Astronomía
FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE

CONICYT
Ministerio de Educación
Gobierno de Chile

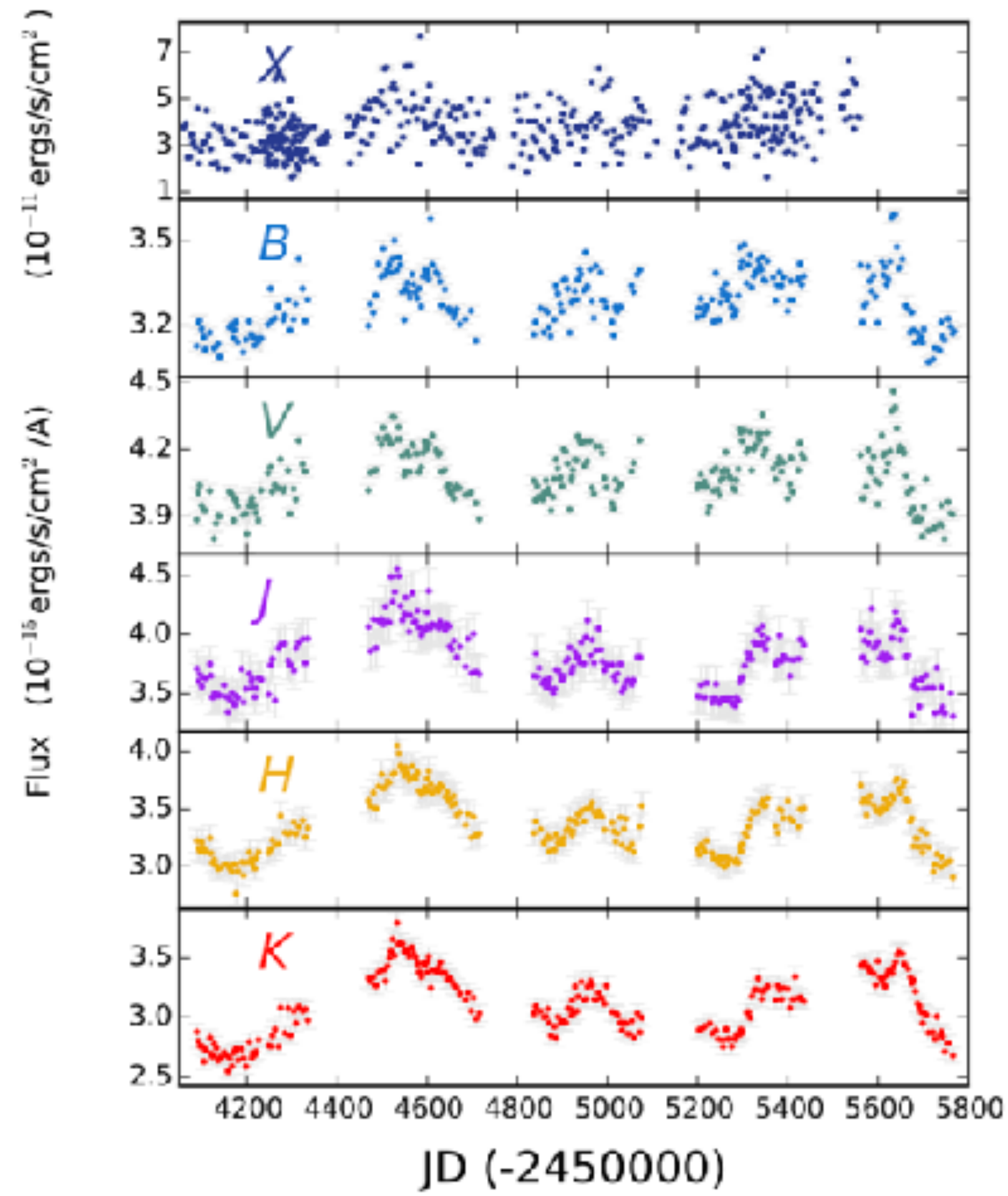
Paula Sánchez-Sáez

Paulina Lira - Konrad Tristram - Patricia Arévalo - Julián Mejía-Restrepo - Luis Ho - Regis Cartier - Paolo Coppi - Minjin Kim - +

CHARACTERIZATION OF AGN VARIABILITY IN THE OPTICAL AND NEAR INFRARED REGIMES

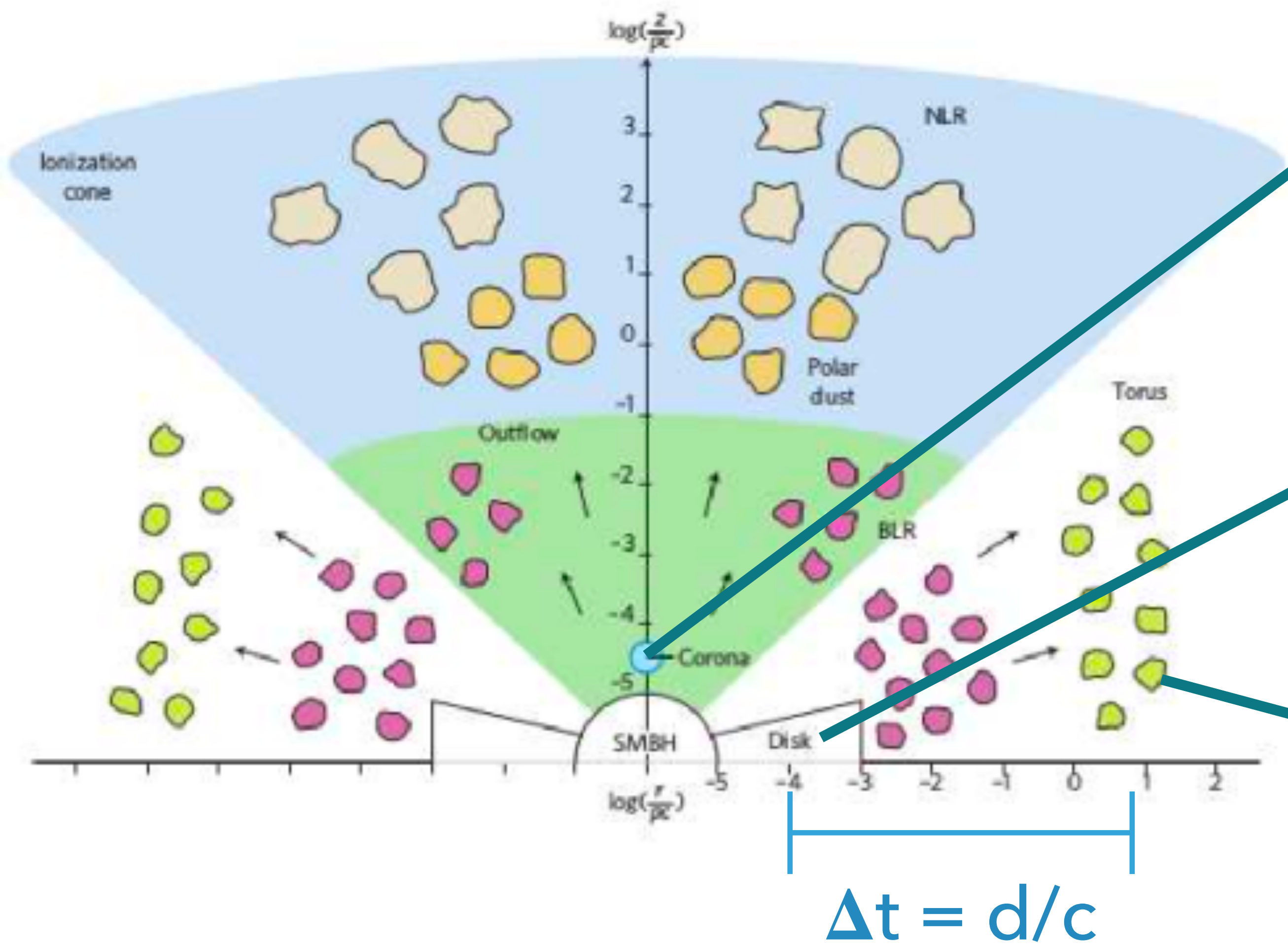
AGN Variability: what do we know?

- The characteristic time-scales of the variability range from hours to years, with the shortest time-scales being associated with shorter emission wavelengths.
- There is a correlation between the variations seen at different wavelengths.

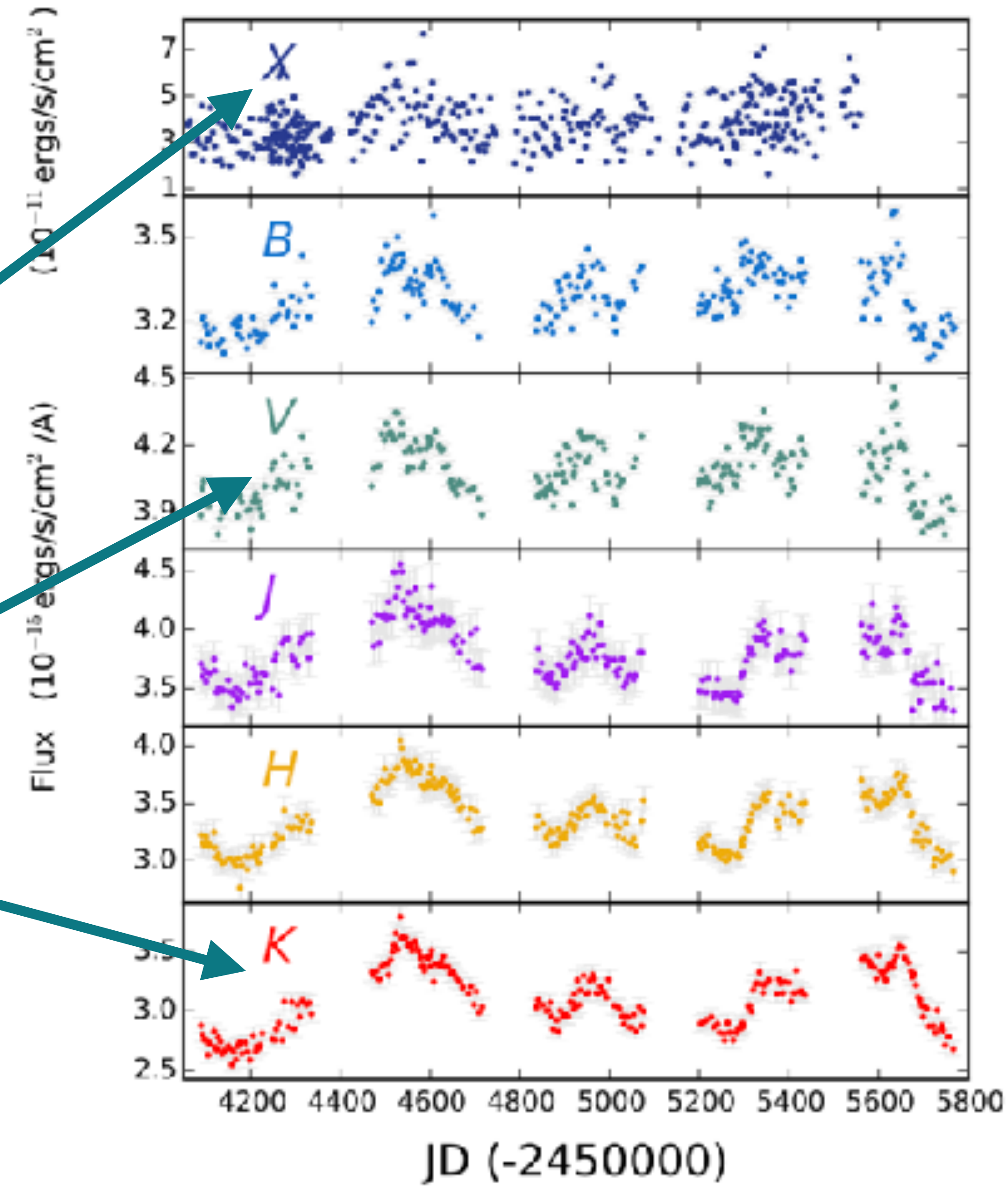


MCG-6-30-15 from Lira et al. 2015

AGN Variability: what do we know?



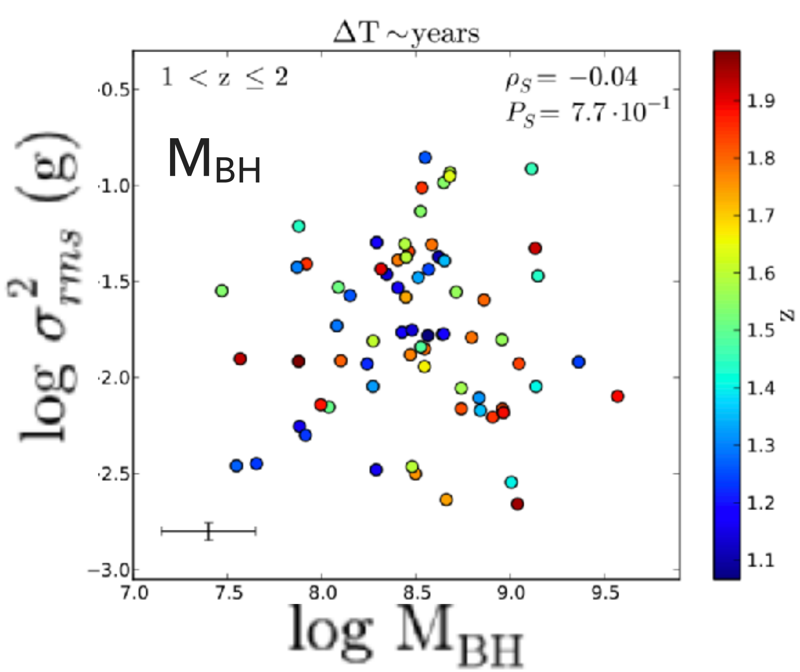
Ramos Almeida & Ricci (2017)

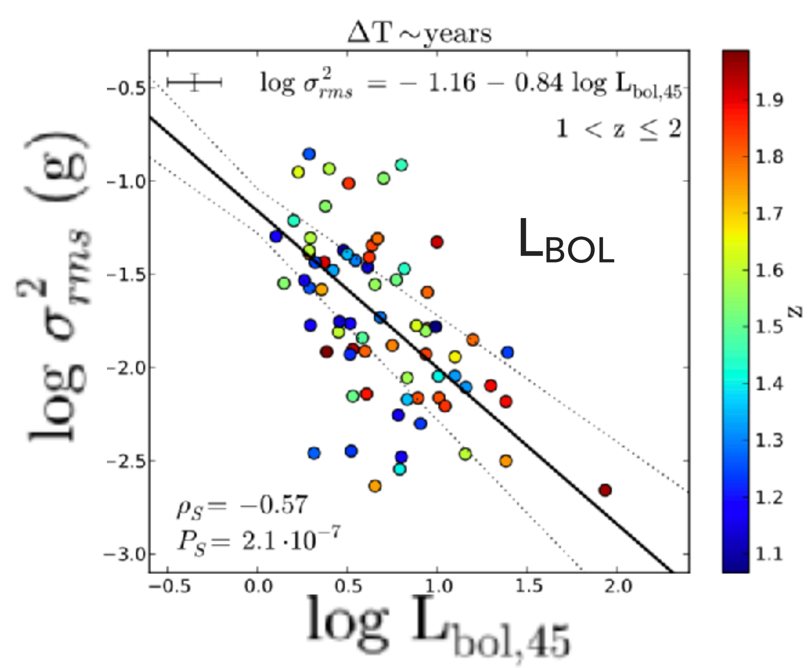


MCG-6-30-15 from Lira et al. 2015

AGN Variability: what do we know?

Connection between AGN variability and black hole physical properties?

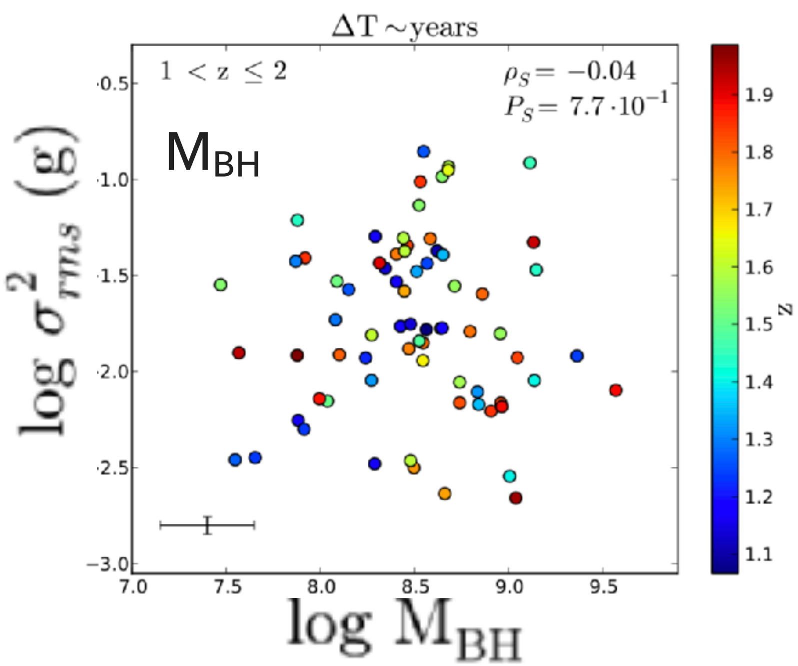


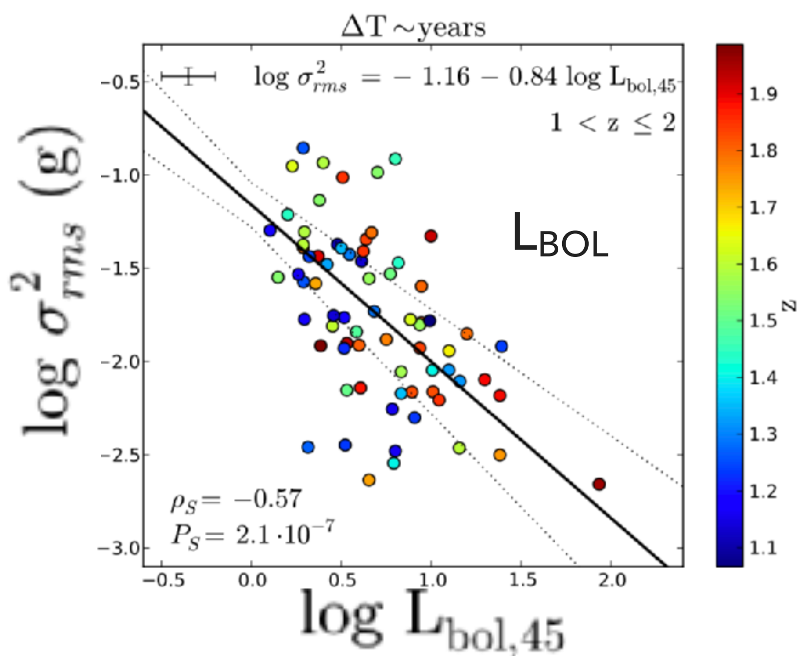


Simm et al. 2016 (**~90 sources**): the **amplitude of the variability is strongly anti-correlated with bolometric luminosity, and there is no evidence of dependency with black hole mass.**

AGN Variability: what do we know?

Connection between AGN variability and black hole physical properties?





