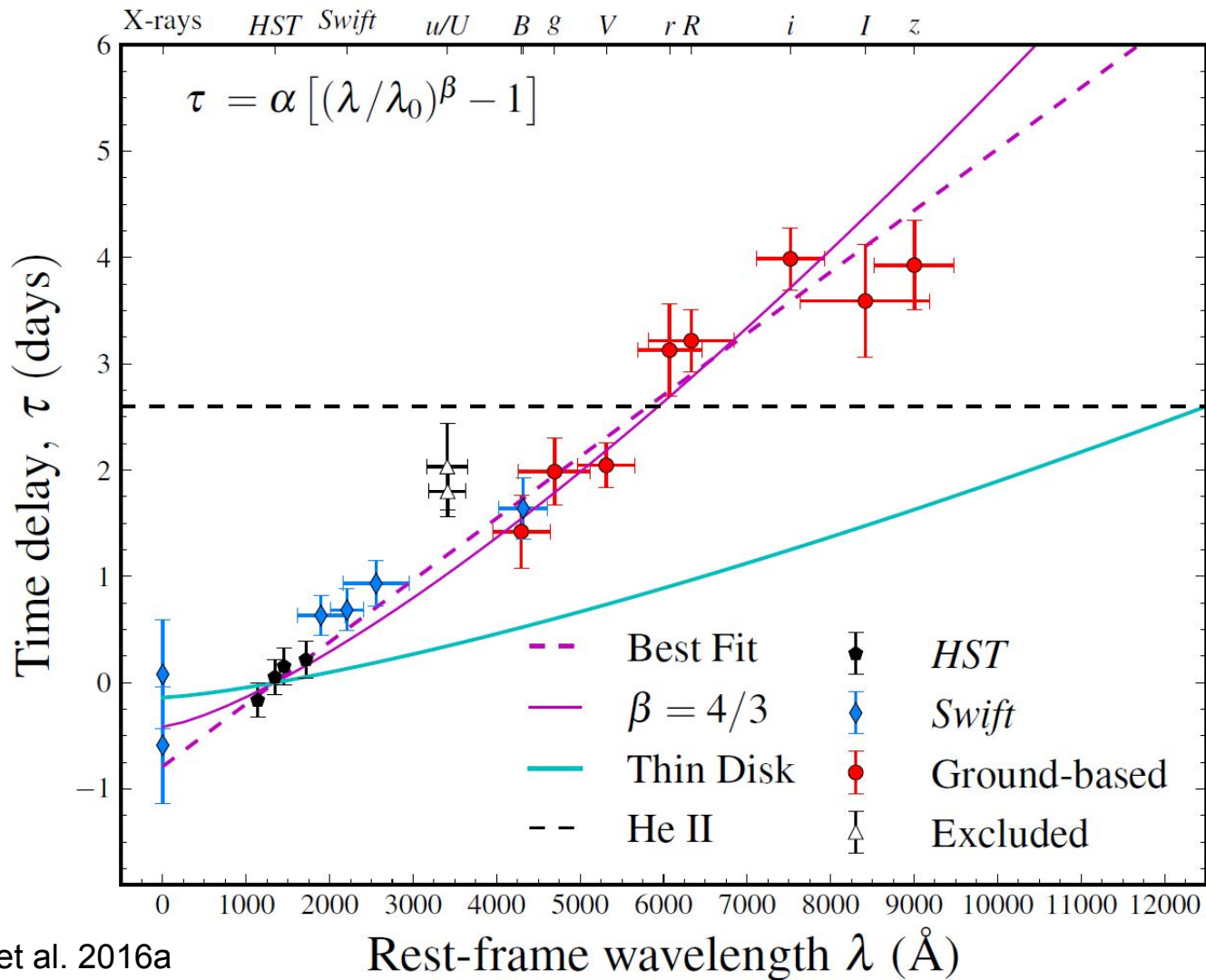
- Space Telescope and Optical Reverberation Mapping Project
- 2014 January to June
- NGC 5548
- HST COS
- 4 space telescopes
- 25 ground-based

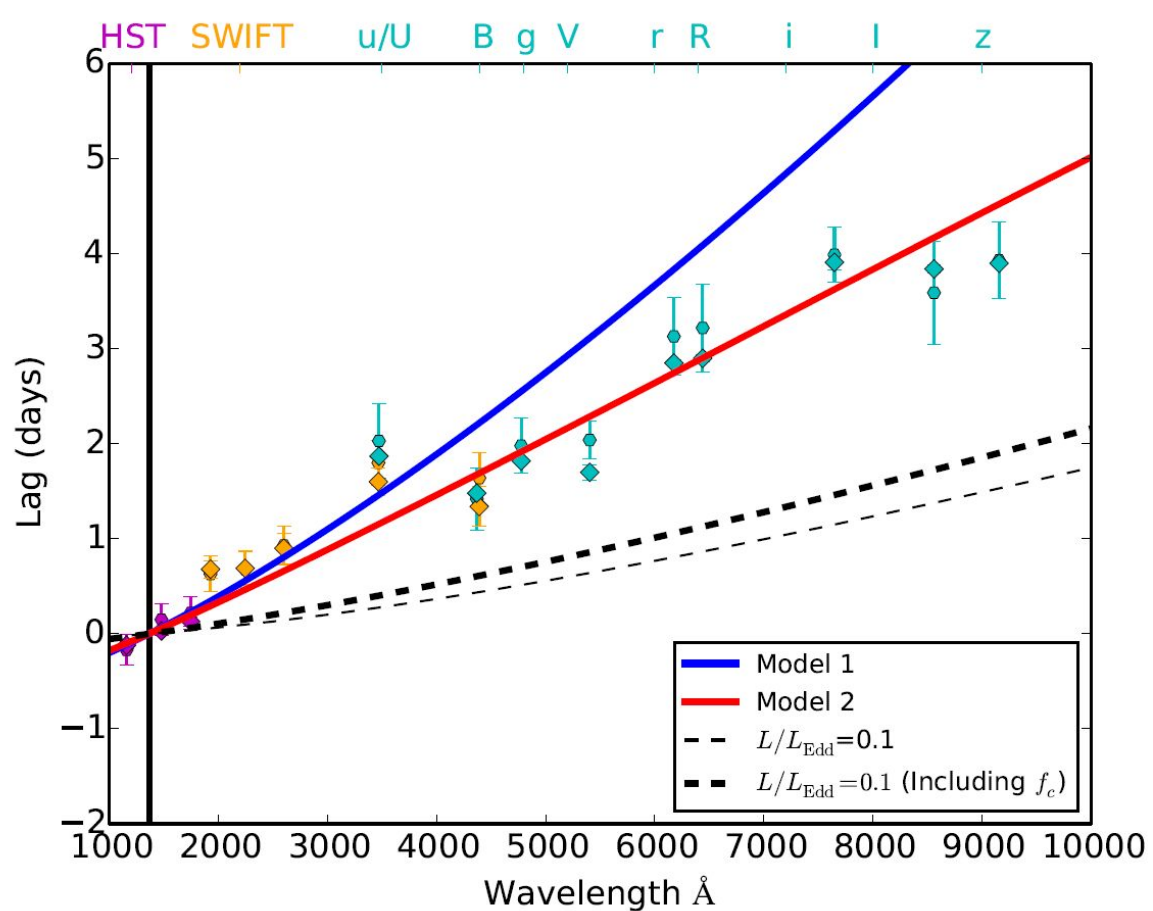
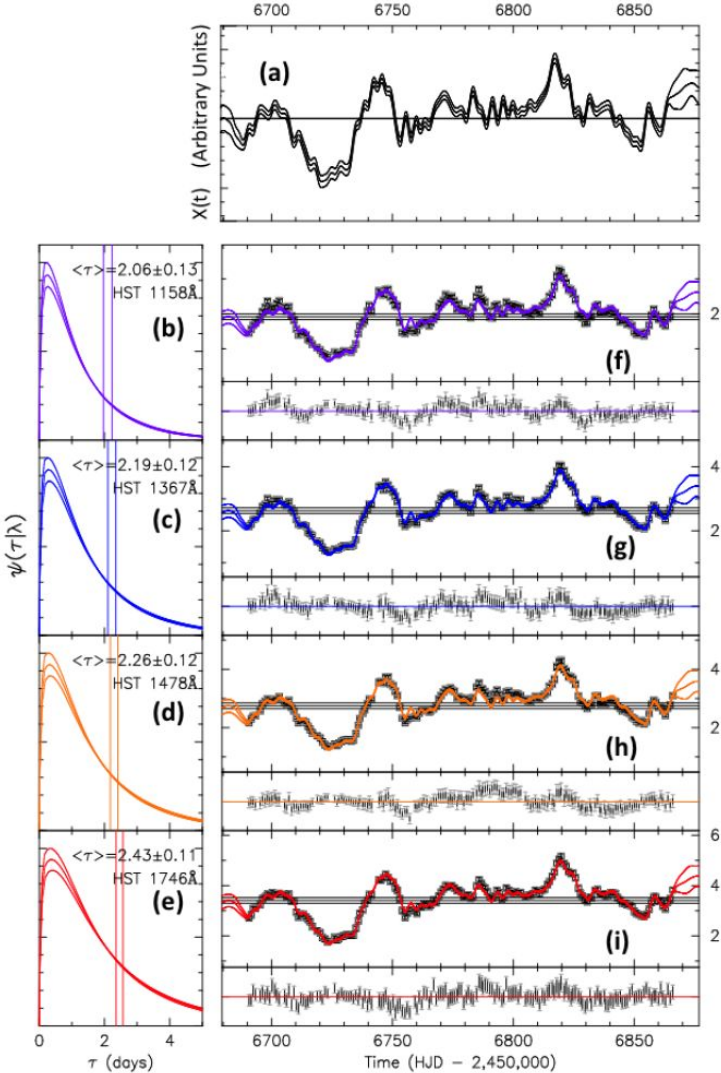


Image Credit: [https://www.nasa.gov/mission\\_pages/hubble/story/index.html](https://www.nasa.gov/mission_pages/hubble/story/index.html)



