



University of
St Andrews

The AGN Variability Archive

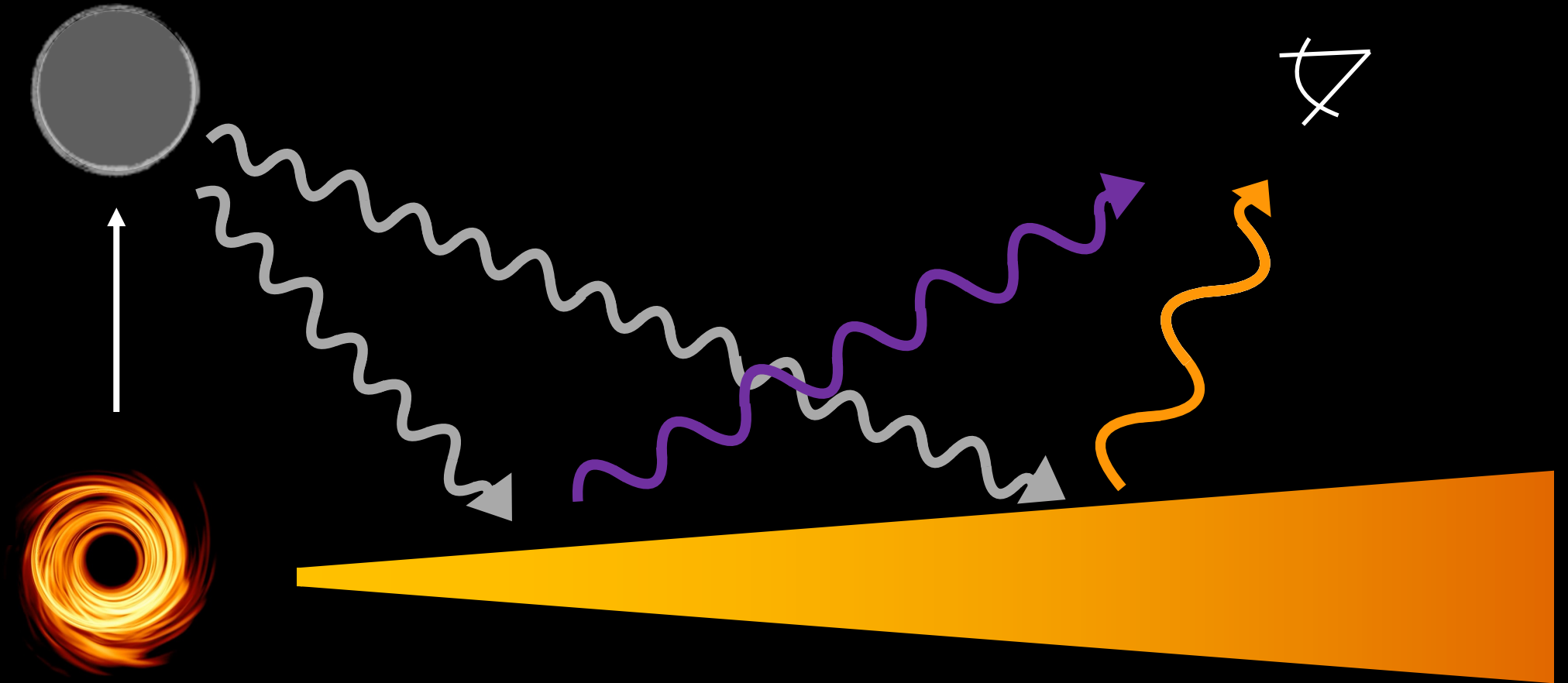
A legacy database of intensive broadband
reverberation mapping experiments

Juan V. Hernández Santisteban

26 June 2023

AGN variability as a probe of the central engine's geometry

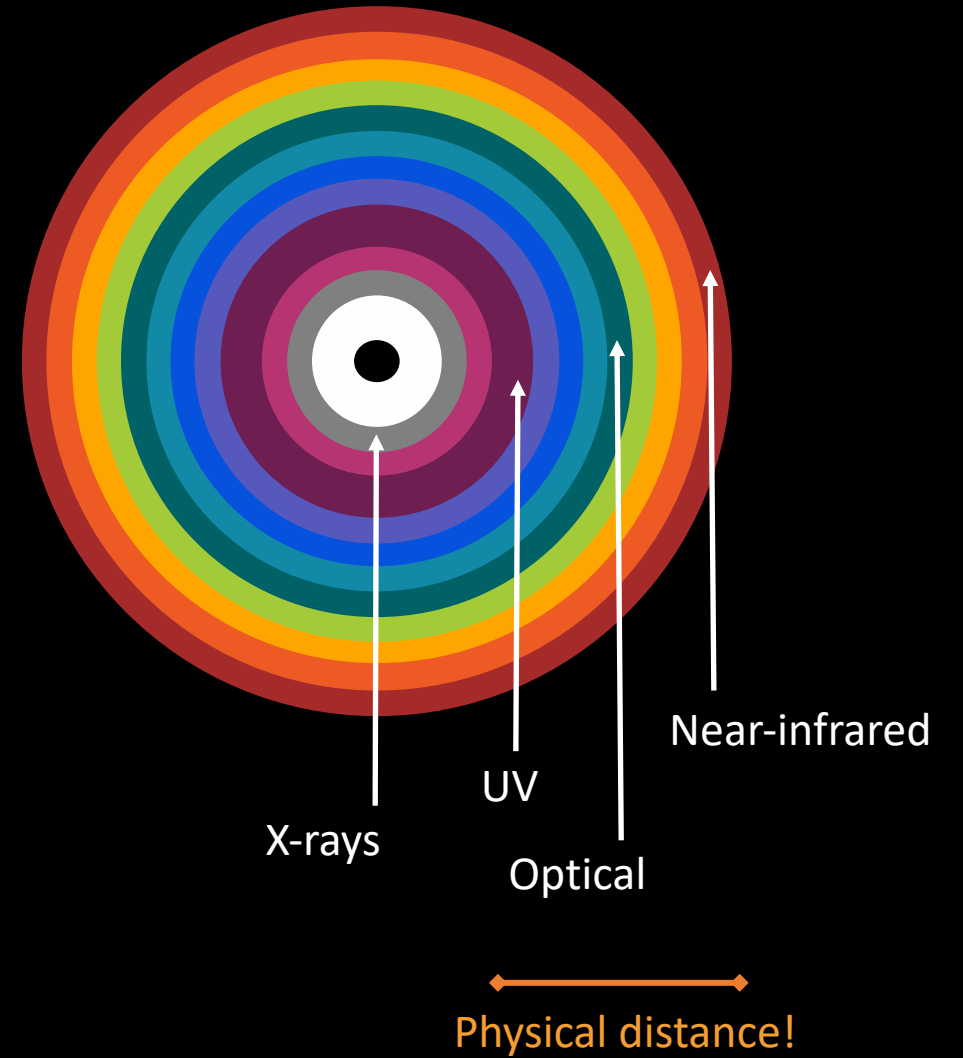
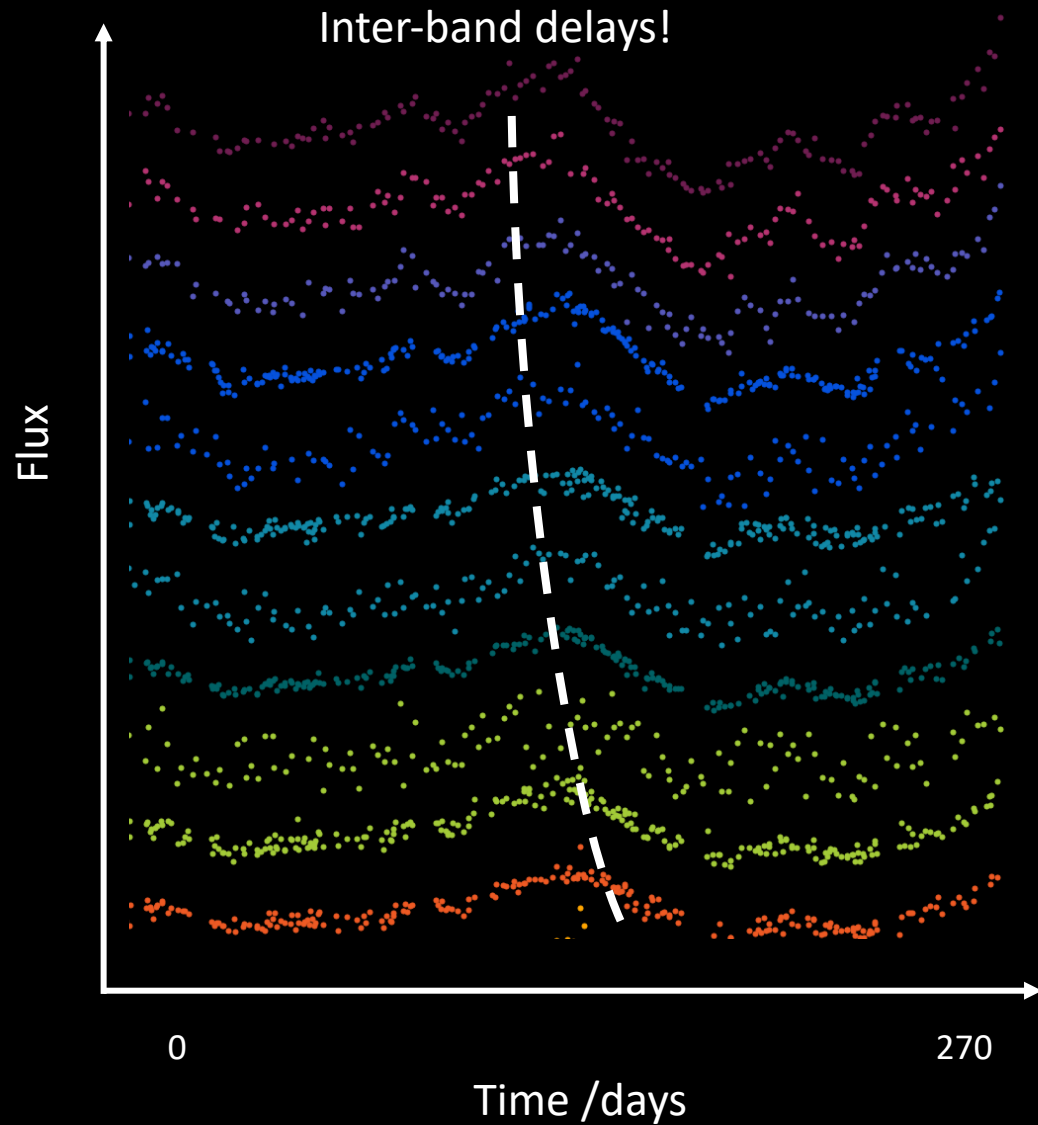
→ Exchanging *spatial* resolution for *temporal* resolution