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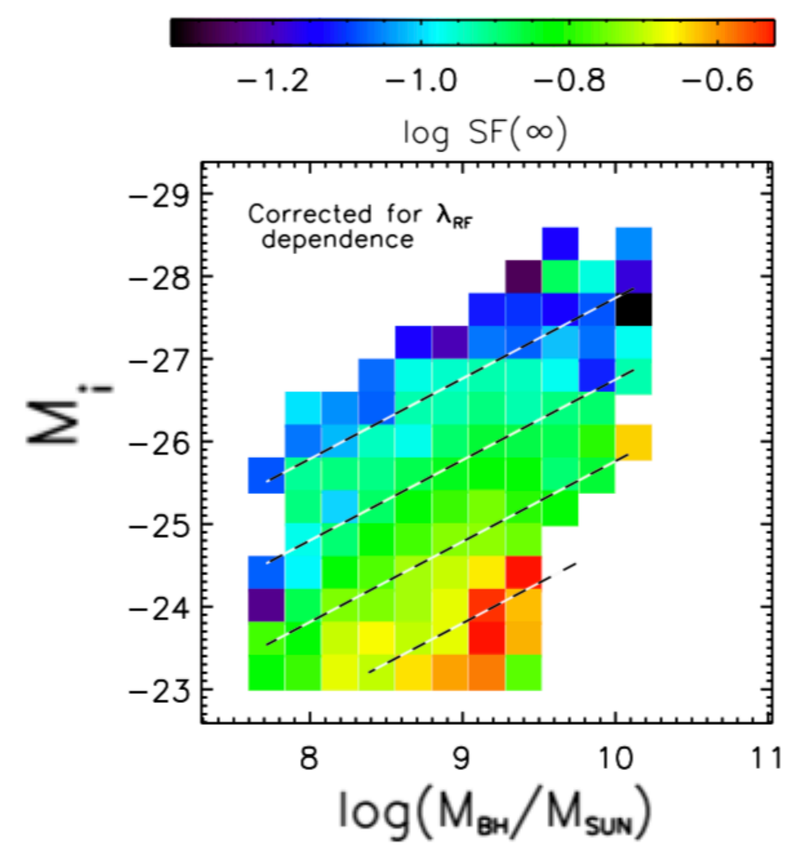
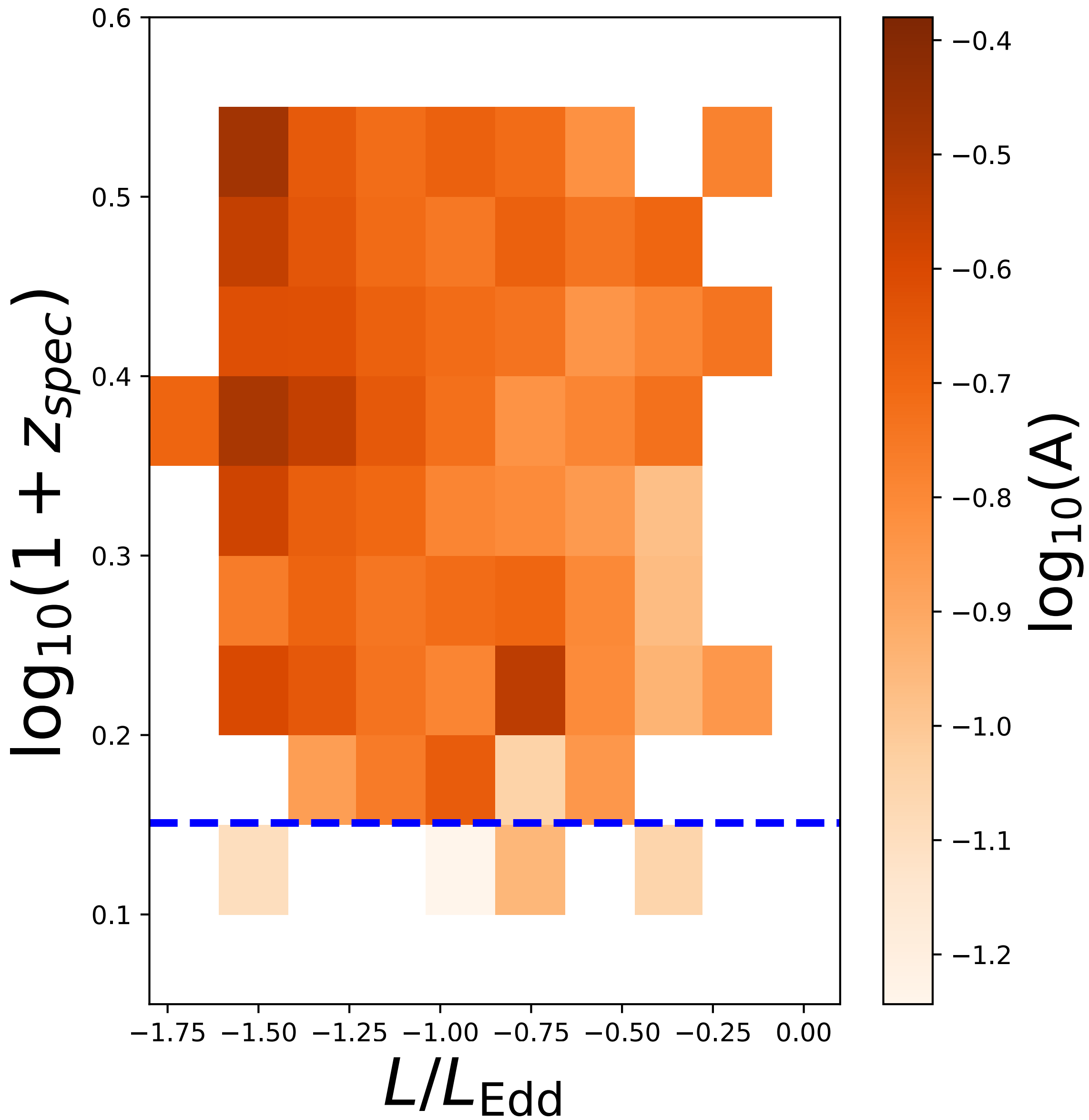


MacLeod et al. 2010 (**~9000 sources**): **the amplitude of the variability correlates with BH mass and anti-correlates with luminosity.**

Variability VS Physical Properties

- Sources from SDSS Data Release 14 Quasar catalog (DR14Q, Pâris et al. 2017a). 1348 QSO with SDSS spectra, and with light curves from the **QUEST-La Silla AGN variability survey** (Cartier et al. 2015).



The amplitude of the variability (A) depends solely on the rest frame emission wavelength and the Eddington ratio, where A anti-correlates with both λ_{rest} and L/L_{Edd}.

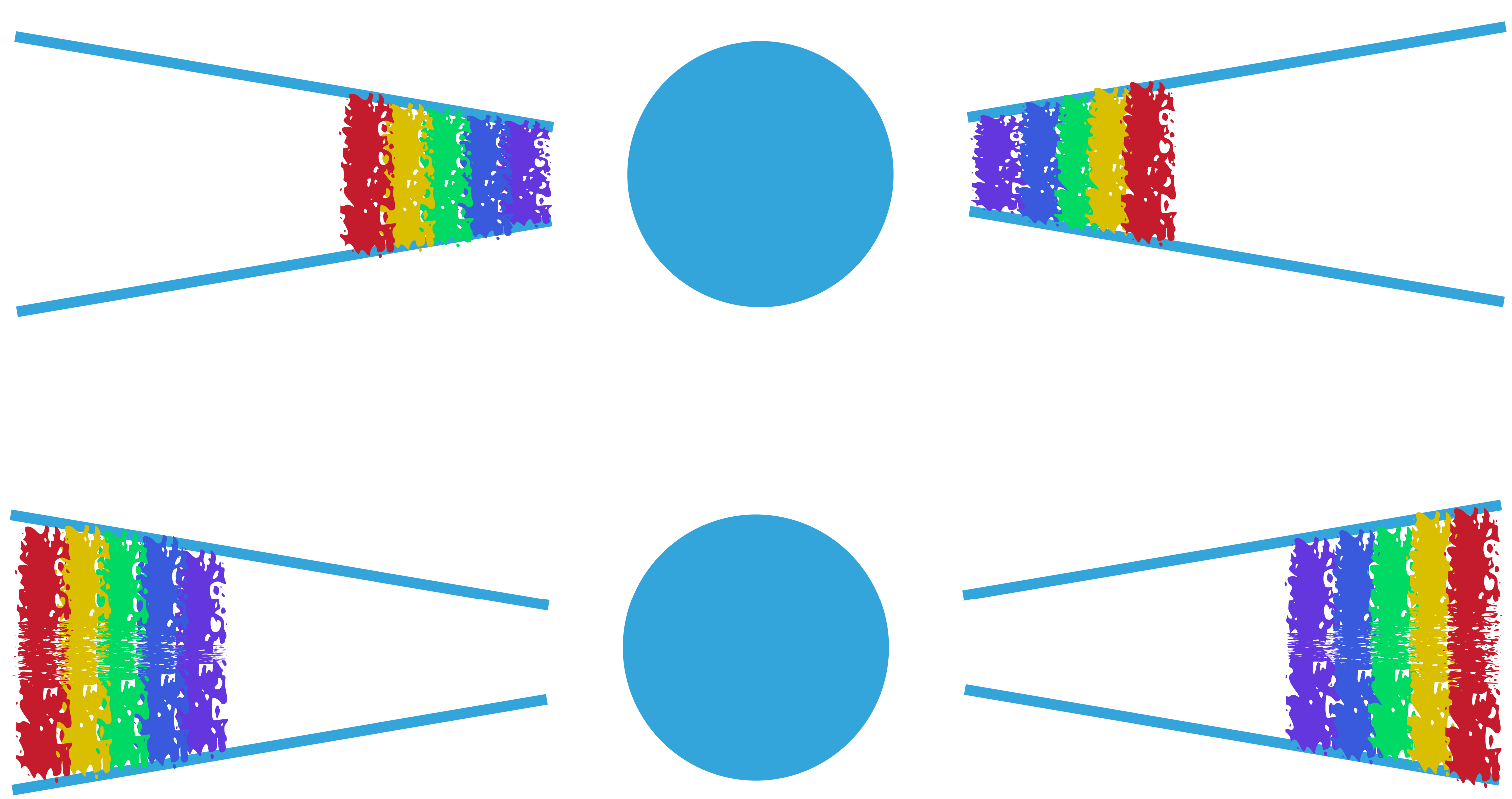
Correlation with z –> anti-correlation with λ_{rest}

Sánchez-Sáez et al. (2018)

L/L_{Edd} as the main driver of the amplitude of the variability

For lower accretion rates, the disk becomes cooler and the innermost, most variable region, will shift its emission from the UV to optical wavebands.

$$r_\lambda \propto M_{\rm BH}^{2/3}(L/L_{\rm Edd})^{1/3}\lambda^{4/3}$$



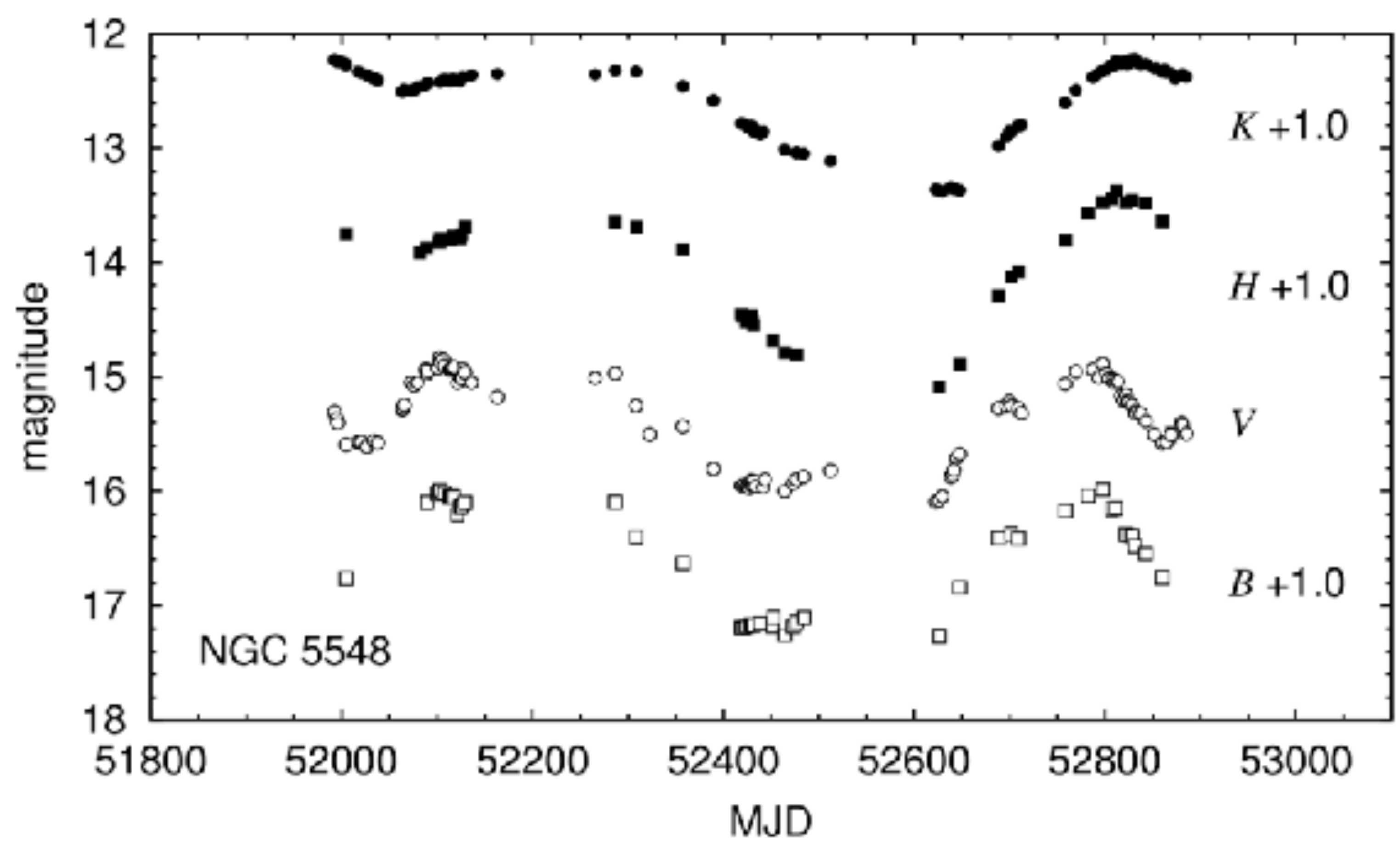
Sánchez-Sáez et al. (2018)

DUST REVERBERATION MAPPING

Dust Reverberation Mapping: what do we know?

Suganuma et al. 2006

- Four nearby Seyfert 1 galaxies.

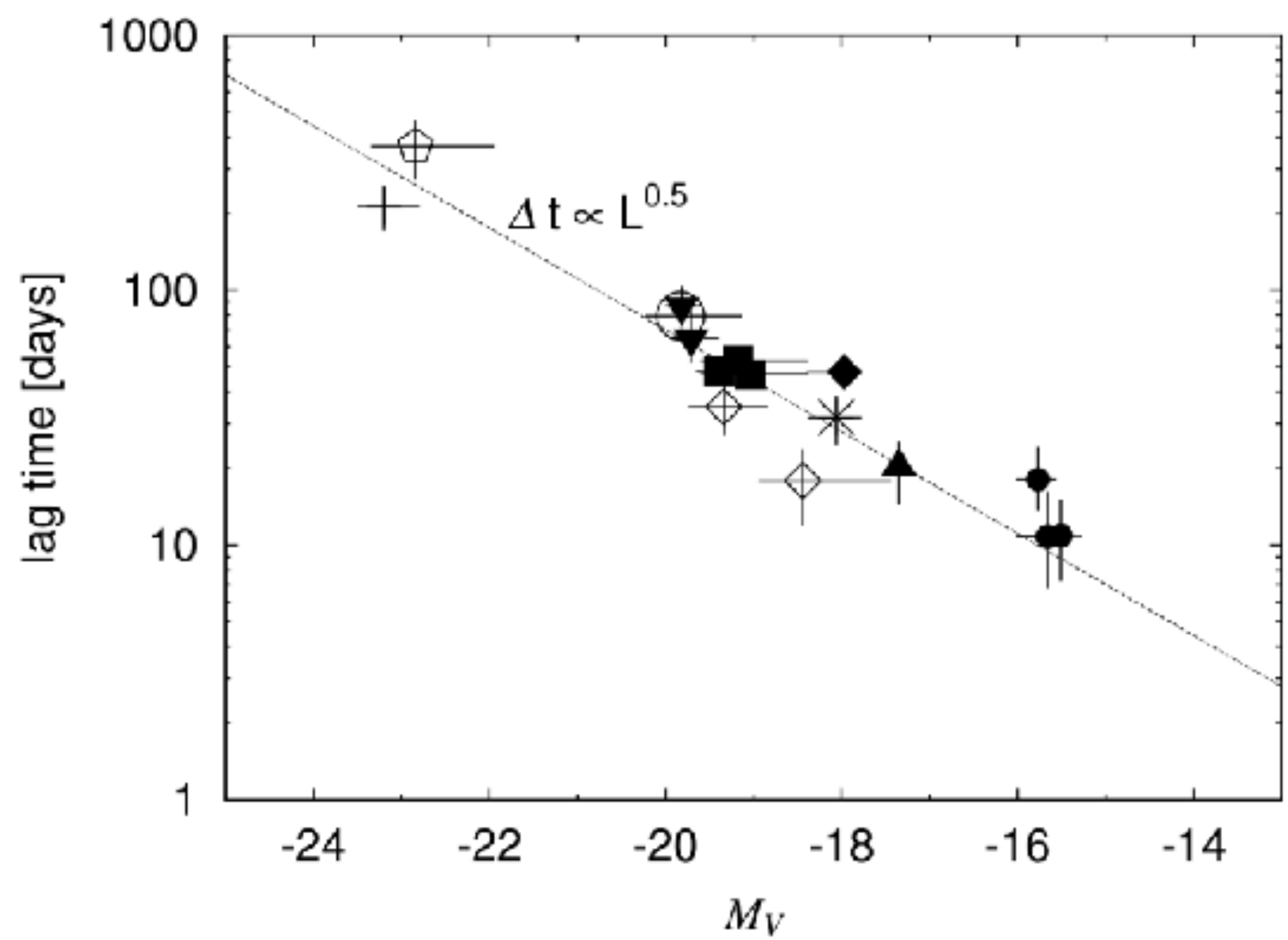


Dust Reverberation Mapping: what do we know?

Suganuma et al. 2006

- Four nearby Seyfert 1 galaxies.
- The lag times are tightly correlated with the optical luminosities.

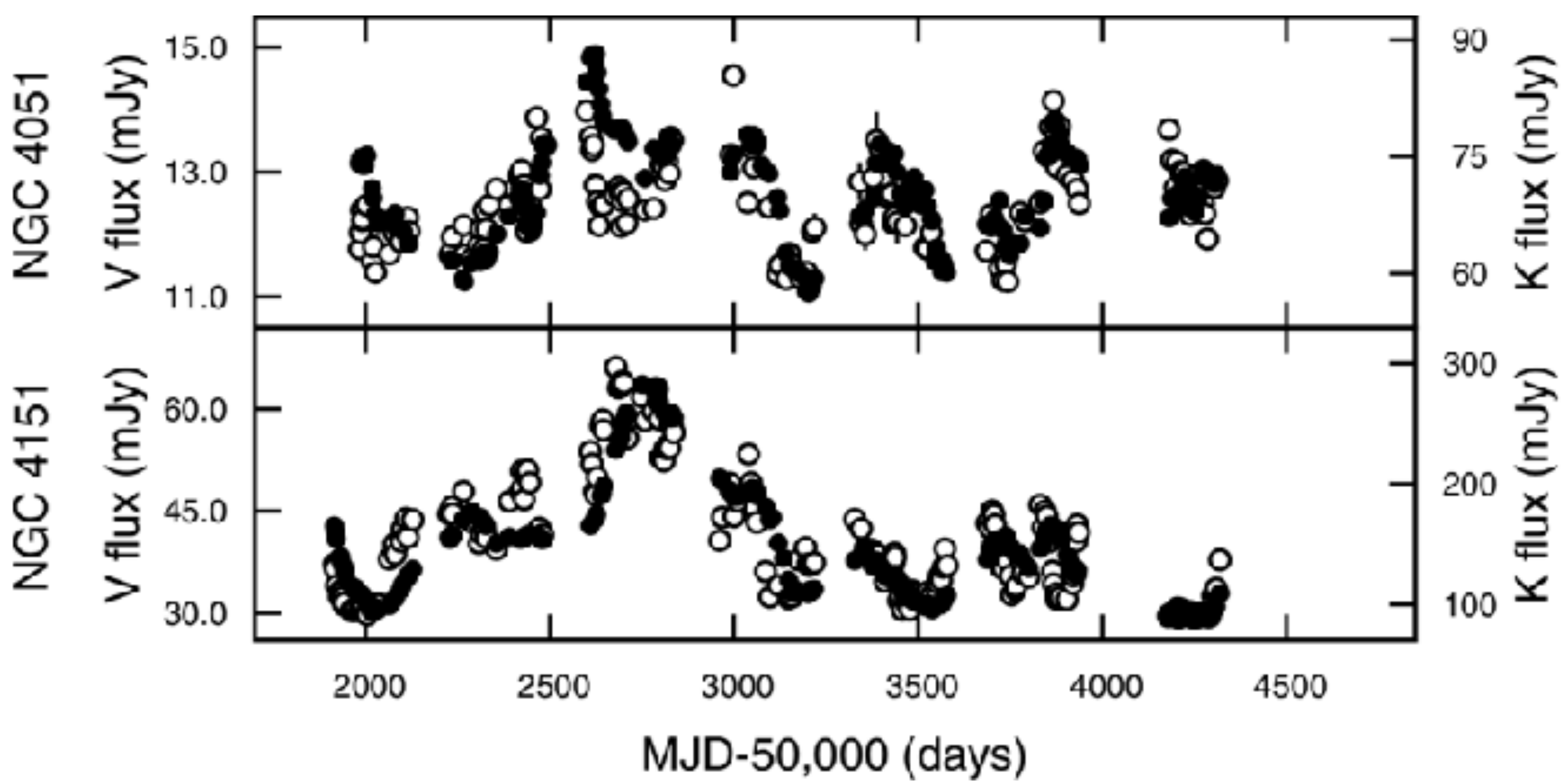
$$\Delta t \propto L^{0.5}$$



Dust Reverberation Mapping: what do we know?