Fausnaugh et al. 2016a



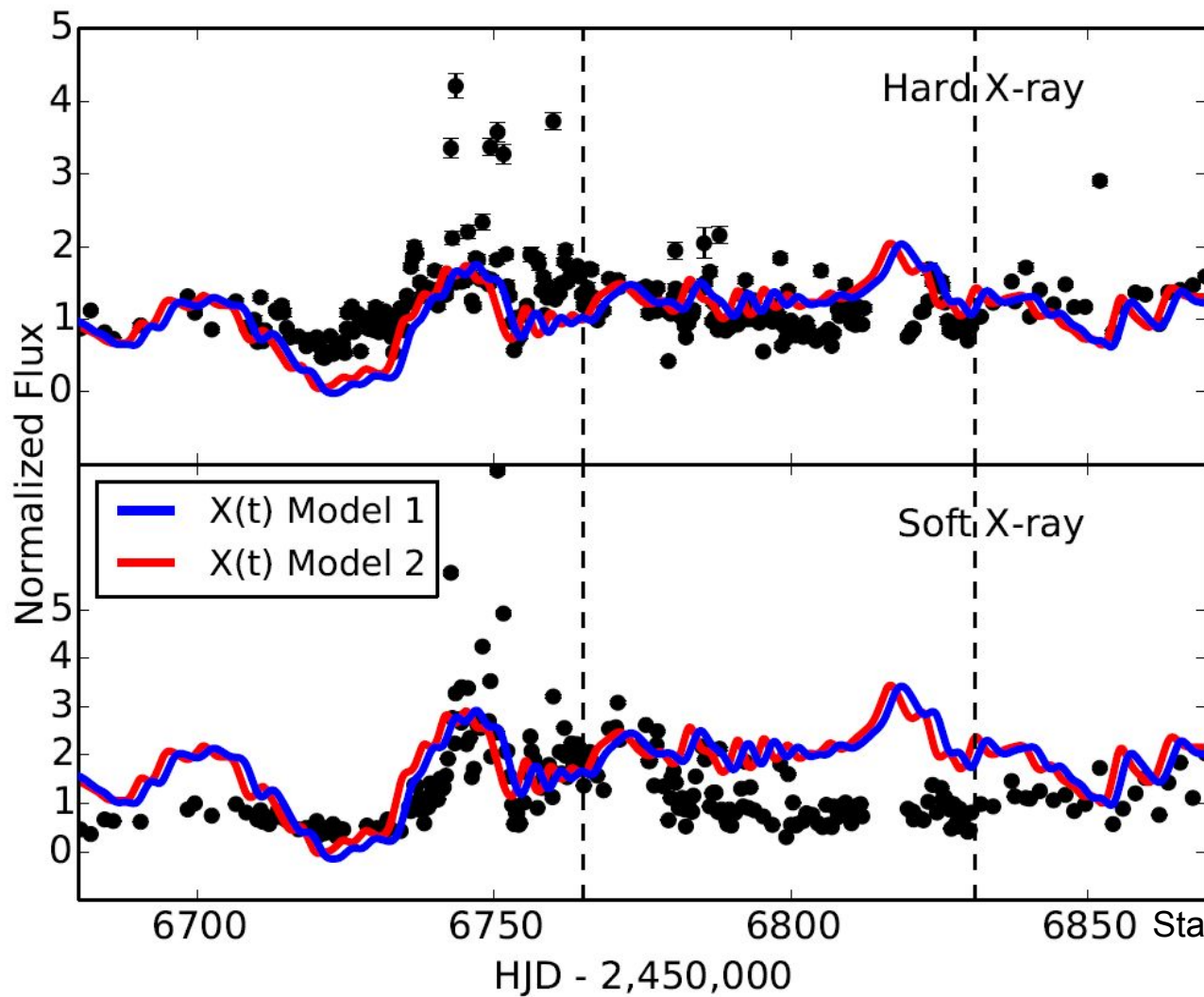


Inclination =  $36 \pm 10$  degrees  $T \sim R^{-0.99}$

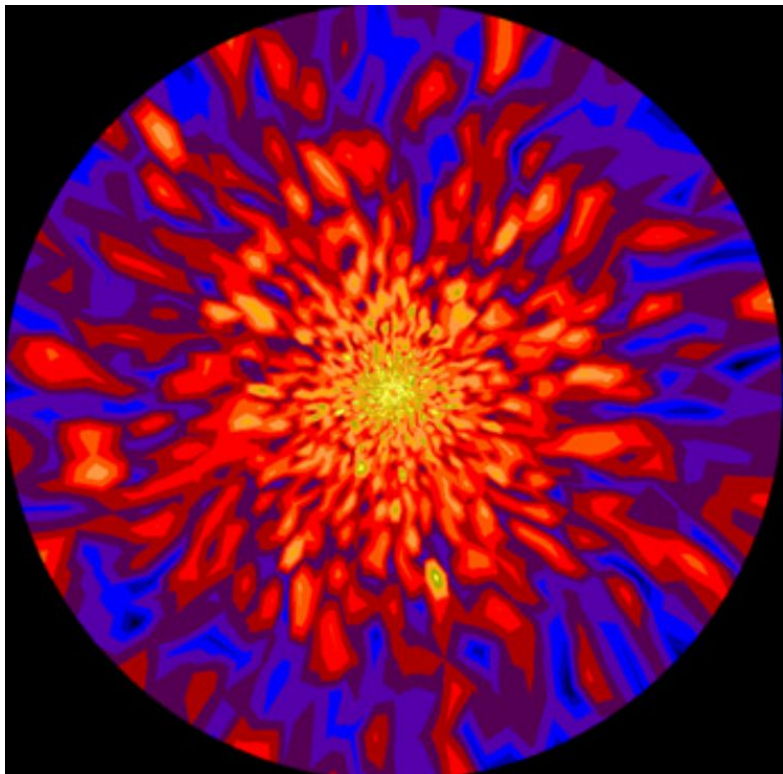
$\dot{M}/\dot{M}_{\text{Edd}} = 1.8$

Starkey et al. 2017

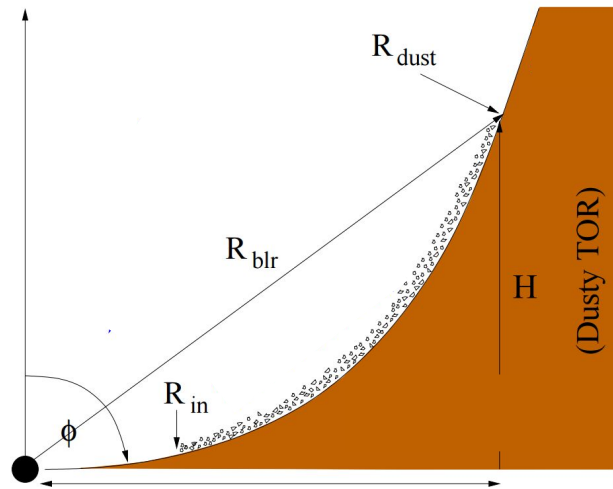
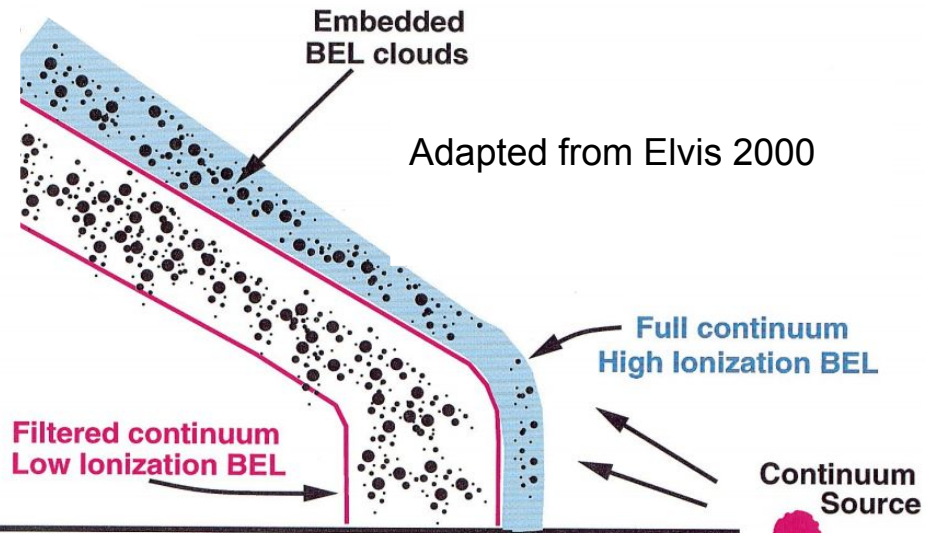




# Ideas?



Dexter & Agol 2011

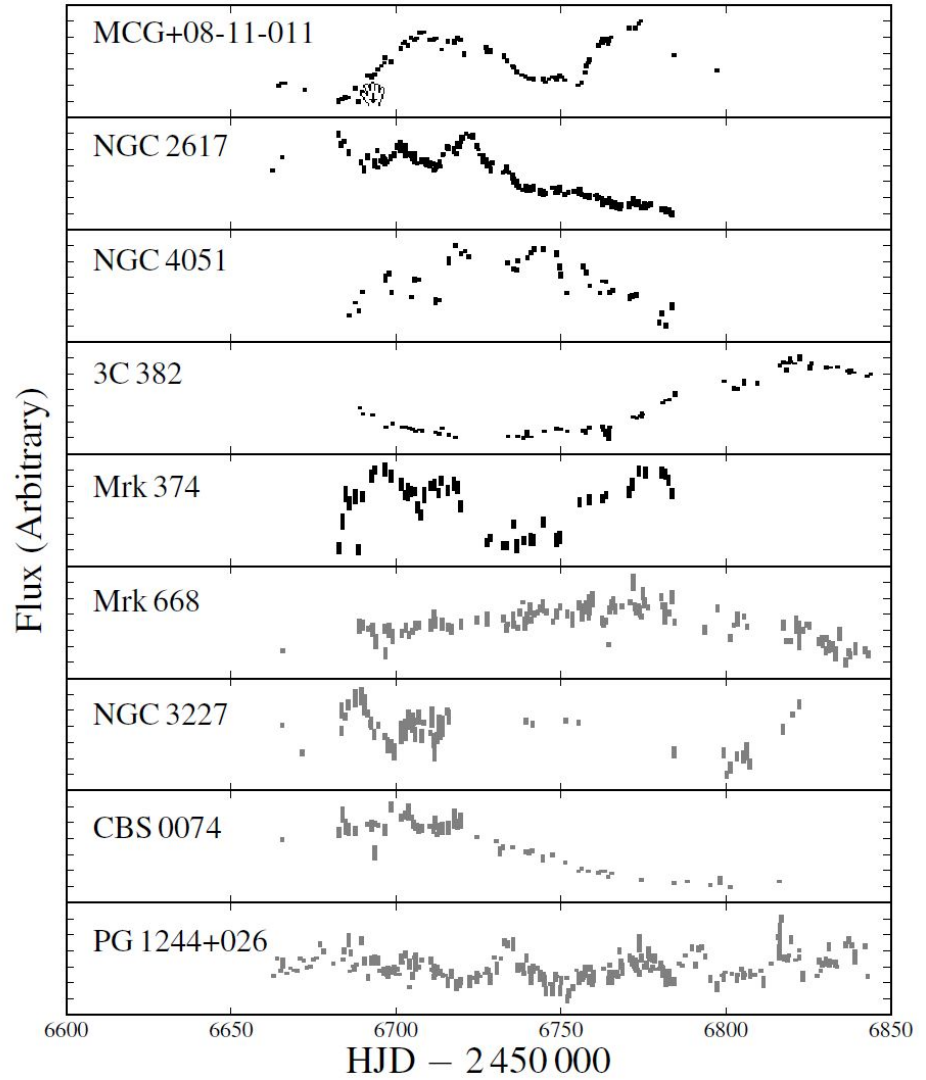


Adapted from Goad et al. 2012

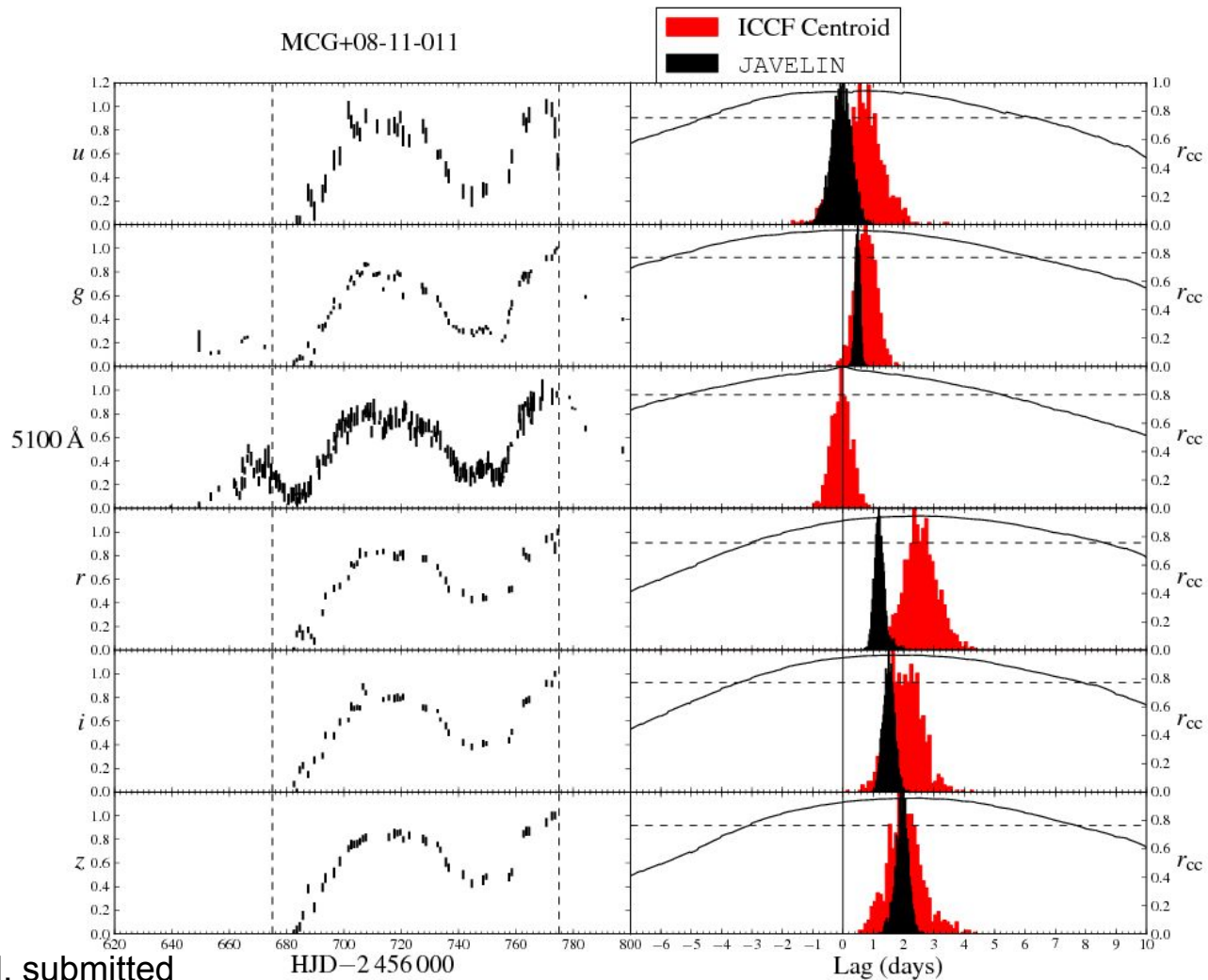
# MDM AGN 2014

- Black Hole Masses
  - MDM spectroscopy
  - H $\beta$  reverberation
  - BLR structure (velocity-resolved)
- Optical continuum lags
  - LCO ugriz imaging

