University of St Andrews

# Testing accretion disc theory with high-cadence reverberation mapping

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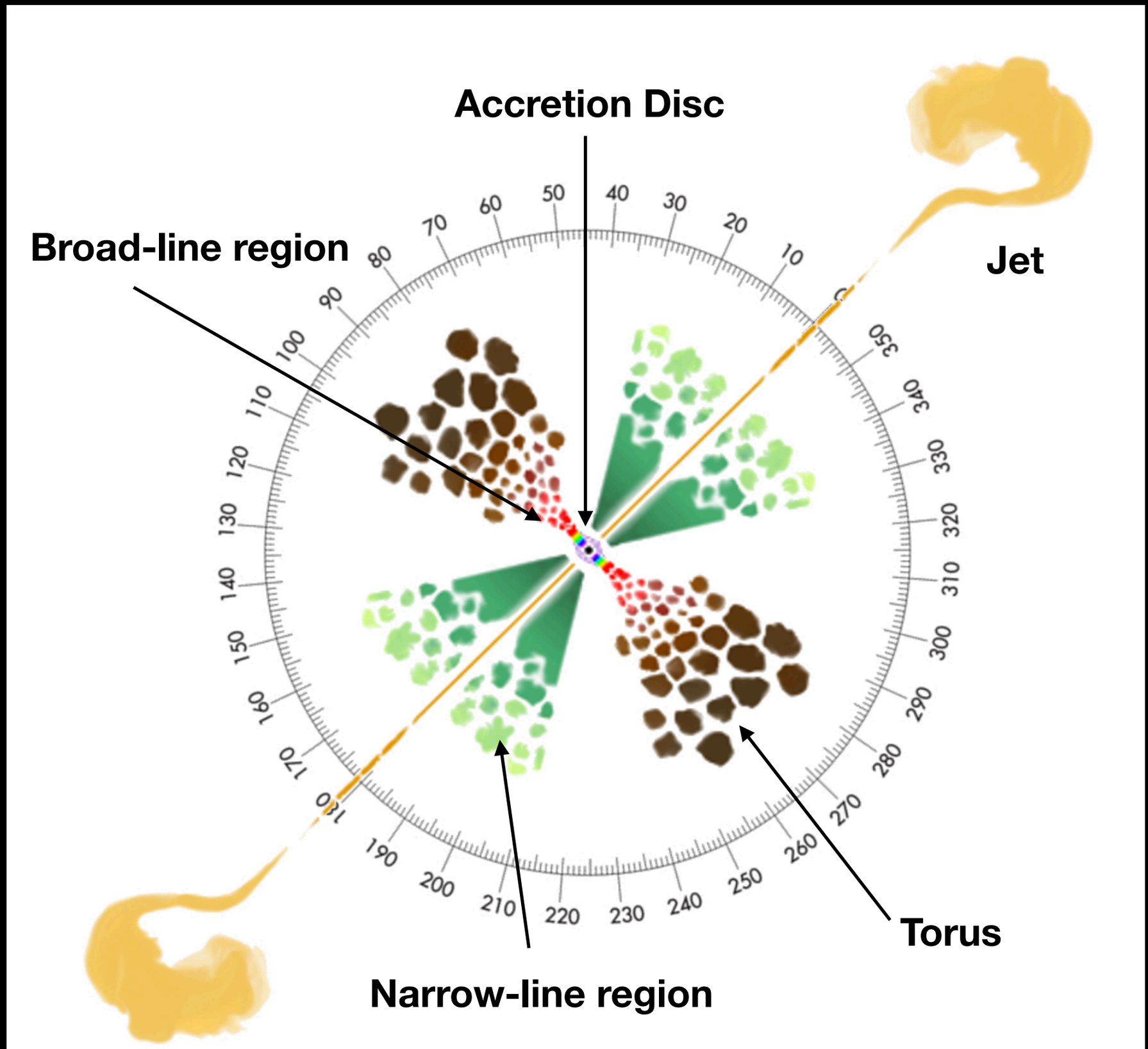
XVII DEX Virtual Workshop
7 January 2021

Image credit: Nika Maisuradze

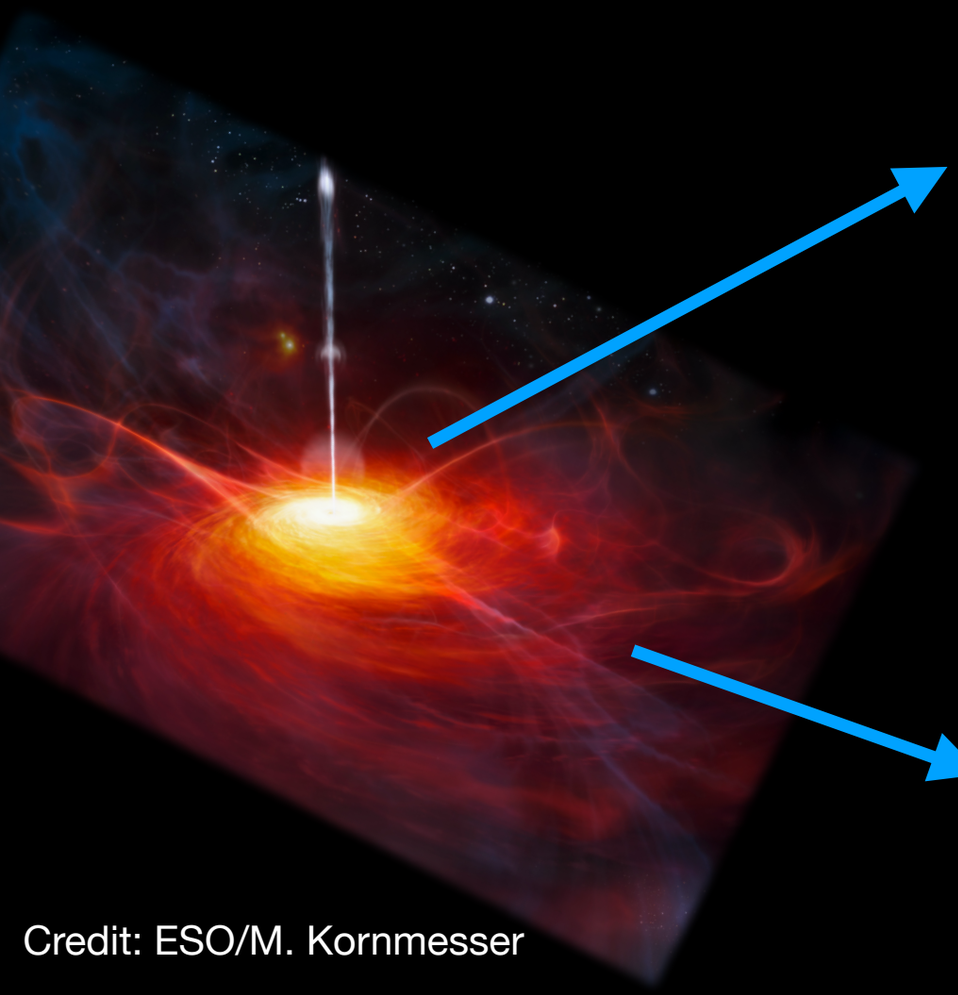
# The structure around a supermassive black hole




Marin, 2016, MNRAS

# Accretion discs in Active Galactic Nuclei

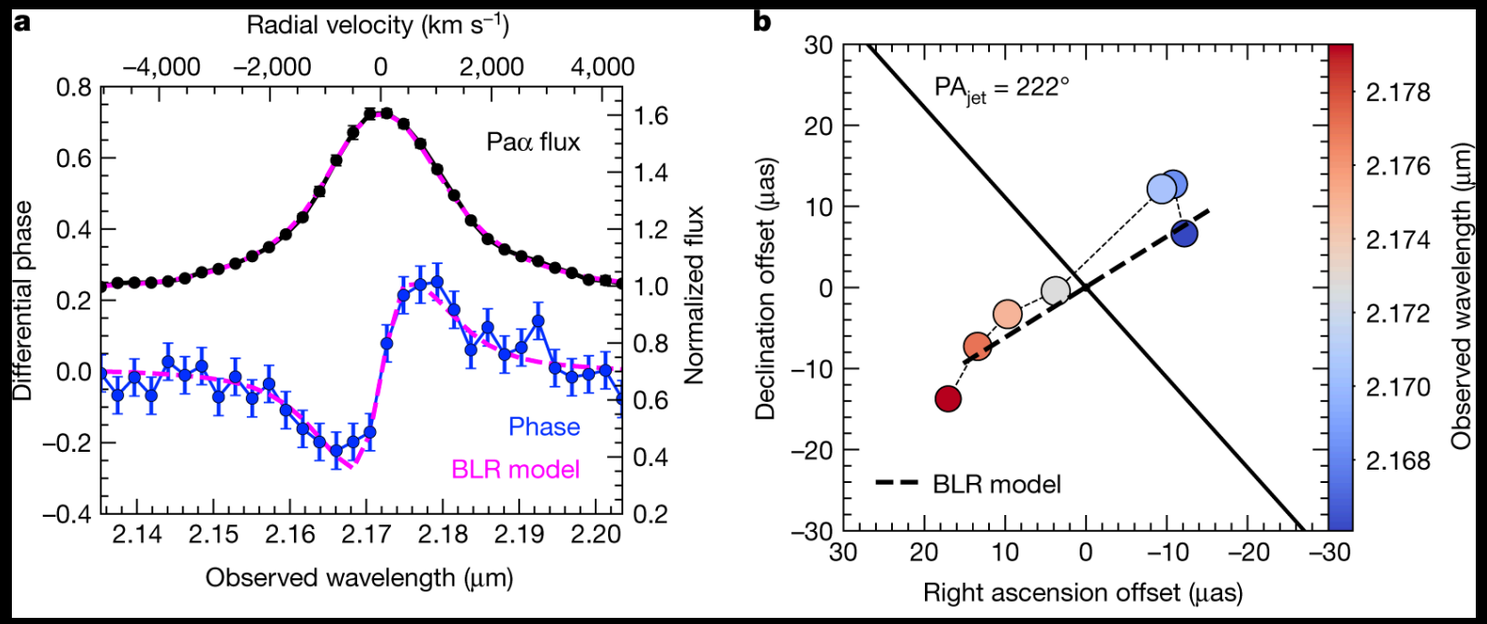
Central Engine of AGN —> small angular size