L. R. Wink & L. Bacula
Goethe University Frankfurt

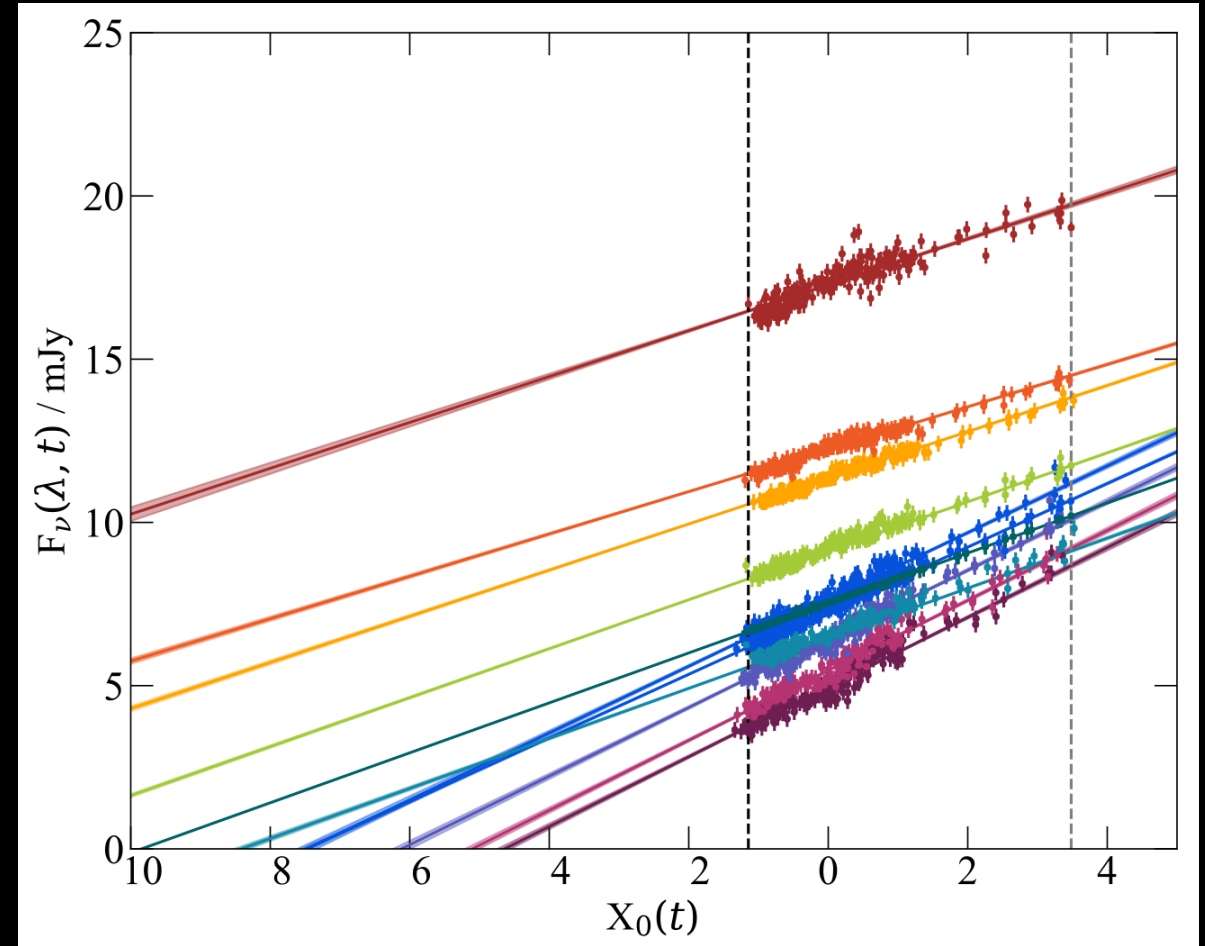
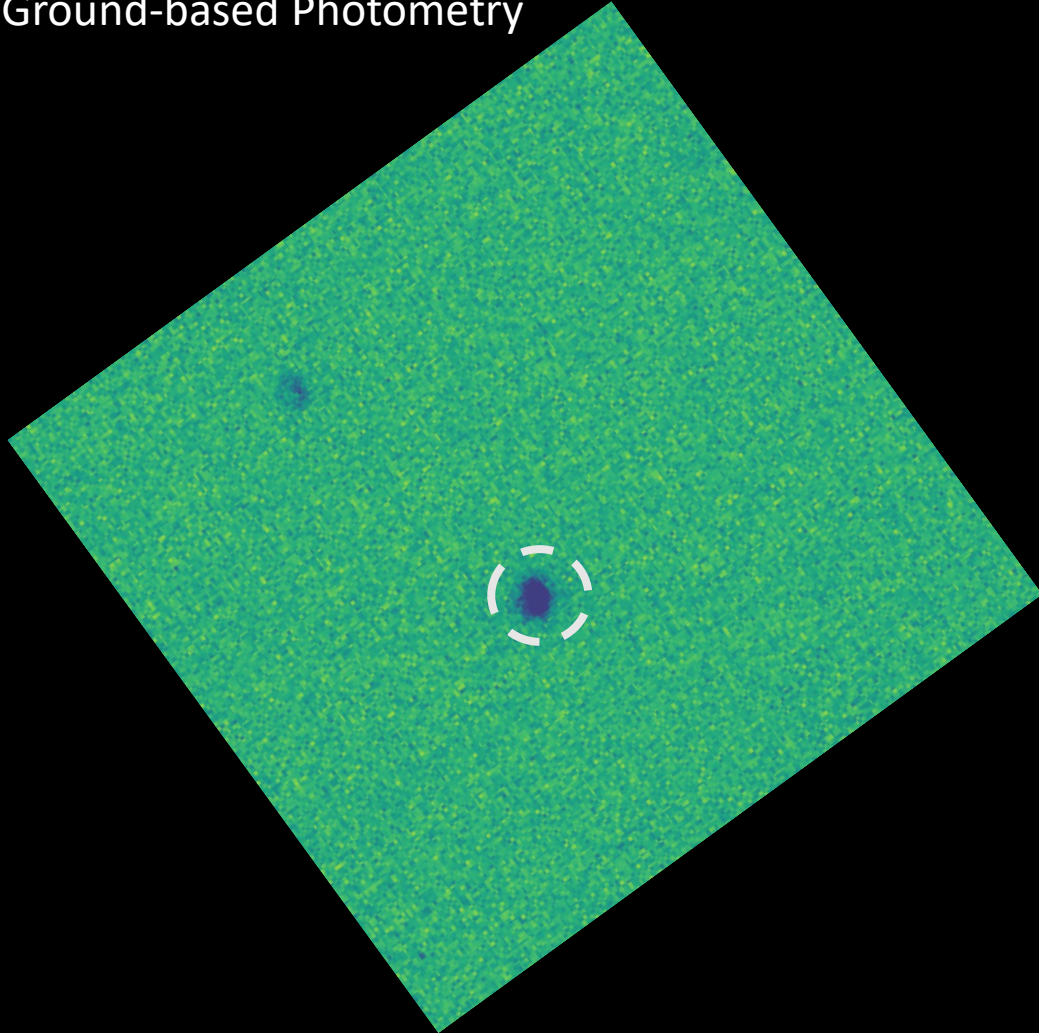
$$\tau = R/c \propto (M\dot{M})^{1/3} \lambda^{4/3}$$