Fausnaugh et al. 2016b

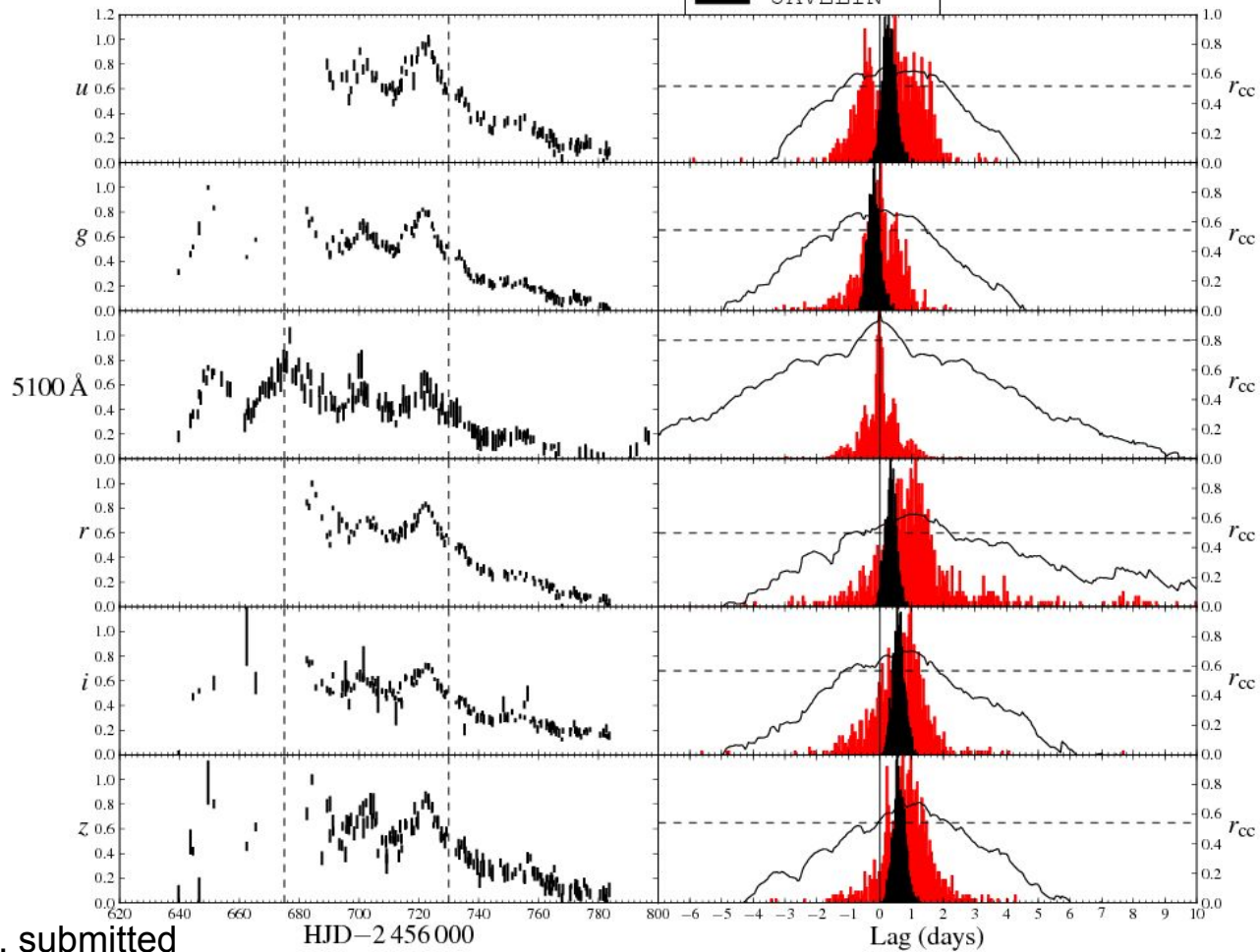


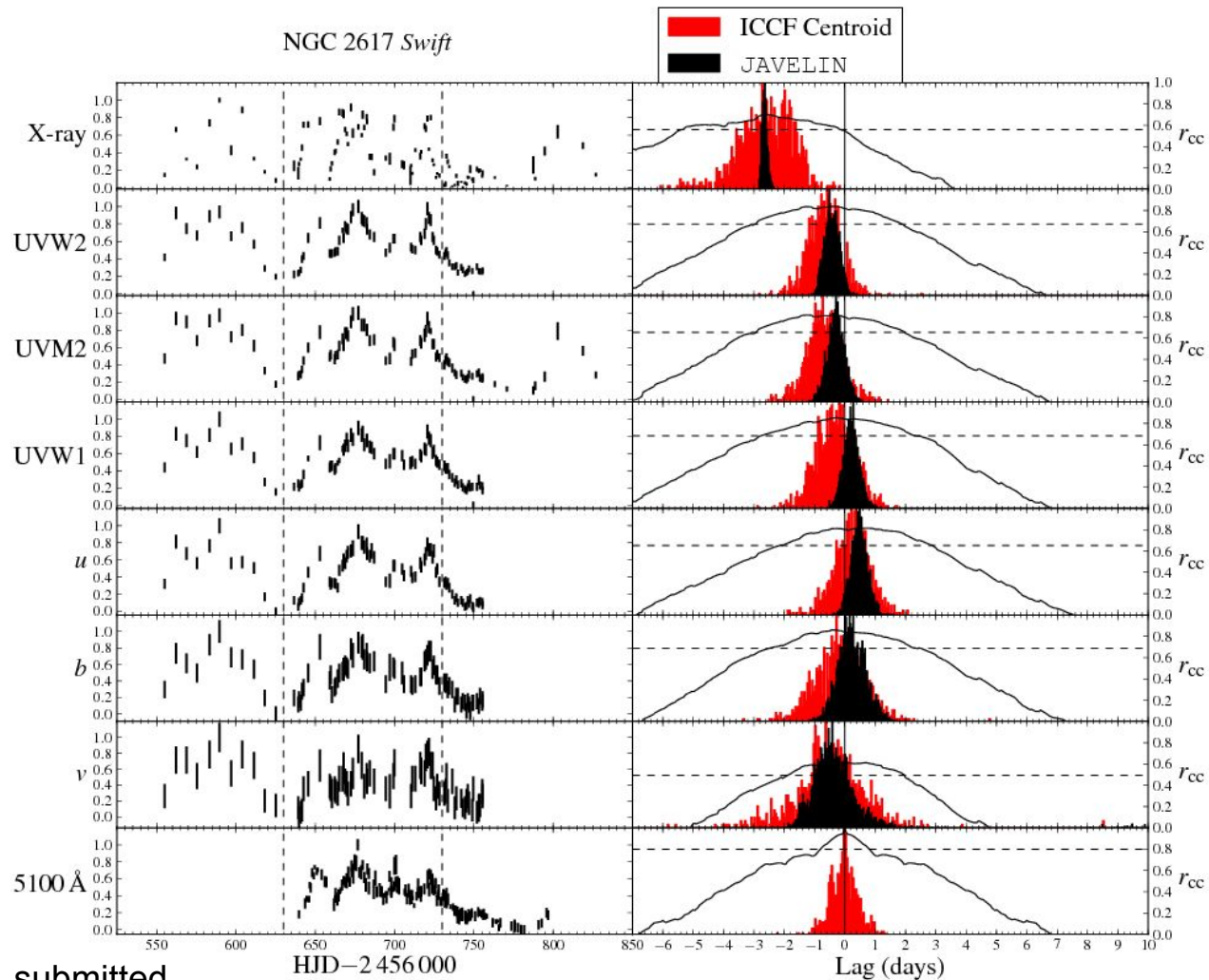
MCG+08-11-011

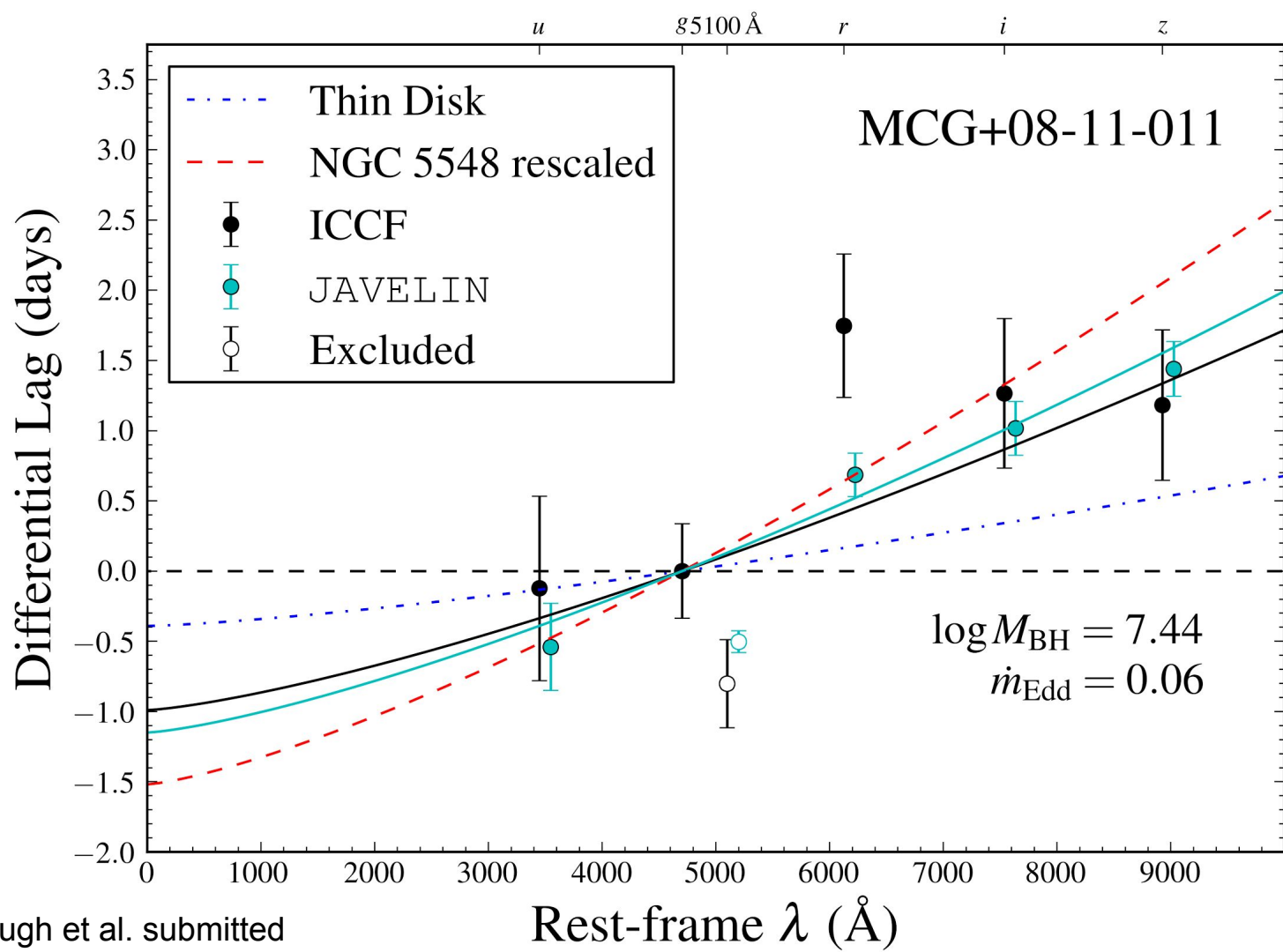


NGC 2617

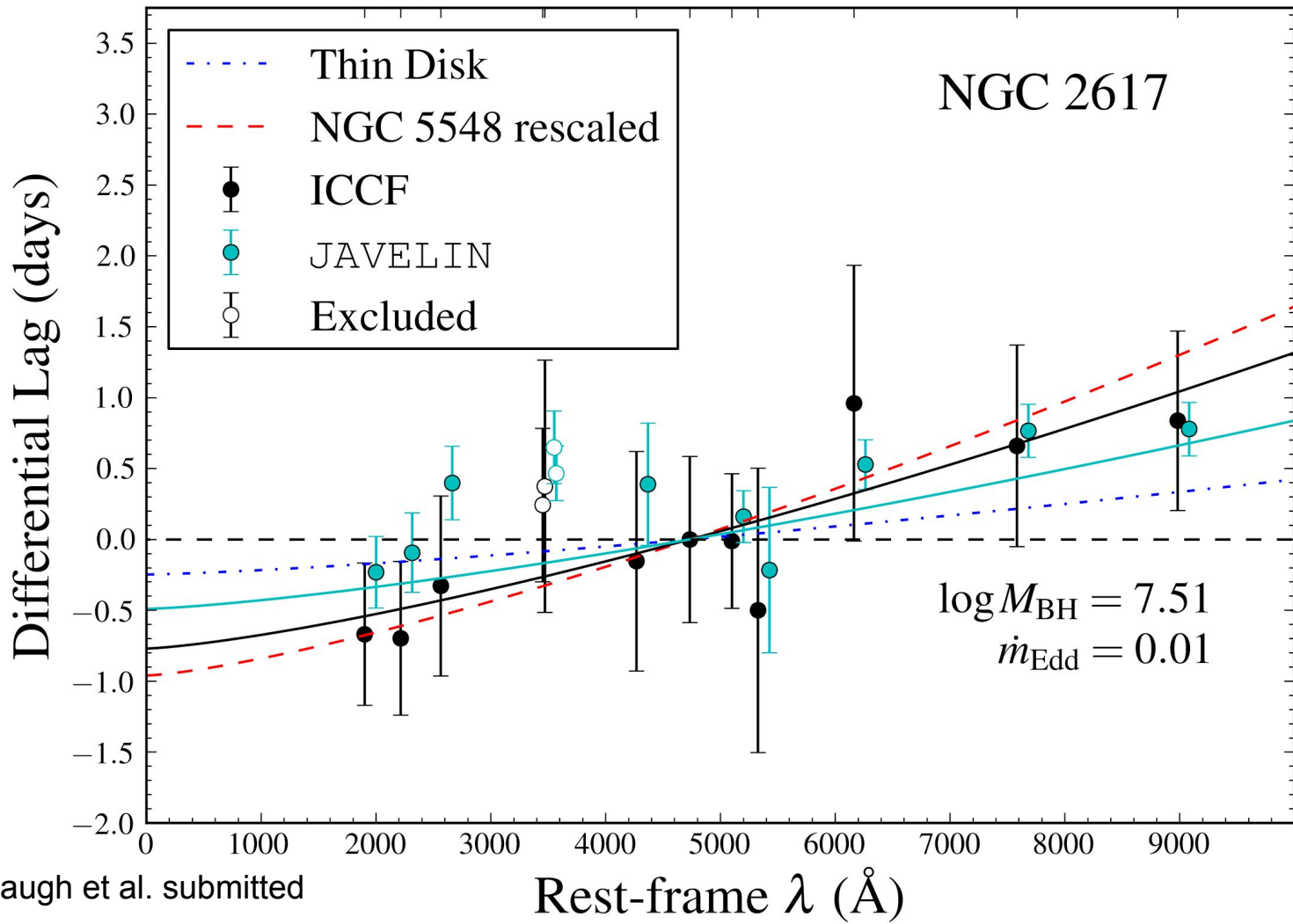
■ ICCF Centroid  
■ JAVELIN



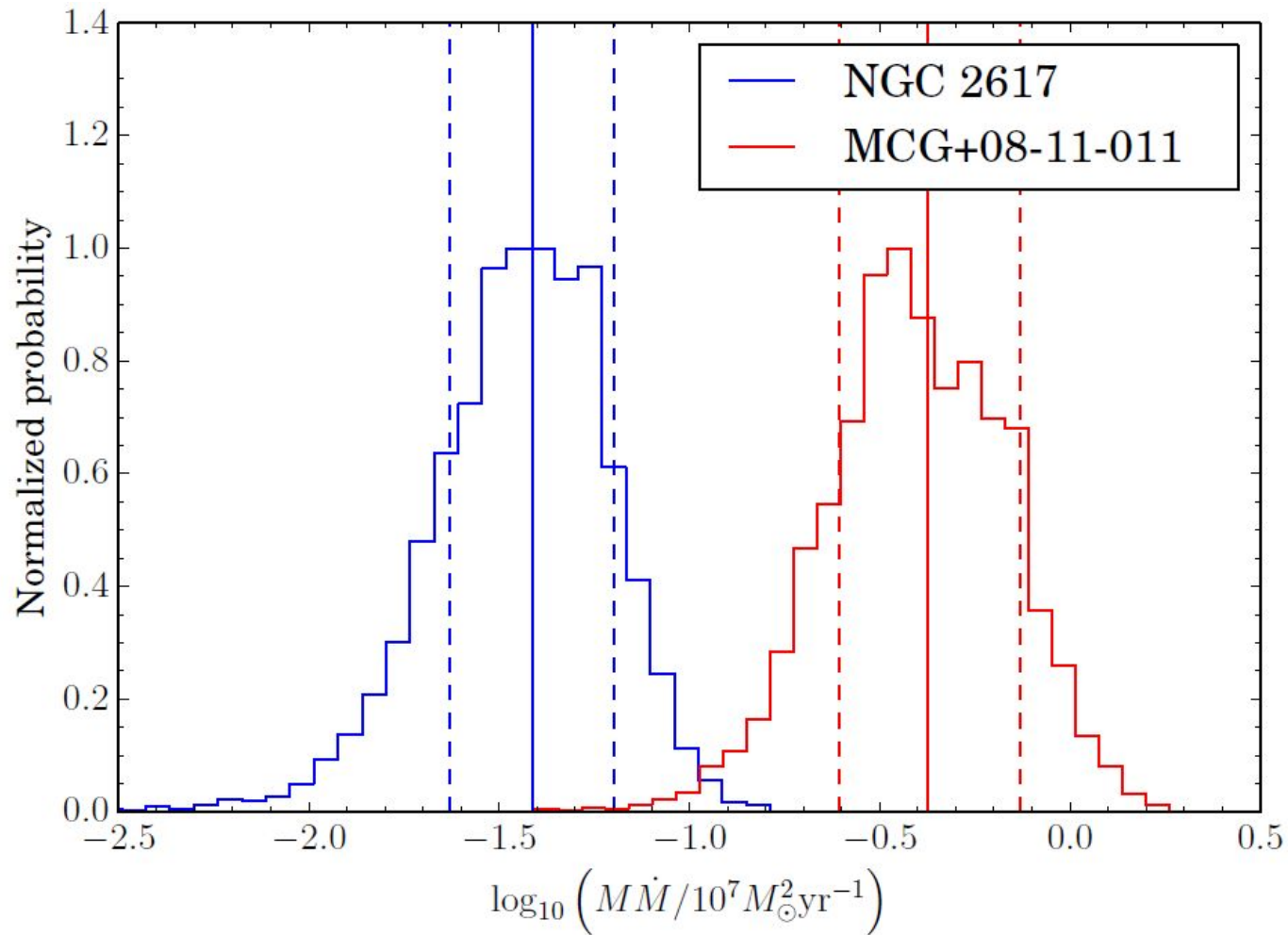