Koshida et al. 2014

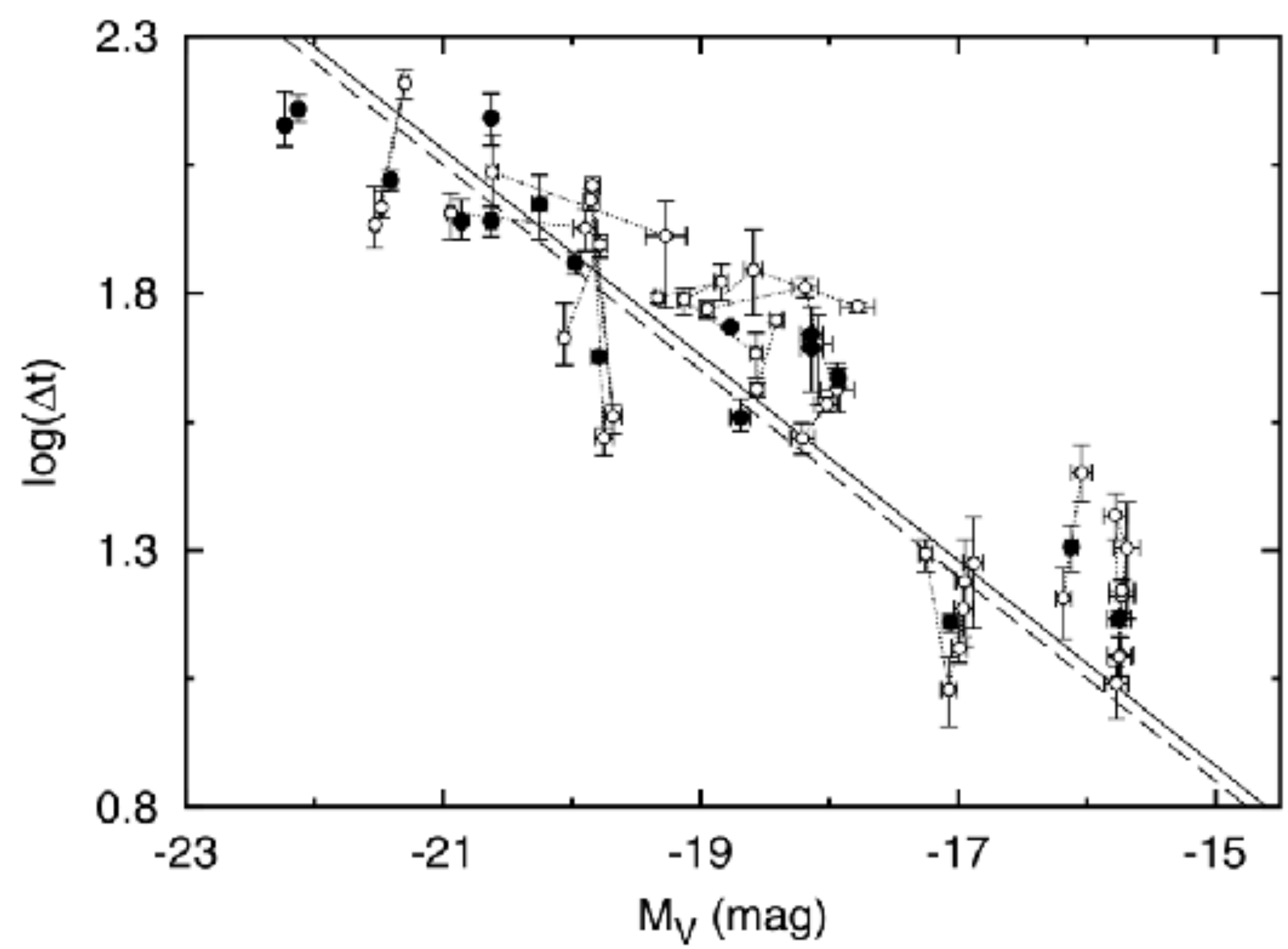
- 17 nearby Seyfert 1 galaxies.



Dust Reverberation Mapping: what do we know?

Koshida et al. 2014

- 17 nearby Seyfert 1 galaxies.
- The lag times strongly correlated with the optical luminosity in the luminosity range of M_V ~ -16 to -22.

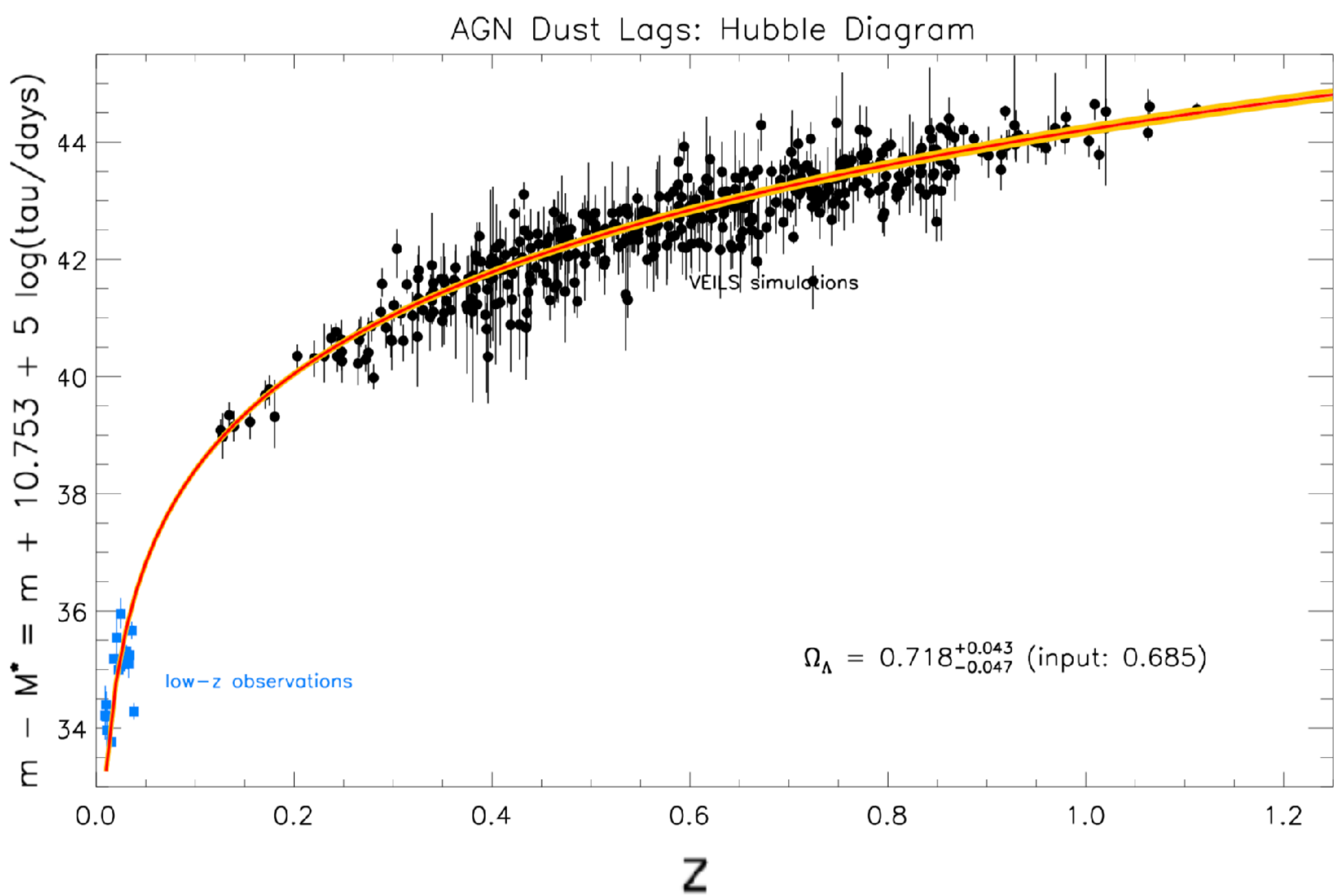


$$\Delta t \propto L^{0.5} \longrightarrow \quad \log_{10}\Delta t = -2.11 - 0.2 M_V$$

Dust Reverberation Mapping: AGN as standard candles?

The tight correlation of the optical-NIR time lag with luminosity can be used to define a new standard candle for cosmology.

Hönig et al. 2017



REVERBERATION MAPPING OF HIGH Z SOURCES

NIR ANALYSIS

ULTRAVISTA SURVEY

ULTRAVISTA DATA

(McCracken et al. 2012)

- Single epoch images of the **COSMOS** field, taken between December 2009 and June 2016.
- Instrument: VIRCAM
- **Y,J,H** and **Ks** bands

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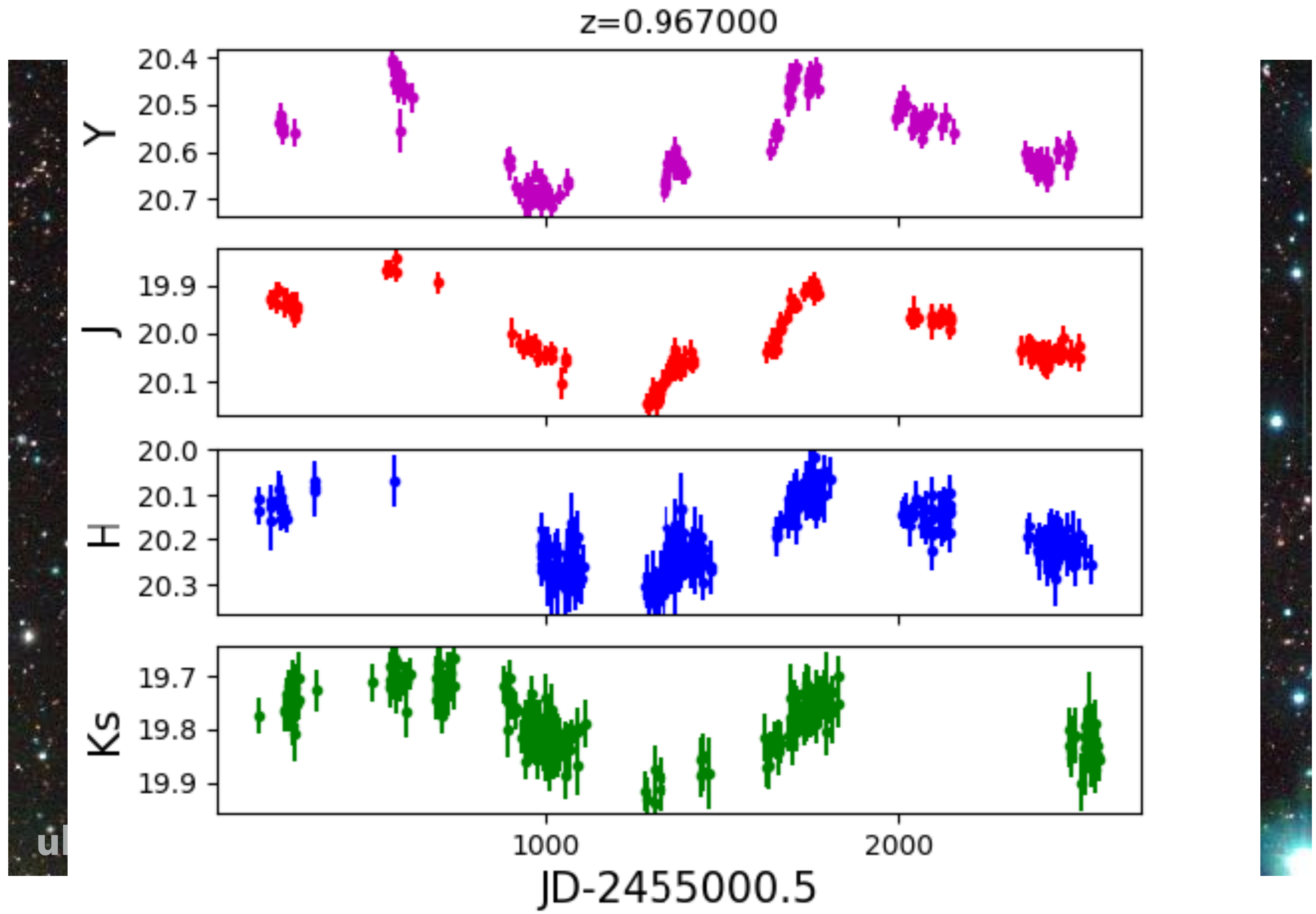
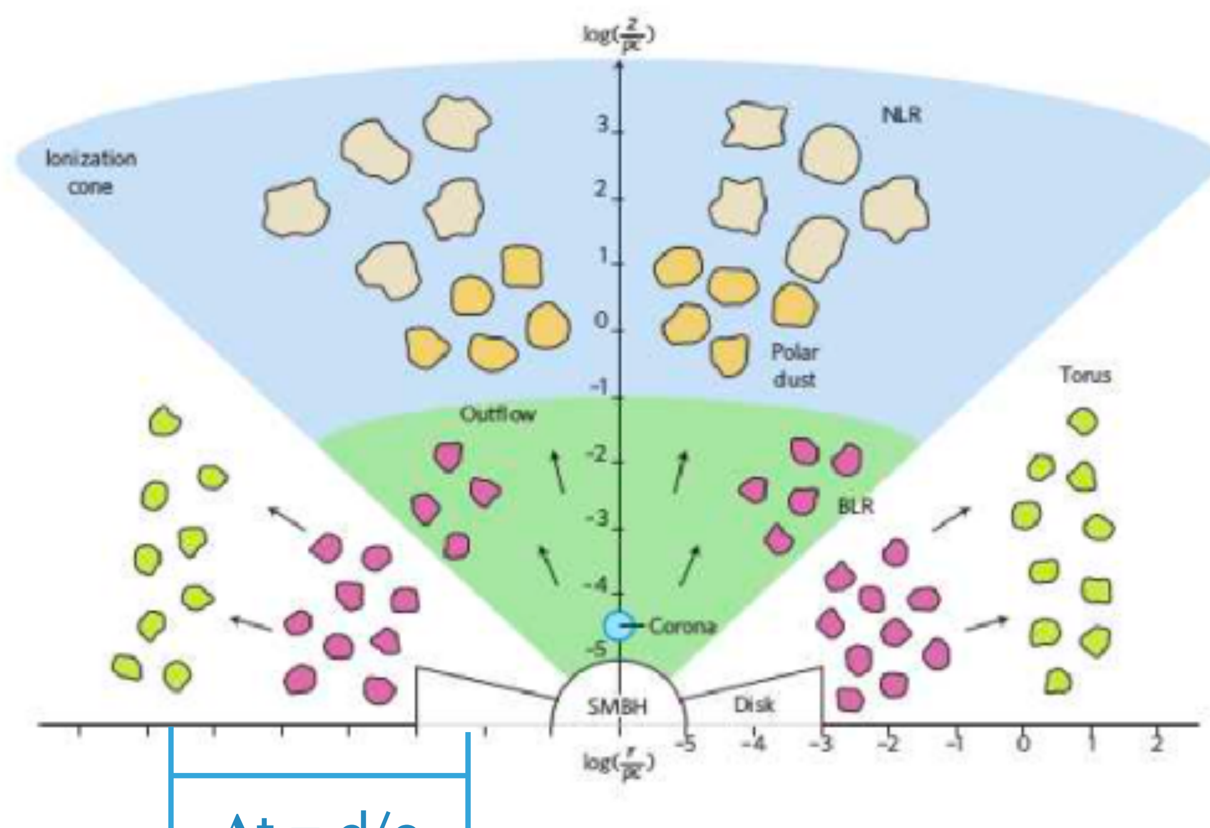


Dust Reverberation Mapping (RM)

- RM analysis of ~100 type 1 AGN with **z<1.2**. (selected from Marchesi et al. 2016 and Flesch 2015) using UltraVISTA data.
  - Is the emission received in the NIR from high redshift sources consistent with emission from the dusty torus or the accretion disk?
  - Is the correlation between luminosity and time delay observed at higher z?



Ramos Almeida & Ricci (2017)

Dust Reverberation Mapping

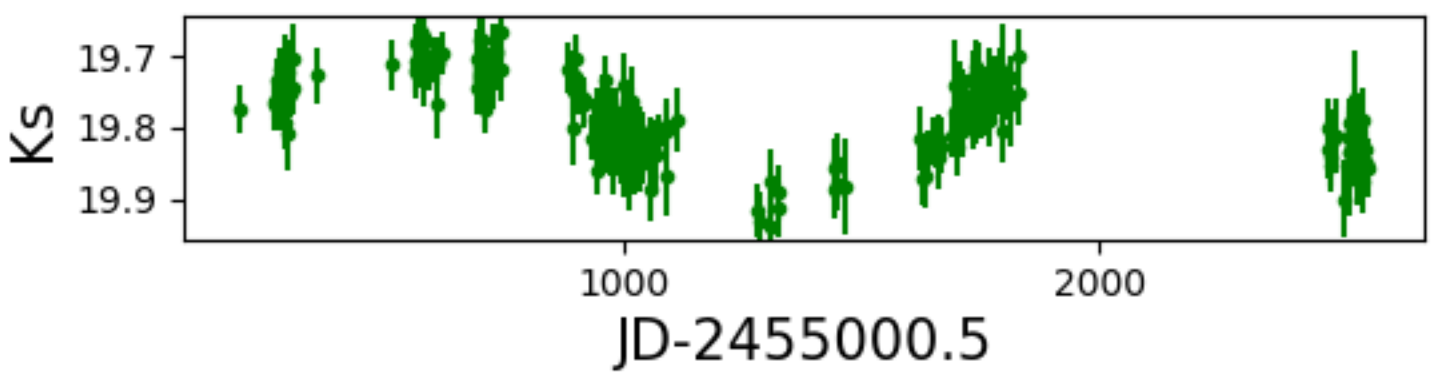
Challenges at z~1

Challenges at z~1

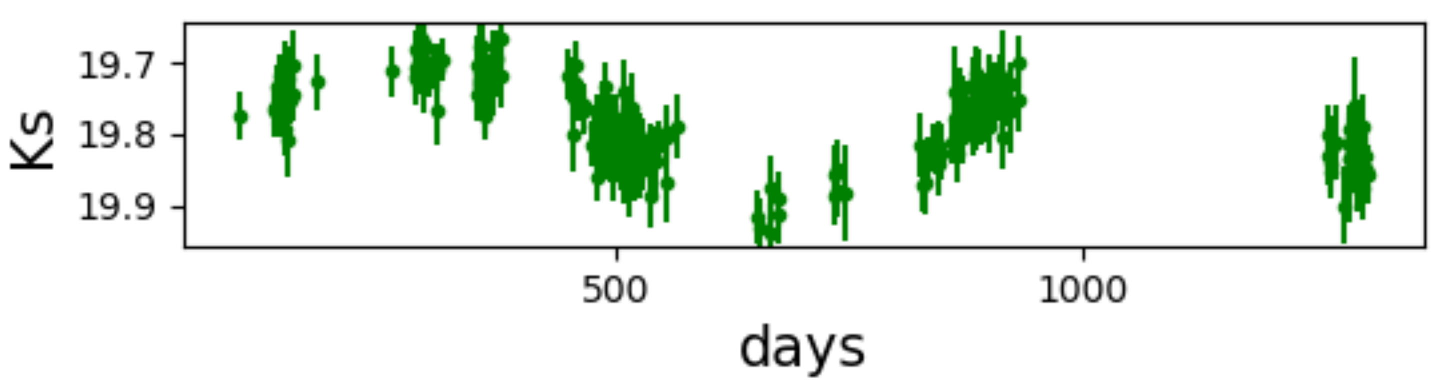
- Time dilation:

$$t_{rest} = \frac{t_{obs}}{(1+z)}$$

Observed frame

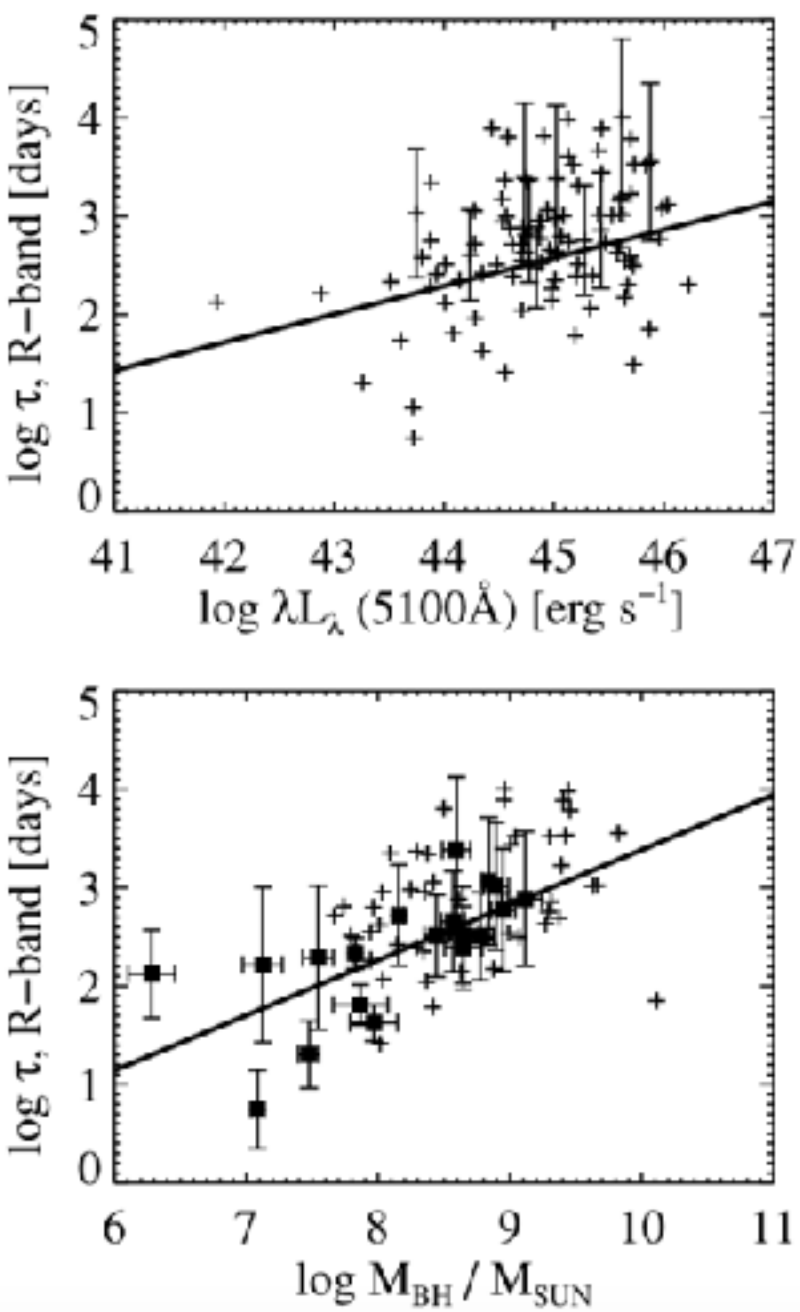


Rest frame



Challenges at z~1

- Time scale of the variability of AGN



Kelly et al. 2009

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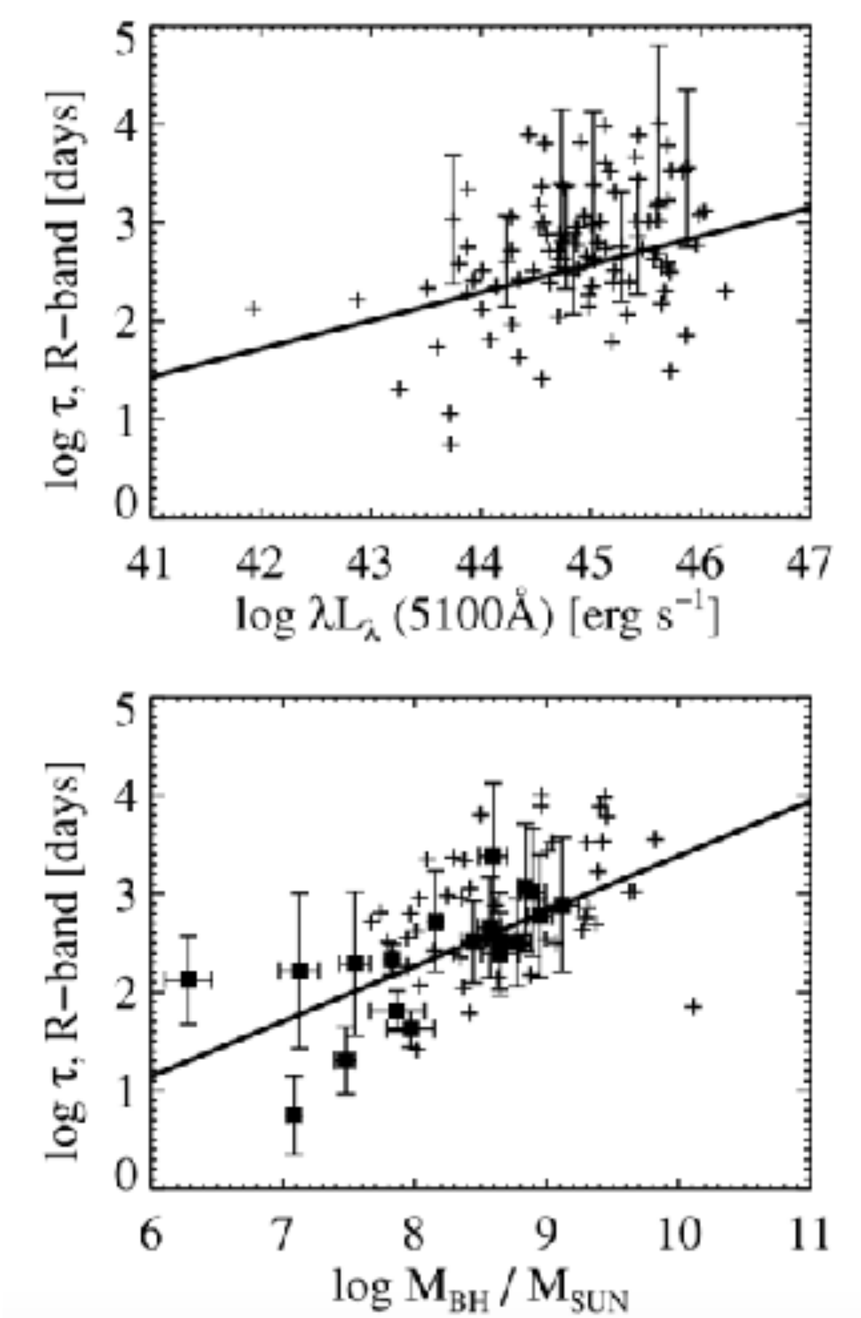
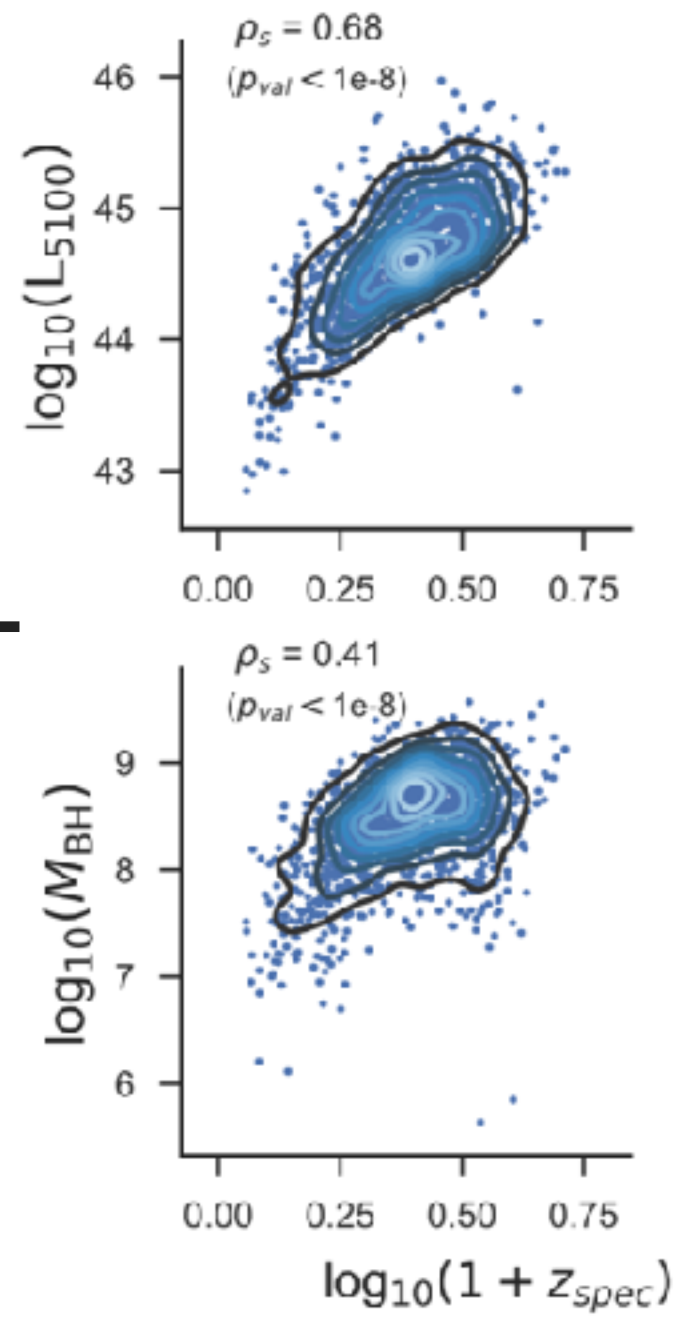


Kelly et al. 2009

+



Sánchez-Sáez et al. 2018

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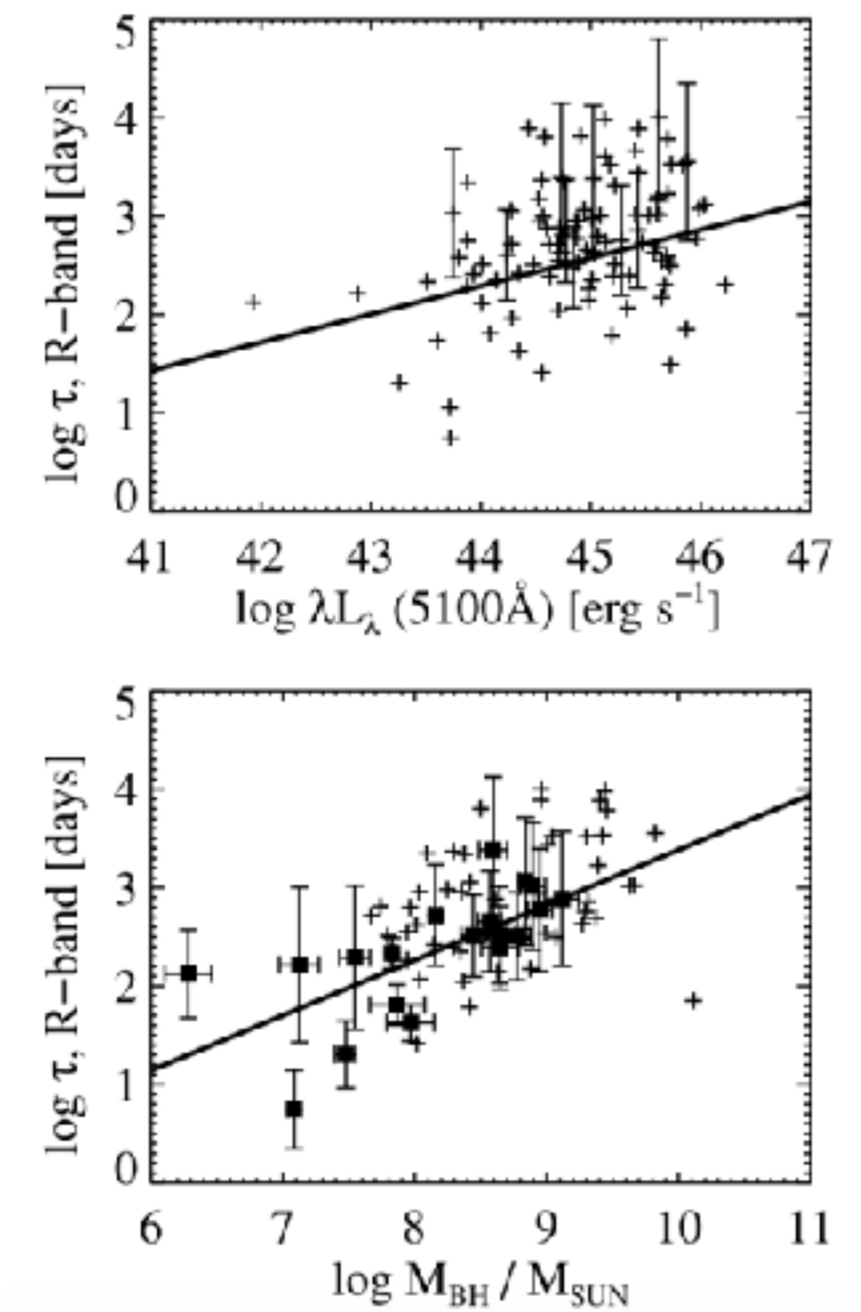

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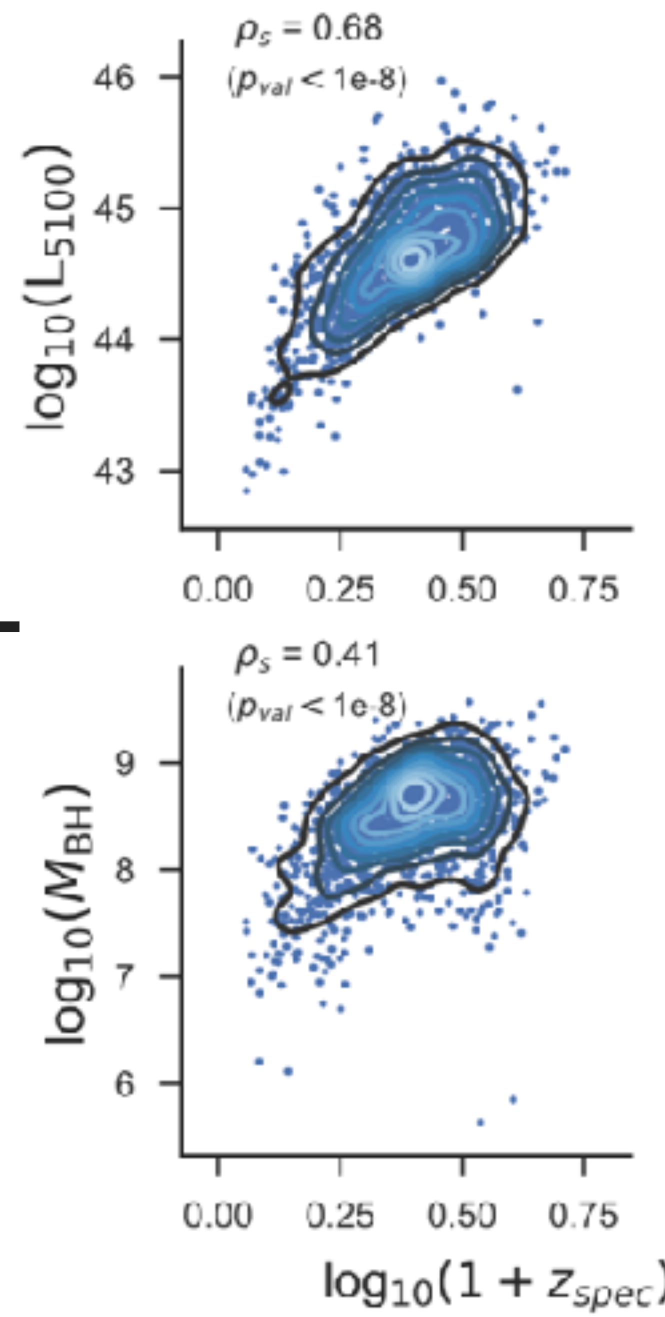
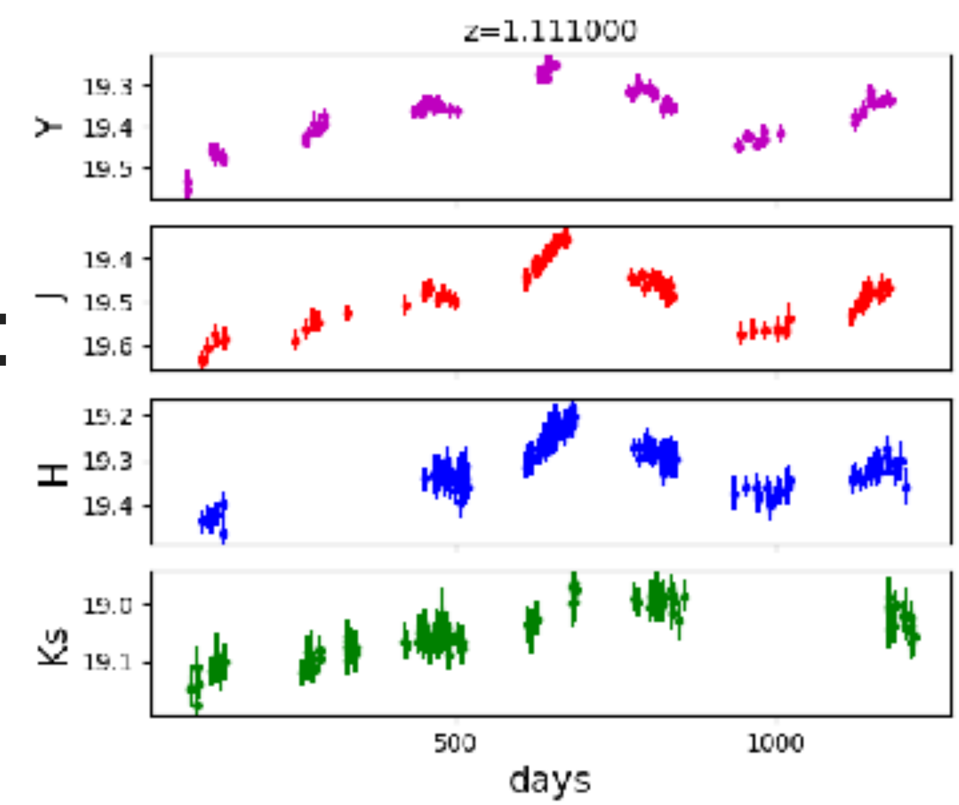


