Reverberation mapping

Two unusual cases of continuum reverberation

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Outline

INTRODUCTION

The disk reverberation mapping

Introduction

Cackett et al. (2021)

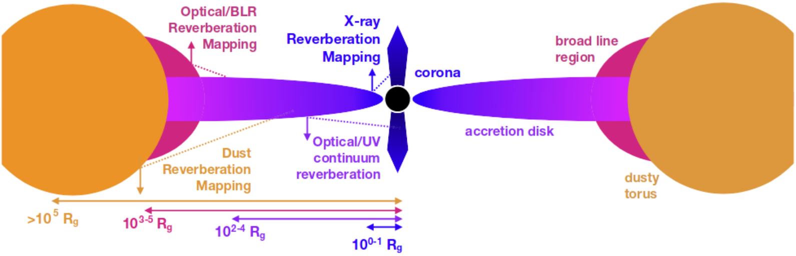


Figure 1. A cross-sectional schematic of an AGN
The schematic highlights the main components and the four types of reverberation discussed in this review: X-ray reverberation (Section 2), optical/UV continuum reverberation (Section 3), broad line region reverberation (Section 4), and dust reverberation (Section 5) with general radial scales from the black hole indicated by labels.

Introduction

Cackett et al. (2021)

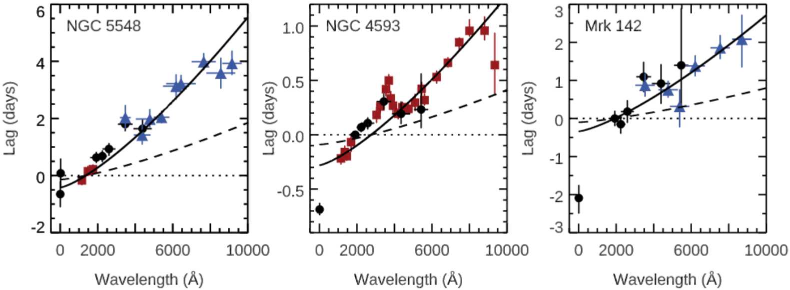
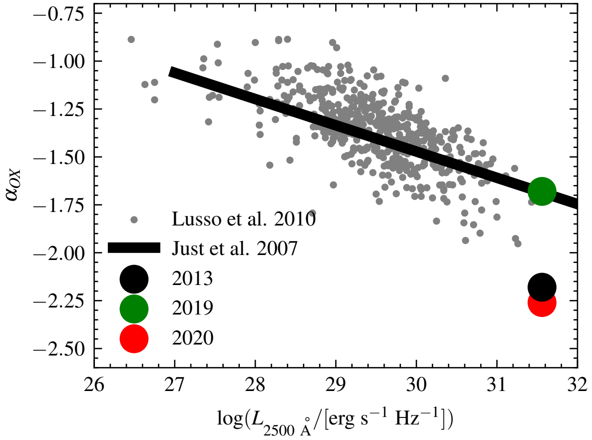
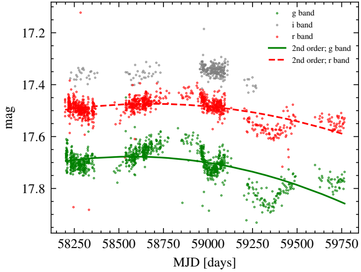


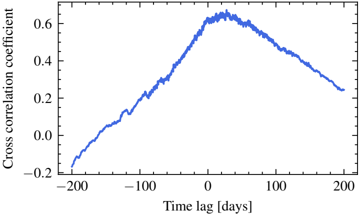
Figure 6. Wavelength-dependent continuum lags in NGC 5548 (Fausnaugh et al., 2016), NGC 4593 (Cackett et al., 2018), and Mrk 142 (Cackett et al., 2020)
Data from *Swift* (black circles), *HST* (red squares), and ground-based observatories (blue triangles). The solid lines show the best-fitting $\tau \propto \lambda^{4/3}$ relation (excluding the X-rays and *u*/*U* bands), while the dashed lines show the predicted lags based on reasonable estimates of the black hole mass and accretion rate (Equation 12 in Fausnaugh et al., 2016)). The difference between the observed (solid line) and predicted (dashed line) relations is the "accretion disk size problem". The lags in the *u*/*U* bands (around 3500Å) show a clear excess, and in NGC 4593, the lag spectrum reveals a broad excess around the Balmer jump. Finally, note also how there is no consistent relationship between the X-rays and the best-fitting $\lambda^{4/3}$ relation.