AGN variability in search for echoes



AGN variability to measure the variable spectrum

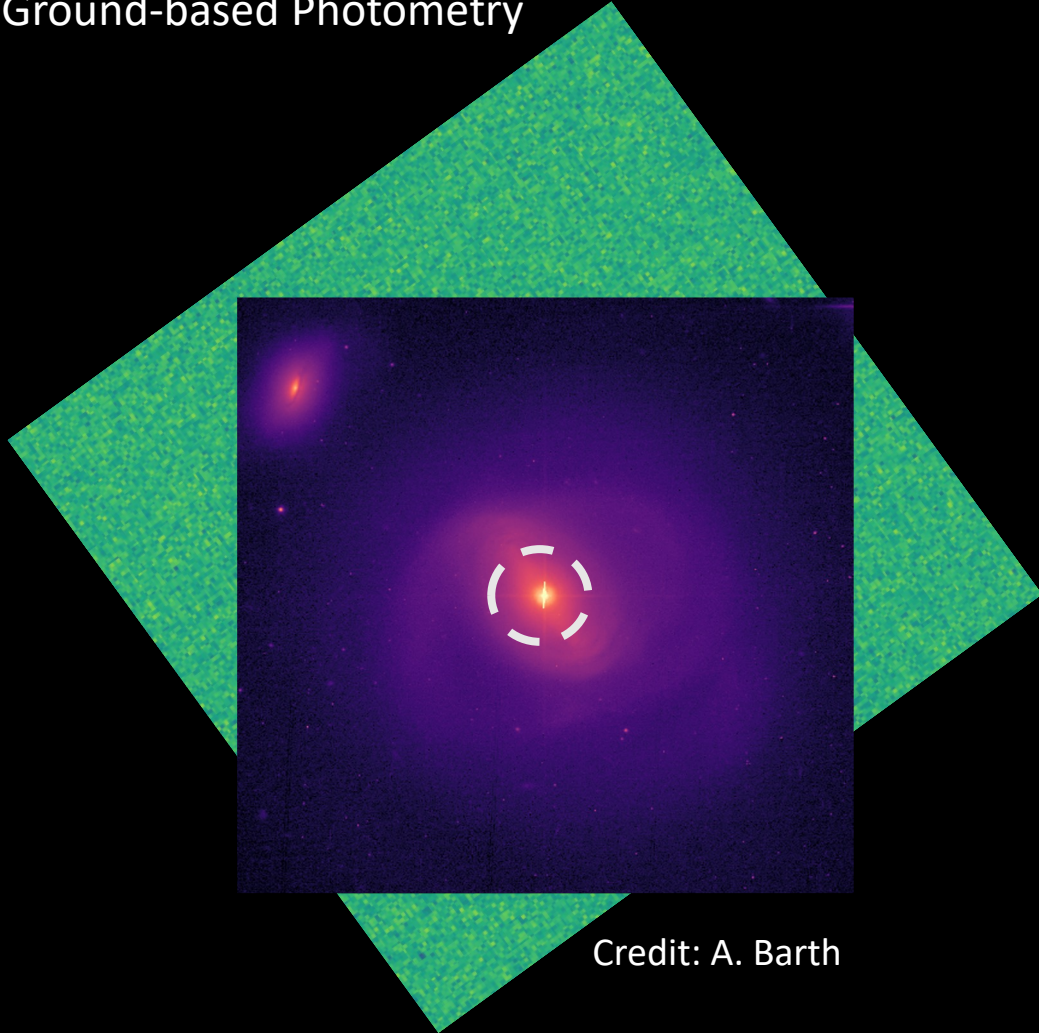
Ground-based Photometry



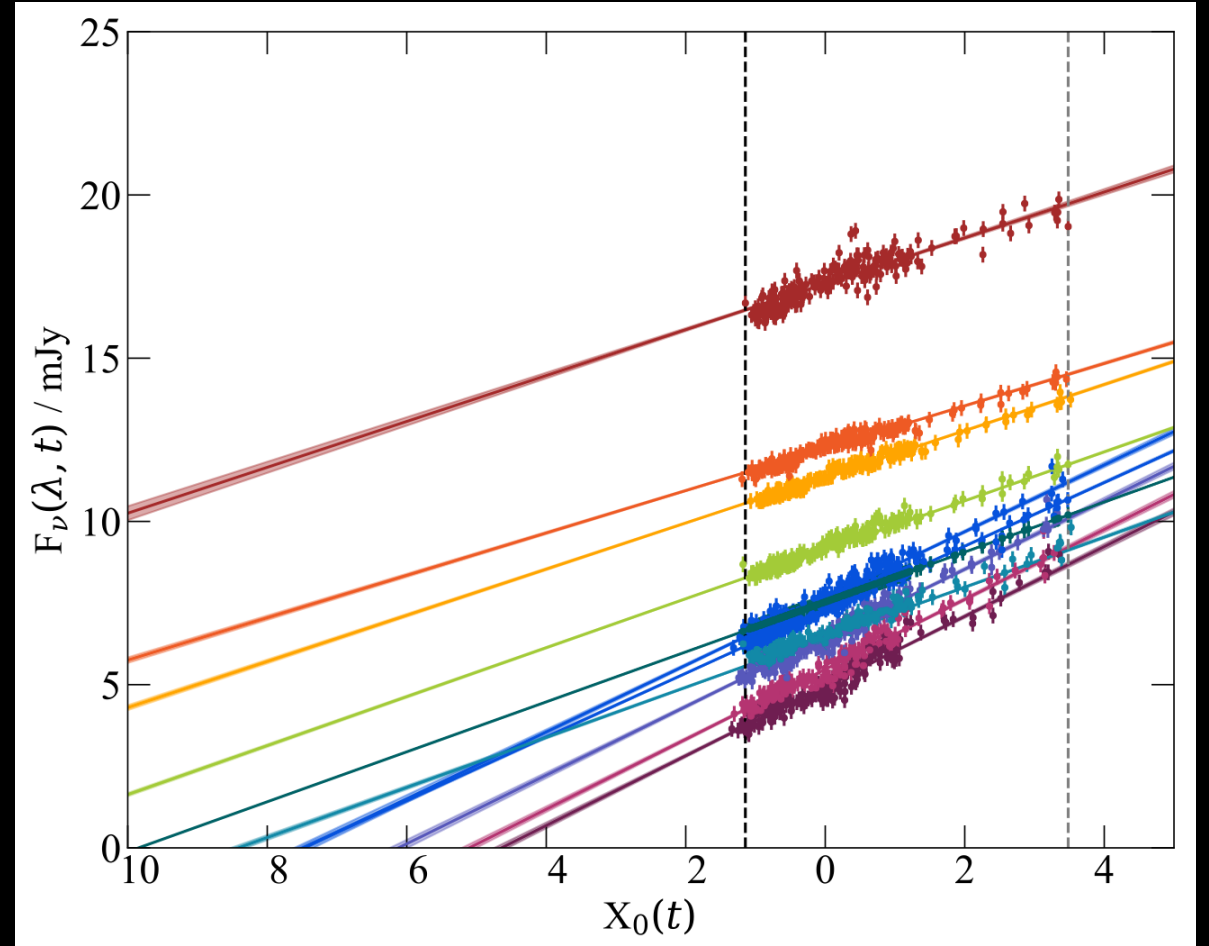
Hernández Santisteban et al. 2020, MNRAS

AGN variability to measure the variable spectrum

Ground-based Photometry



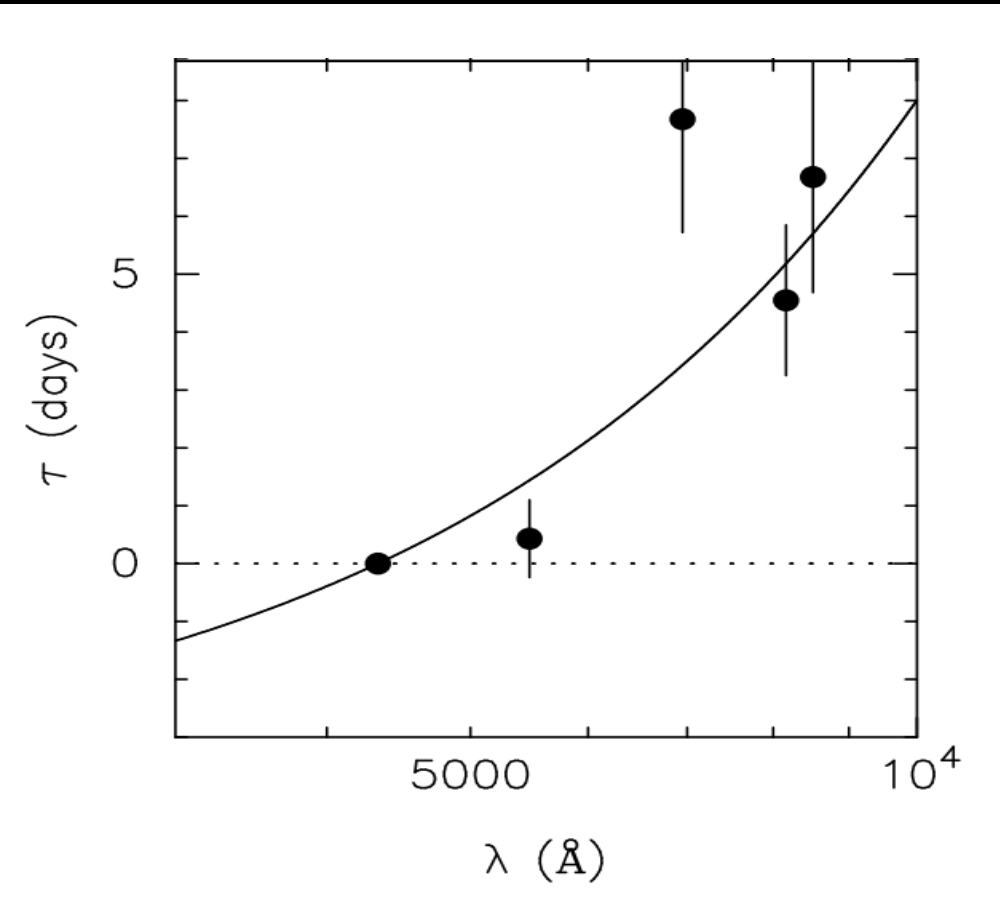
Credit: A. Barth



Hernández Santisteban et al. 2020, MNRAS

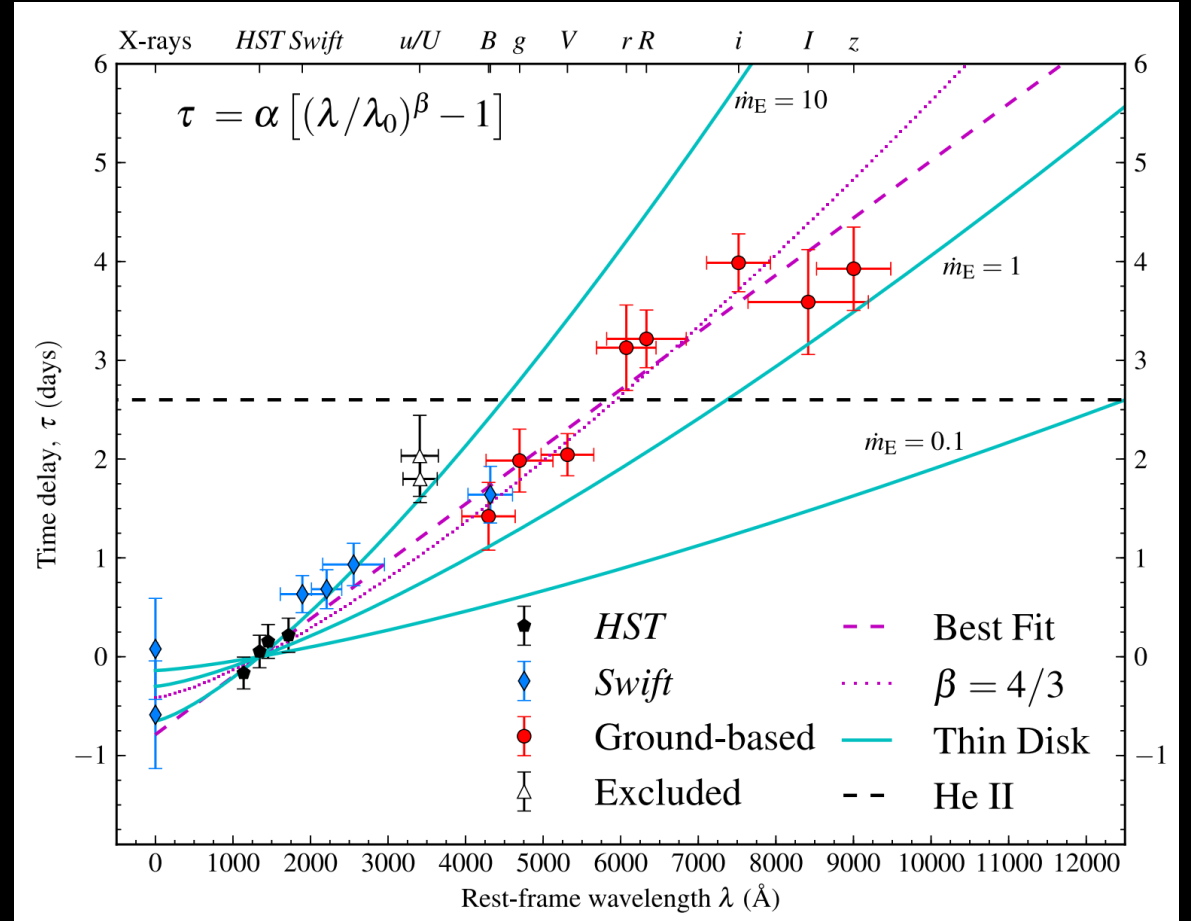
Intensive Broadband Reverberation Mapping: in practice

NGC 5548



Cackett+ 2007, MNRAS, 380, 669

Ten years make a difference!