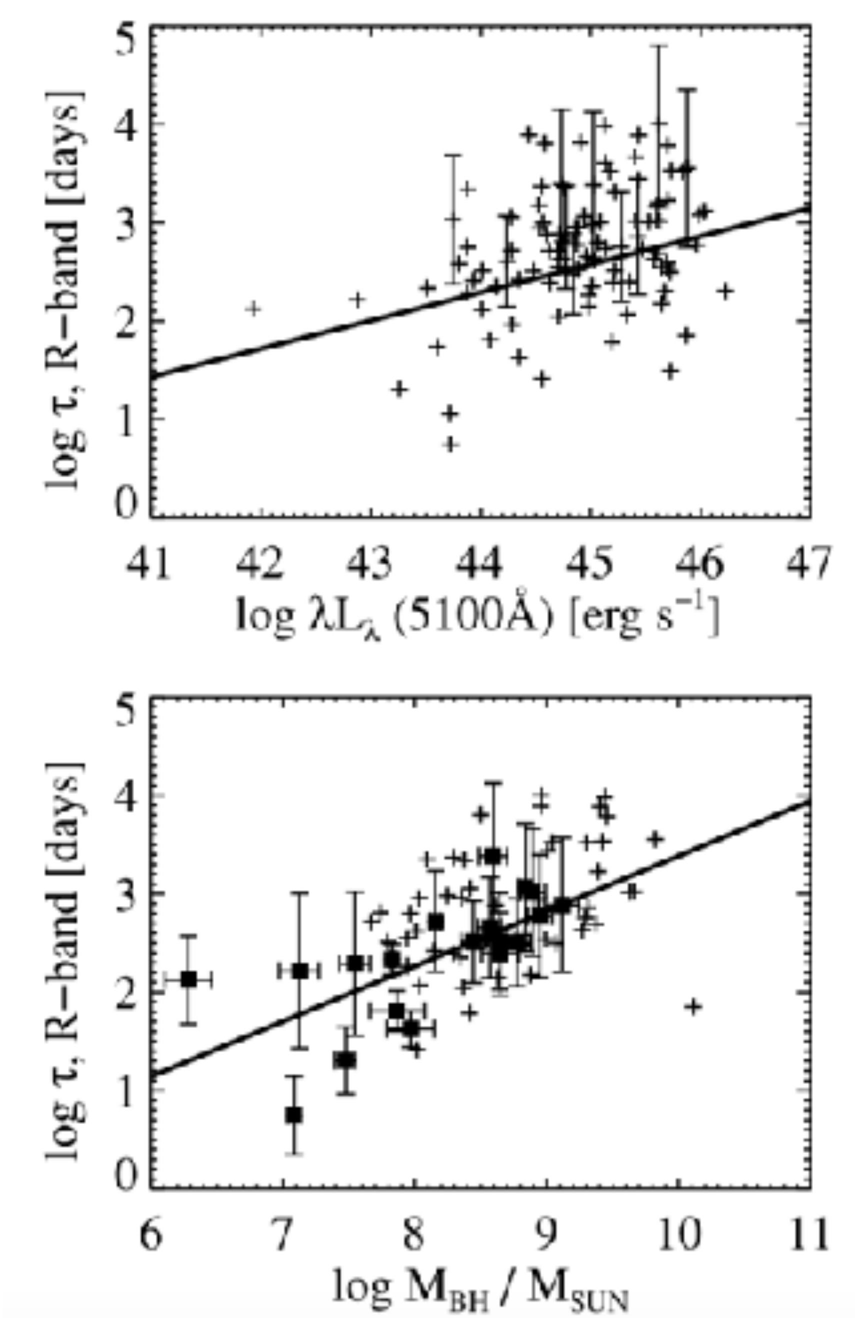
Sánchez-Sáez et al. 2018



$M_V \sim -24$

Challenges at z~1

- Time scale of the variability of AGN



Kelly et al. 2009

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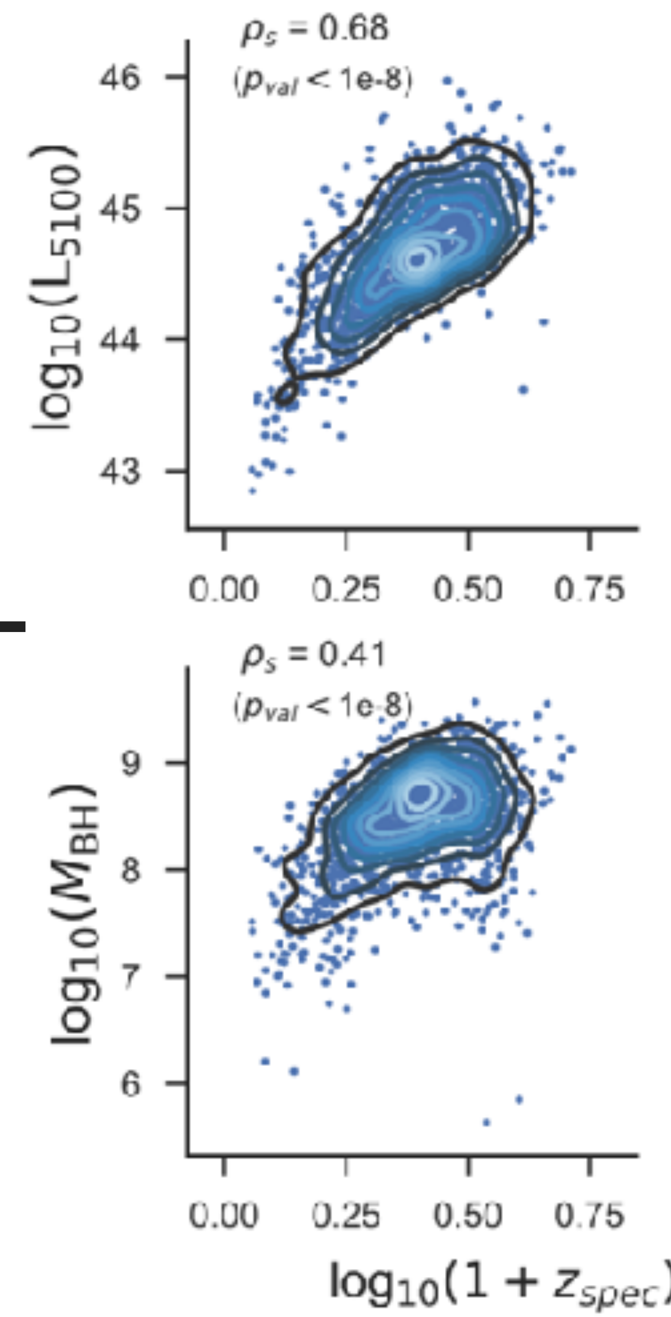

Sánchez-Sáez et al. 2018

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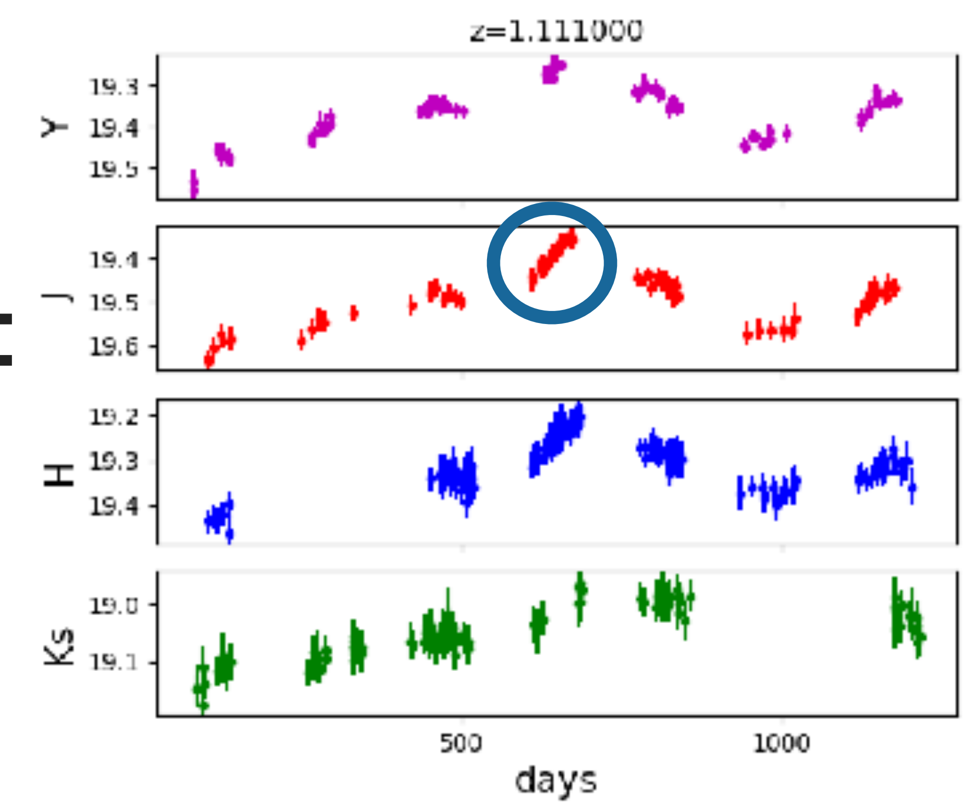
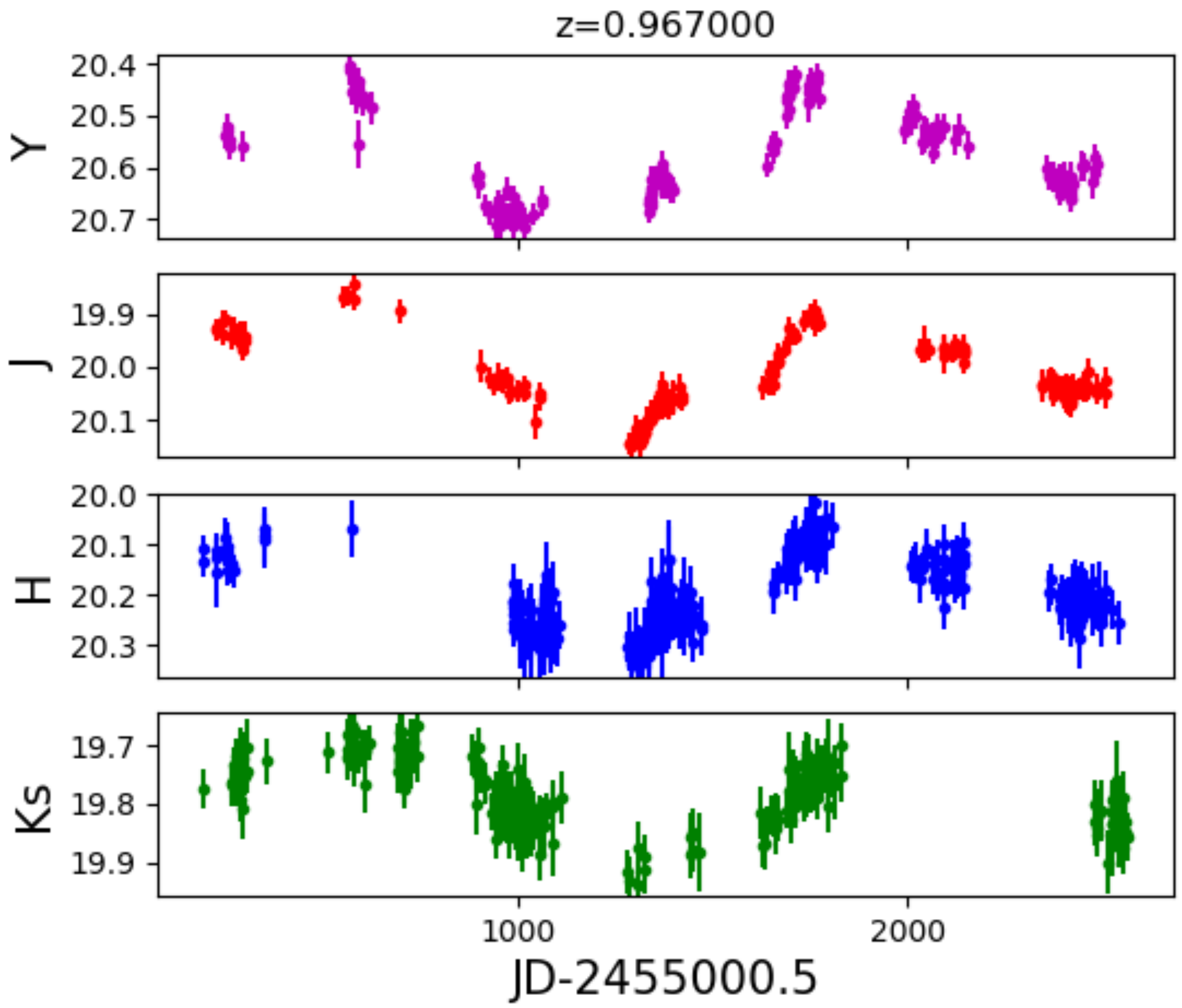


M_V ~ -24

Challenges at z~1

- Light curve cadence: GAPS



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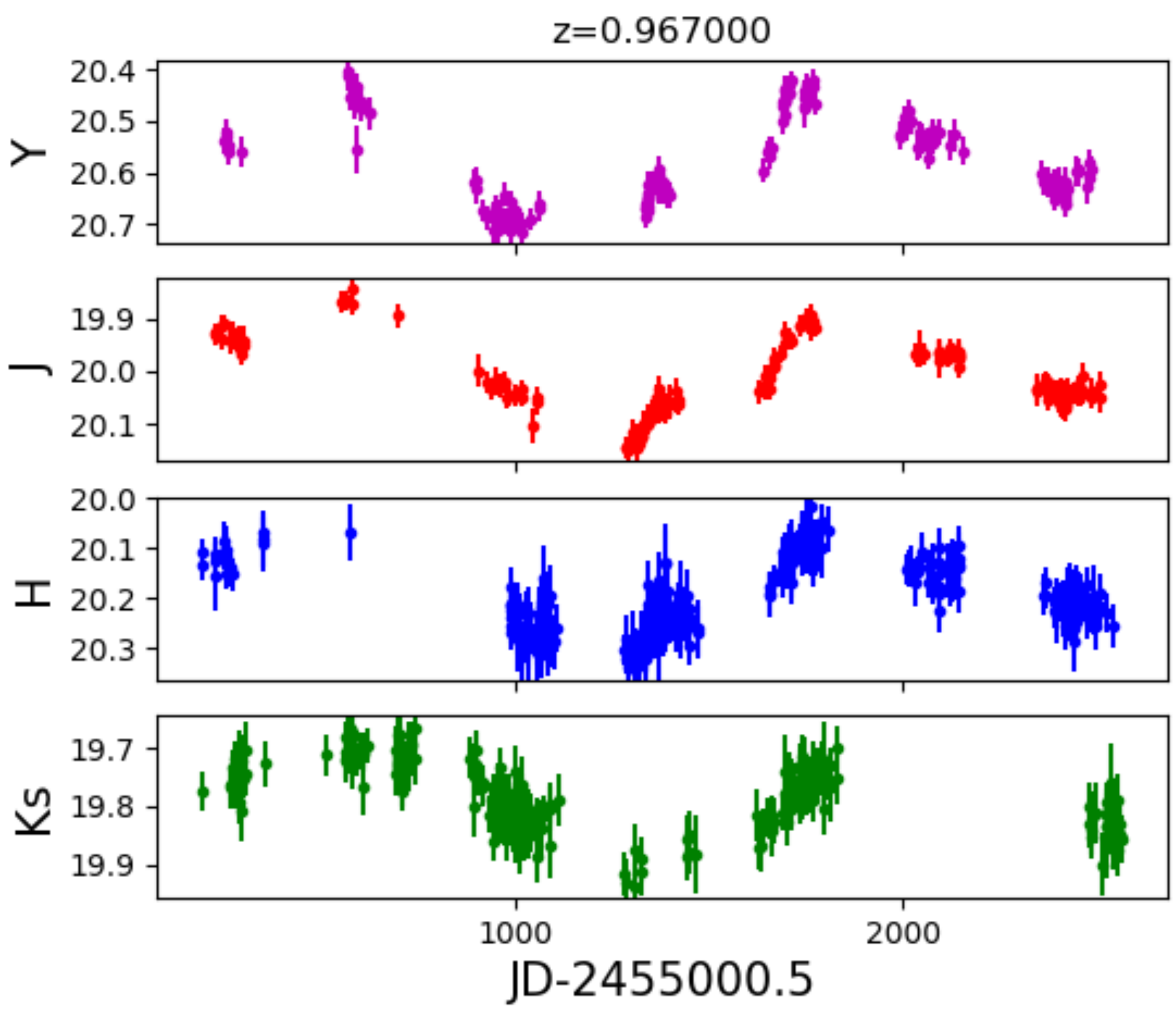
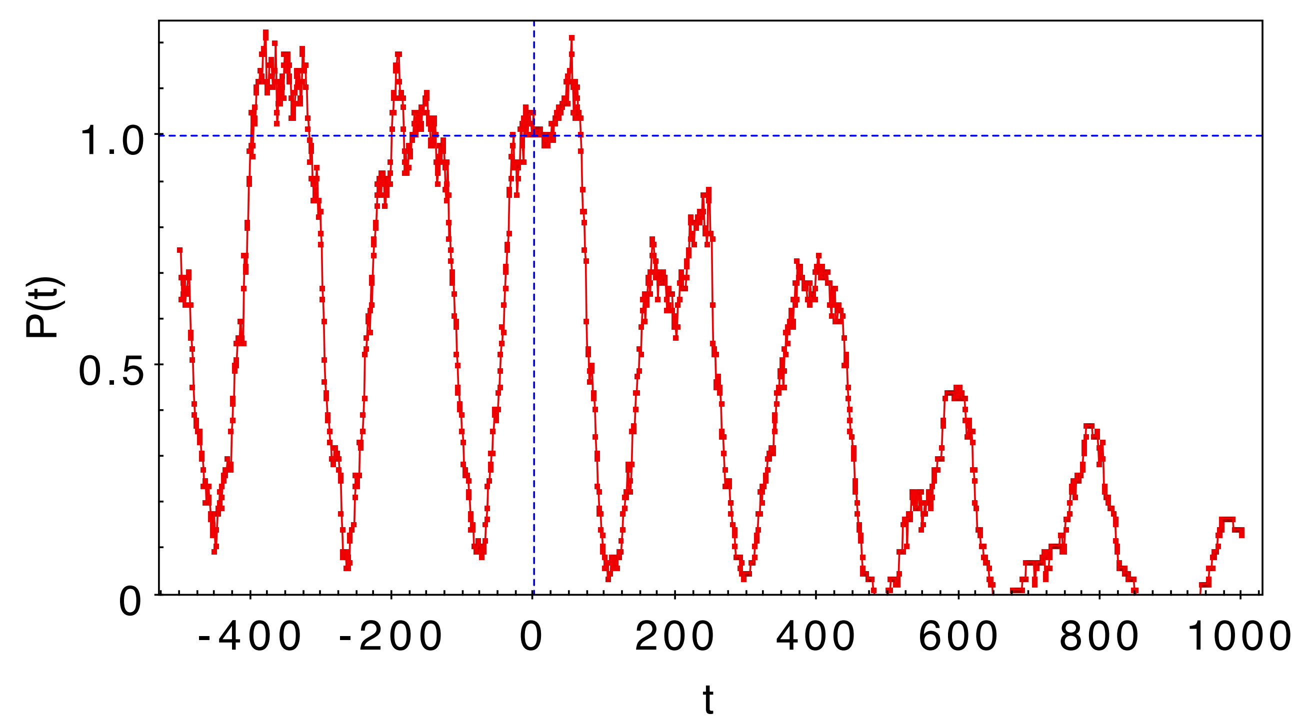


