Testing accretion disc theory with high-cadence reverberation mapping

Juan V. Hernández Santisteban
Keith Horne, Rick Edelson, Jonathan Gelbord,
The structure around a supermassive black hole

Marin, 2016, MNRAS
Accretion discs in Active Galactic Nuclei

Central Engine of AGN $\rightarrow$ 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

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

Temperature profile?

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

\[ \tau = \frac{R}{c} \propto (M \dot{M})^{1/3} T^{-4/3} \]

\[ \propto (M \dot{M})^{1/3} \lambda^{4/3} \]

\[ \propto M^{2/3} \left( \frac{L}{L_{Edd}} \right)^{1/3} \lambda^{4/3} \]

Lamp-post model

Trade-off angular resolution for **temporal resolution**
As mass moves inwards, temperature increases!

\[ \tau = \frac{R}{c} \propto \left( \frac{M \dot{M}}{\lambda} \right)^{1/3} T^{4/3} \]

We expect larger lags at lower temperatures (large wavelengths)

“Jaw-breaker schematic”
Disc Reverberation Mapping

NGC 5548

\[ \tau = \alpha \left( \frac{\lambda}{\lambda_0} \right)^\beta - 1 \]


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

U-band excess $\rightarrow$ **Diffuse Continuum Emission** from the BLR!

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e.g. Korista & Goad 2019
Intense Disc Reverberation Mapping

Fairall 9

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
Absorption is not responsible for the variability observed

$\rightarrow$ Clean view of the central engine!

Evidence for continuum lag

$\rightarrow$ 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

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

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

Fairall 9: Two variability components

A)

Smooth Component

B)

C)

Disc Reverberation

ICCF

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

\[ \tau \propto \lambda^{1.26\pm0.21} \]

Aperture Photometry

Credit: A. Barth

\[ F(\lambda, t) = C(\lambda, t) \cdot X_0(t) + S(\lambda, t) \]
Fairall 9: Dissecting the Variable Component

\[ F_\nu \propto \nu^{1/3} \]

SS73 Disc
\[ L_{\text{Edd}} = 0.025, \ a=0.7 \]

AGN high - low
AGN rms
Asmus+ 2014

Galaxy Contribution

\[ L_\nu / \text{erg s}^{-1} \text{Hz}^{-1} \]

Wavelength / Å

### Intensive disc reverberation mapping targets

Select an object for more information

**archived** = All the available 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.

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<th>DEC (° : ' : ″)</th>
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<th>log(L) (erg/s)</th>
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Showing 1 to 10 of 35 entries
Conclusions

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