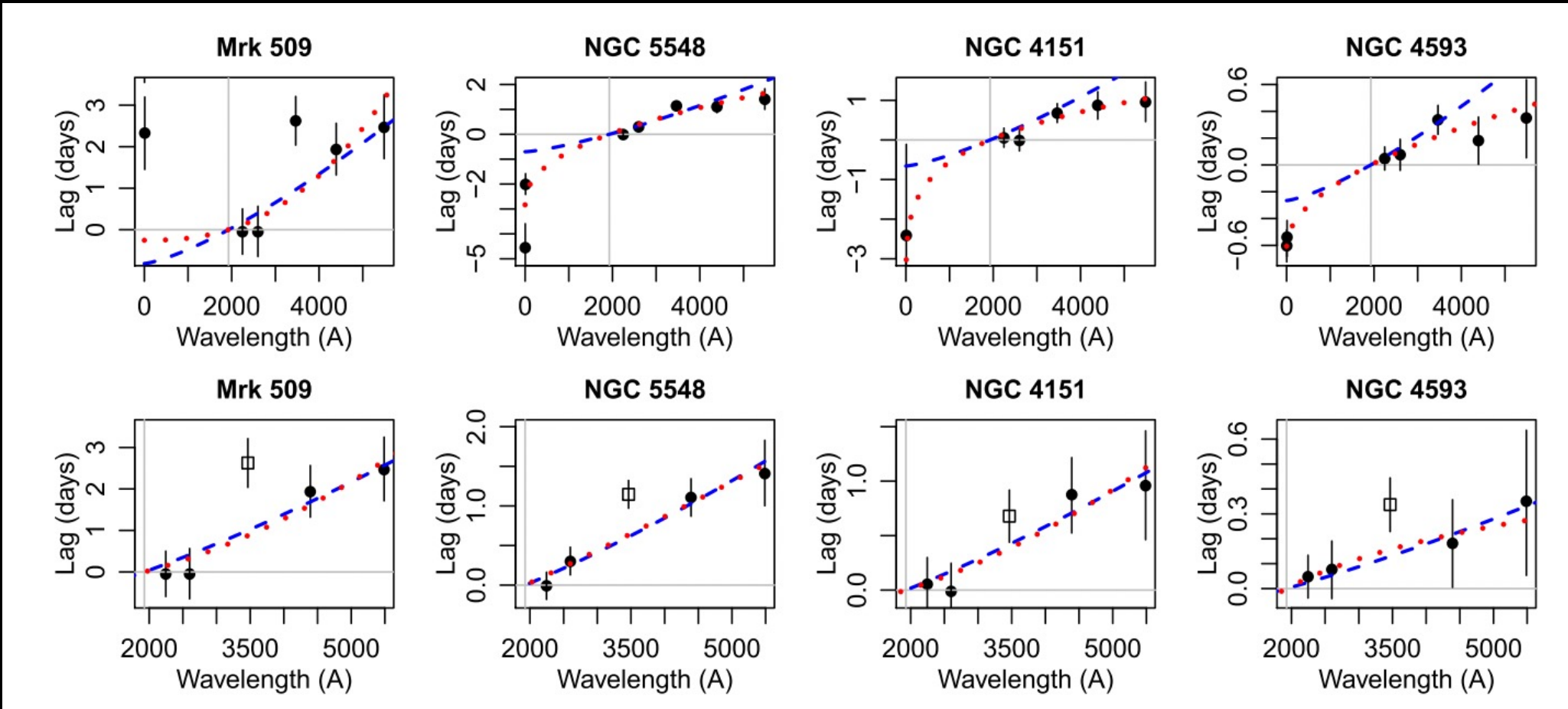


Fausnaugh+ 2016, ApJ, 821, 56

Intensive Broadband Reverberation Mapping: Results

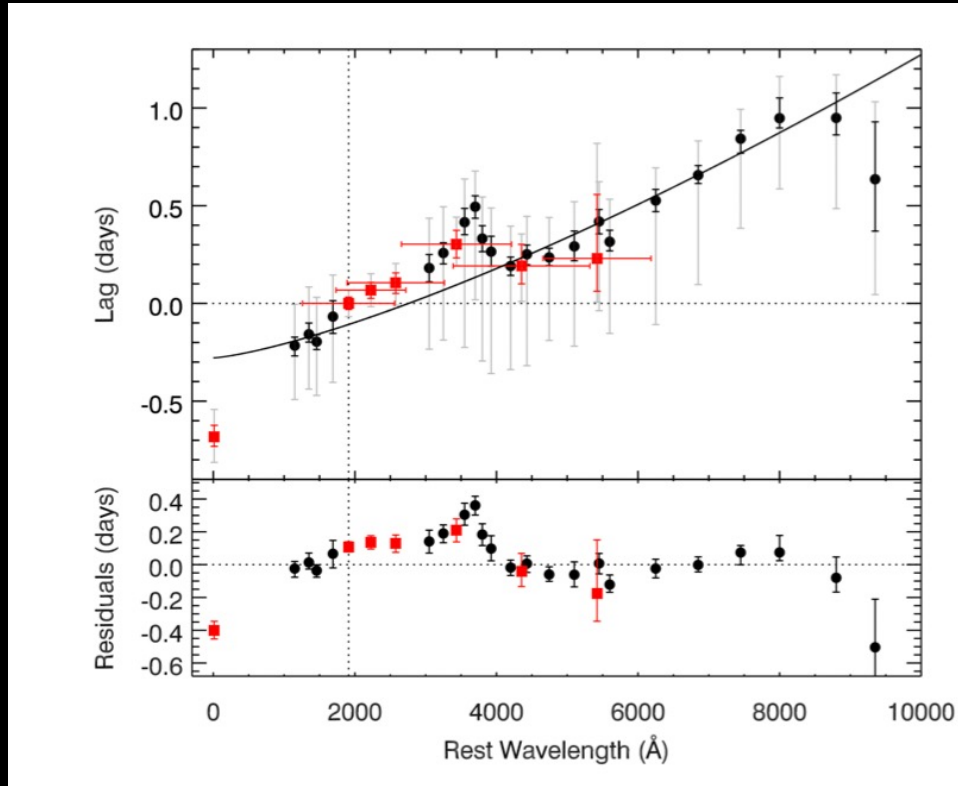
- We observe **strong correlations ($>3\sigma$)** throughout the optical/UV, with the longer wavelength variations lagging behind the shorter wavelengths by **roughly $\tau \propto \lambda^{4/3}$** , as predicted by standard thin disk models (Shakura & Sunyaev, 1973, Cackett et al 2007).
- Strong **excess lags in U band** (which contains the Balmer jump), and **disc sizes are larger than predicted** (e.g., Fausnaugh et al., 2016; Edelson et al., 2019).
 - This is strong evidence for an additional variability component, **Diffuse Continuum Emission** from the broad line region (DCE, Korista & Goad 2001; Netzer 2022) .
- Perhaps most puzzling, the **correlations** between the **X-ray and optical/UV variations are weak** and inconsistent, casting grave doubt on the simple reprocessing scenario.
 - This has forced development of new models to interpret the puzzling disconnect between the putative driving (X-ray) and reprocessed (optical/UV) light curves (e.g., Gardner & Done, 2017; Sun et al., 2020; Mahmoud & Done, 2020; Kammoun et al., 2021; Starkey et al., 2023).

Intensive Broadband Reverberation Mapping: Results

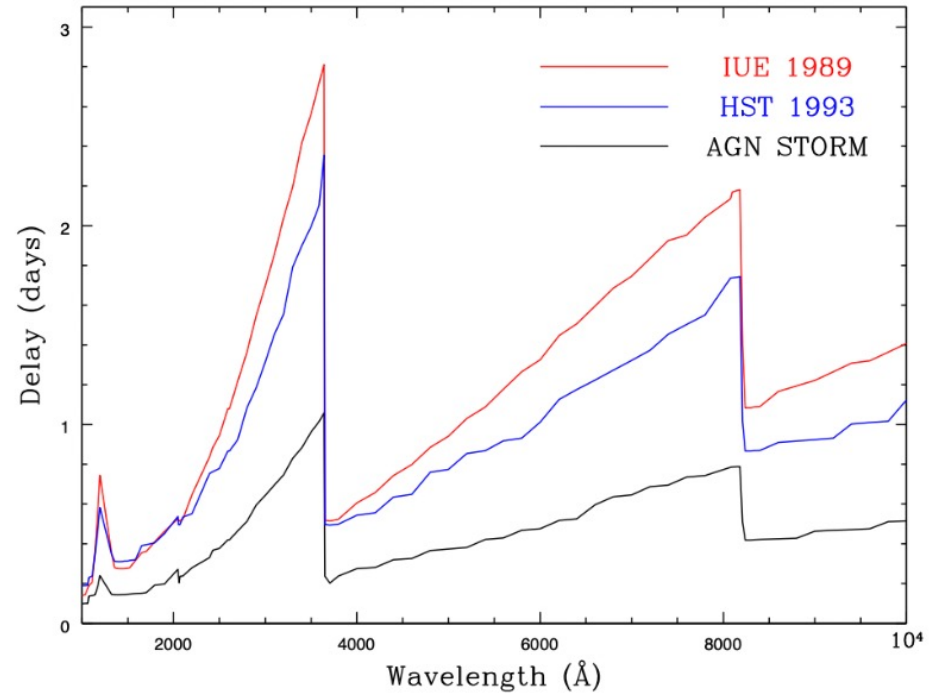


Edelson+ 2019, ApJ

Intensive Broadband Reverberation Mapping: Results



Cackett+ 2018, ApJ



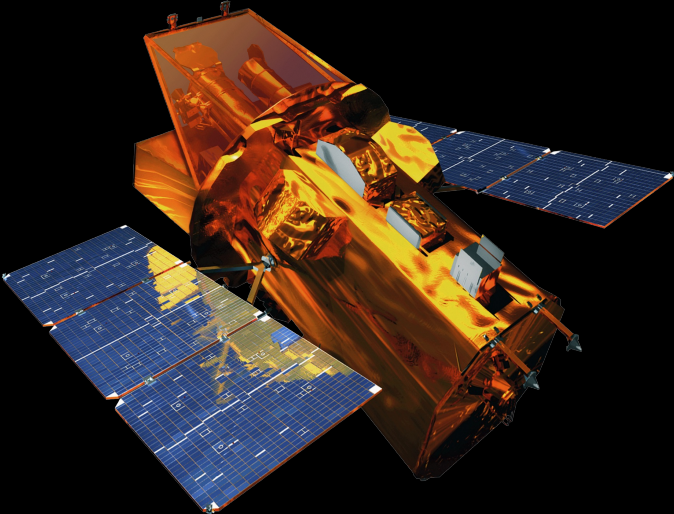
Korista & Goad, 2019, MNRAS

Several alternative Interpretations:

A. Secunda, I. Papadakis, Neustadt, Z-Y Cai & E. Kammoun talks this afternoon!

Intensive Broadband Reverberation Mapping: in practice

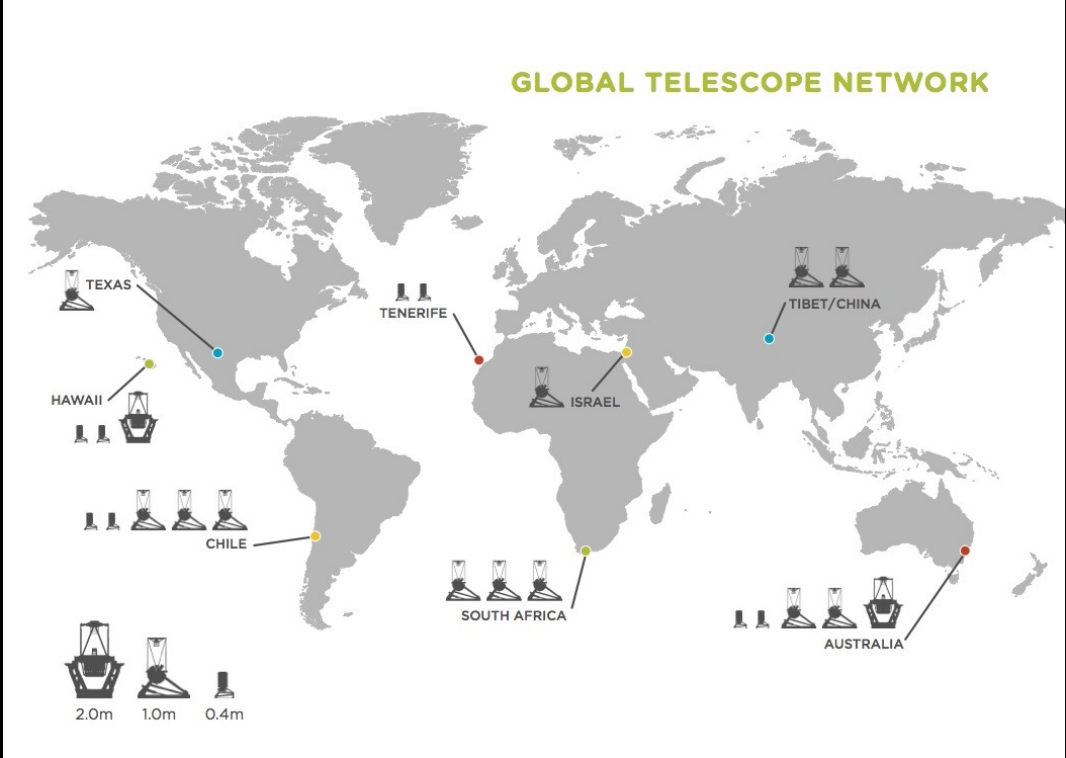
The Neils Gehrels
Swift Observatory



X-rays & Ultraviolet

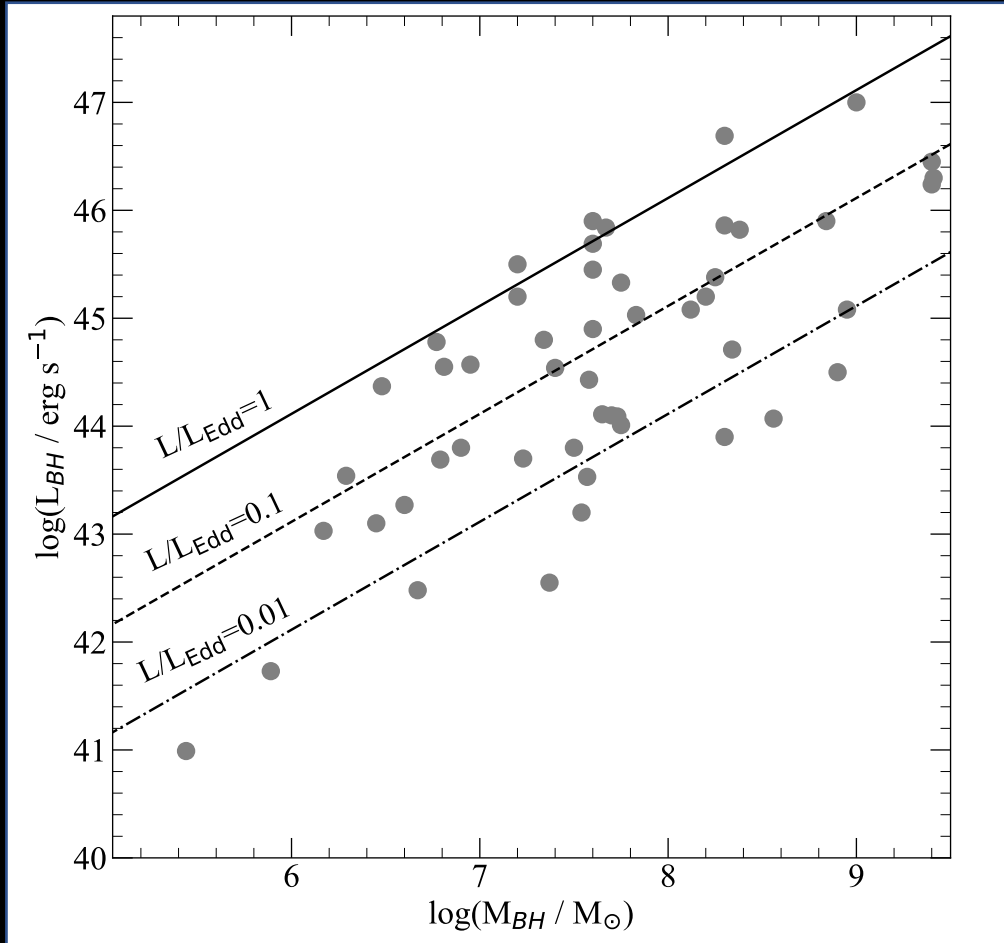


Las Cumbres Observatory



Optical & infrared

Ground-based photometric and spectroscopic optical monitoring through **4 LCO Key Projects**



Hernández Santisteban, 2023, OjA, in prep

- **2014 – K. Horne (PI)**
- **2018 – R. Edelson (PI)**
- **2020 – Hernández Santisteban (PI)**
- **2023 – Hernández Santisteban (PI)** *starting in July*

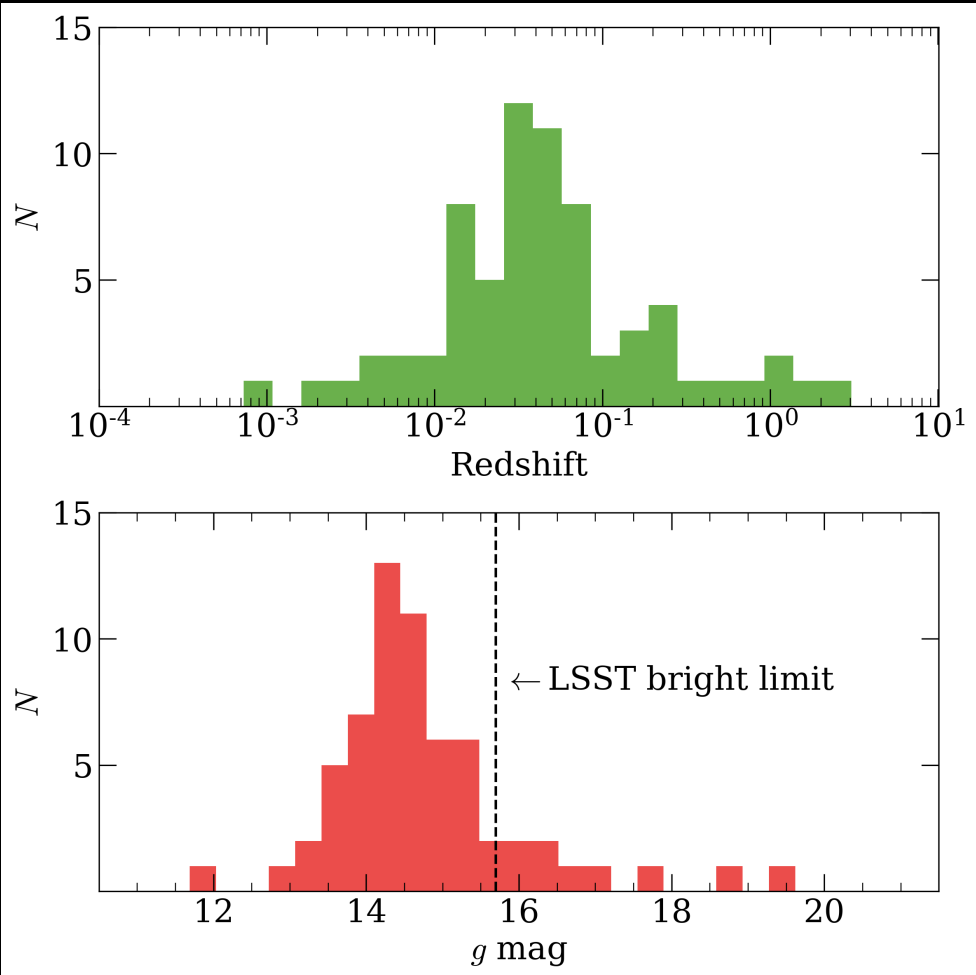
58 Bright, variable and local AGN (mostly Seyfert-1)
 → **5 decades** in **luminosity** and **mass**

Bvugriz photometry → 0.3-2 day cadence (**46 AGN**)
 → >7-9 month campaigns
 → *Multi-year follow-up*

300 – 1000 nm spectroscopy → 2-10 day cadence
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Hernández Santisteban, 2023, OjA, in prep

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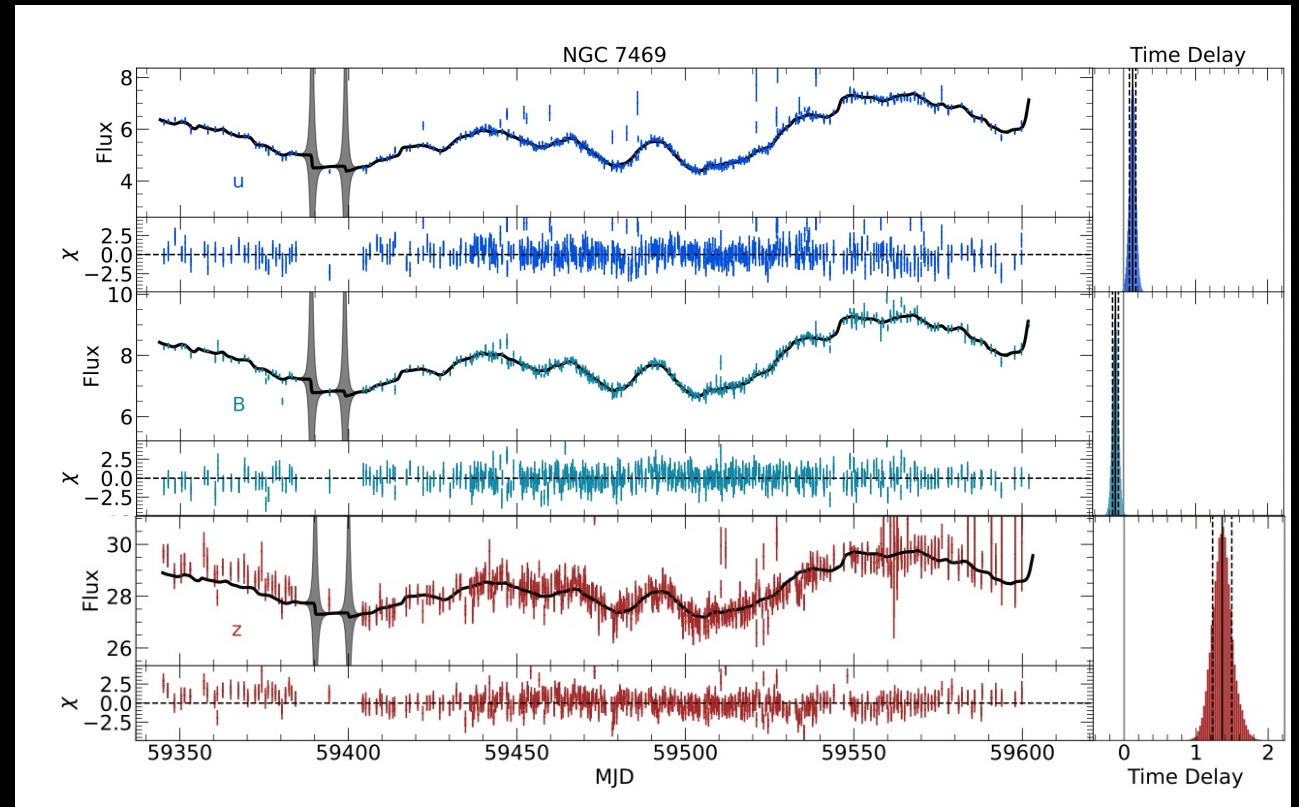
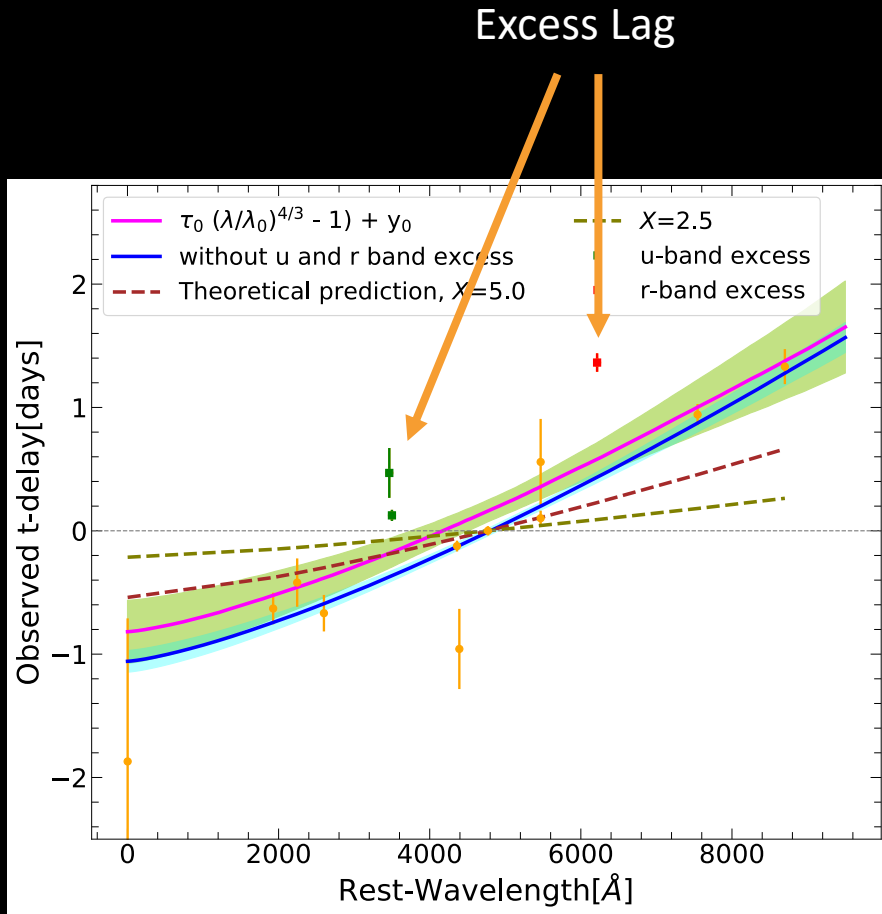
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NGC 7469

Excess lags in both U & r-bands!