Swift UV u b g v r i z





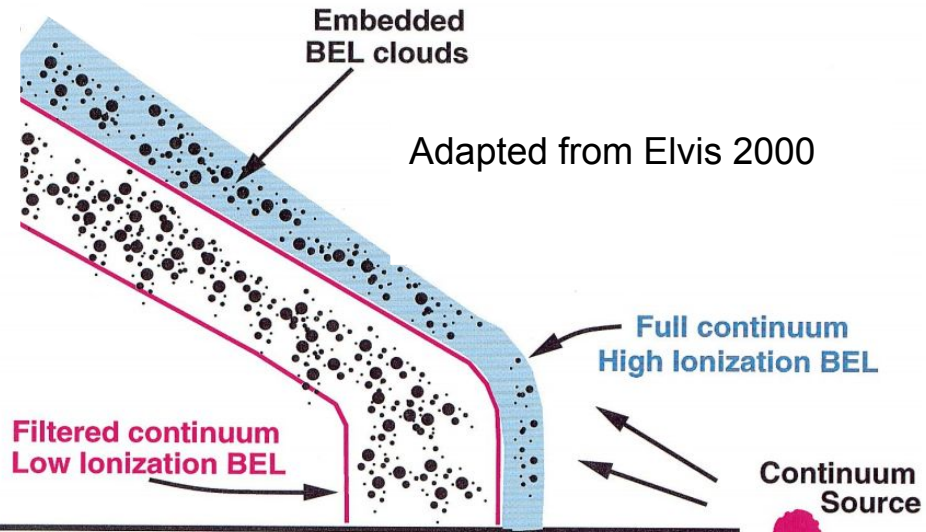


## CREAM Modeling:

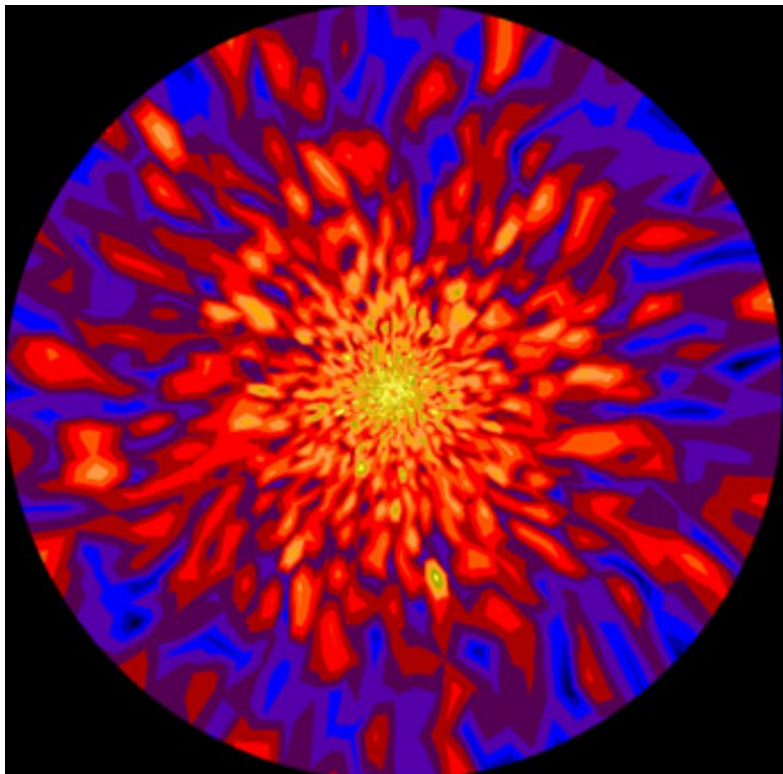
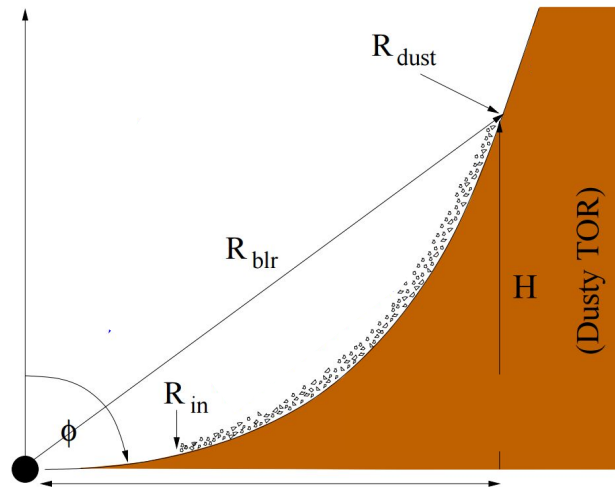
MCG+08-11-011:  
 $\dot{M}/\dot{M}_{\text{Edd}} = 0.23$

NGC 2617:  
 $\dot{M}/\dot{M}_{\text{Edd}} = 0.01$   
Inclination: 43 +/-  
20 degrees