$$P(t) = \frac{N(t)}{N(0)}$$



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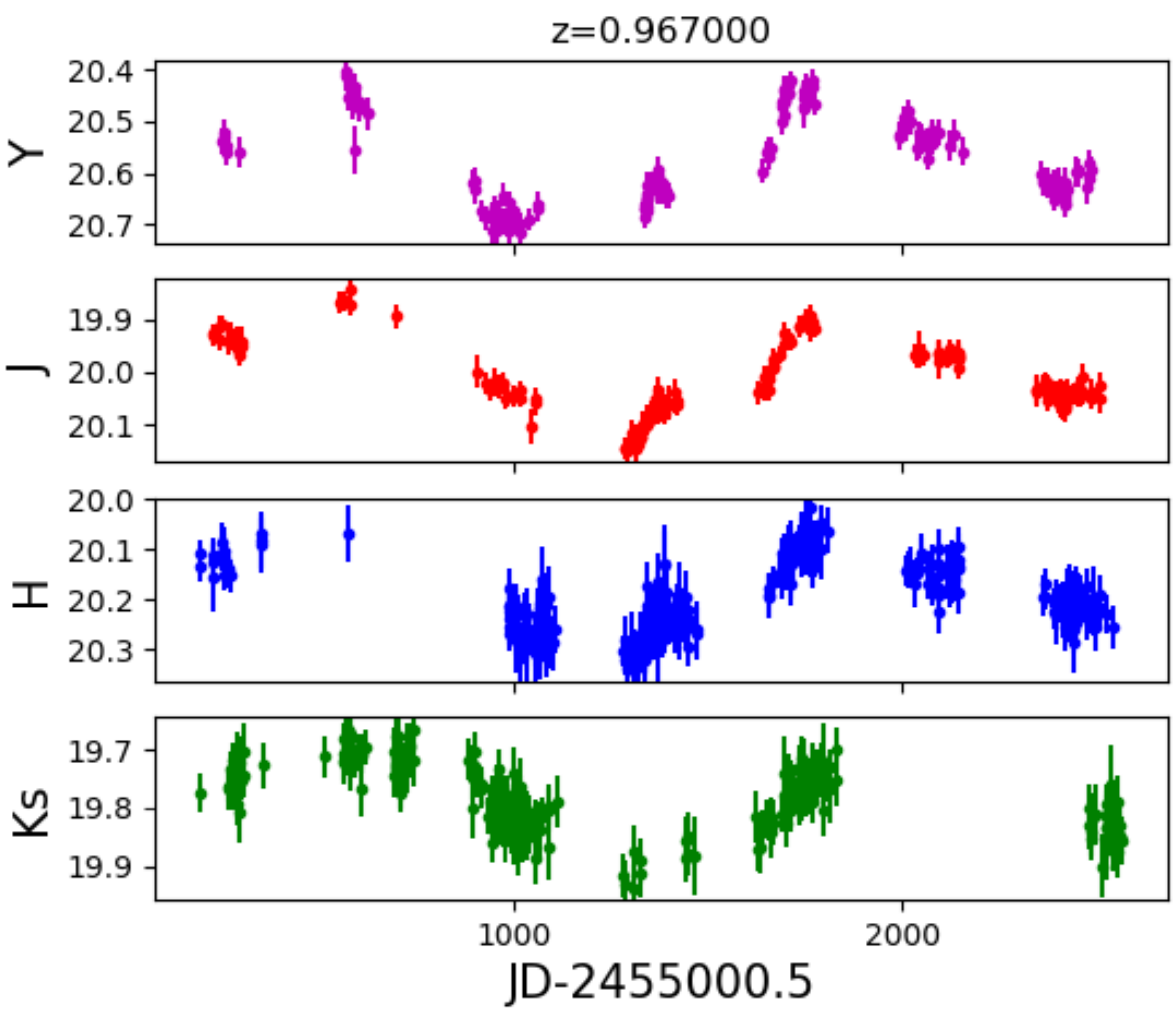
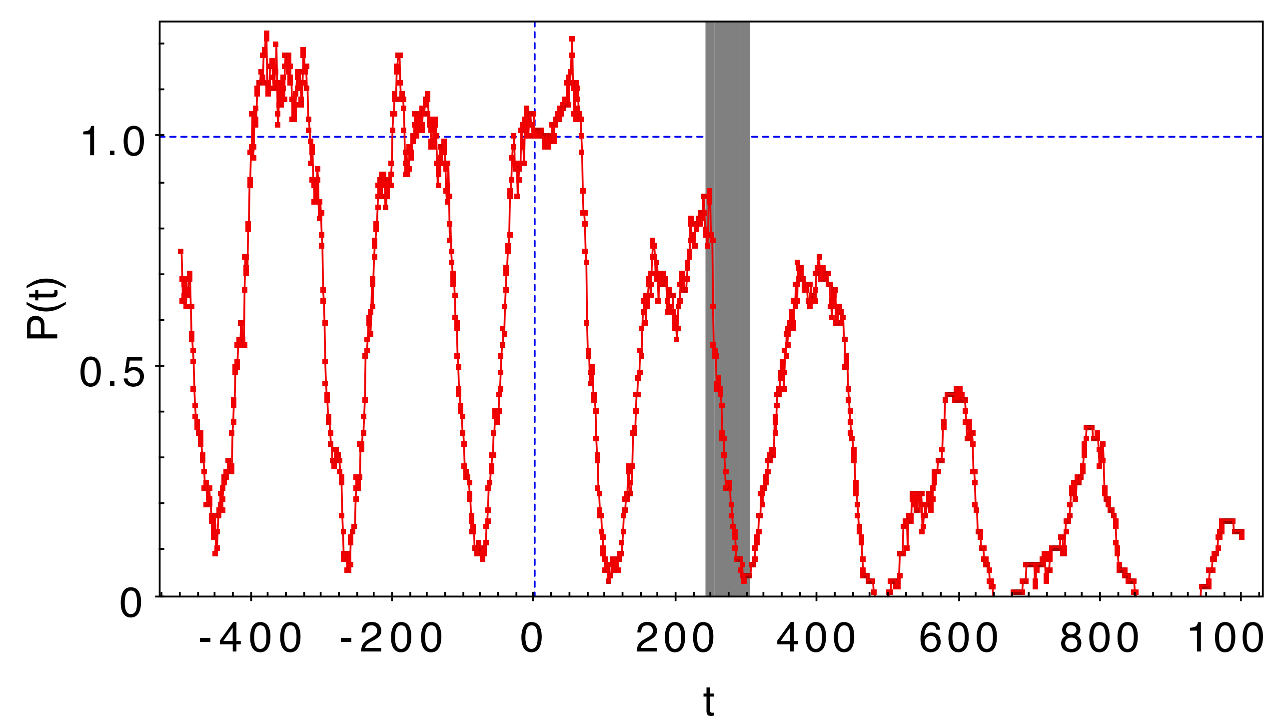
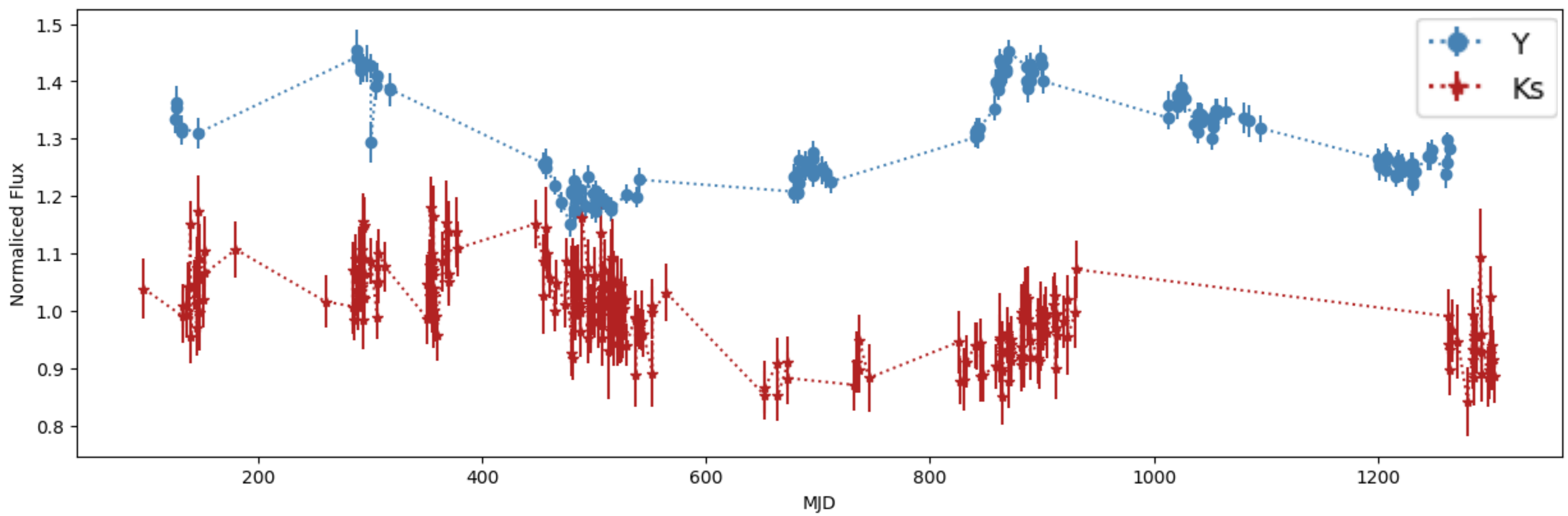


Lag range predicted from Koshida et al. 2014

$M_V \sim -22.7$



Measuring the time delays



ICCF

- Interpolate between real data points to obtain a regular sampling.
- Estimates errors by FR/RSS

$$\mathrm{CCF}(\tau) = \frac{E[(a(t) - E_a)(b(t+\tau) - E_b)]}{\sqrt{V_a V_b}}$$

ZDCF

- Bins the data over discrete time intervals with different widths.
- Estimates errors by Monte Carlo simulations.

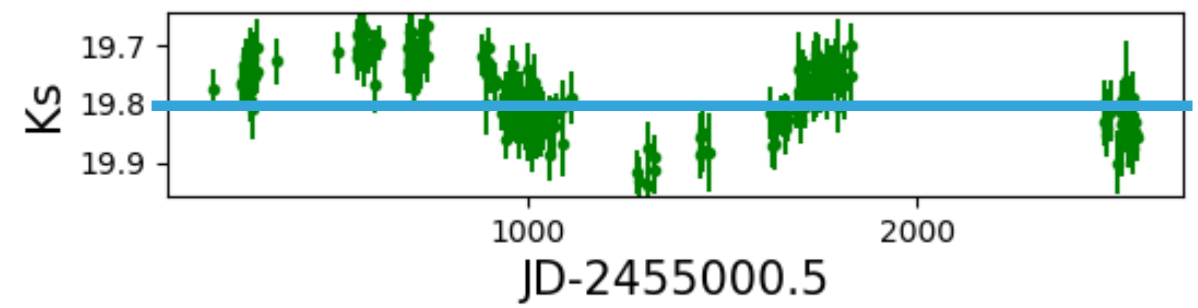
$$r = \frac{\sum_i^n (a_i - \bar{a})(b_i - \bar{b})/(n-1)}{s_a s_b}$$

Javelin

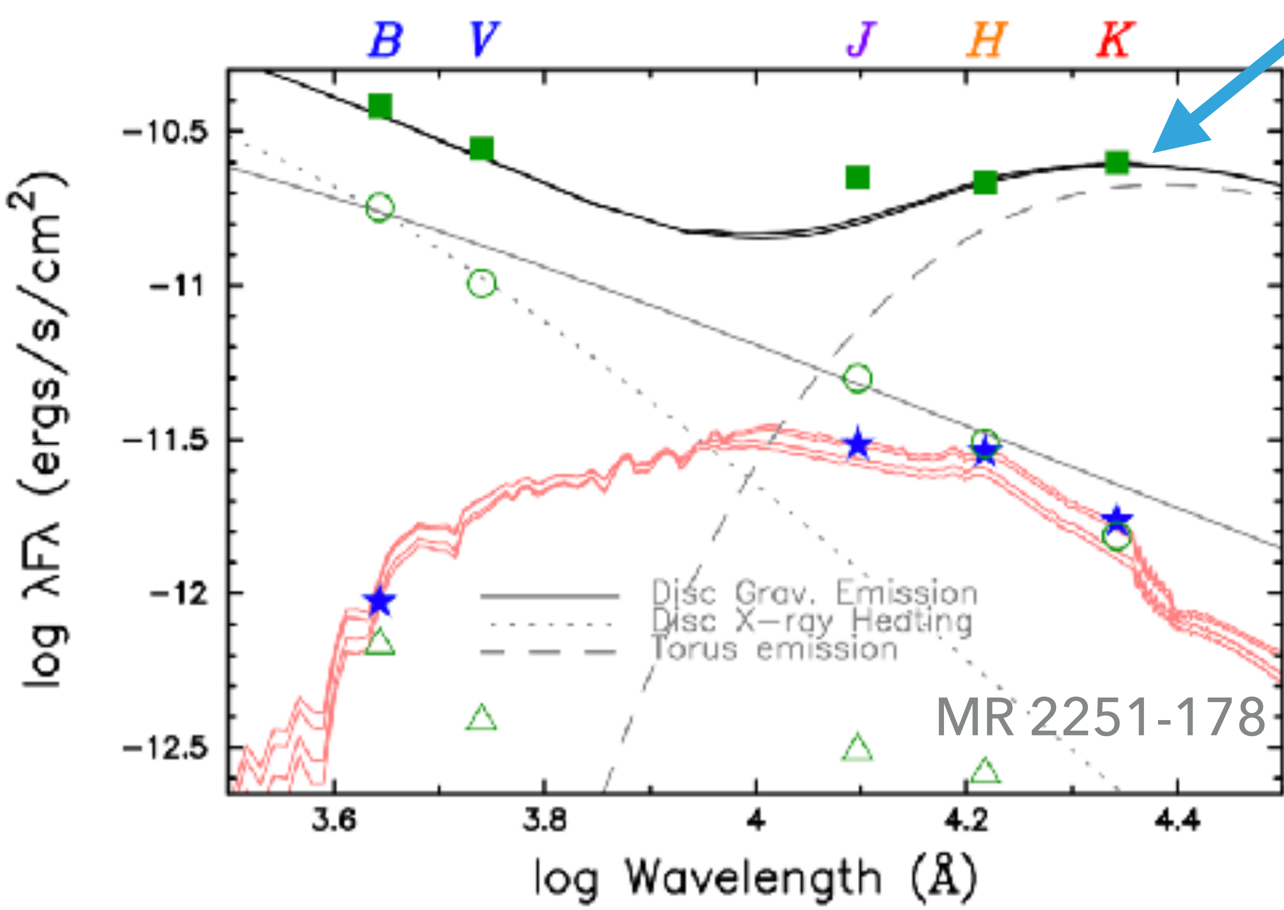
- Damp Random Walk (DRW) modeling of the light curves.
- Errors are included in the modeling.

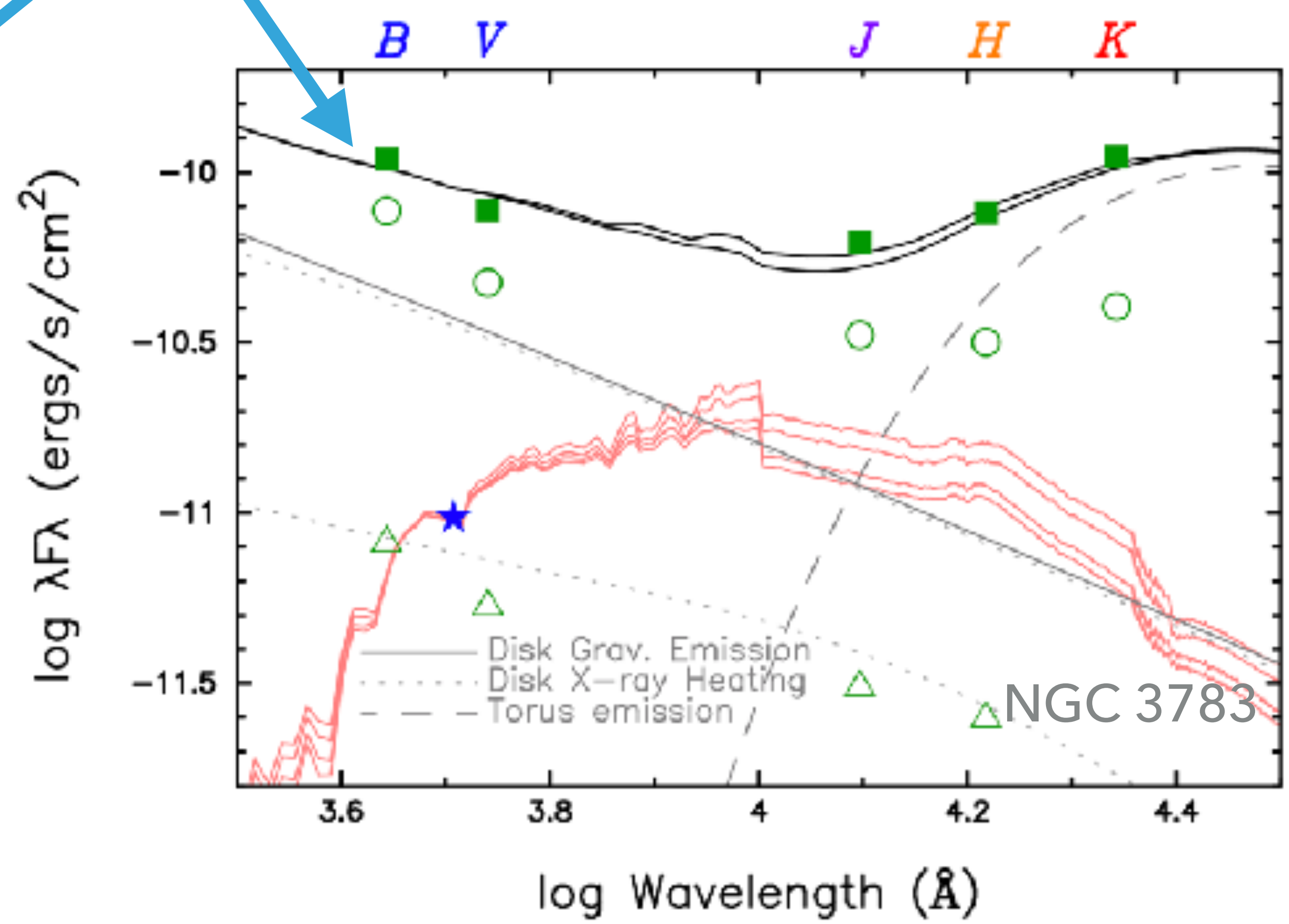
$$dX(t) = -\frac{1}{\tau} X(t) dt + \sigma\sqrt{dt}\ \epsilon(t) + b\ dt$$