Credit: ESO/M. Kornmesser

Event Horizon Telescope

EHT+, 2019, ApJL




GRAVITY COLLABORATION+, 2018, Nature

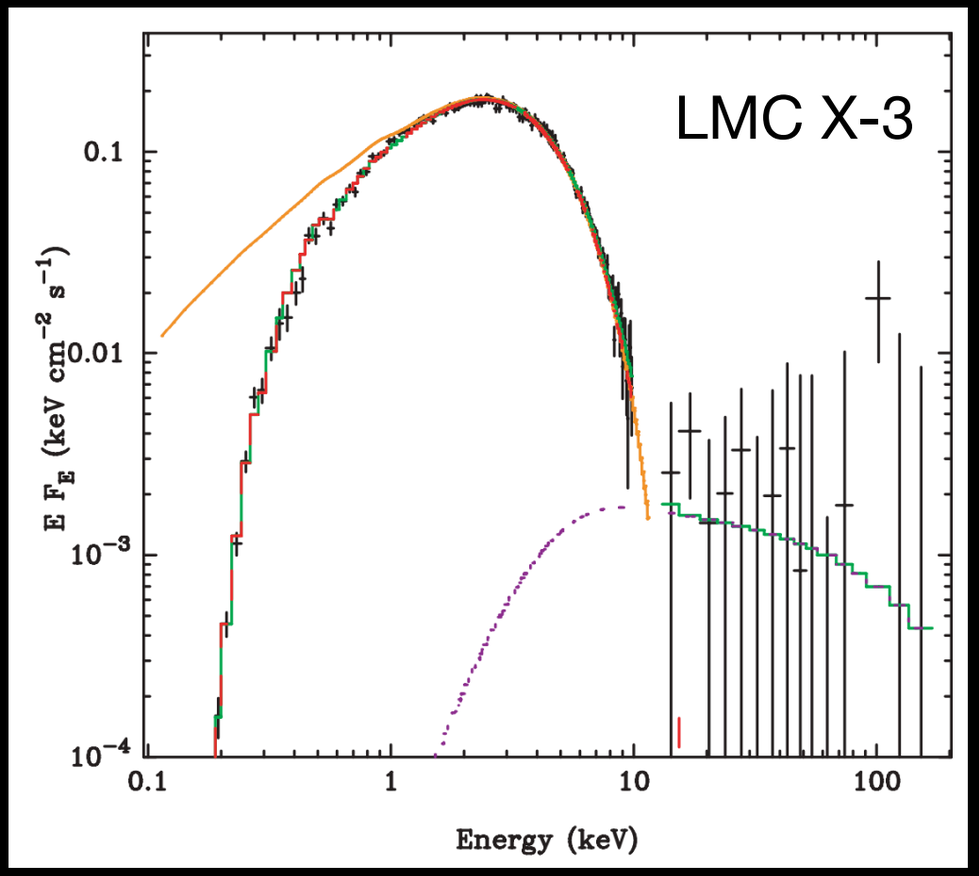
# Testing accretion onto AGN

- AGN Spectral Energy distribution (SED) is different from LMXBs “analogues”
- Timescales of change (Changing Look Quasars)
- Accretion disc sizes don’t agree

Stringent tests of accretion theory are required!

# Testing accretion onto AGN

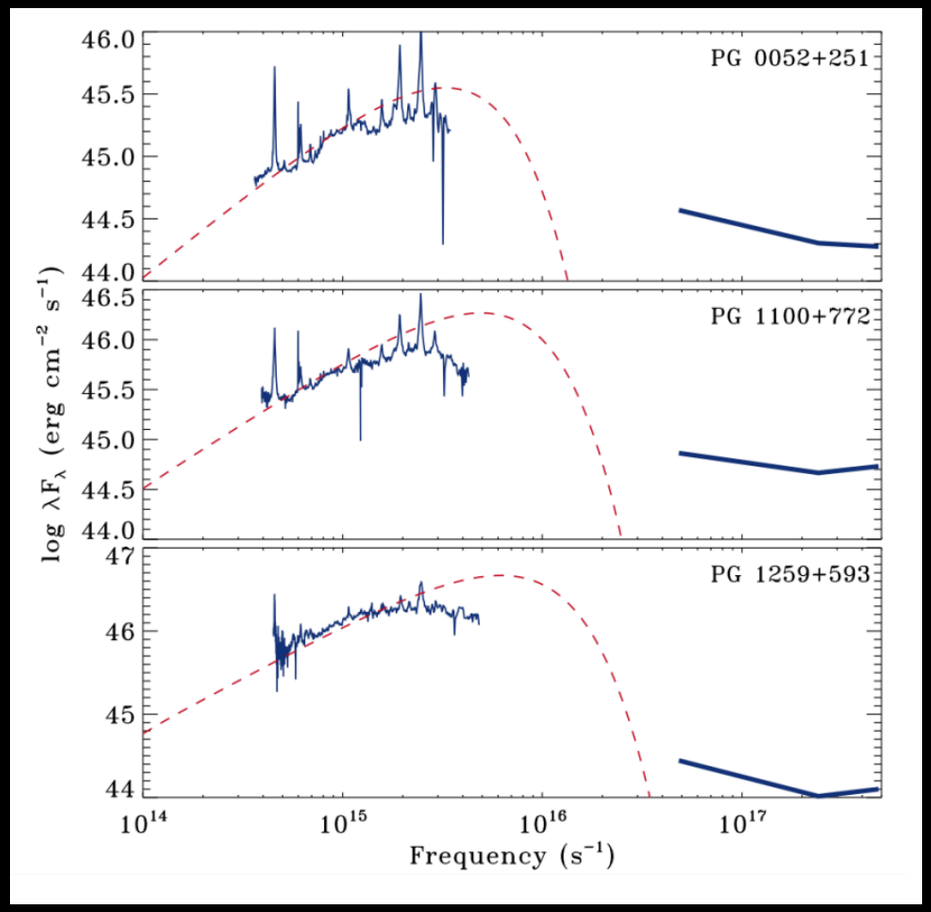
- **AGN SED**
- **Timescales of change (CLQs)**
- **Sizes don’t agree**




Davis, Done & Blaes 2006, ApJ, 647, 525

Temperature profile?

Should peak in the EUV,
but peak is closer to 100 nm

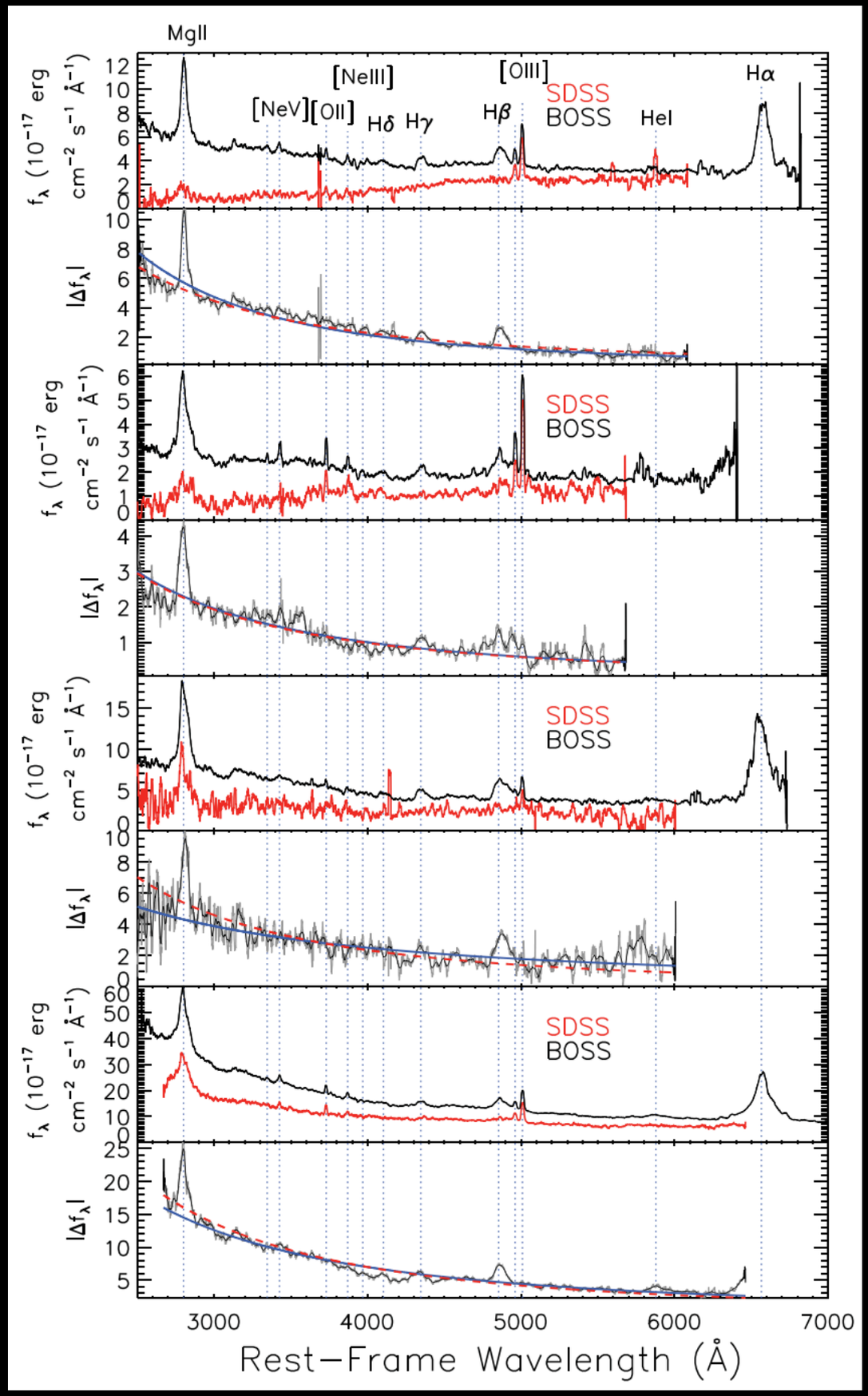



UV opacities might be key?