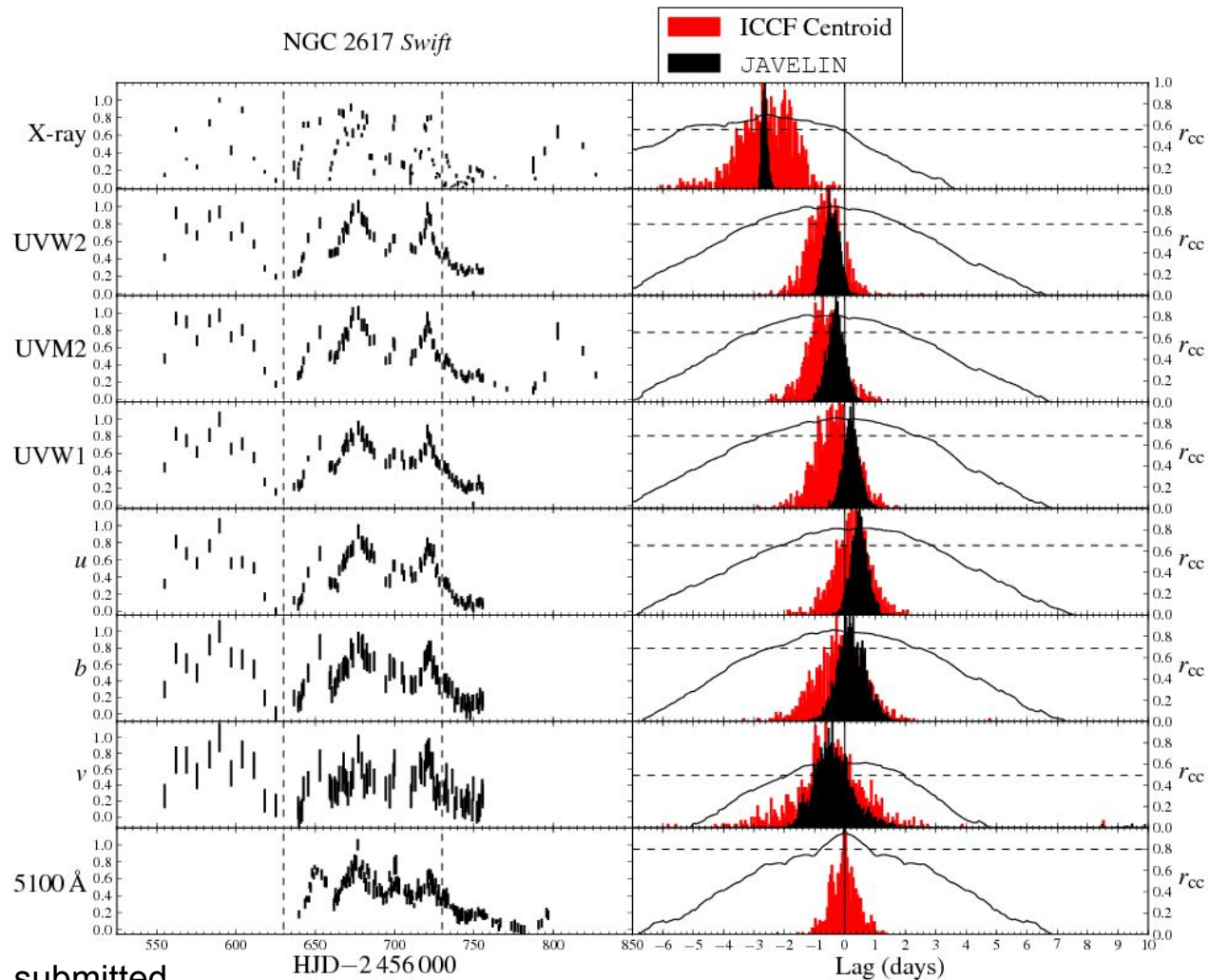
# Ideas?