Check **Raj Prince's** poster!



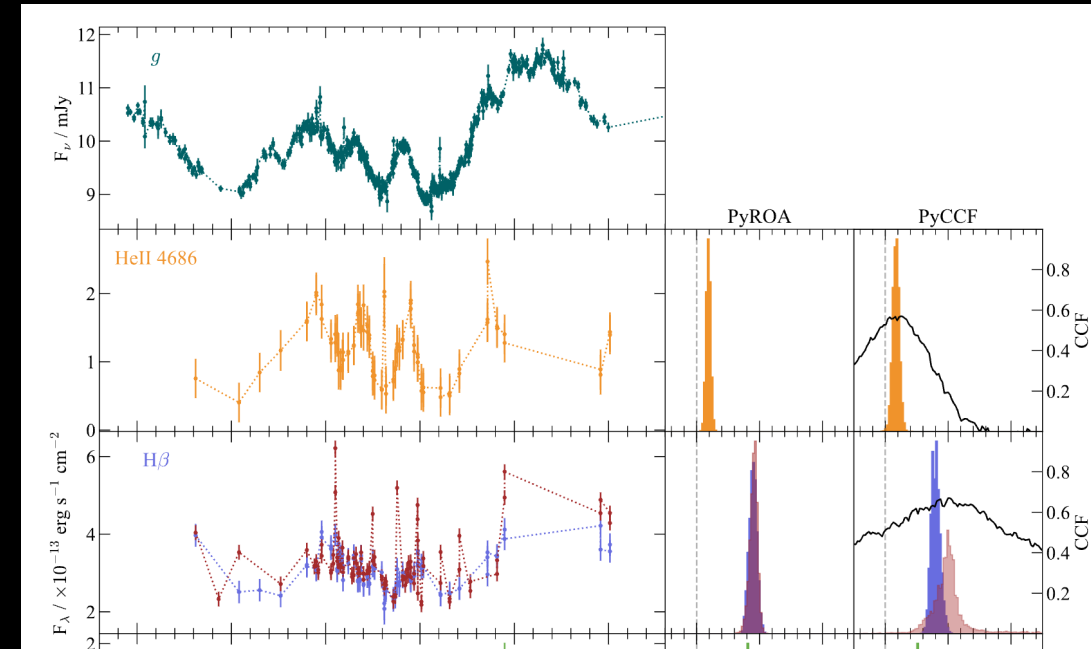
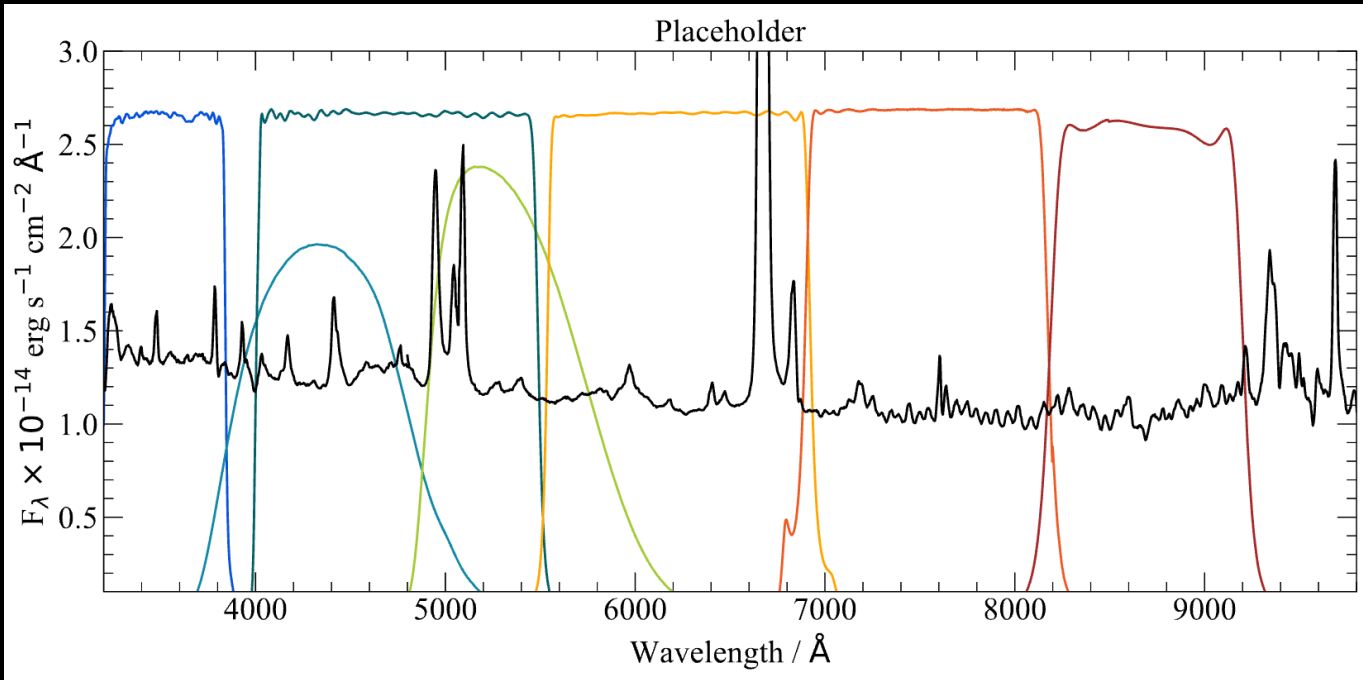
Prince, Hernández Santisteban+ 2023, in prep

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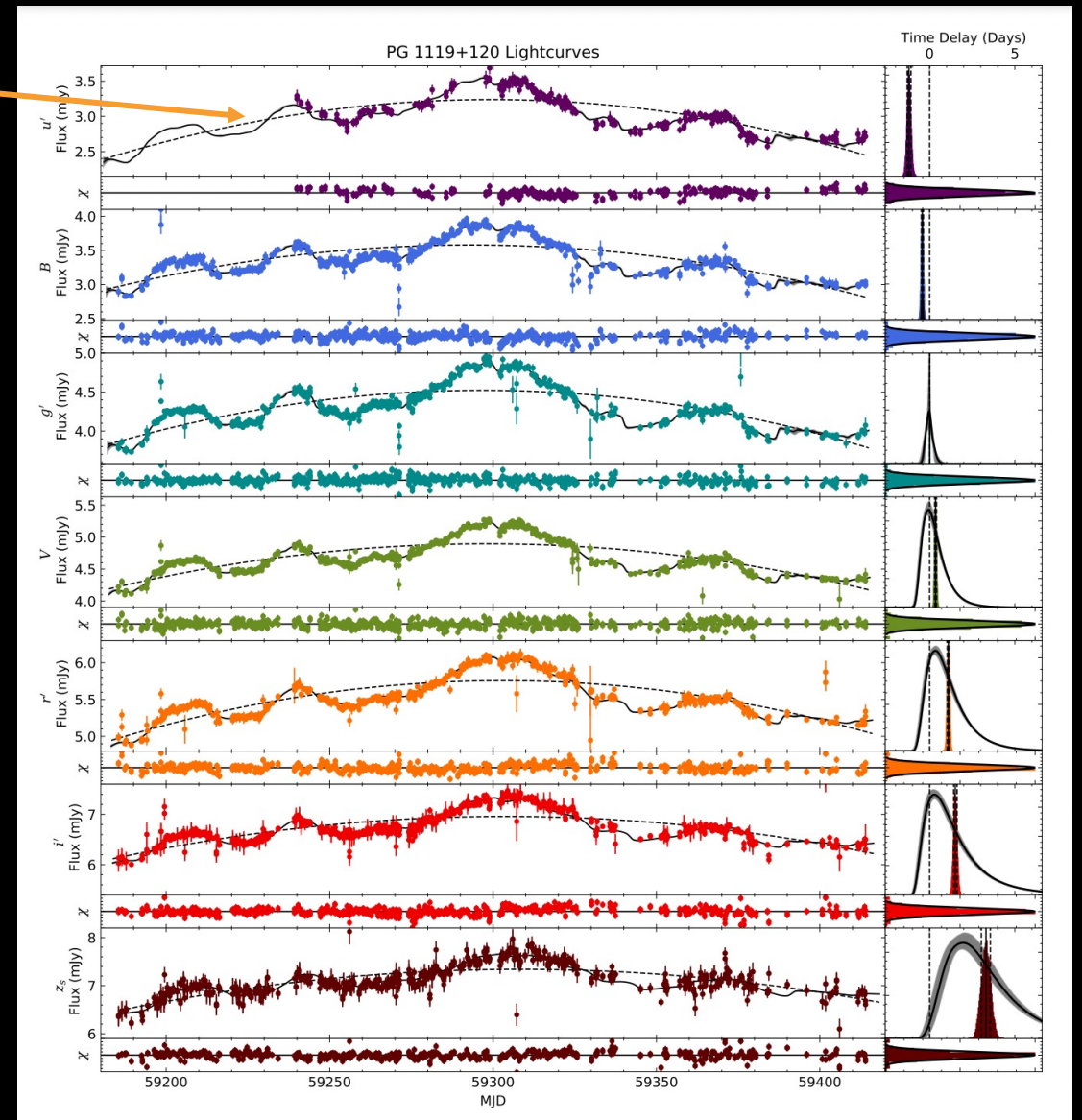
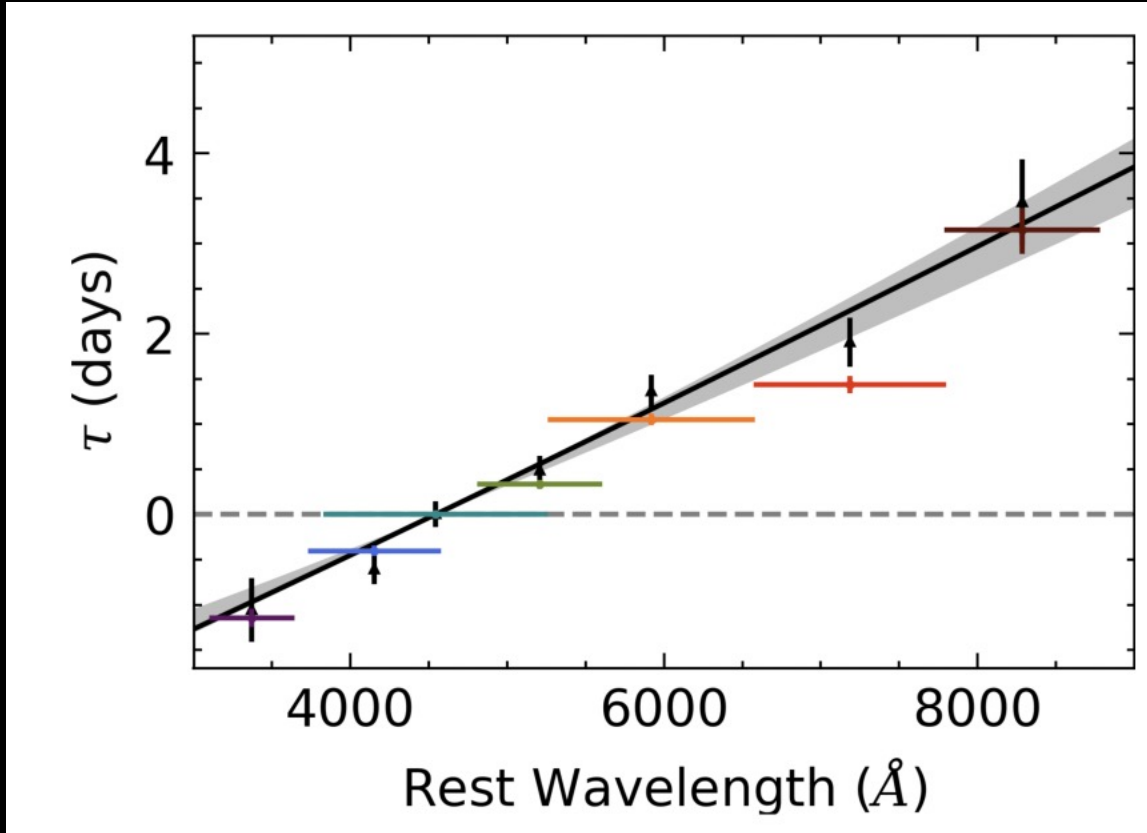
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PG 1119+120