SED analysis



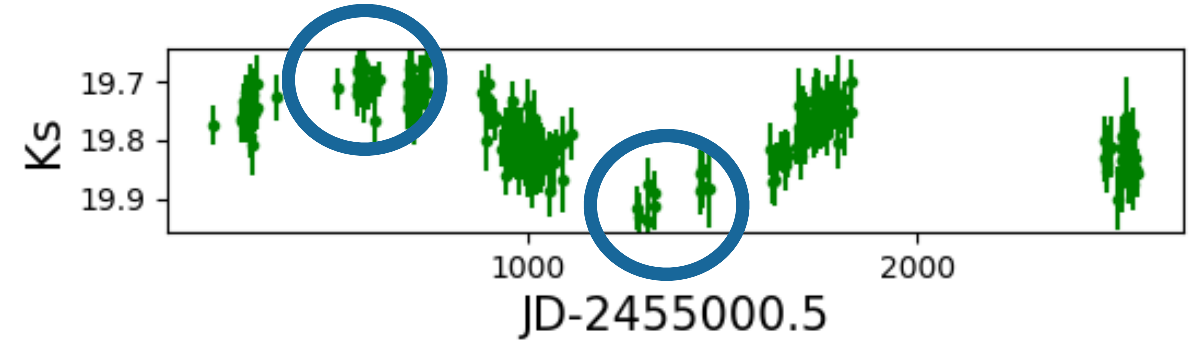
Average component



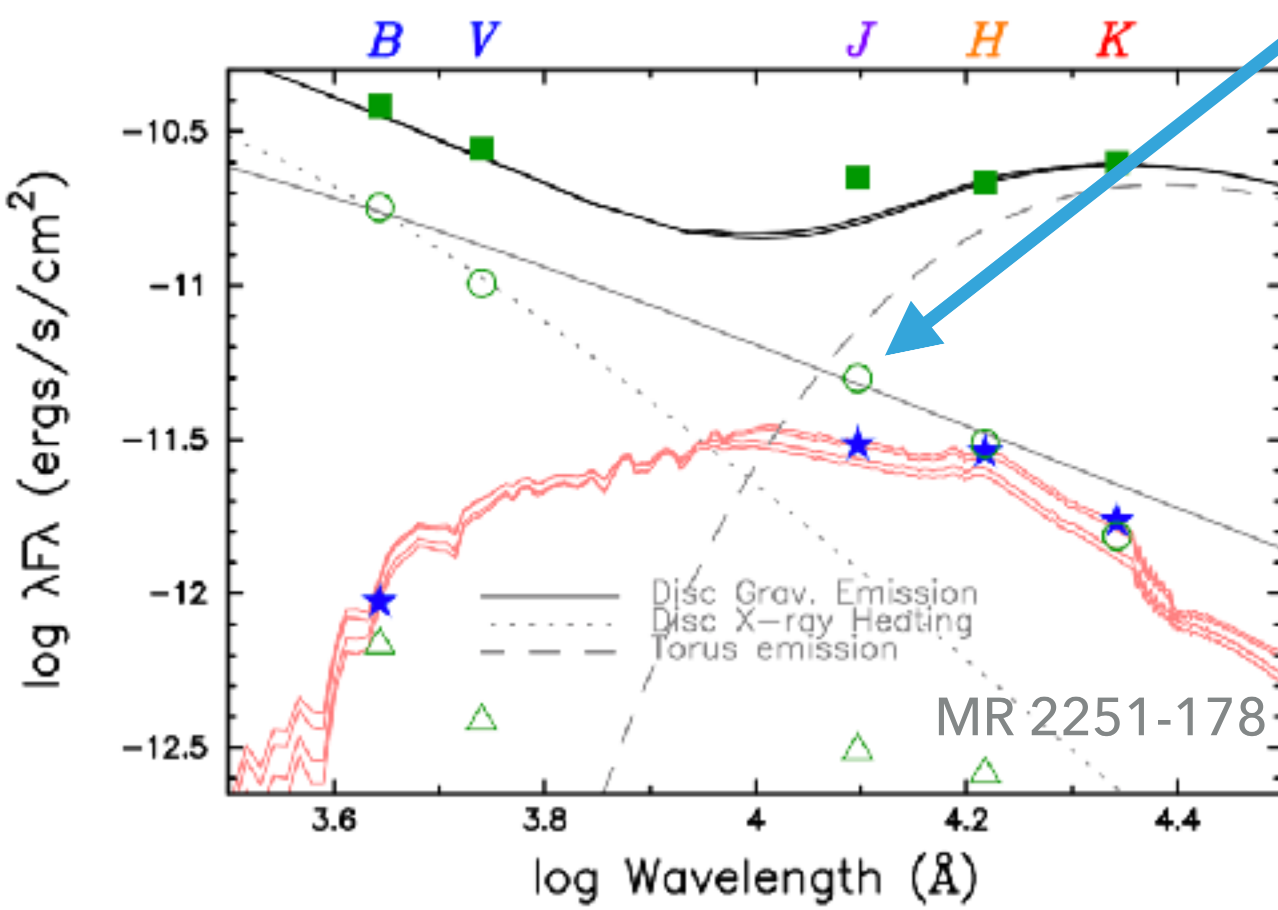


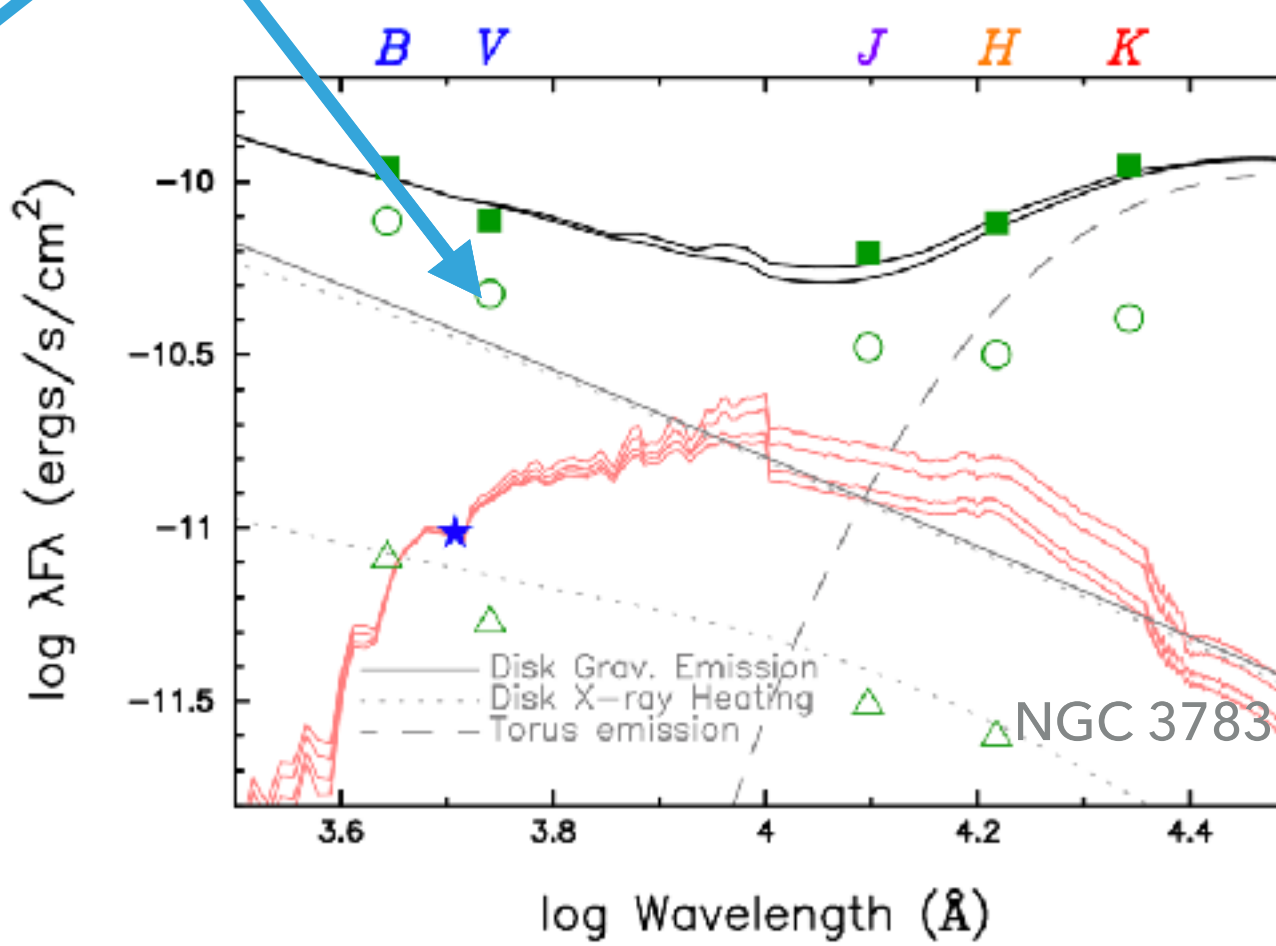
Lira et al. 2011

SED analysis



Variable component

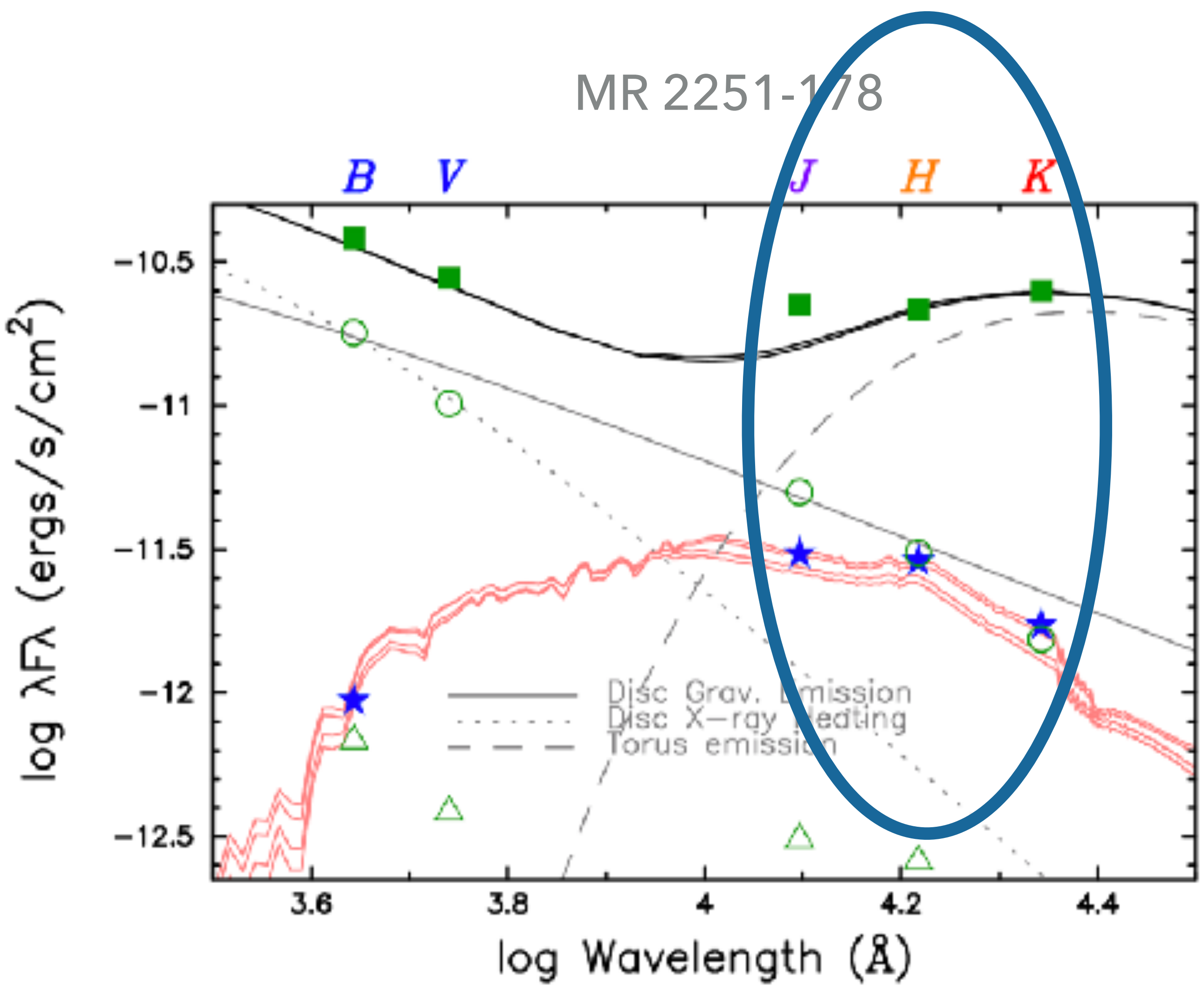




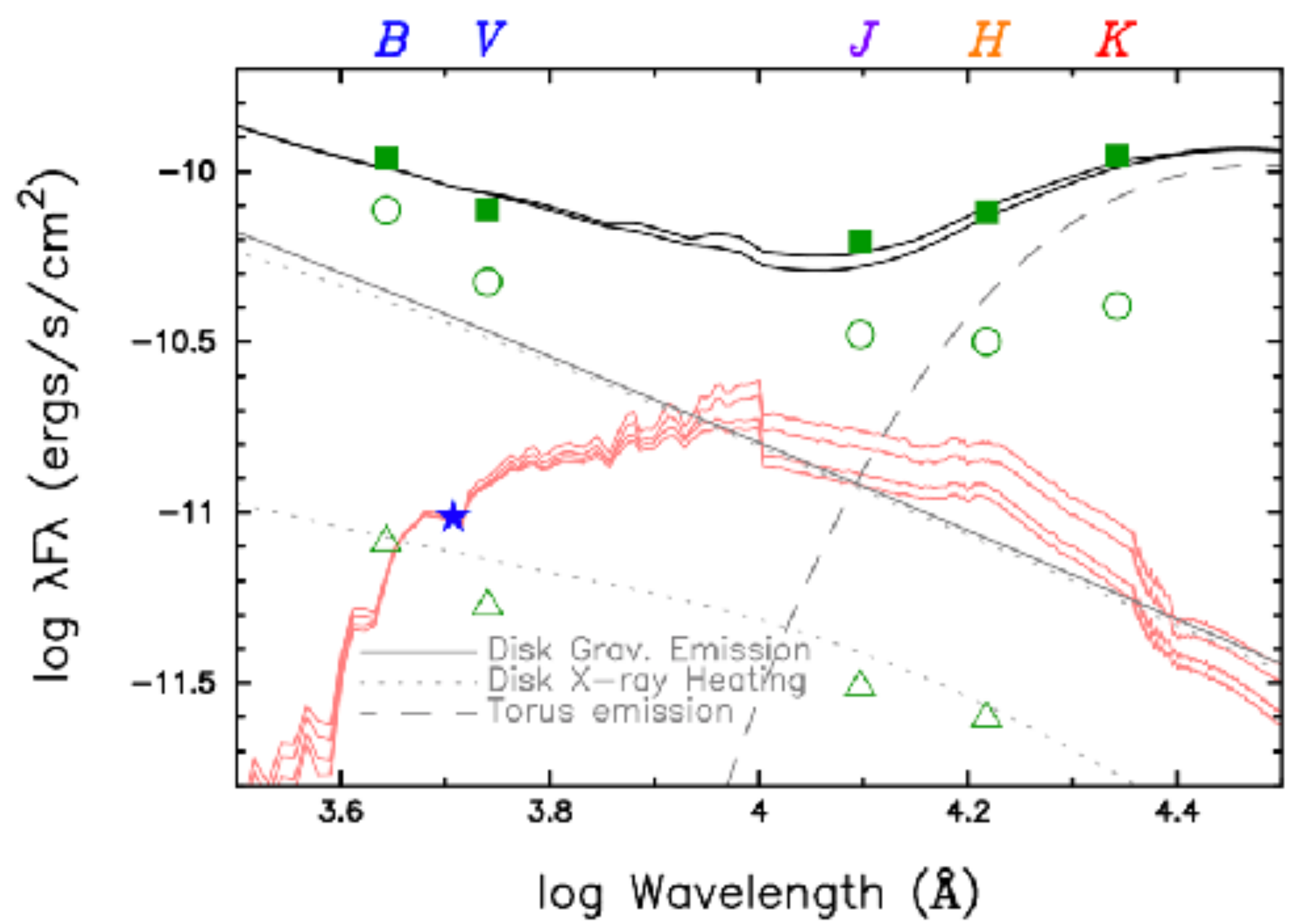
Lira et al. 2011

SED analysis

MR 2251-178



NGC 3783



Lira et al. 2011

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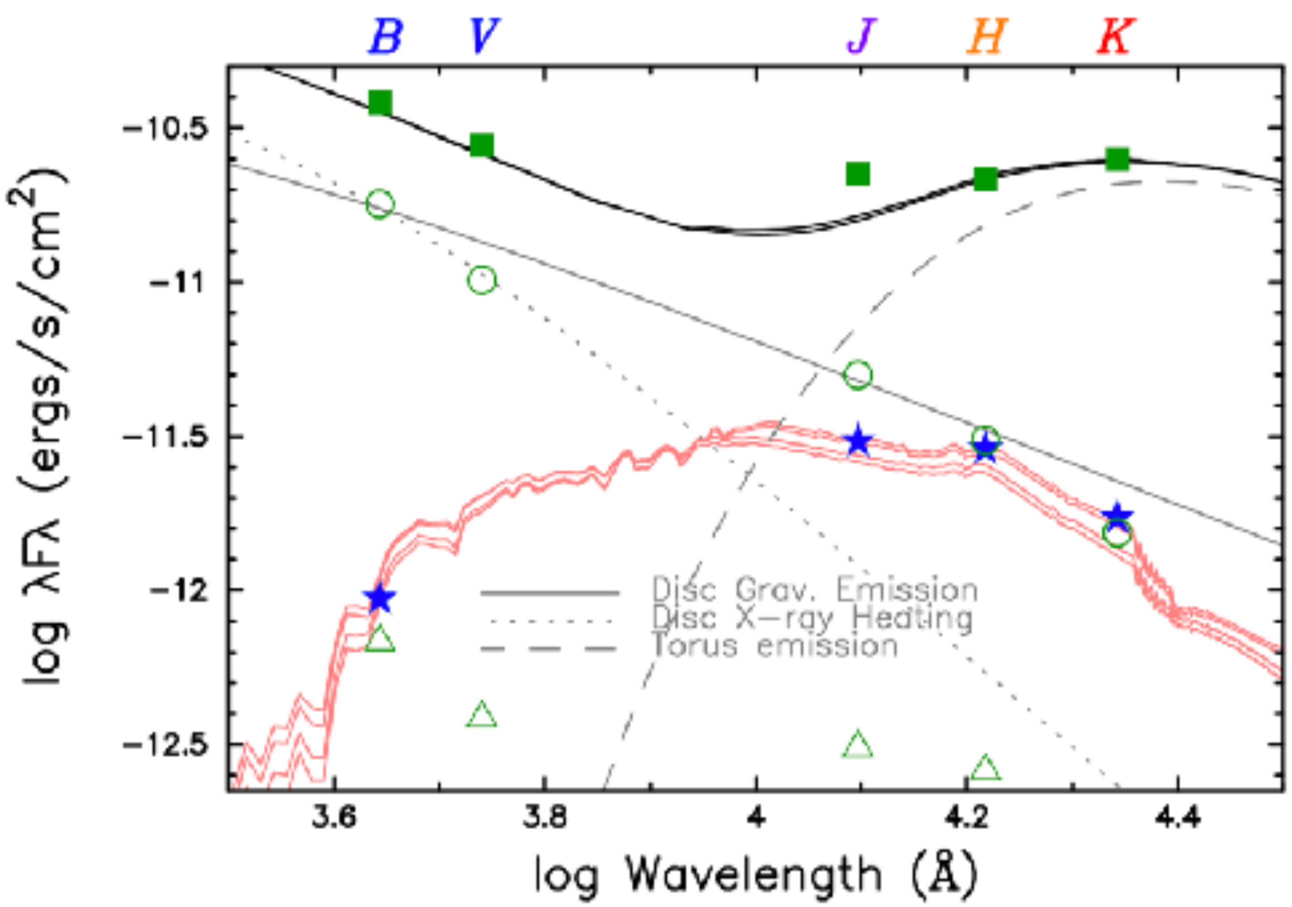
MR 2251-178



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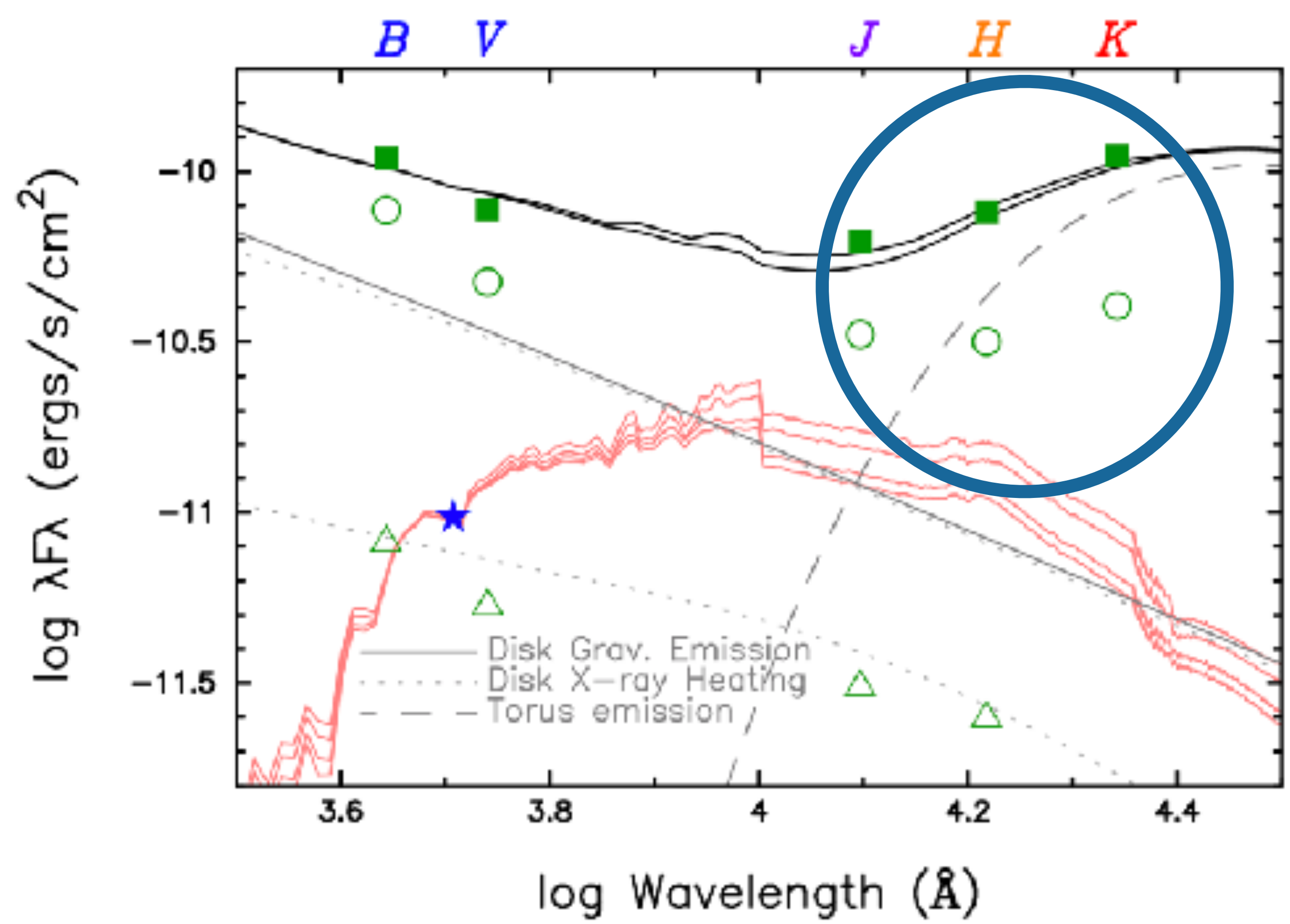

Lira et al. 2011

Preliminary results with UltraVISTA

- Type 1 AGN in the COSMOS selected from Marchesi et al. 2016 and Flesch 2015.
- Light curves with 6.5 years of coverage and ~150 epochs per band

Filter	Y	J	H	Ks	All
# type 1	88	89	125	162	85
# var	59	59	55	95	42

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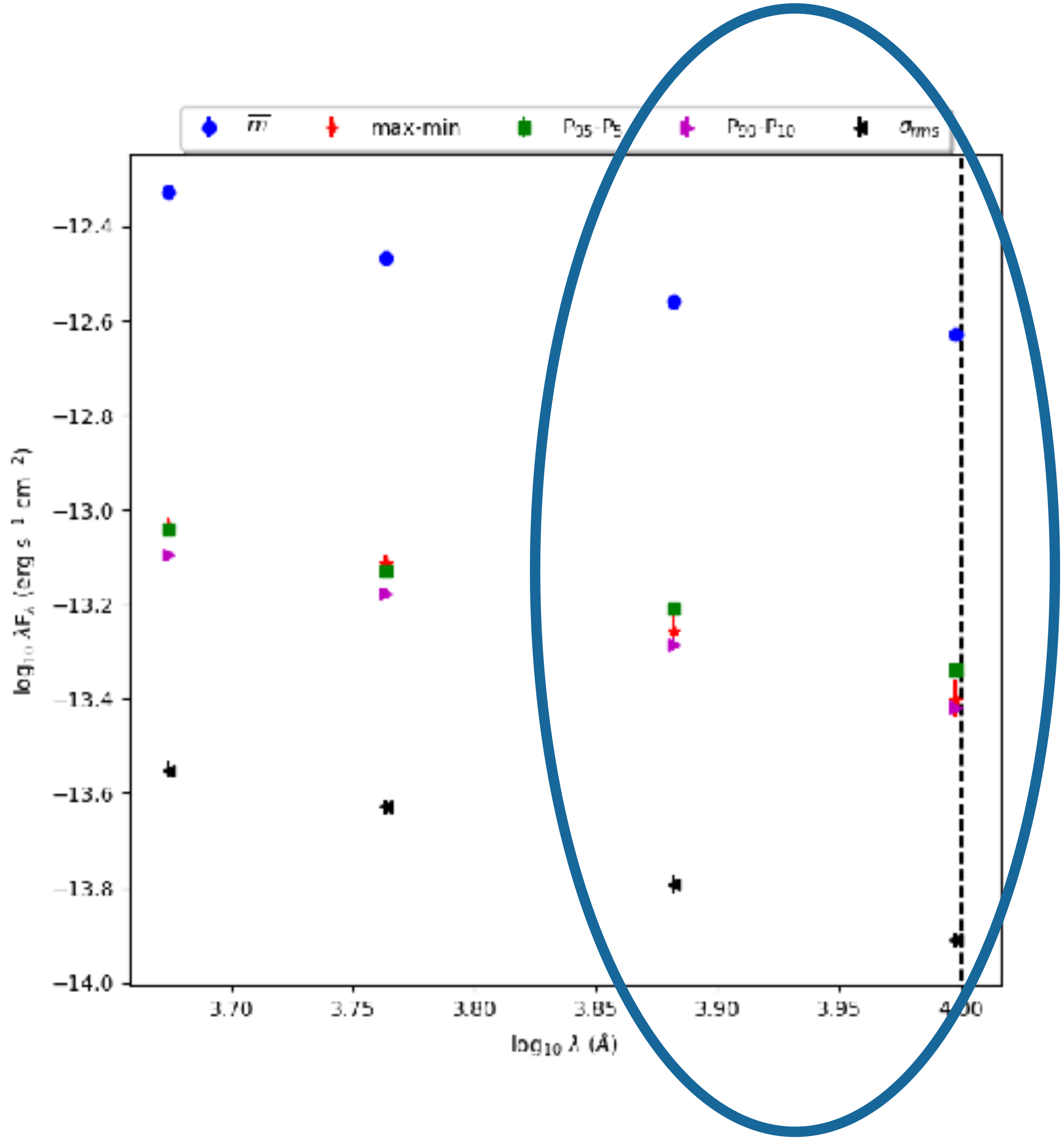
Preliminary results with UltraVISTA