# Testing accretion onto AGN

- AGN SED
- **Timescales of change**
  (Changing-Look Quasars)
- Sizes don’t agree

Disappearing broad emission lines
In timescales of <10 yr



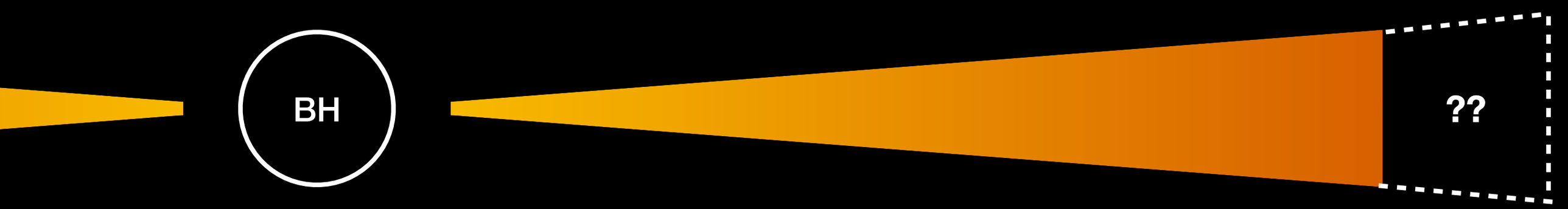

e.g. MacLeod 2016, MNRAS, 457, 389

# Testing accretion onto AGN

- AGN SED
- Timescales of change (CLQs)
- **Sizes don’t agree**

**Microlensing ( factor ~3-30 larger)** e.g., Poole+ 2007, Morgan+ 2018

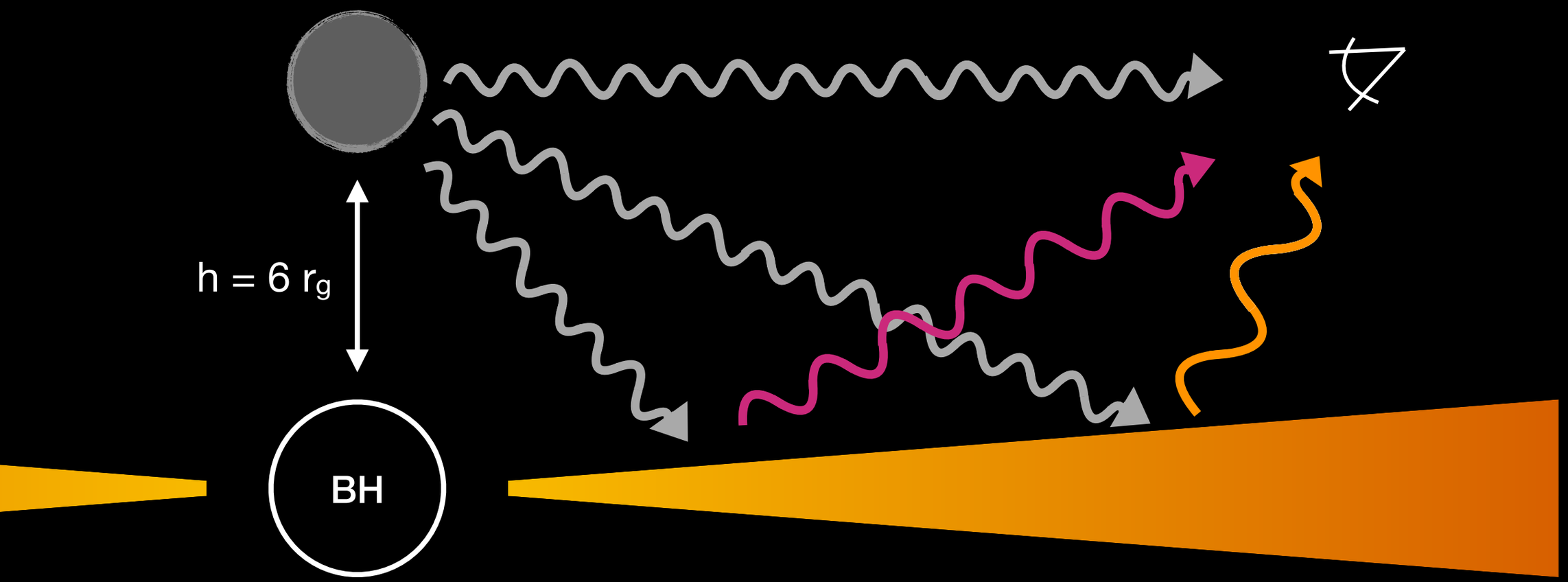
**Disc Reverberation Mapping ( factor ~3-5 larger)** e.g., Edelson+ 2019



# Disc Reverberation Mapping

- AGN SED
- Timescales of change (CLQs)
- **Sizes don’t agree**

$$\tau = R/c \propto (M\dot{M})^{1/3} T^{-4/3}$$
$$\propto (M\dot{M})^{1/3} \lambda^{4/3}$$
$$\propto M^{2/3} (L/L_{Edd})^{1/3} \lambda^{4/3}$$

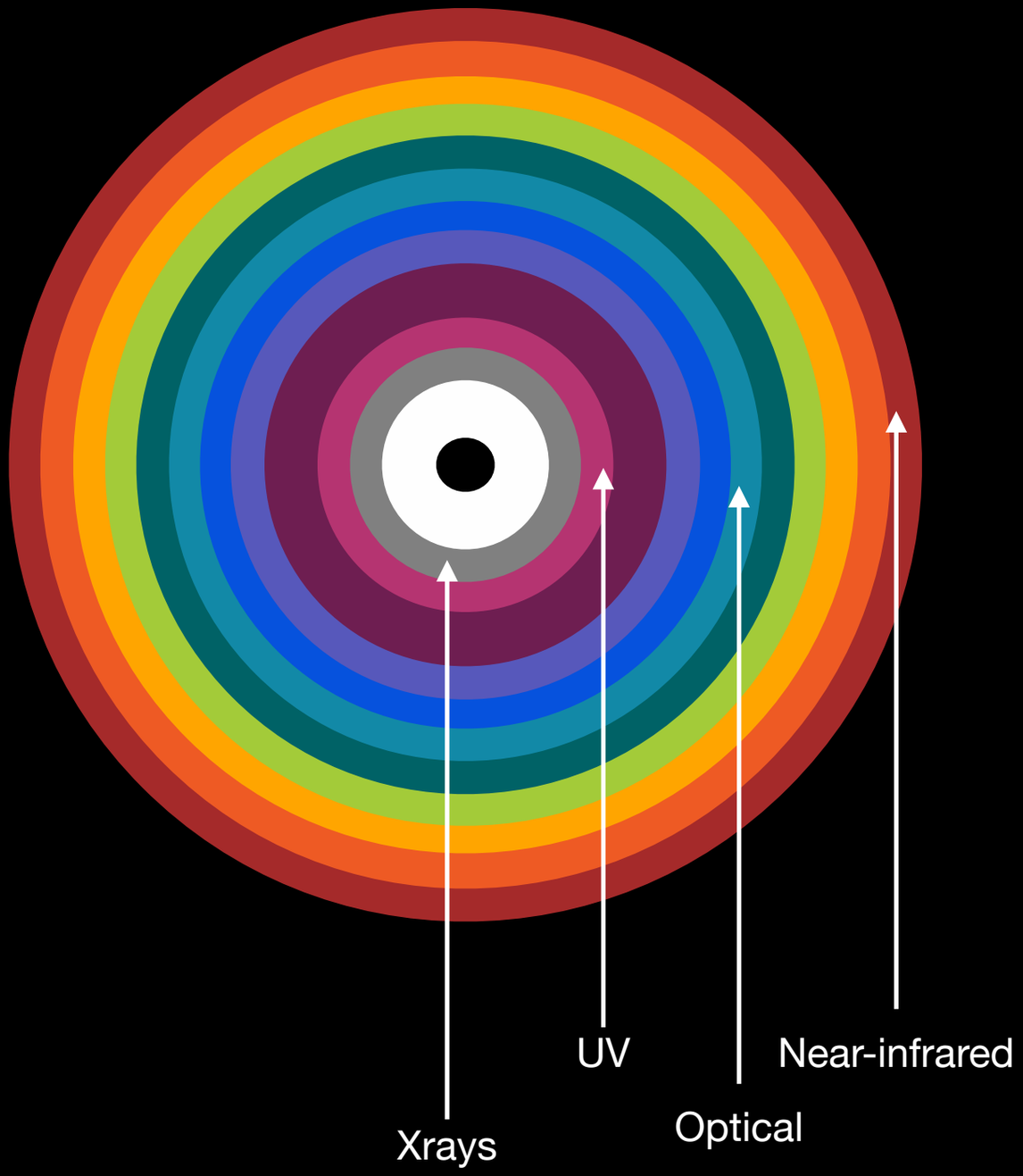



**Lamp-post model**

Trade-off angular resolution for temporal resolution

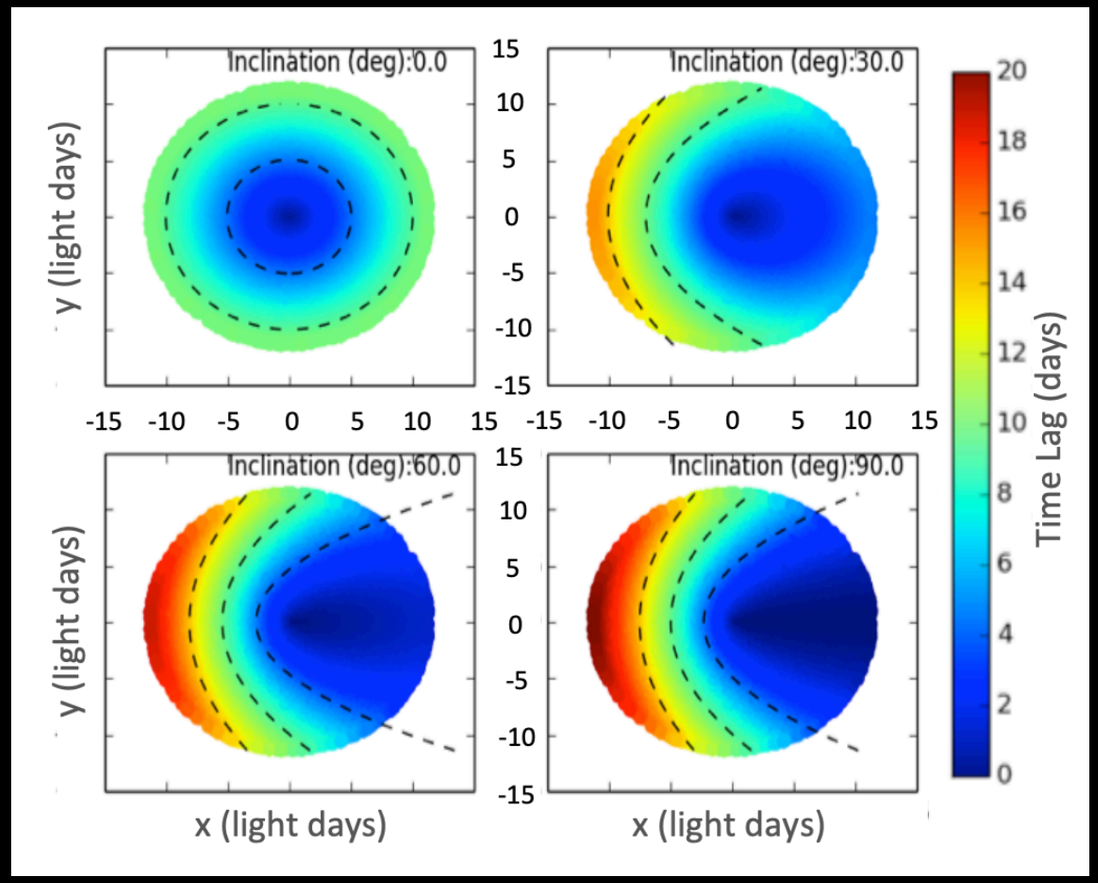
# Disc Reverberation Mapping

As mass moves inwards,
temperature increases!