high-luminosity AGN

Slow component



Check Fergus Donnan poster!

Donnan, *Hernández Santisteban*+ 2023, MNRAS

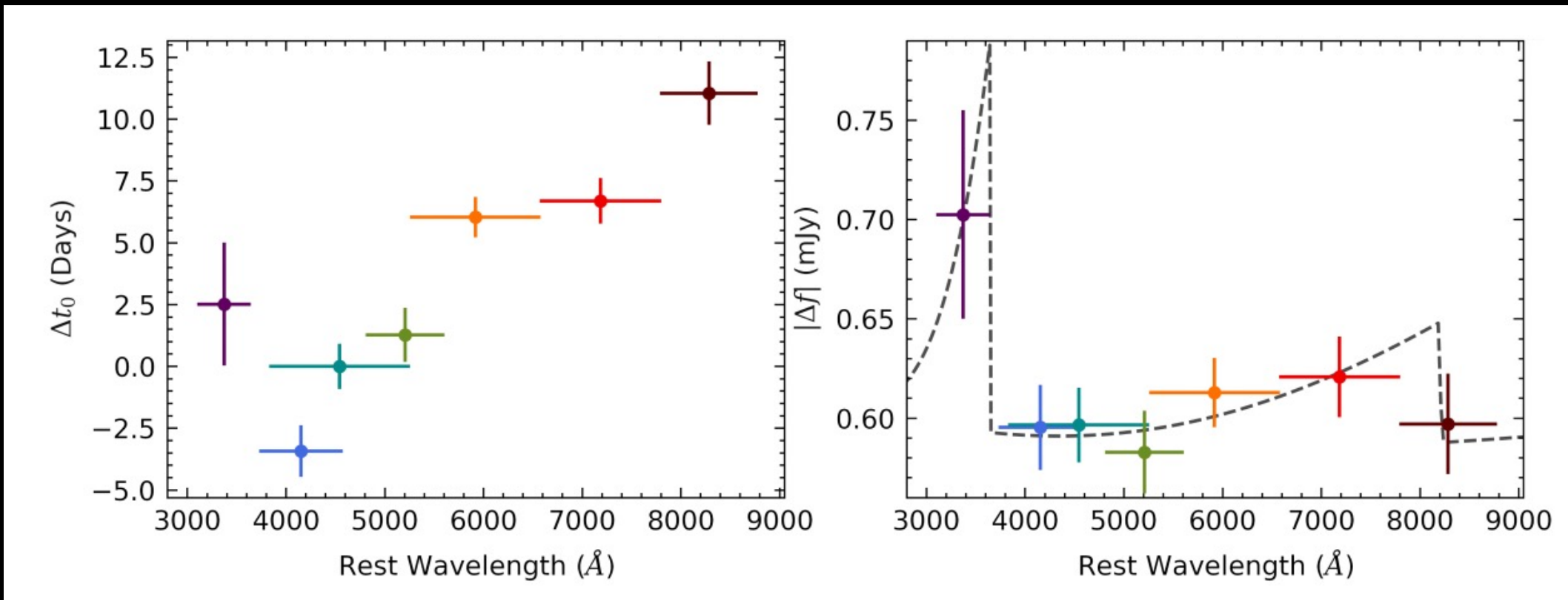
PG 1119+120

high-luminosity AGN

Slow component

Delay Spectrum

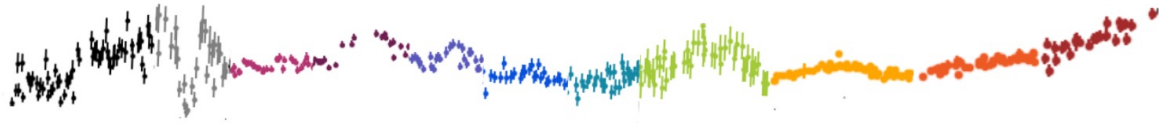
Spectral Energy Distribution



Check Fergus Donnan's poster!

Donnan, *Hernández Santisteban*+ 2023, MNRAS

AVA AGN Variability Archive



Hernández Santisteban, 2023, OjA, in prep

Develop a **fully-automated pipeline** to retrieve, extract and calibrate daily light curves from our AGN monitoring campaign.

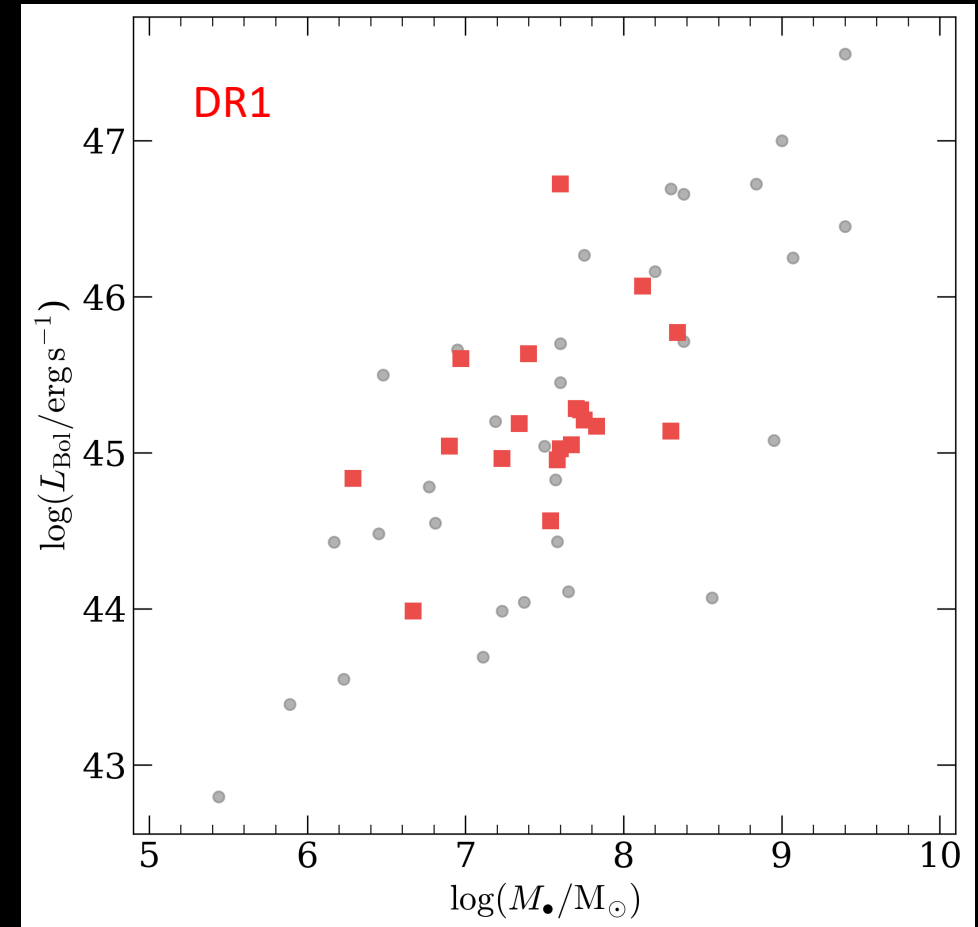
Consistent data reduction and processing.

Data intercalibrated with **PyROA**

(Donnan, *Hernández Santisteban+* 2023, MNRAS)

Develop a **living database**, that will contain science-ready data products → long-lasting resource for the community

<http://alymantara.com/ava>



Intensive broadband reverberation mapping targets

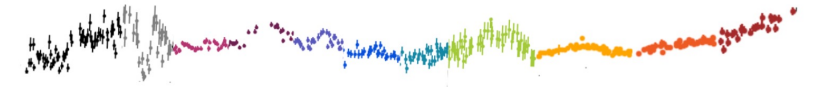
Select an object for more information

Observing = Data collected in the last 30 days. Archived = All the available data is processed and archived. to be processed = Target has been observed but not archived.