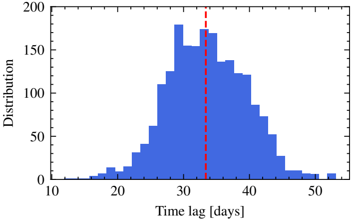
SDSS J153913.47+395423.4



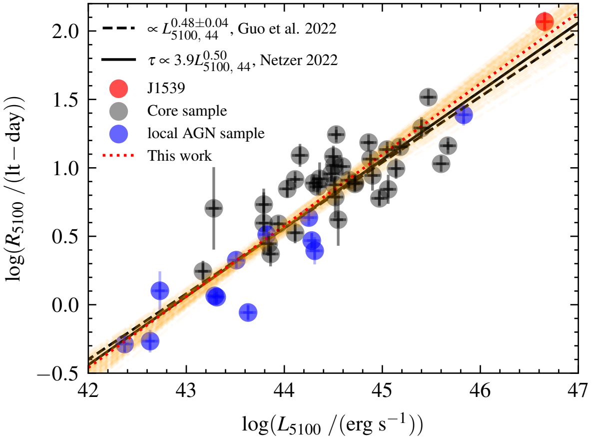
SDSS J153913.47+395423.4





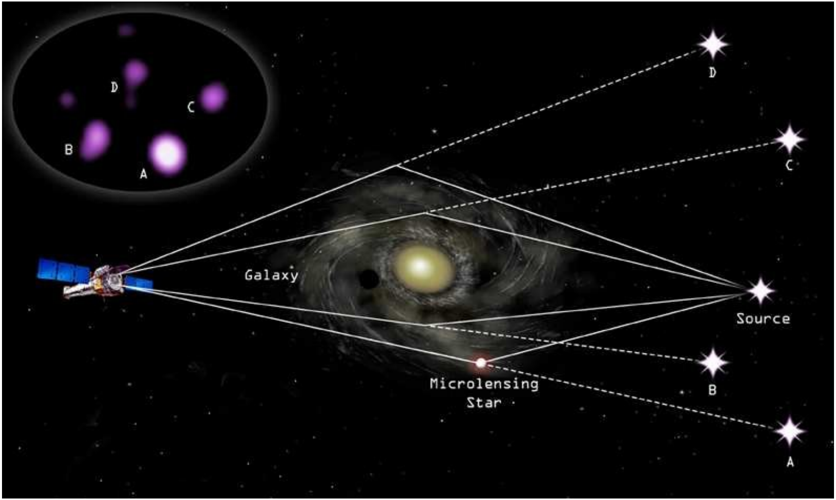


SDSS J153913.47+395423.4

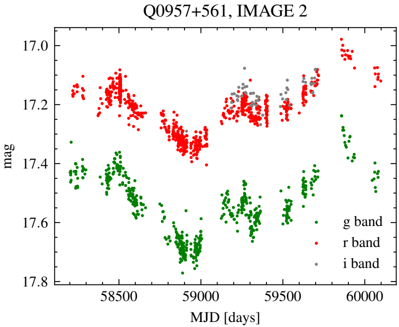


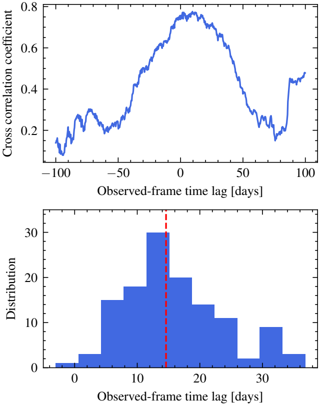
1. Significant cross correlation with a time delay of $\sim 32 \pm 5$ days (OF),
2. time delay 3 times larger than standard AD,
3. If X-ray reprocessing is correct
    - solutions: a) anisotropic, b) shielding
    - obs. -> X-ray should be stronger
4. if X-ray reprocessing is incorrect:
    - models: CHAR, FUV

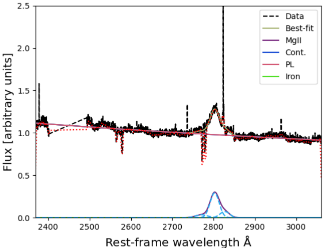
The disk reverberation mapping - lensed quasar

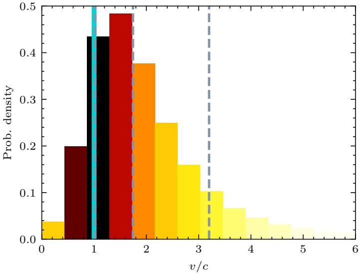


Credit: NASA


Q0957+561, IMAGE 2
17.0
17.2
17.4
17.6
17.8
mag
58500
59000
59500
60000
MJD [days]
g band
r band
i band


0.8
0.6
0.4
0.2
Cross correlation coefficient
−100
−50
0
50
100
Observed-frame time lag [days]
30
20
10
0
Distribution
0
10
20
30
Observed-frame time lag [days]





- New epoch + improved M_{BH},
- In combination with the half-light radius, the propagation velocity of the variability mechanism should be $1.7^{+1.5}_{-0.7}$ times the speed of light.

1. Significant cross correlation with a time delay of $\sim 15 \pm 6$ days (OF),
2. Apparent propagation velocity may exceed light speed due to X-ray reprocessing in an inhomogeneous disk, i.e., large half-light radii and small continuum time lags,
3. The presence of local temperature fluctuations in accretion disks results in a significant underestimation of the actual light travel time,
4. CHAR, not X-ray reprocessing, could explain small inter-band lags,
5. If the propagation velocity matches c, it suggests X-ray reprocessing drives UV/optical variability in quasars.

Thank you!

Figure: X-ray weak RM; Marculewicz et al. 2023

Figure: Lensed QSO RM; Marculewicz et al. 2024