*"Jaw-breaker schematic"*

$$\tau = R/c \propto (M\dot{M})^{1/3}\lambda^{4/3}$$

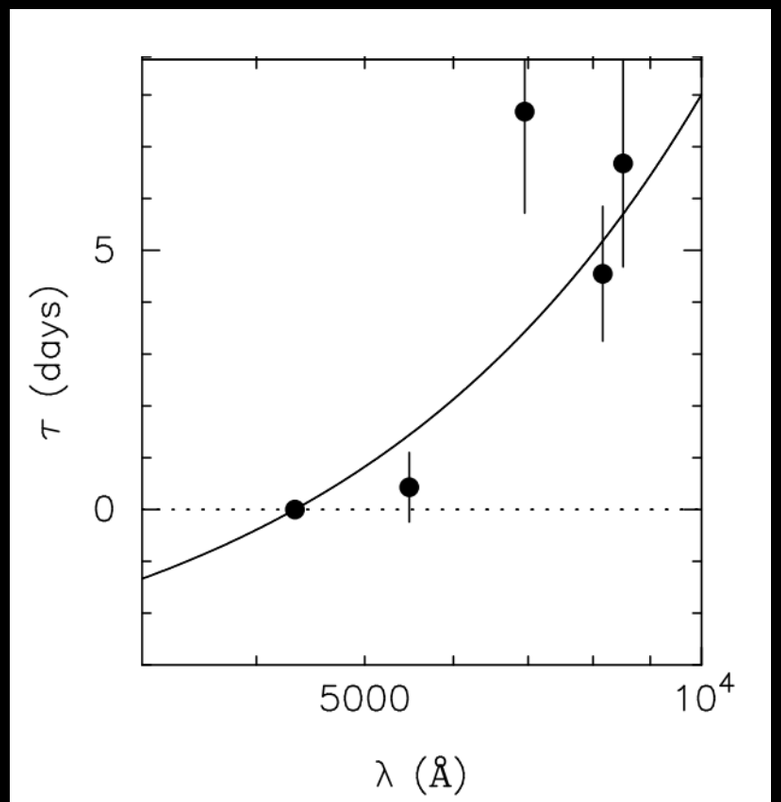



Starkey+ 2016

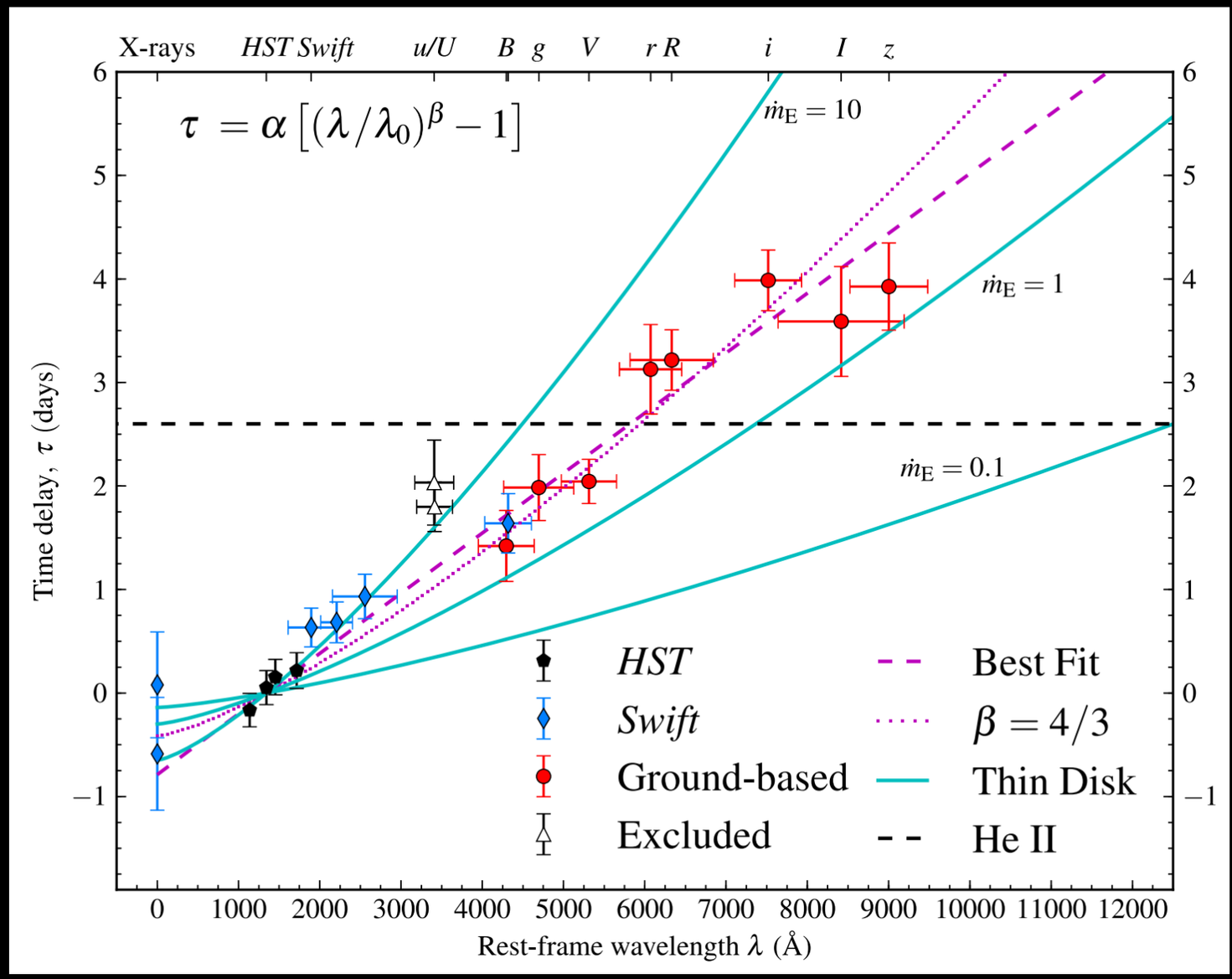
We expect larger lags at
lower temperatures (large wavelengths)