Show entries

Search:

ID	Name	RA (h : m : s)	DEC (° : ' : ")	V _{mag}	log(L _{Bol}) (erg/s)	log(M _*) (M _⊙)	redshift	LCO filters	<Cadence> (days)	Status
29	Mrk 335	00:06:19.52	+20:12:10.48	14.54	44.96	7.23	0.025785	BVugriz	1.04	Observing
7	I Zw 1	00:53:34.94	+12:41:36.20	14.48	45.60	6.97	0.061169	BVugriz	0.87	Observing
1	Fairall 9	01:23:45.78	-58:48:20.81	13.74	45.14	8.3	0.046145	BVugriz	0.39	Observing
64	Mrk 359	01:27:32.55	+19:10:43.79	14.56	43.55	6.23	0.016958	BVugriz	1.04	Observing
70	RX J0134.2-4258	01:34:16.90	-42:58:27.01	15.97	0.00	0	0.237134	BVgriz	1.01	Observing
38	Mrk 590	02:14:33.56	-00:46:00.08	14.57	44.83	7.57	0.026385	BVugriz	1.03	Observing
68	NGC 1365	03:33:36.37	-36:08:25.44	13.77	0.00	6.3	0.005457	BVugriz	1.03	Observing
50	Ark 120	05:16:11.42	-00:08:59.39	14.11	45.17	7.83	0.032713	BVugriz	1.00	Observing
54	ESO 362-G18	05:19:35.80	-32:39:27.29	13.89	44.11	7.65	0.012445	BVugriz	1.04	Observing
21	PG 0804+761	08:10:58.60	+76:02:42.50	13.98	46.16	8.2	0.1005	BVugriz	4.89	Observing
4	PG 0844+349	08:47:42.47	+34:45:04.39	14.23	46.72	7.6	0.064	BVugriz	4.23	Observing
12	Mrk 110	09:25:12.87	+52:17:10.54	14.63	45.63	7.4	0.035291	BVugriz	1.08	Observing
16	PG 0923+201	09:25:54.72	+19:54:05.15	15.07	46.25	9.07	0.192696	BVugriz	4.69	Observing
52	Mrk 1230	09:52:19.10	+01:26:42.45	14.42	44.55	6.81	0.019927	BVugriz	1.10	Observing



<http://alymantara.com/ava>

Hernández Santisteban, 2023, OjA, in prep

Fairall 9

[← Back](#)

[Simbad](#) | [NED](#) | [Bentz DB](#)

RA (h:m:s) DEC (d:m:s) RA (deg) DEC (deg):
01:23:45.78 -58:48:20.81 20.94074 -58.80578

Basic Information

Redshift	0.046145	
E(B-V)	0.026	Schlafly & Finkbeiner (2011)
Black Hole Mass	8.3 M_{\odot}	Bentz & Katz (2015)
L_{5100}	43.92 (erg/s)	Bentz & Katz (2015)
L_{Bol}	45.14 (erg/s)	$k_{\text{bol}}=16.52$, Netzer (2019)
L_{Edd}	0.053	(caution)

Photometric Data Summary

Facility	Cadence (days)	Start (MJD)	End (MJD)	↓
Swift	0.99	2018-05-13	2020-02-21	🕒
LCO	0.39	2018-06-02	2023-02-21	🕒

Spectroscopic Data Summary

Facility	Cadence (days)	Epochs	Start (MJD)	End (MJD)	↓
LCO	4.95	194	2018-05-25	2023-02-25	🕒

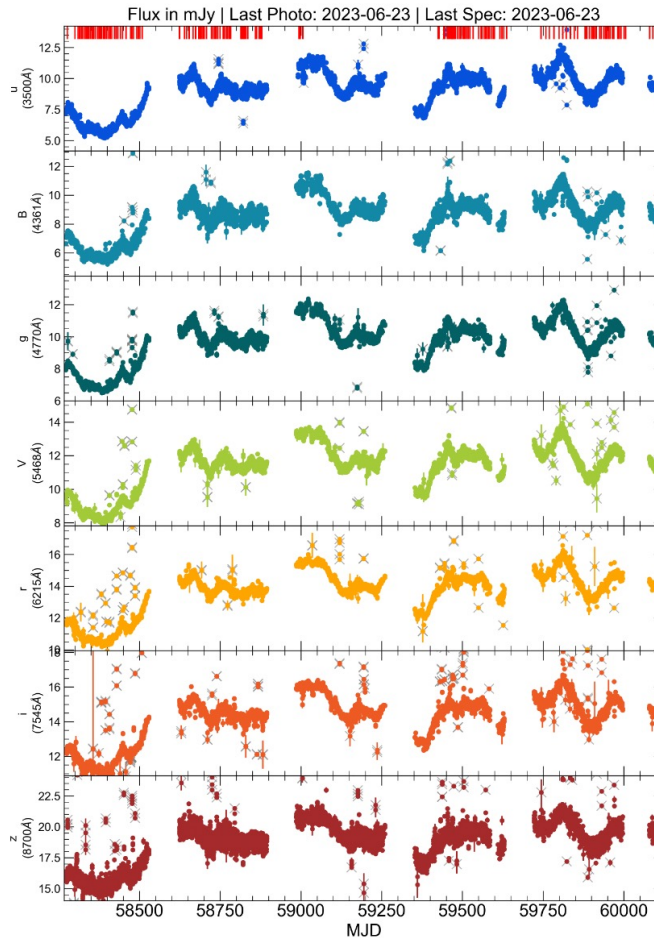
Data Citation

- [Hernandez Santisteban et al. 2020, MNRAS, 498, 5399](#)
- [Edelson et al, in prep](#)

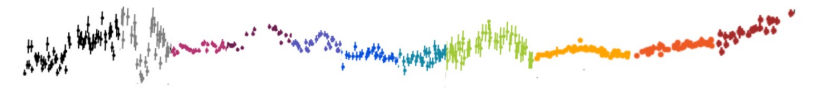
Photometric Light curves

Photometry **Image** Sky Standards Spectroscopy

LCO **LCO last 60 d**



AVA AGN Variability Archive

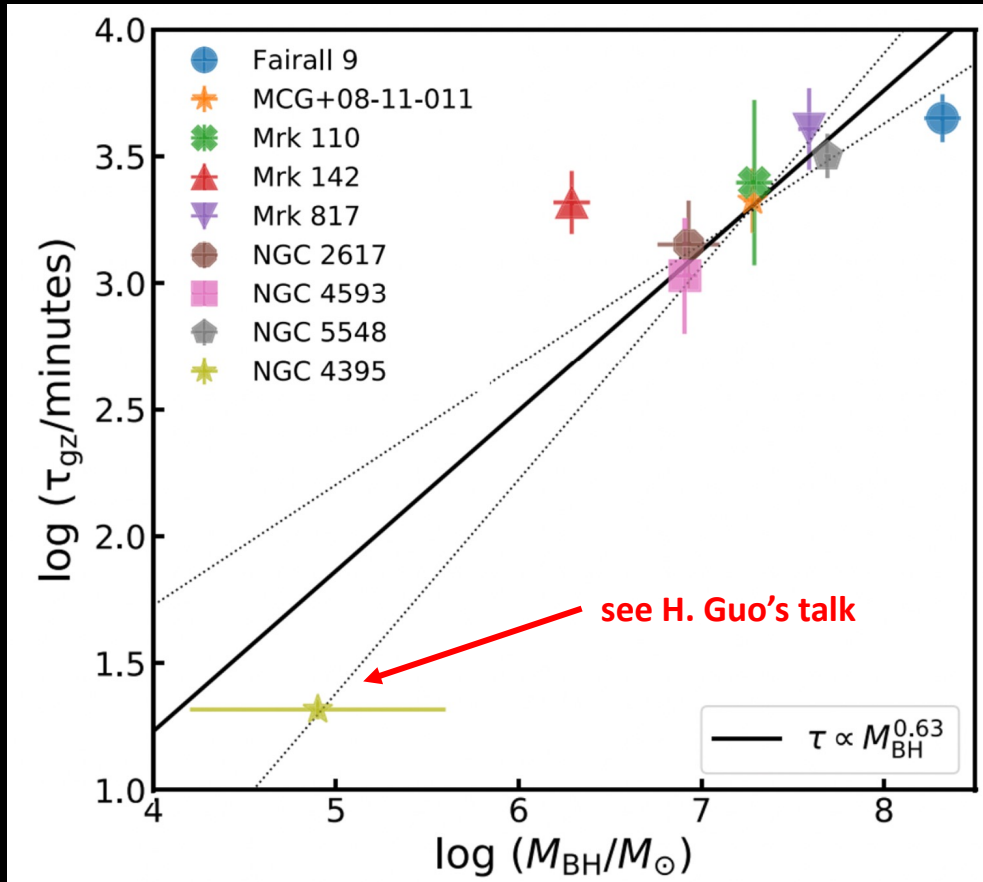


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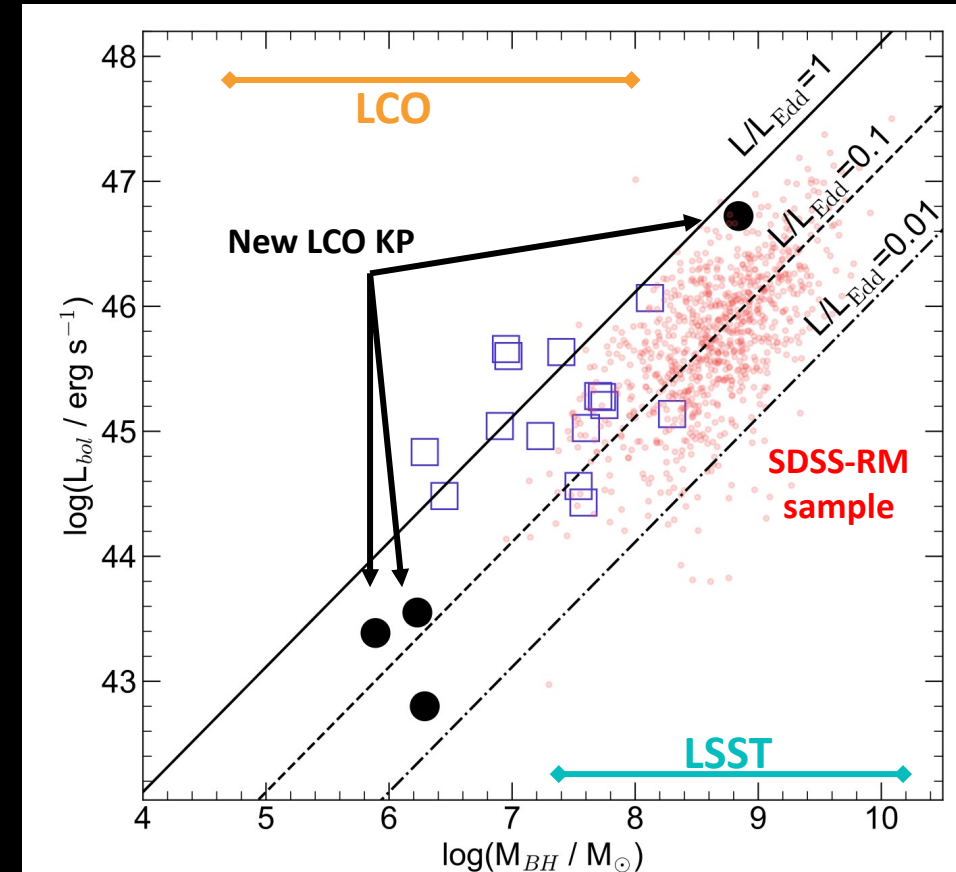
Hernández Santisteban, 2023, OjA, in prep

Intensive Broadband Reverberation Mapping: the future

We will fill in the gaps! → Low- & high-mass AGN



Montano,...,Hernández Santisteban, ApJL, 2022



Conclusions

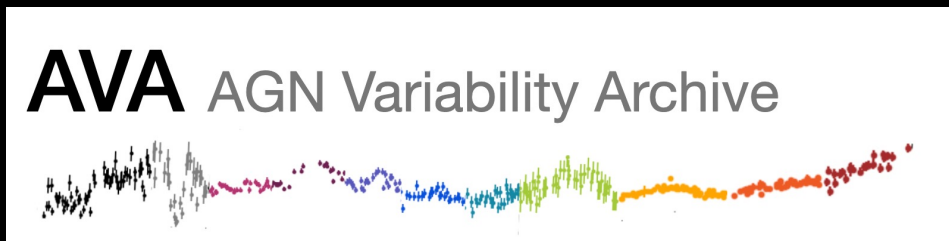


Intensive Broadband Reverberation Mapping campaigns have provided high-quality datasets for testing accretion theory onto SMBH

IBRM campaigns have provided **broadly consistent results with accretion disk theory**, but many discrepancies still remain.

Dedicated multi-band IBRM campaigns will **fill in the gap** in both luminosity and mass-scale **in the LSST era**.

Developing a **living database – AVA**, that will contain science-ready data products → long-lasting resource for the community



Hernández Santisteban, 2023, OjA, in prep

<http://alymantara.com/ava>