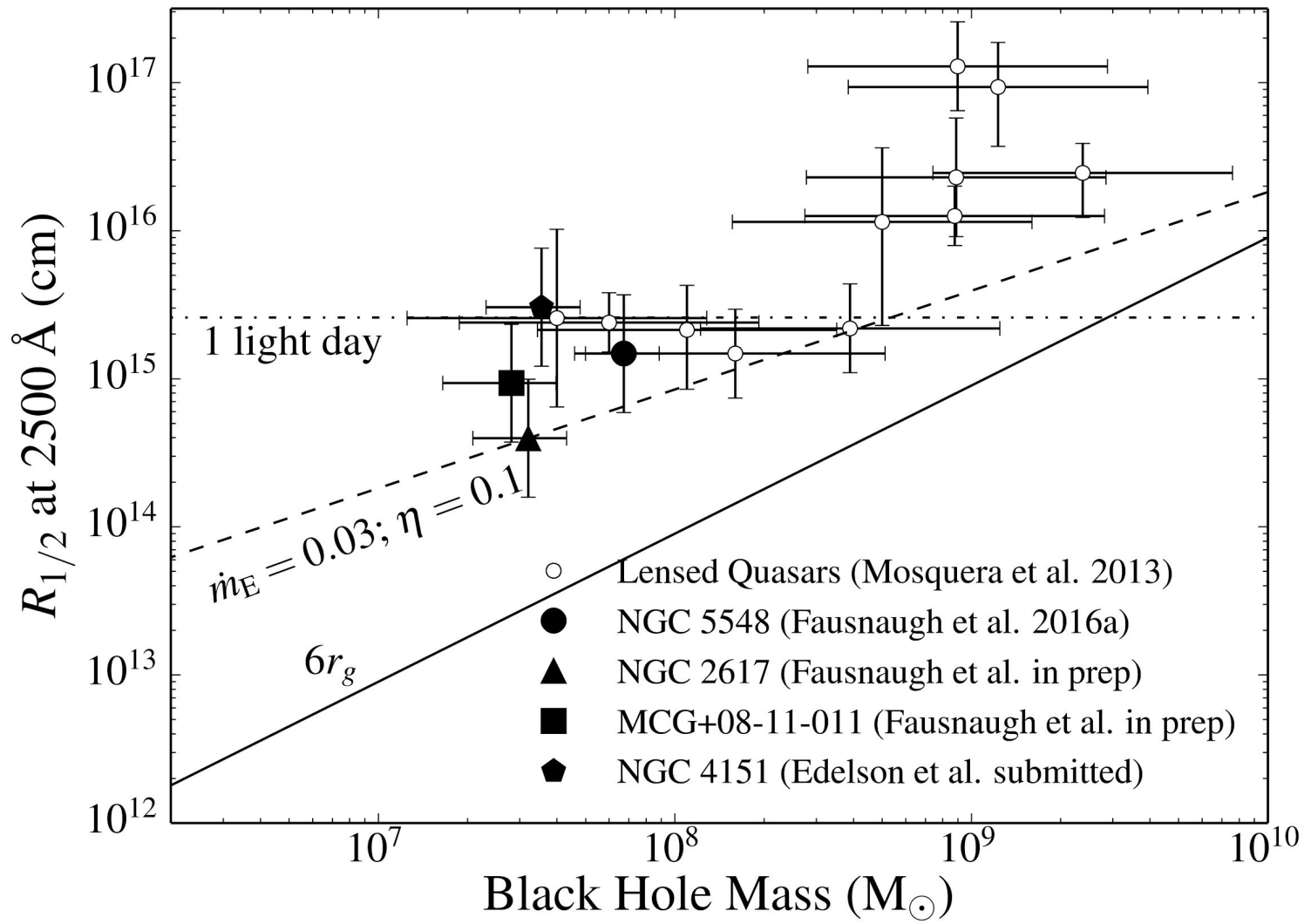


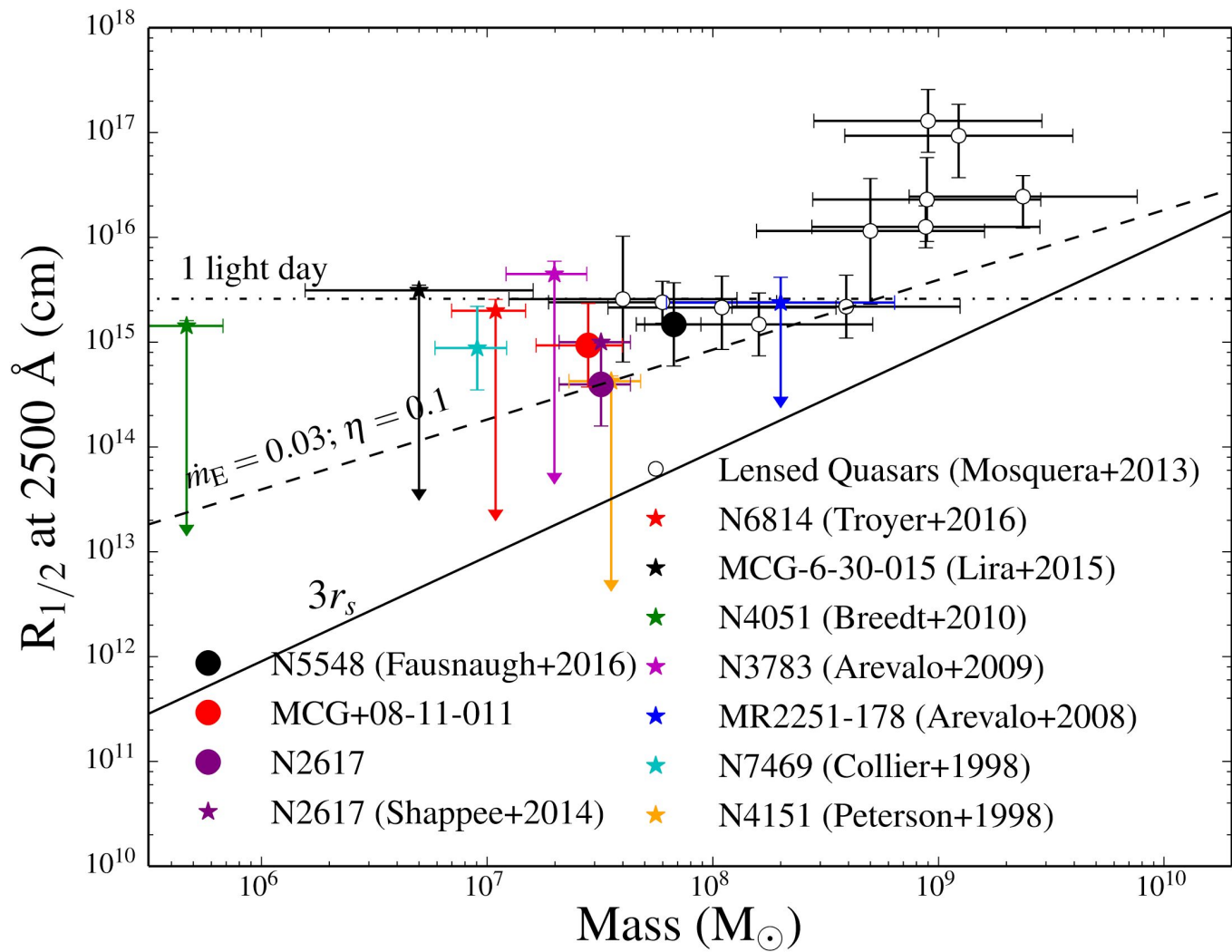
Adapted from Goad et al. 2012



Dexter & Agol 2011





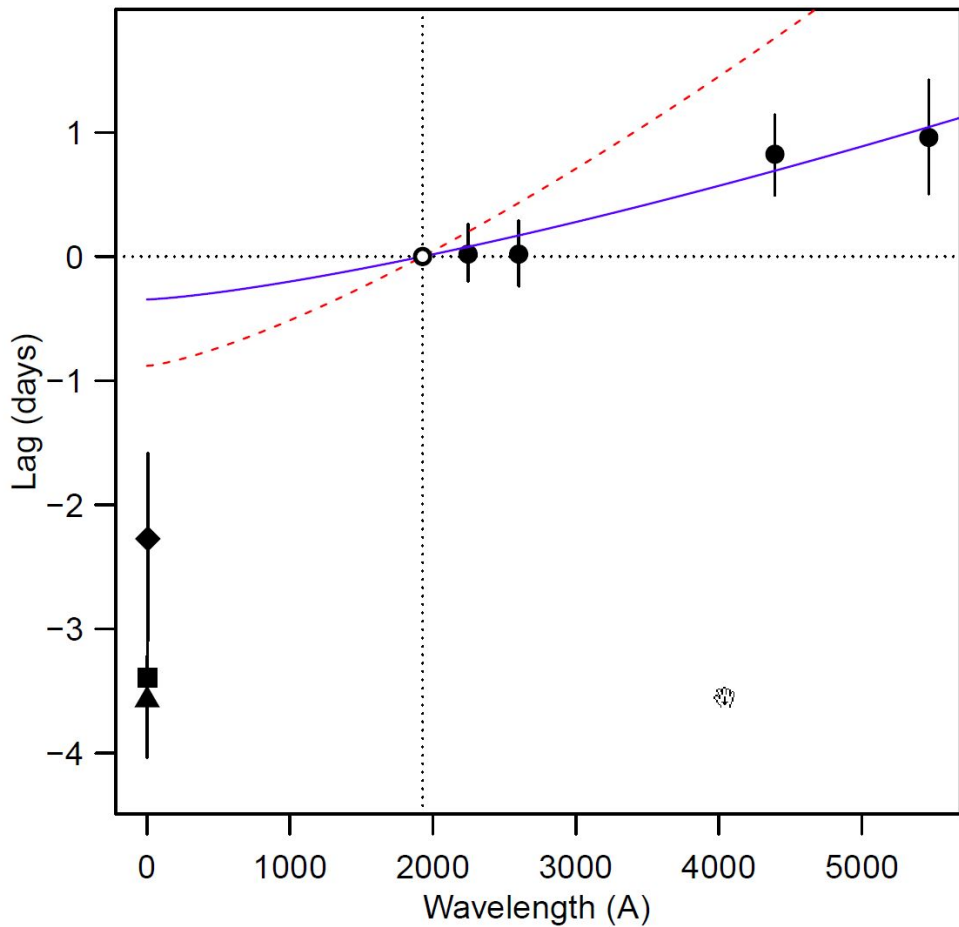
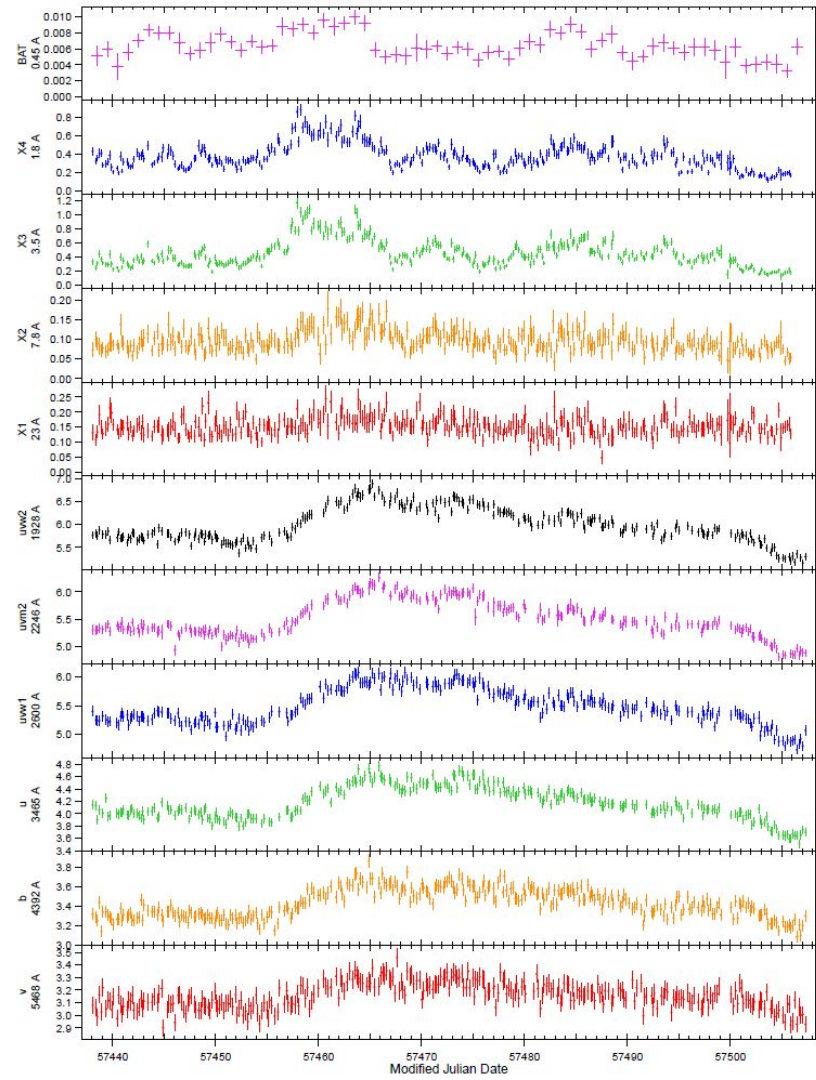


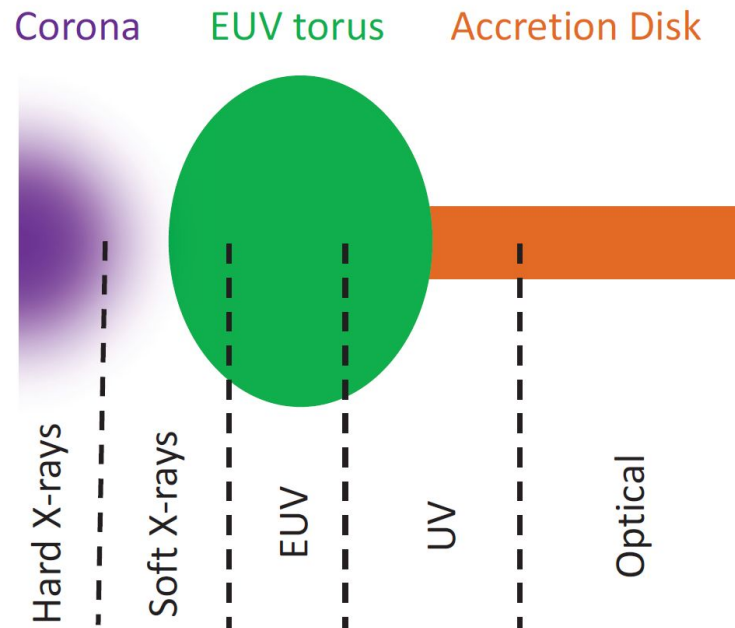
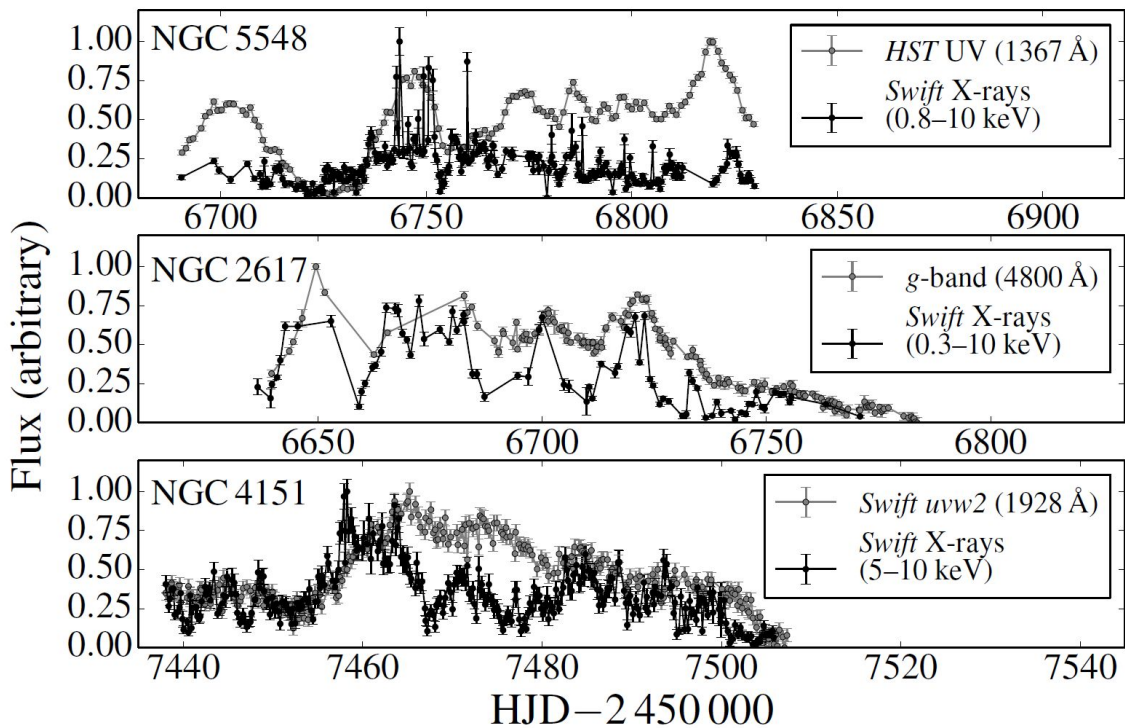
# Summary

- 3 (+1) objects with well-resolved continuum lags
- Disks are consistent with  $T \propto R^{-3/4}$
- (These) Disks are larger than standard predictions