# Disc Reverberation Mapping

## NGC 5548

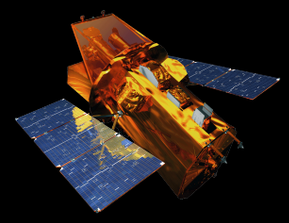


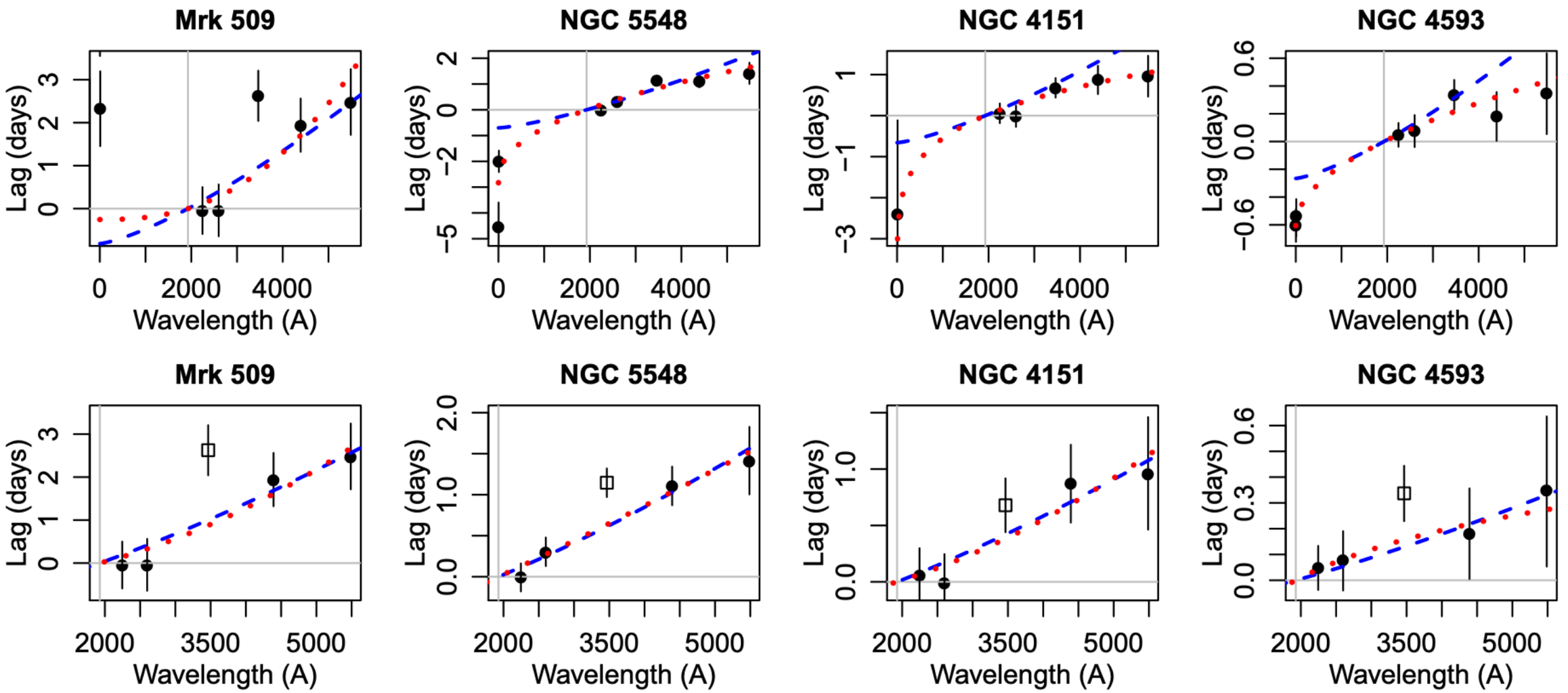

Cackett+ 2007, MNRAS, 380, 669




Fausnaugh+ 2016, ApJ, 821, 56

# “INTENSIVE” Disc Reverberation Mapping






Edelson+ 2019 , ApJ, 870, 123

Lags largely consistent with $\tau \propto \lambda^{4/3}$

**U-band excess —> Diffuse Continuum Emission** from the **BLR!** e.g. Korista & Goad 2019

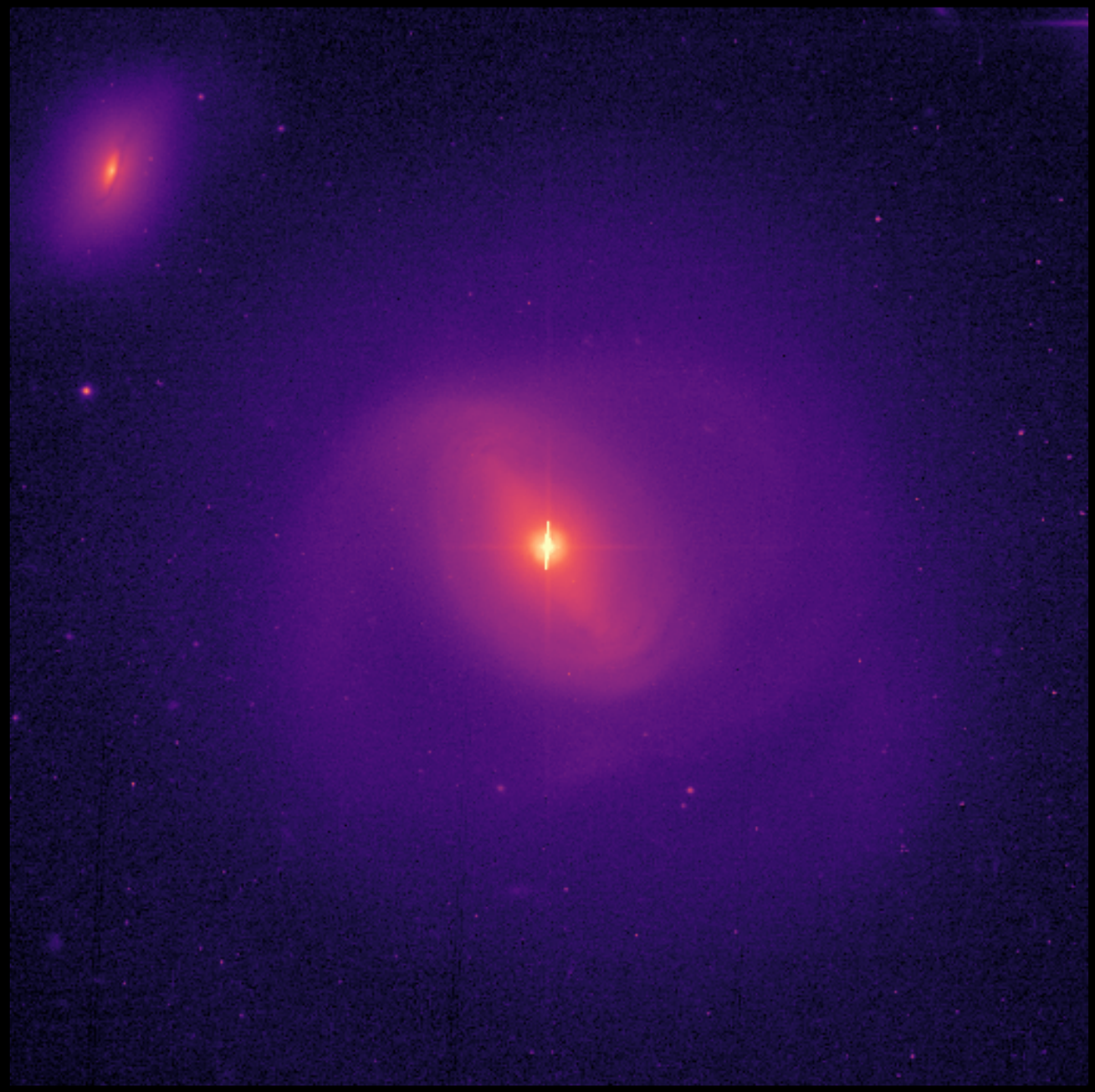
# Intense Disc Reverberation Mapping

## Fairall 9

Hernández Santisteban+ 2020, MNRAS, 498,  5399

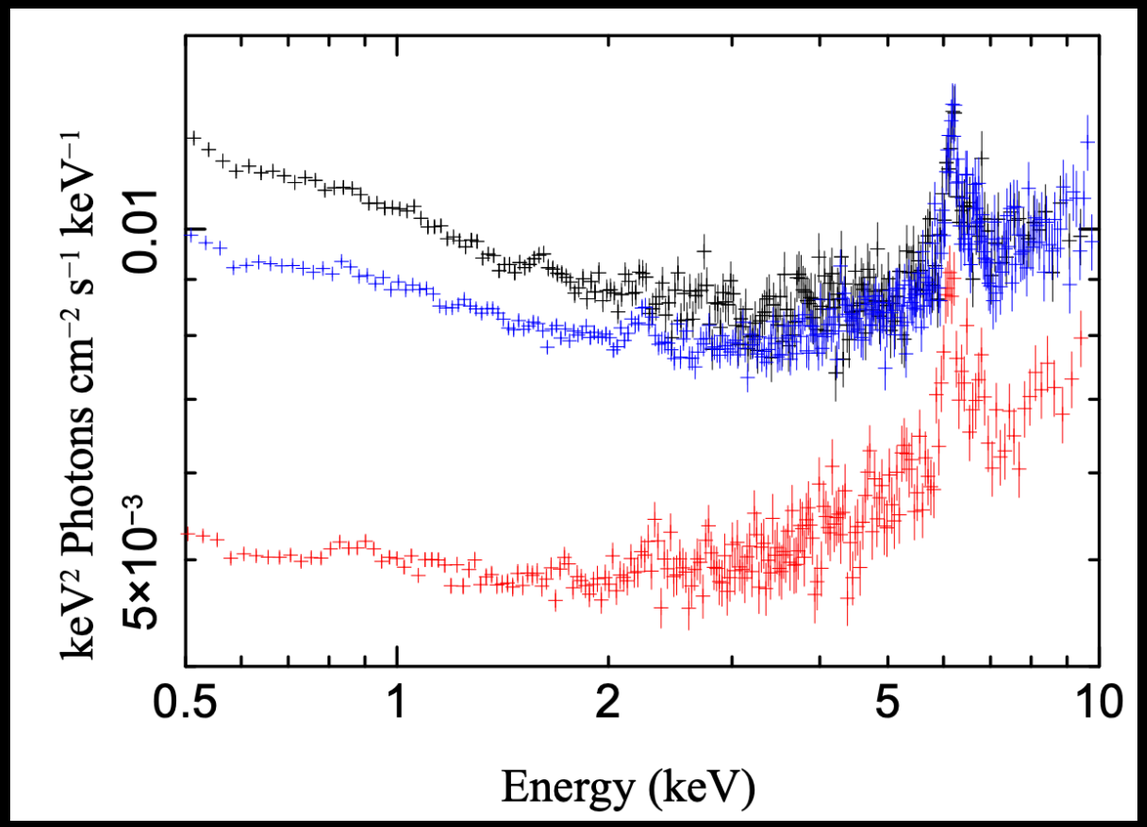
# Fairall 9: test case

- Seyfert 1
- $z$ = 0.047
- Low extinction; E(B-V)=0.024
- $M_{BH} = 2.6 \times 10^8 M_\odot$
- X-rays, very clean source



HST image. Credit: A. Barth

# Fairall 9

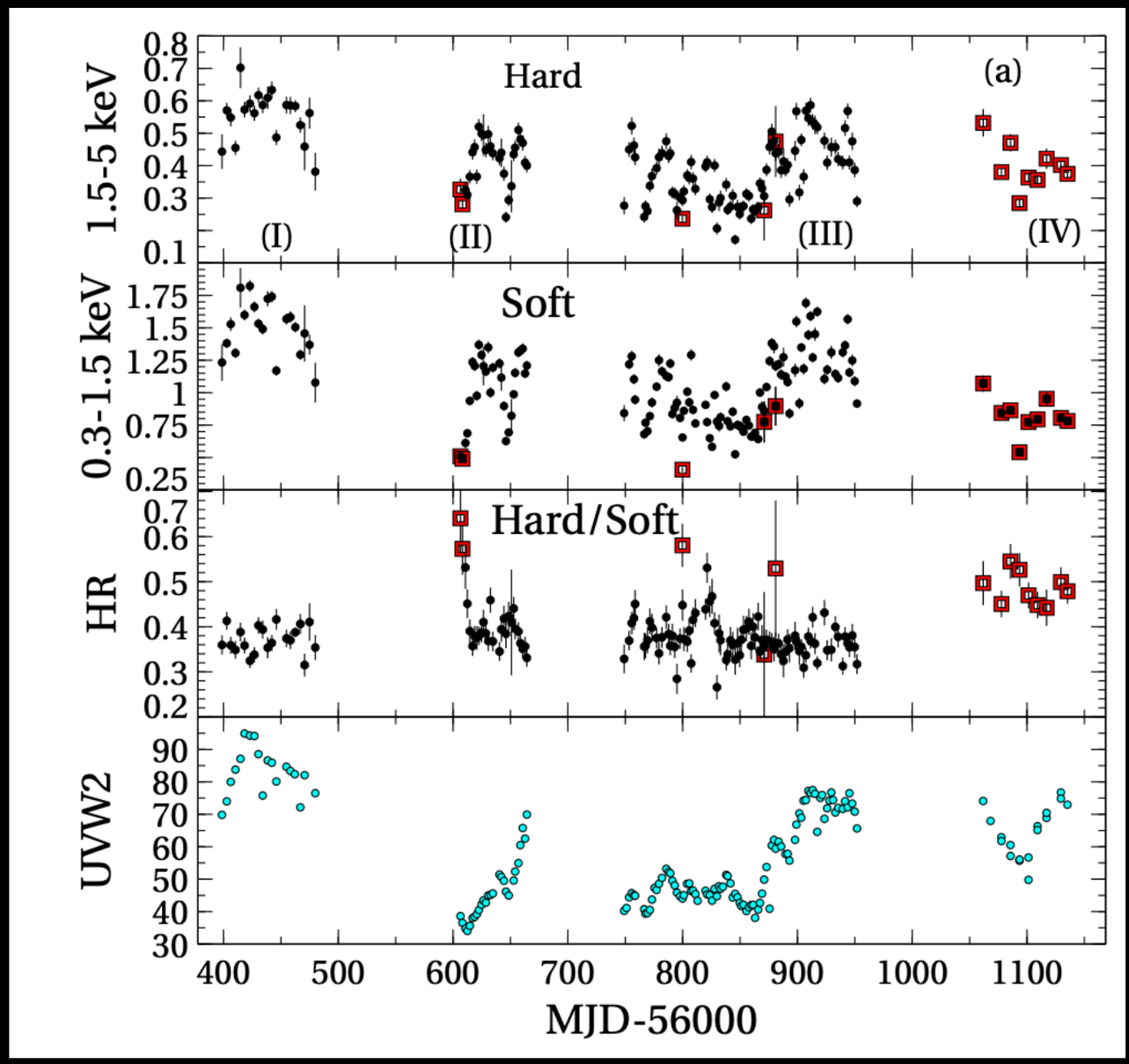



Lohfink+, 2016, ApJ, 821, 11

$n_H$~$10^{20}$ $cm^{-2}$

Absorption is not responsible for the variability observed

—> Clean view of the central engine!