TORUS detected from SED analysis

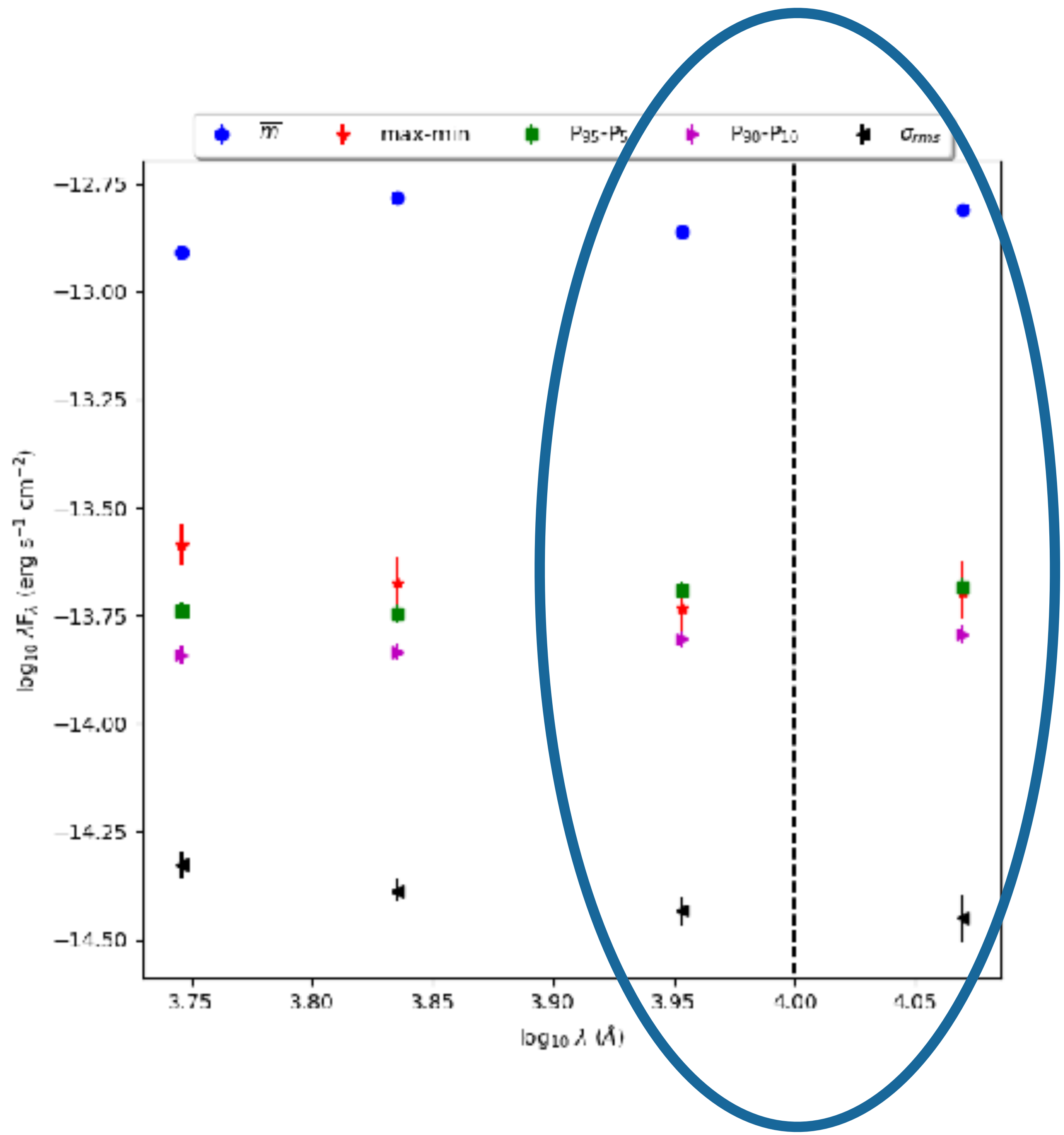
- 10 sources without TORUS detected



Preliminary results with UltraVISTA

TORUS detected from SED analysis

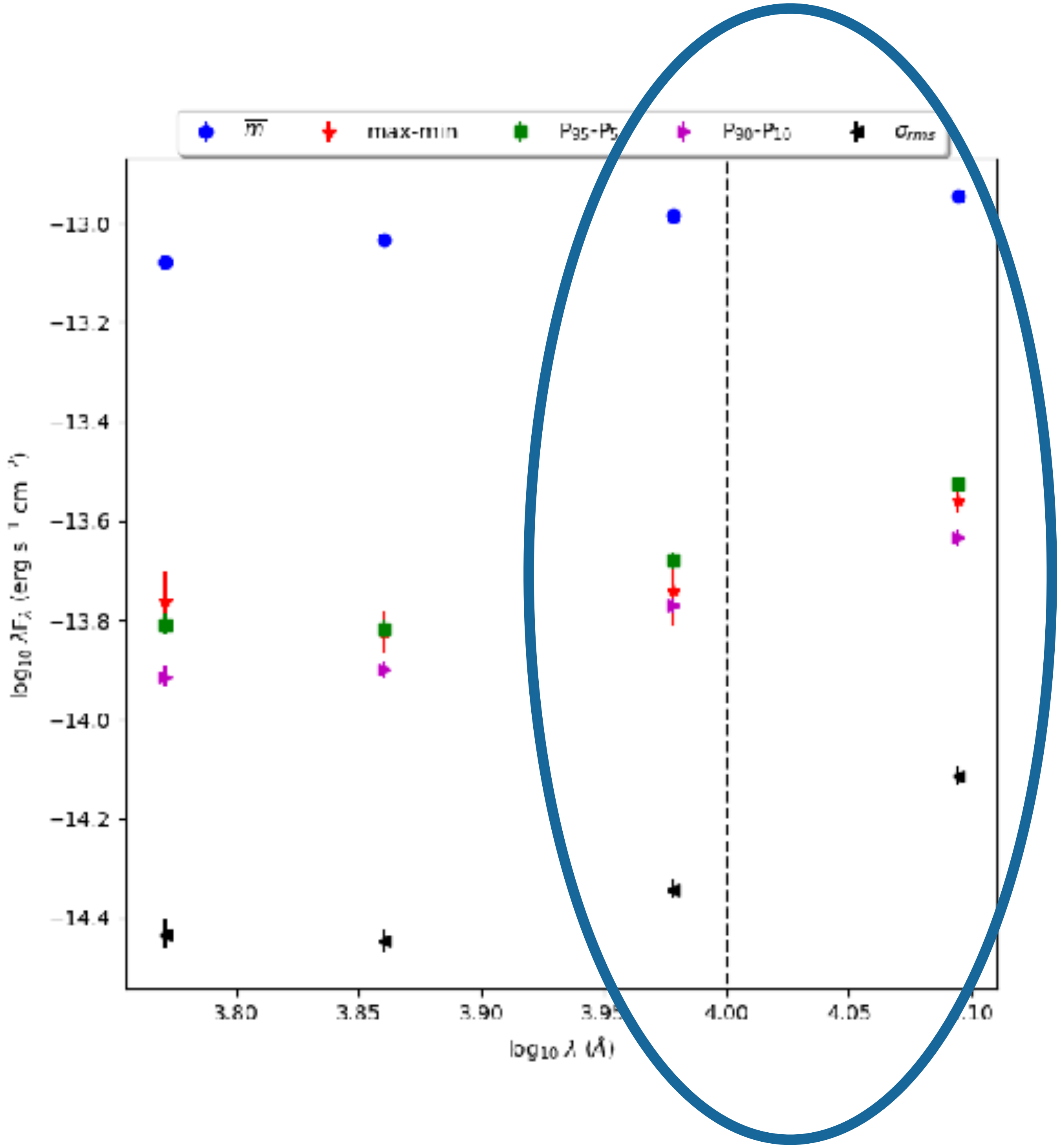
- 10 sources without TORUS detected
- 12 sources with unclear detection



Preliminary results with UltraVISTA

TORUS detected from SED analysis

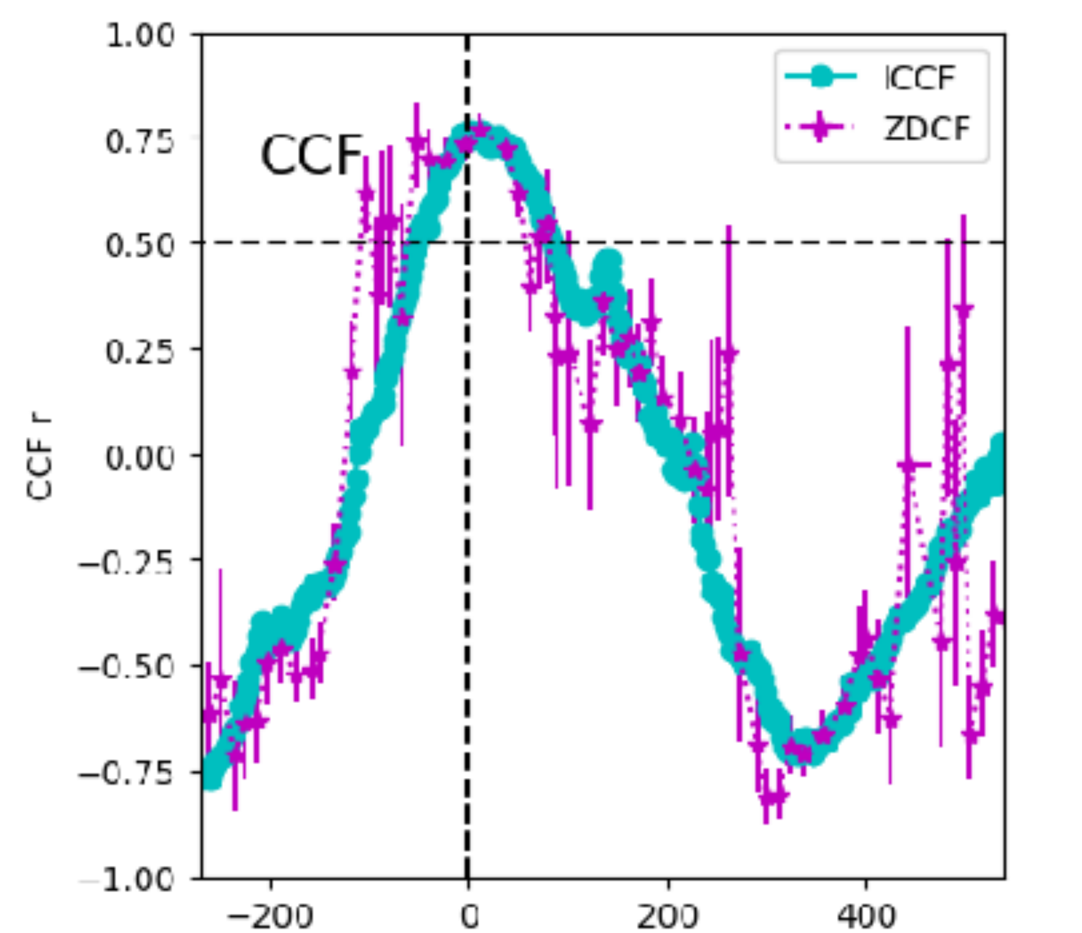
- 10 sources without TORUS detected
- 12 sources with unclear detection
- 20 sources with TORUS detected



Preliminary results with UltraVISTA

Time delay estimates

- 13 sources with time delays consistent with emission from the accretion disk

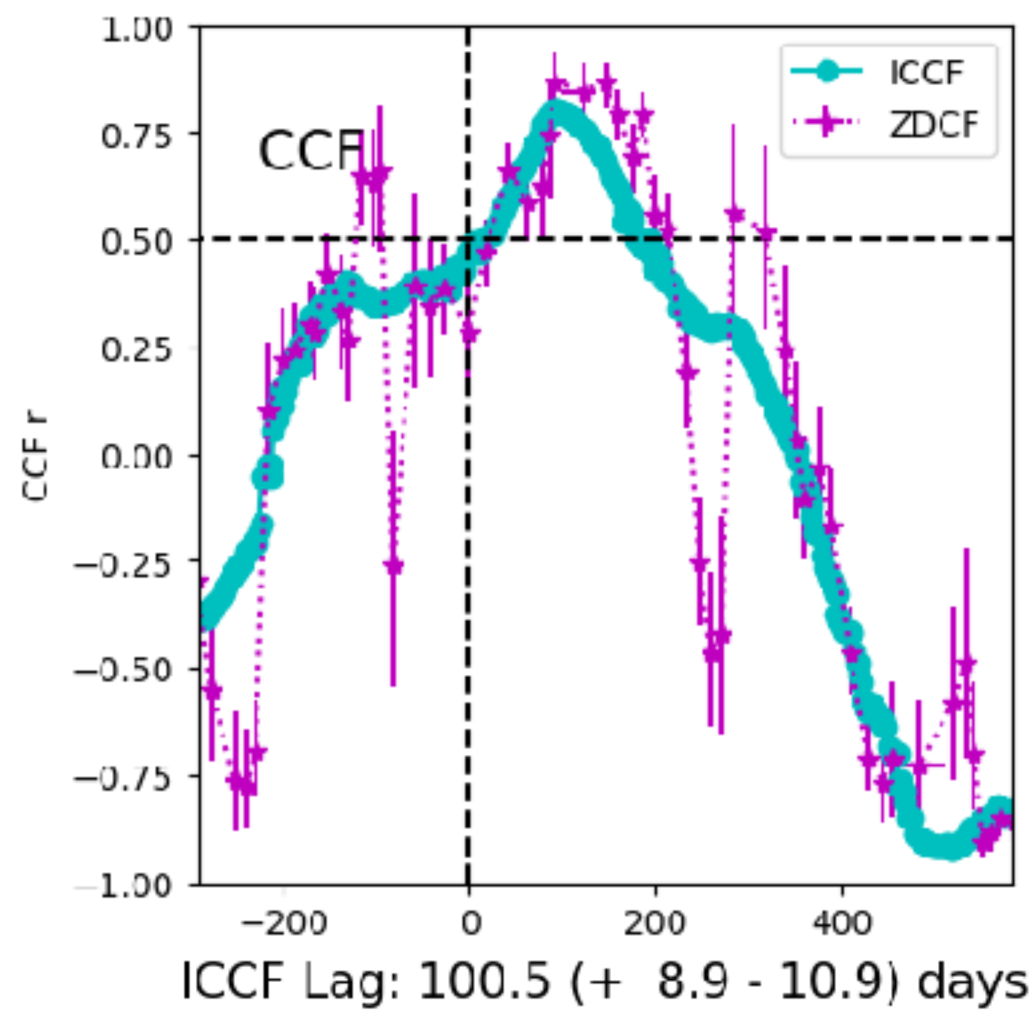


Centroid Lag: 15.1 (+ 22.4 - 10.7) days

Preliminary results with UltraVISTA

Time delay estimates

- 14 sources with time delays consistent with emission from dusty torus

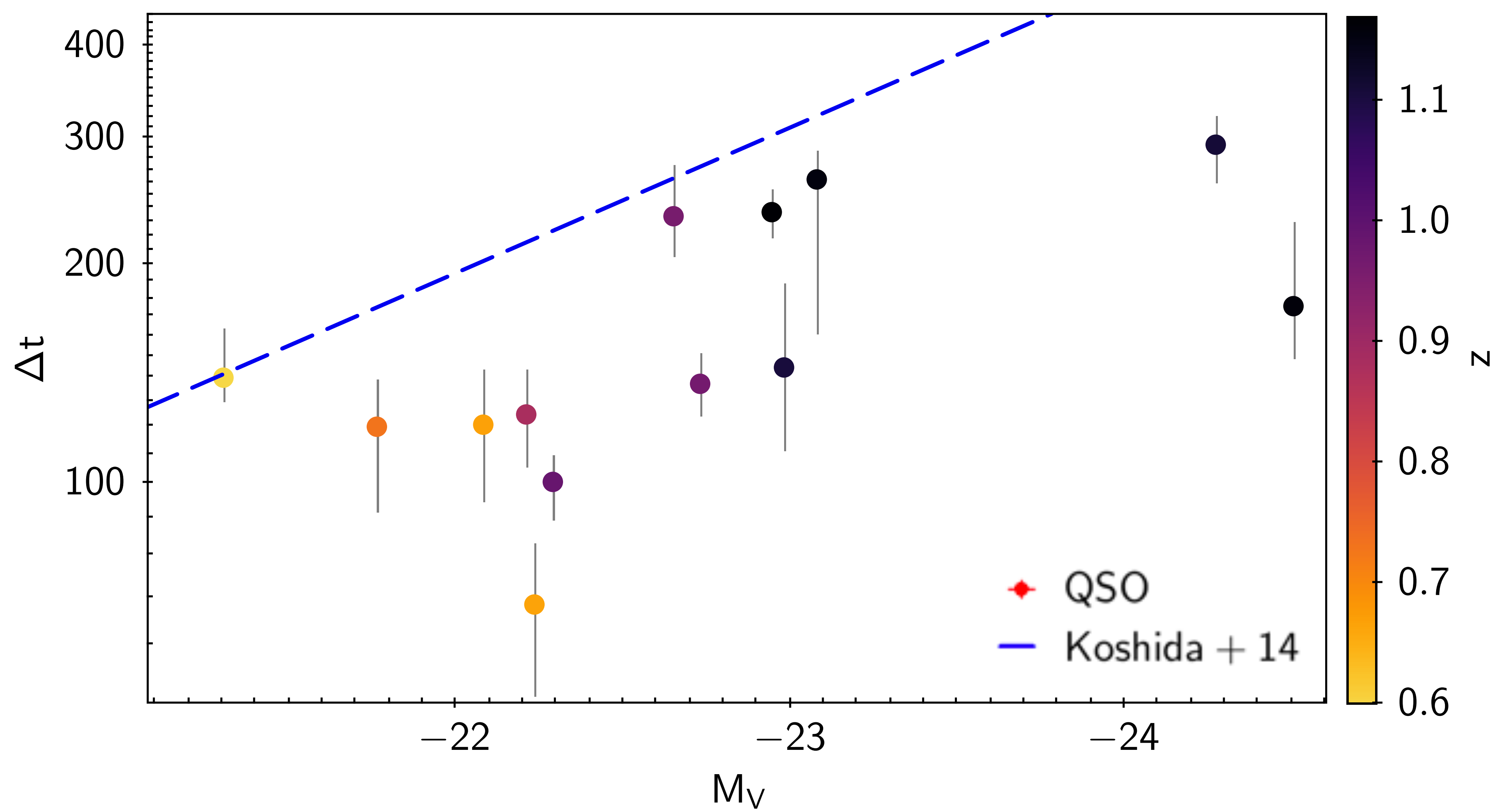


Preliminary results with UltraVISTA

Time delay estimates

- 14 sources with time delays consistent with emission from dusty torus

M_V upper limits!



SUMMARY

- We found that the amplitude of the variability (A) depends solely on the rest frame emission wavelength and the Eddington ratio, where A anti-correlates with both λ_{rest} and L/L_{Edd}.
- RM at z~1 is needed if we want to use AGN as standard candles.
- RM at z~1 is challenging: we need longer light curves, the analysis at individual periods of observations is limited by the time scale of the variability, and the time delays are affected by the presence of gaps.
- SEDs can be used to detect a variable torus component.
- We need proper estimations of the absolute magnitude in order to test any correlation between time delay and luminosity.
- **If we want to use LSST for dust reverberation mapping at z~1 we need a complementary program in the NIR.**