Image Credit: <https://www.cfa.harvard.edu/imagelist/2013-07>



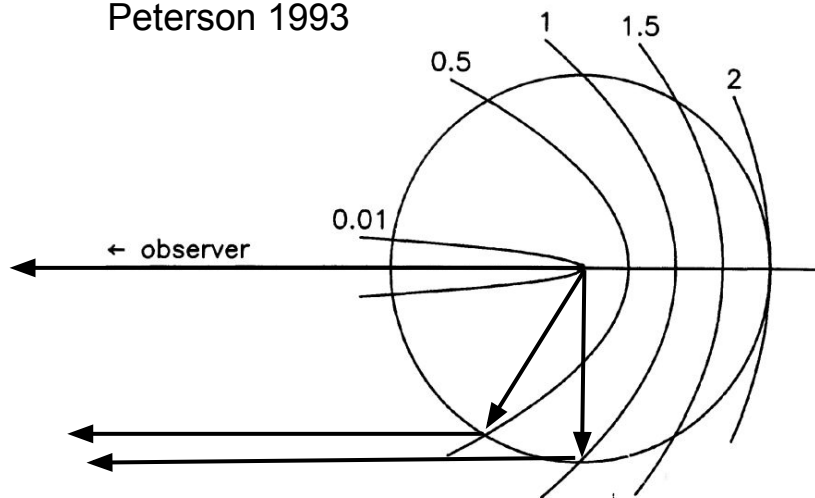


Gardner & Done 2016;  
 Edelson et al., accepted to ApJ

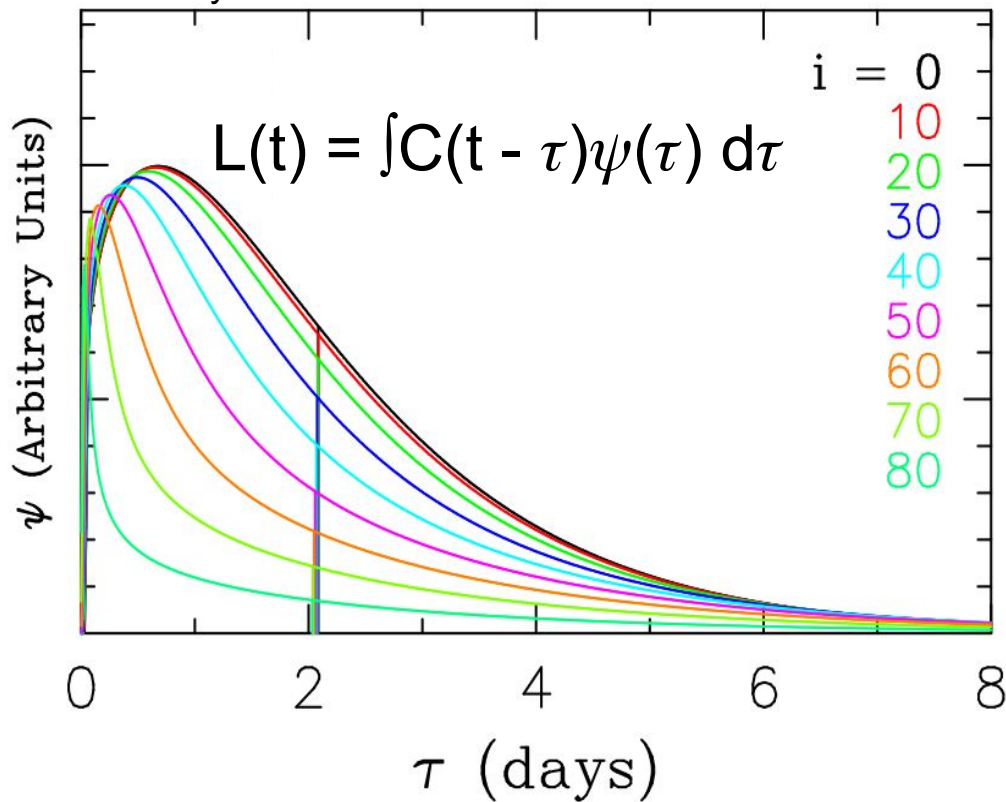


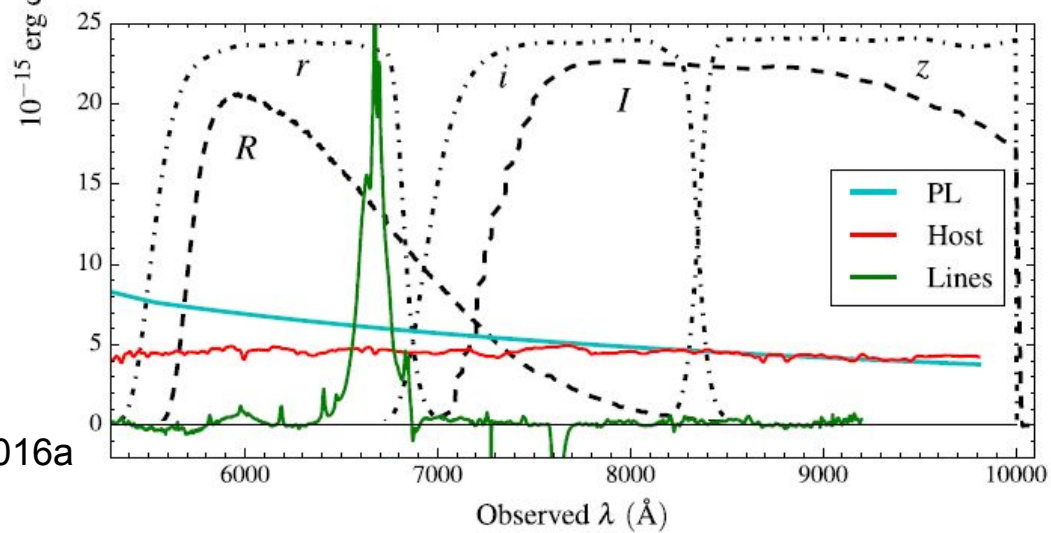
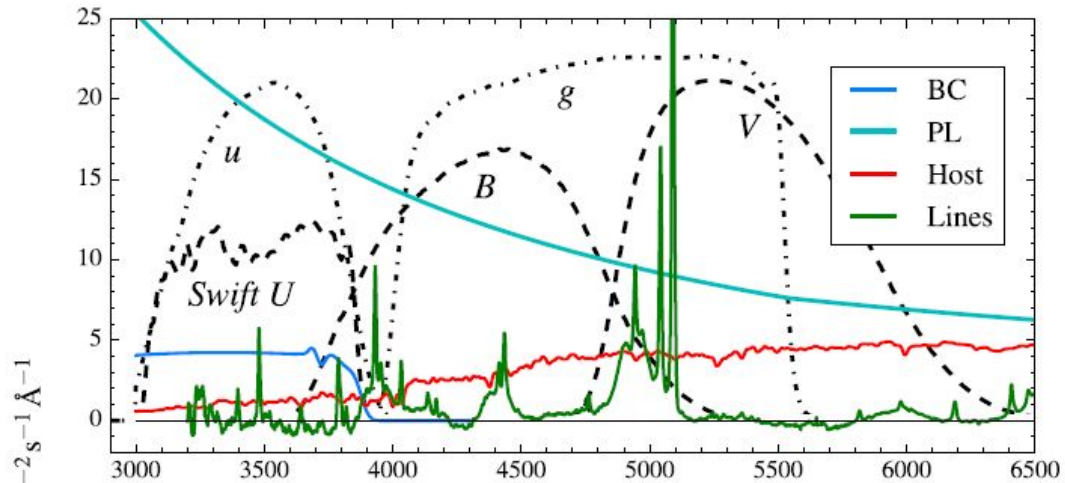
# Reverberation Mapping

Adapted from  
Peterson 1993



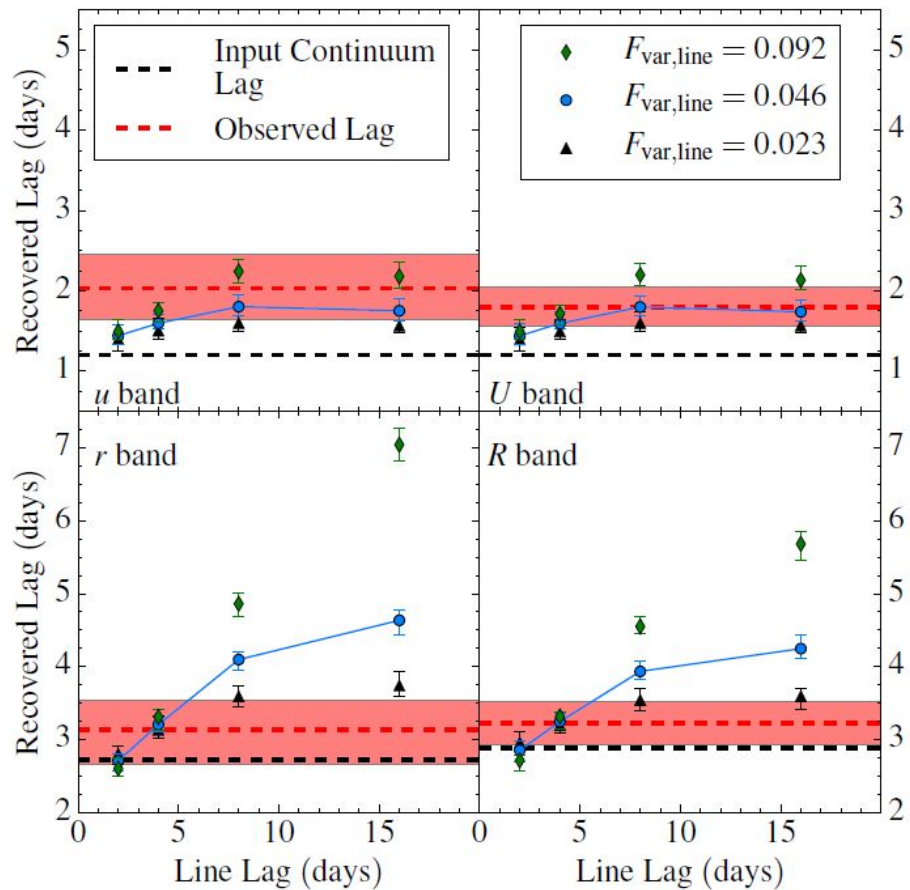
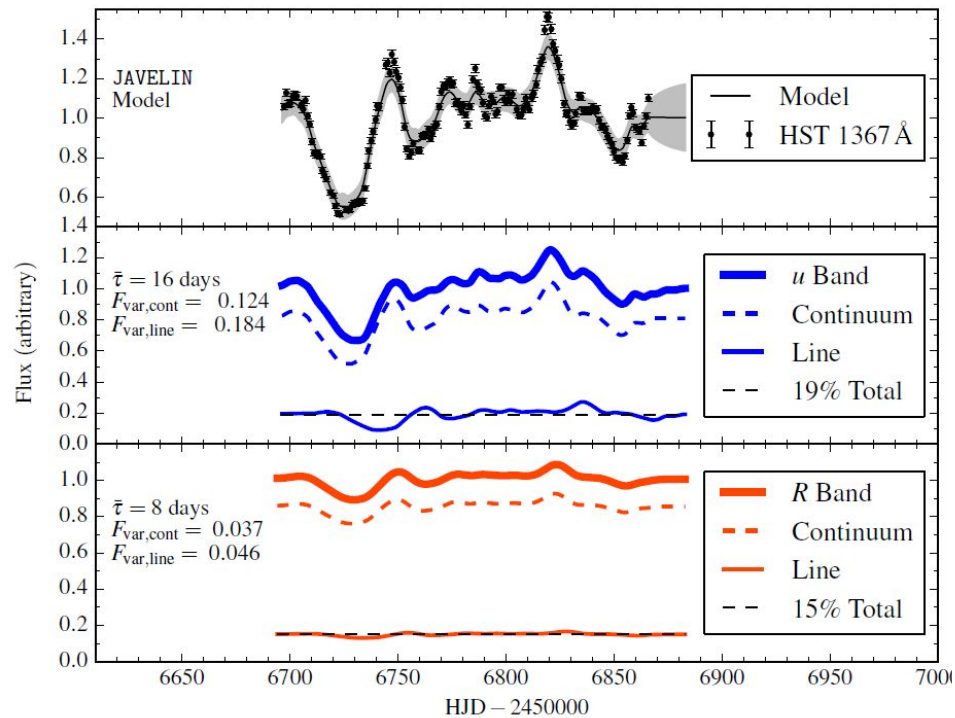
Starkey et al. 2016a