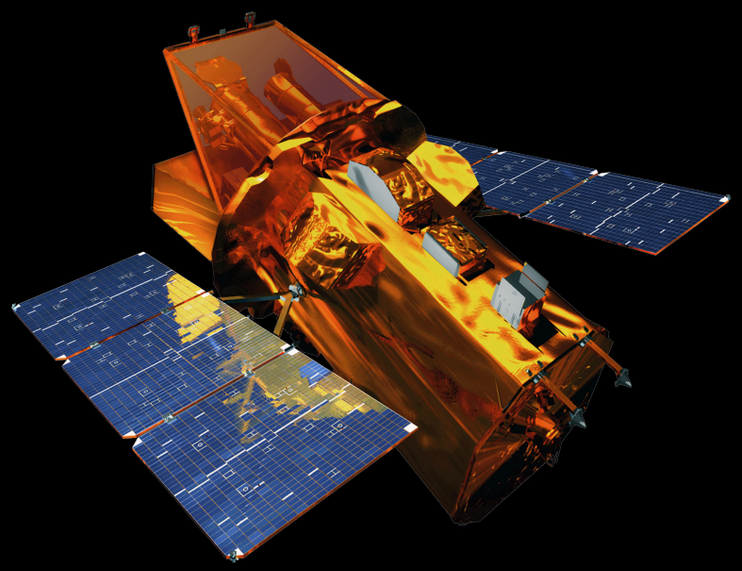

Pal+, 2017, MNRAS, 466, 1777

Evidence for continuum lag

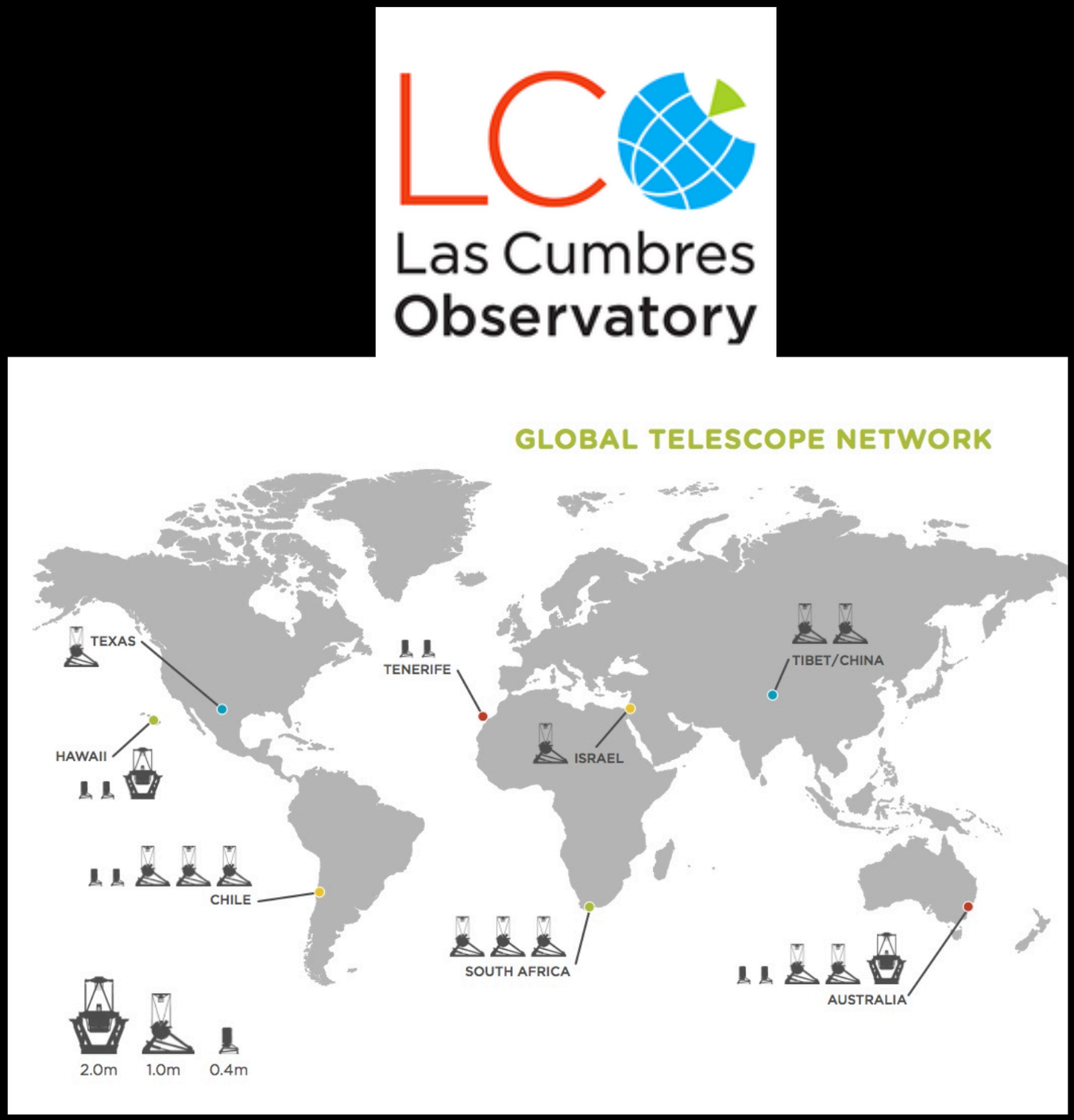
—> CAVEATS: large uncertainties

# Intensive Disc Reverberation Mapping

## Key Projects in:



Monitoring 3+ years on daily cadence



## Fairall 9: the data

**Year 1**

**High signal to noise:** SNR~50-80

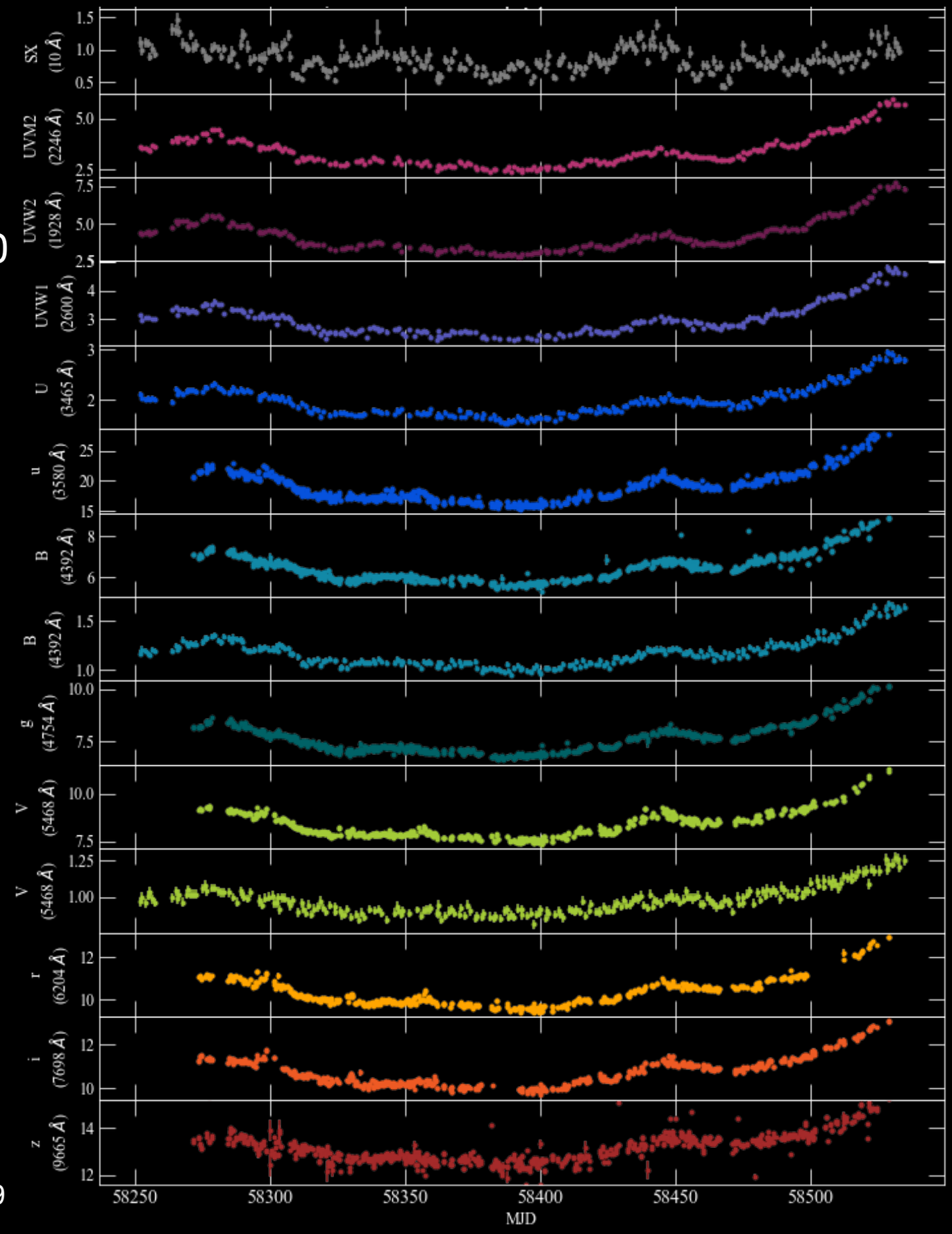
<u>Swift</u>

- Xrays (SX & HX)
- UV (3 filters)
- Optical (3 filters)
- Mean Cadence ~1.1 days

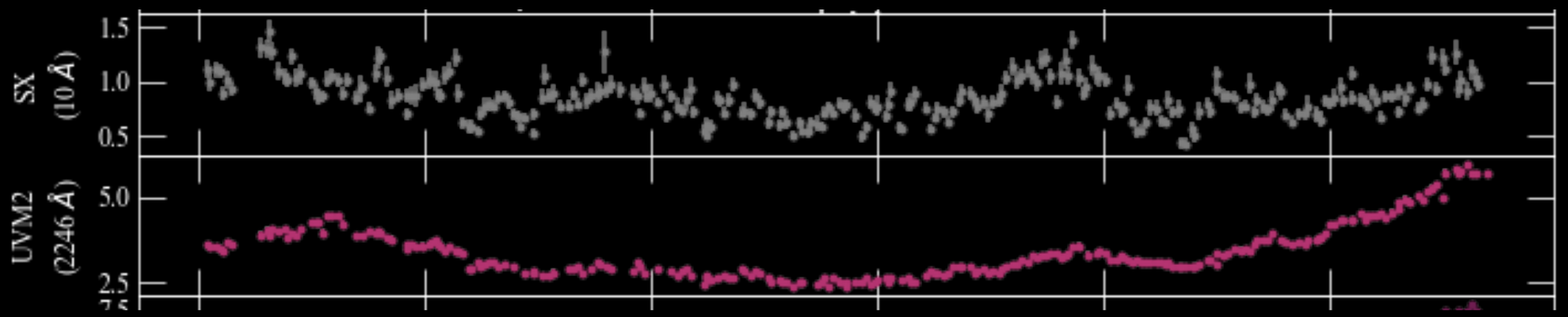
<u>Las Cumbres Observatory</u>

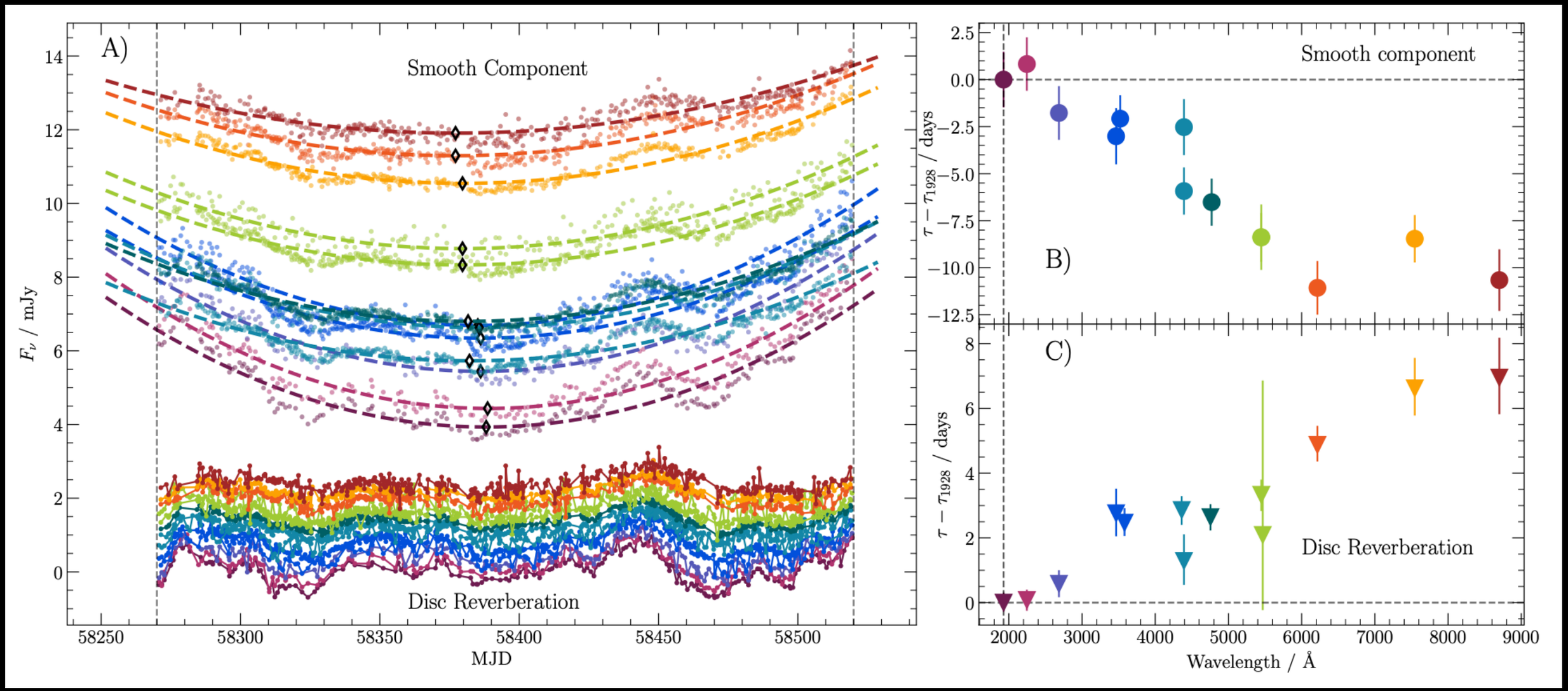
- Optical (7 filters, 400-900 nm)
- Mean cadence **~0.36 days**
- Total Exposure: 630 ks
- Additional spectroscopy, 4 day cadence

Hernández Santisteban+ 2020, MNRAS, 498, 5399



# Fairall 9: Two variability components



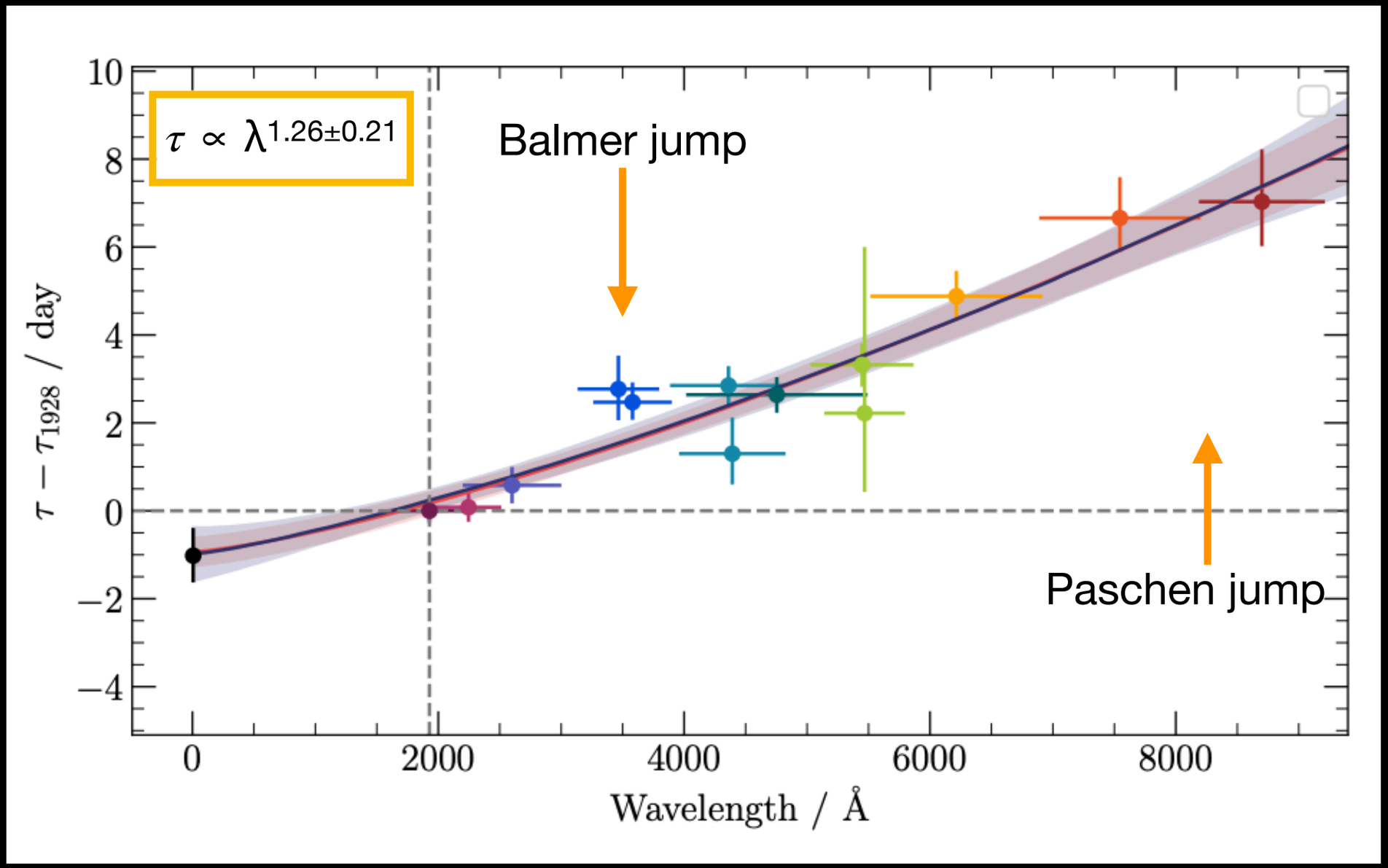




Hernández Santisteban+ 2020, MNRAS, 498, 5399

# Fairall 9: Lag Spectrum

## ICCF

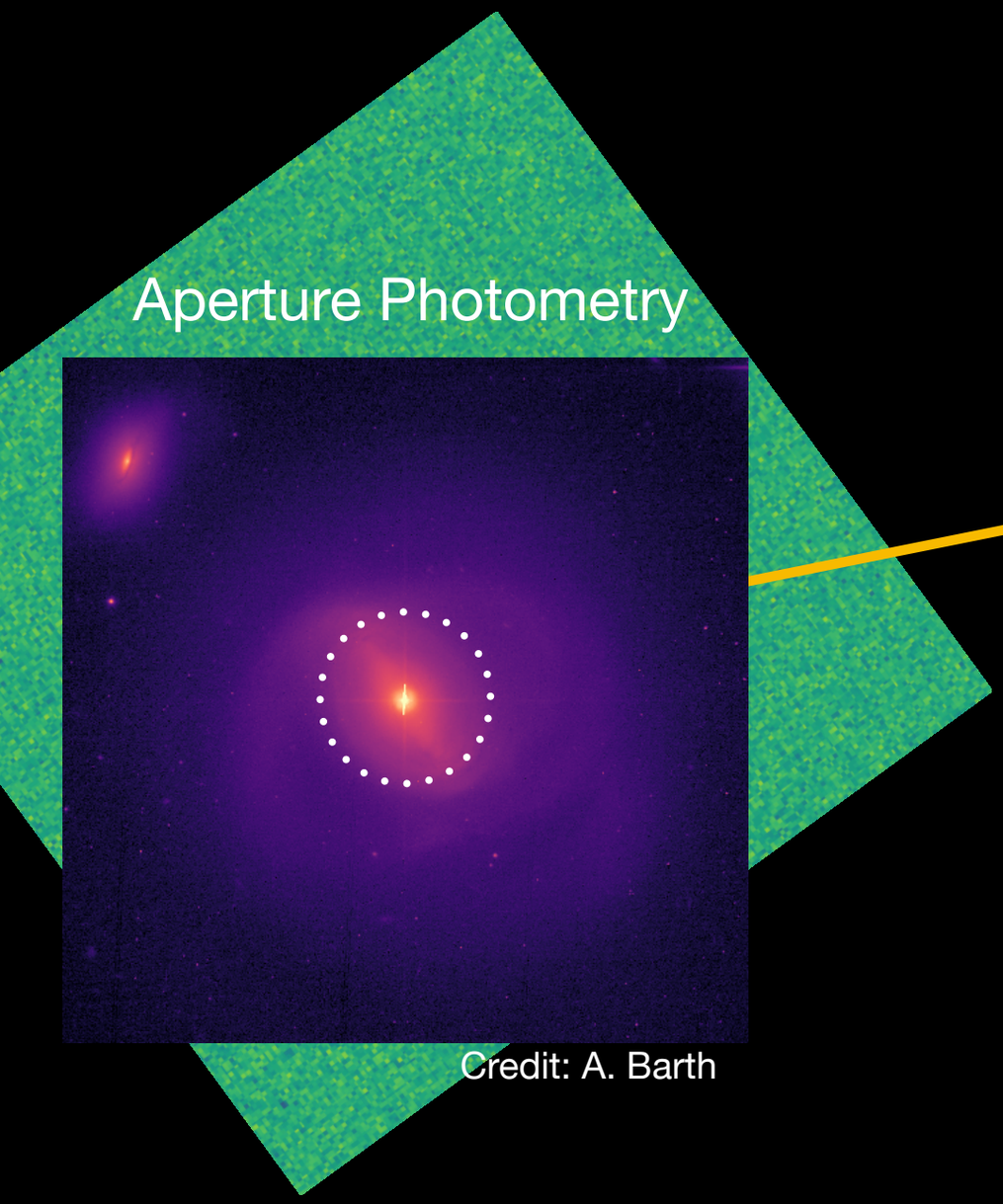
- Lags larger than predicted!
- Evidence for diffuse continuum in the lag spectrum