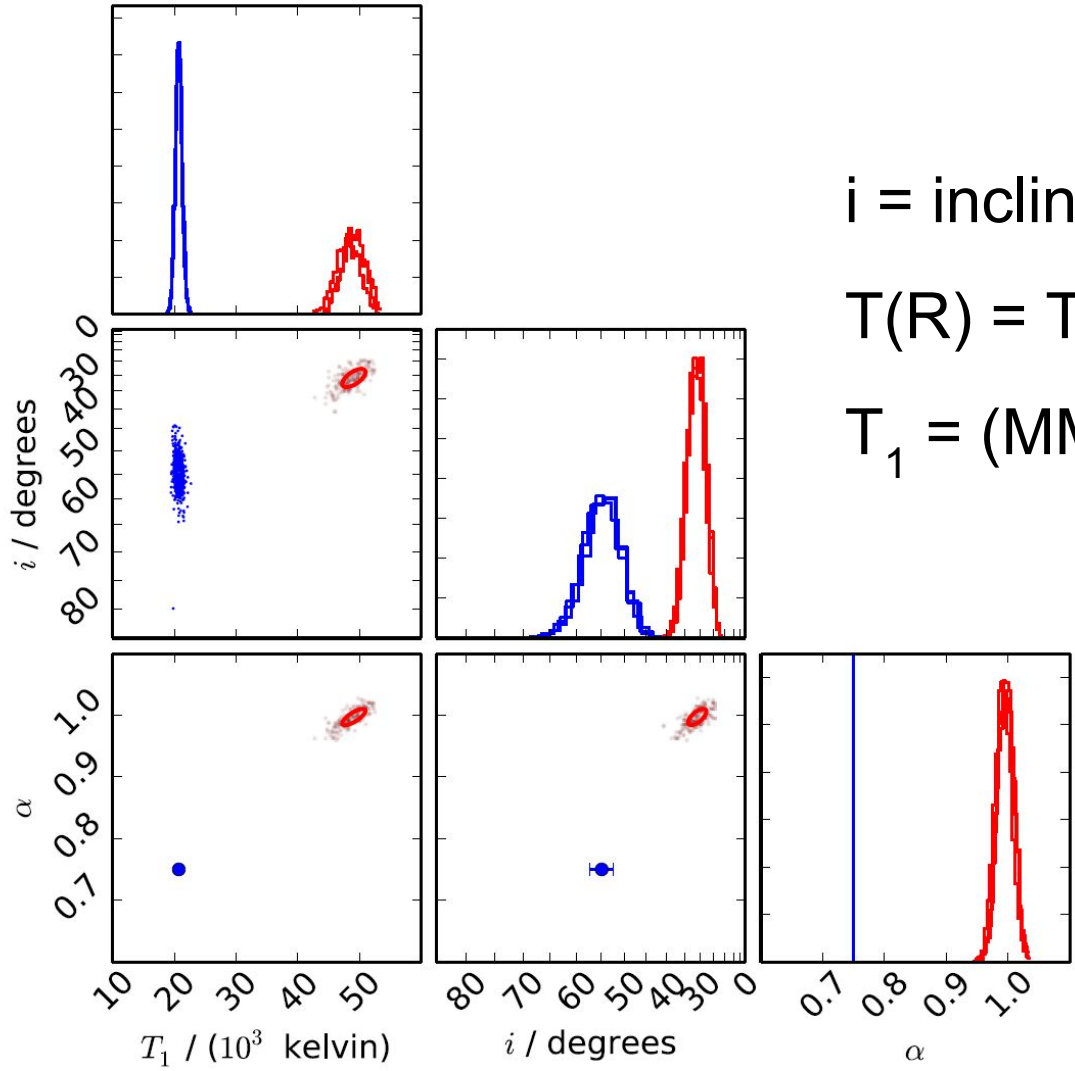




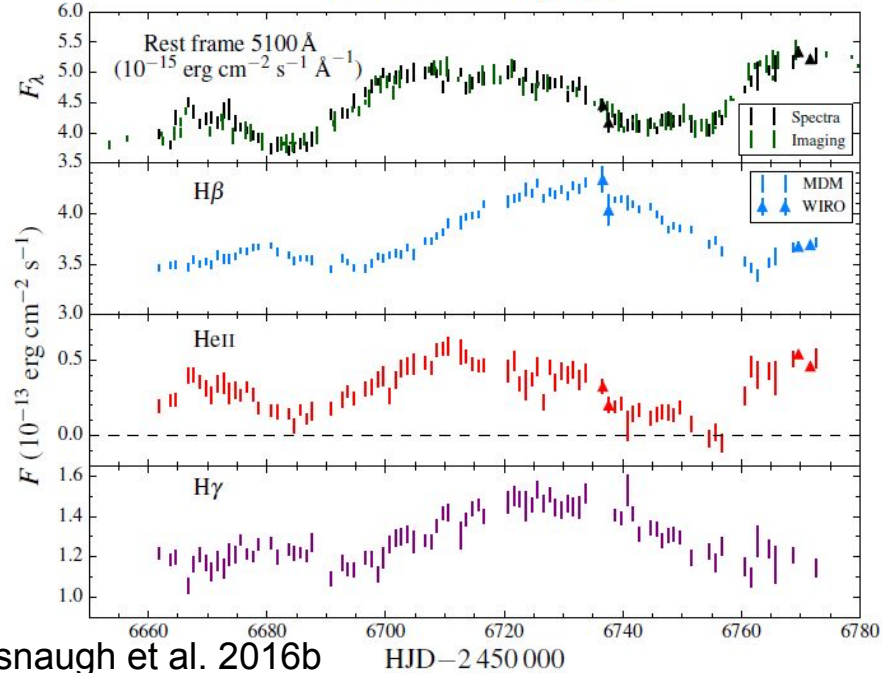
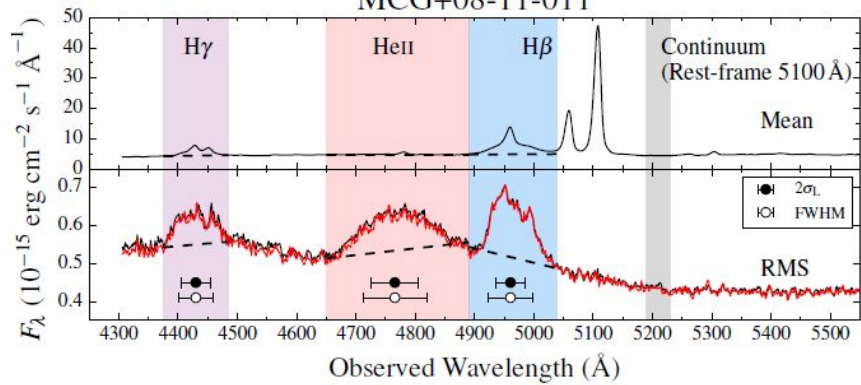
Fausnaugh et al. 2016a

Fausnaugh et al. 2016a

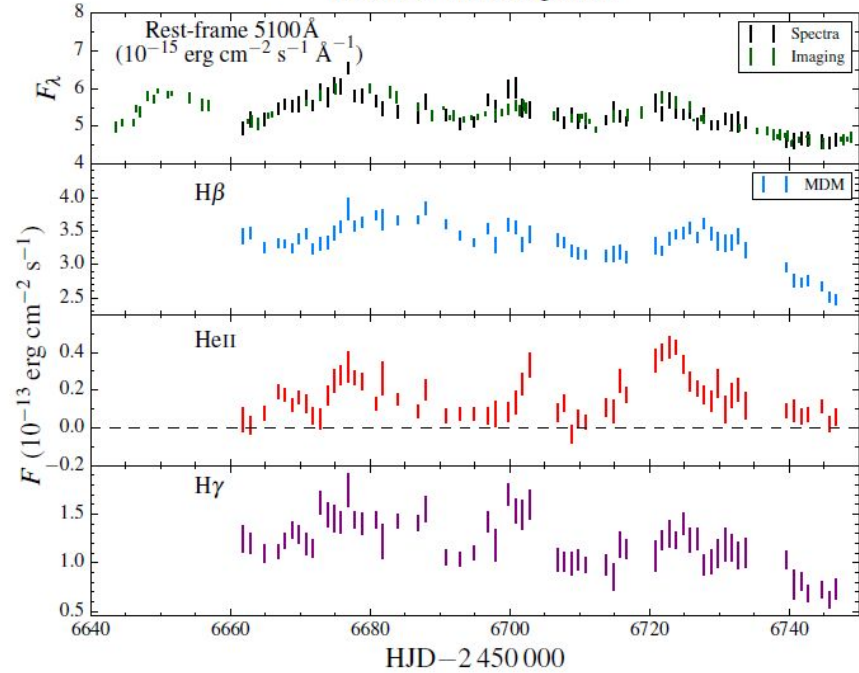
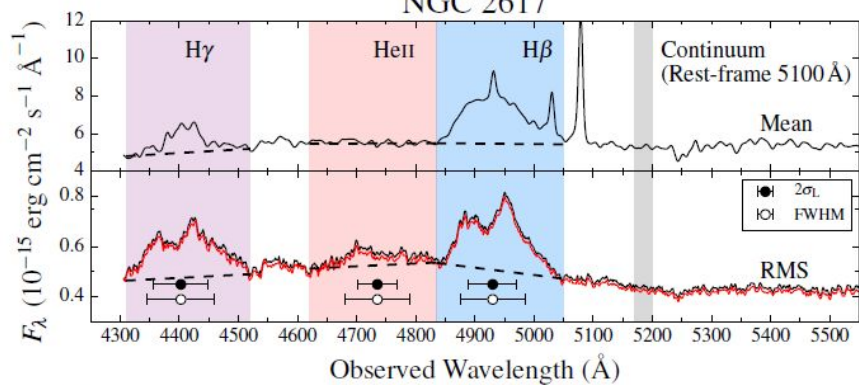




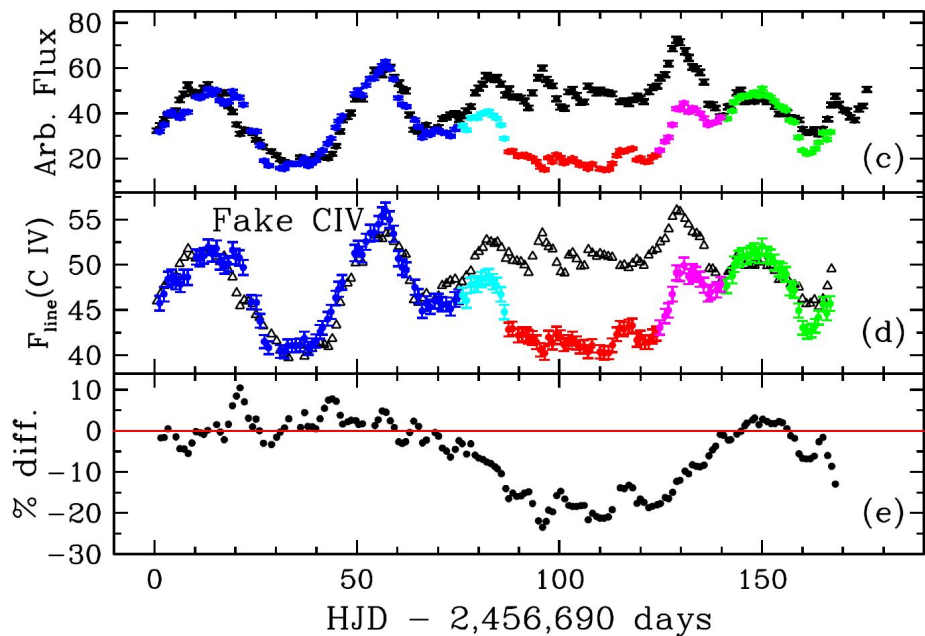
MCG+08-11-011



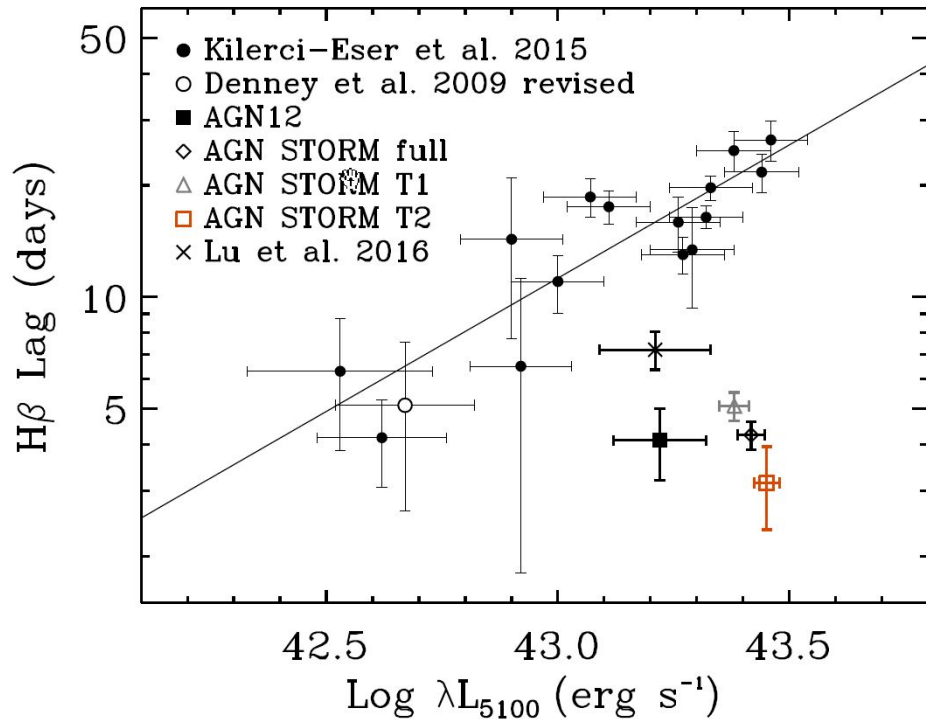
NGC 2617

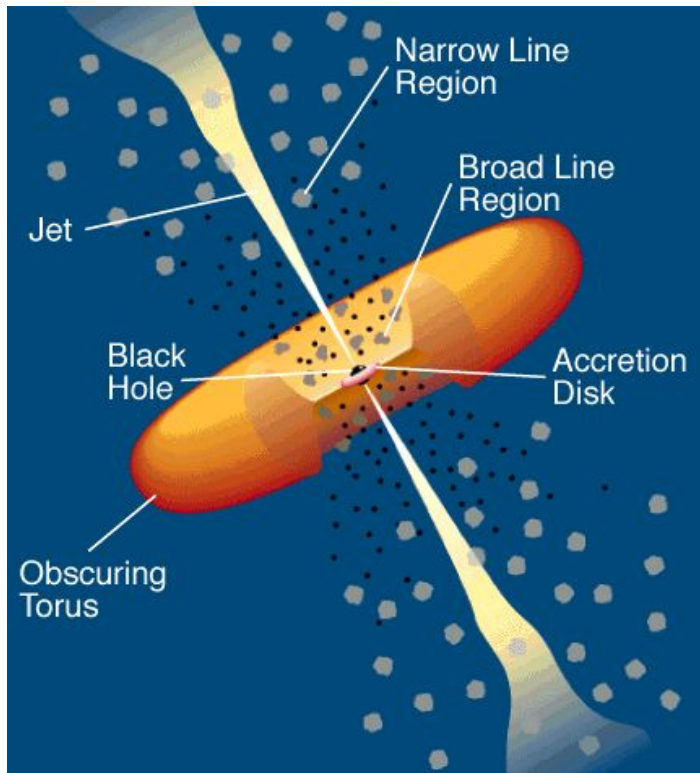


Goad et al. 2016 (STORM Paper IV)



Pei et al., accepted to ApJ (STORM Paper V)





<https://heasarc.gsfc.nasa.gov/docs/cgro/images/epo/gallery/agns/>