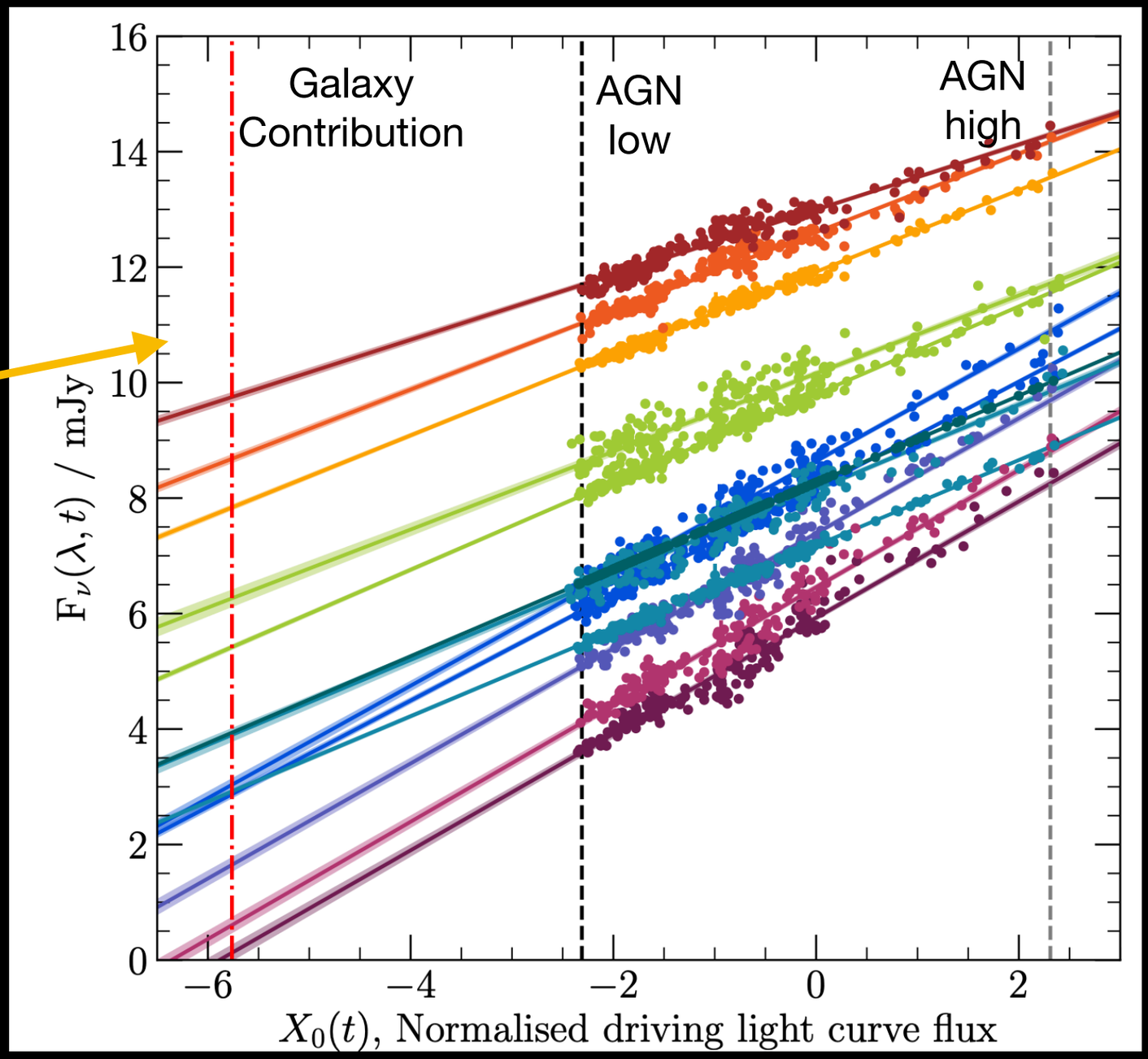



Hernández Santisteban+ 2020, MNRAS, 498, 5399

# Fairall 9: Dissecting the Variable Component

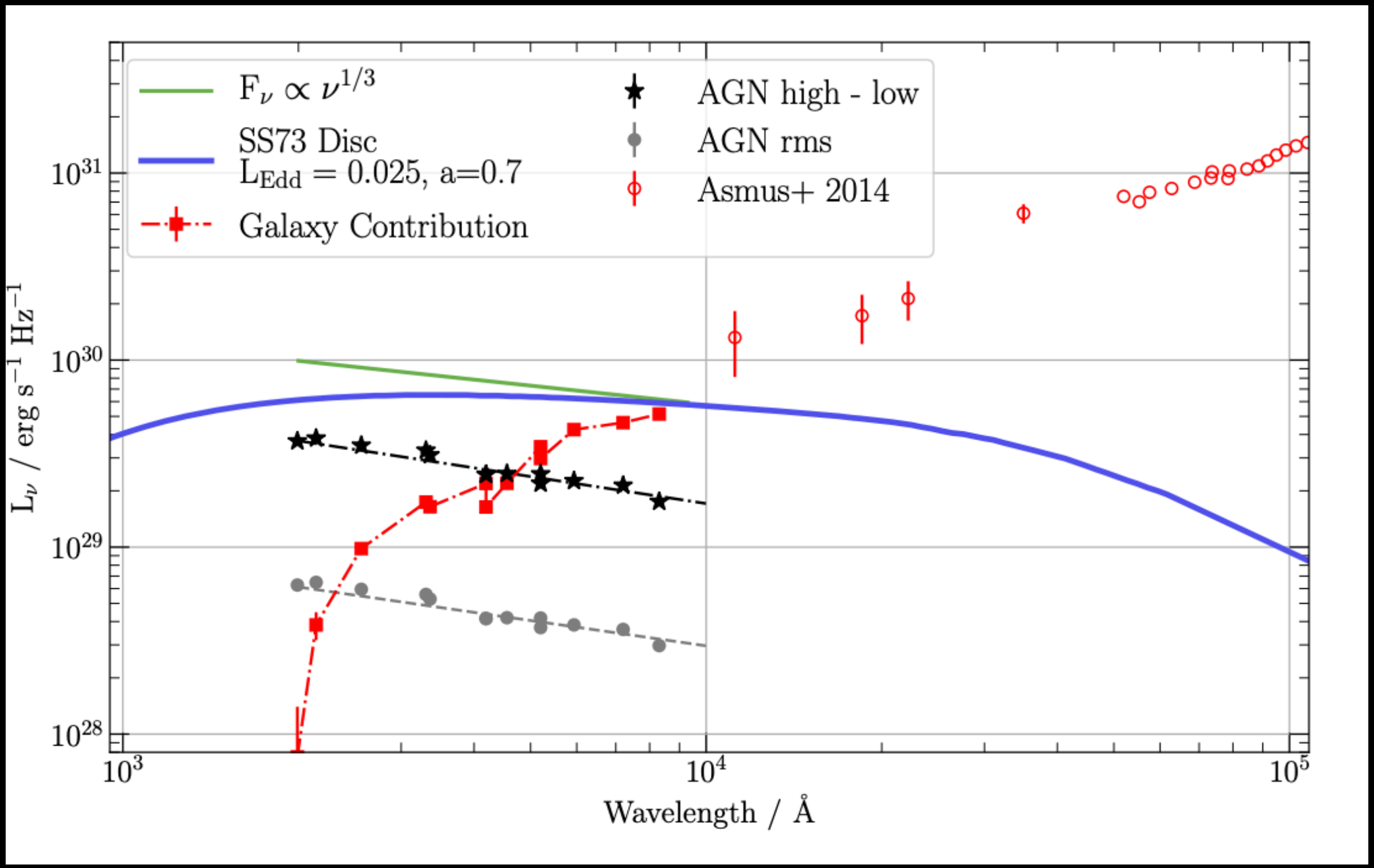
$$F(\lambda, t) = C(\lambda, t) \cdot X_0(t) + S(\lambda, t)$$




Hernández Santisteban+ 2020, MNRAS, 498, 5399

# Fairall 9: Dissecting the Variable Component




Hernández Santisteban+ 2020, MNRAS, 498, 5399

# AVA - AGN Variability Archive

Las Cumbres Observatory

**2020 LCO Key Project**

Legacy Database for AGN variability studies!

(PI Hernandez Santisteban)

**AVA** AGN Variability Archive

AVA Archive | About | Data Format | Publications

## Intensive disc reverberation mapping targets

**Select an object for more information**

archived = All the avaialble data is processed and archived. ongoing = Data is being collected. programmed = Observation campaigns are scheduled. to be added = Target has been observed but **not** archived.

**Show** 10 **entries** **Search:**

| ID | Name | RA (h : m : s) | DEC (° : ' : ") | $V_{mag}$ | log(L) (erg/s) | log(M) ($M_\odot$) | redshift | LCO (ks) | Swift (ks) | Other (ks) | Status |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | Mrk 110 | 09:25:12.8 | 52:17:10.38 | 16.41 | 44.54 | 7.4 | 0.0355 | 0 | 0 | | archived |
| 35 | Mrk 1220 | 08:54:39.24 | 17:41:22.42 | 16.3 | 0 | 0 | 0.06546 | 0 | 0 | | archived |
| 10 | Mrk 142 | 10:25:31.29 | 51:40:34.9 | 16.2 | 43.54 | 6.29 | 0.045 | 0 | 0 | | archived |
| 29 | Mrk 335 | 00:06:19.53 | 20:12:10.61 | 13.85 | 0 | 0 | 0.02541 | 0 | 0 | | archived |
| 11 | Mrk 509 | 20:44:09.75 | -10:43:24.72 | 13.2 | 45.08 | 8.12 | 0.034076 | 0 | 233.85 | | archived |
| 9 | Mrk 876 | 16:13:57.21 | 65:43:10.7 | 15.4 | 44.71 | 8.34 | 0.139 | 0 | 0 | | archived |
| 34 | NGC 2617 | 08:35:38.79 | -04:05:17.90 | 13.2 | 43.63 | 7.51 | 0.0143 | 0 | 0 | | archived |
| 14 | NGC 4151 | 12:10:32.57 | 39:24:21.05 | 11.4 | 43.2 | 7.54 | 0.0032 | 0 | 314.45 | | archived |
| 13 | NGC 4593 | 12:39:39.44 | -05:20:39.03 | 13.15 | 43.8 | 6.9 | 0.0083 | 0 | 172.31 | | archived |
| 8 | NGC 5548 | 14:17:59.5 | 25:08:13 | 13.7 | 44.1 | 7.7 | 0.01718 | 0 | 166.88 | | archived |

Showing 1 to 10 of 35 entries

Previous 1 2 3 4 Next

Hernández Santisteban, Horne & Edelson, in prep

# Conclusions

University of St Andrews

- **Multi-mission echo mapping experiments** are providing high-quality data to test accretion physics onto Supermassive black holes

- **Fairall 9** is a fantastic clean test-site for many experiments
  - **Lags are consistent** with thin accretion disc prediction: $\tau \propto \lambda^{4/3}$
  - **Two distinct variability** components in opposite directions

- New **2020 LCO Key Project** will deliver 8 more targets for 3 more years!!!

@Alymantara

alymantara.com/idrm

Las Cumbres **Observatory**

https://lco.global/science/keyprojects/