From Chandra to Einstein: Dramatic Long-Term X-ray Variability in AGN

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Introduction

- Currently, the accretion histories of supermassive black holes (SMBHs) in galactic nuclei – and how they relate to the evolution of their host galaxies – are not well understood.
- Active galactic nuclei (AGN) that have exhibited dramatic and persistent changes in their continuum luminosity and optical spectroscopic classification – so-called "changing look AGN" (CLAGN; Deeney et al. 2014; LaMassa et al. 2015; Ruan et al. 2016; Runnoe et al 2016; MacLeod et al. 2016; McElroy et al. 2016; Gezari et al. 2017; Yang et al. 2018) – could represent examples of AGNs that have undergone accretion state changes.
- X-ray emission is directly linked to black hole accretion. Thus, serendipitous X-ray source surveys should provide a straightforward means of identifying AGNs that have undergone dramatic changes in their accretion states.
- However, the durations of the active phases of AGNS appear to be long compared to the history of X-ray astronomy, so wide-area surveys separated in time by many years are needed to maximize discovery rates..
- **Goal of this project: to identify CLAGN candidates using X-ray data, which through follow-up observations of their host galaxies, could provide insight into the conditions associated with transitions in SMBH activity states.**

Methods and Design

- The Einstein Observatory (1978 – 1981) observed ~2500 sq. deg. of high-latitude sky, much of which overlaps with fields observed with the Chandra X-ray Observatory, giving us a 20-40 year baseline for our X-ray variability study.
- We searched the Chandra Source Catalog (CSC; Evans et. al. 2010) for Chandra detections that are within the error circle of sources listed in the Einstein IPC Two Sigma Catalog (ETS; Moran et. al. 1996).
- We converted count rates to flux assuming a Γ=2.0 power-law spectral model with Galactic absorption, and selected sources that varied by at least a factor of 10 in the 0.5-2.0 keV band.
- We used the Chandra Footprint Service to confirm that ETS sources not detected by Chandra were included in the Chandra field of view, and for those that were observed but not detected, we used CIAO to determine upper limits to the soft X-ray flux.

Optical Identifications

Dramatic AGN Variability

(1)180115.2+662401

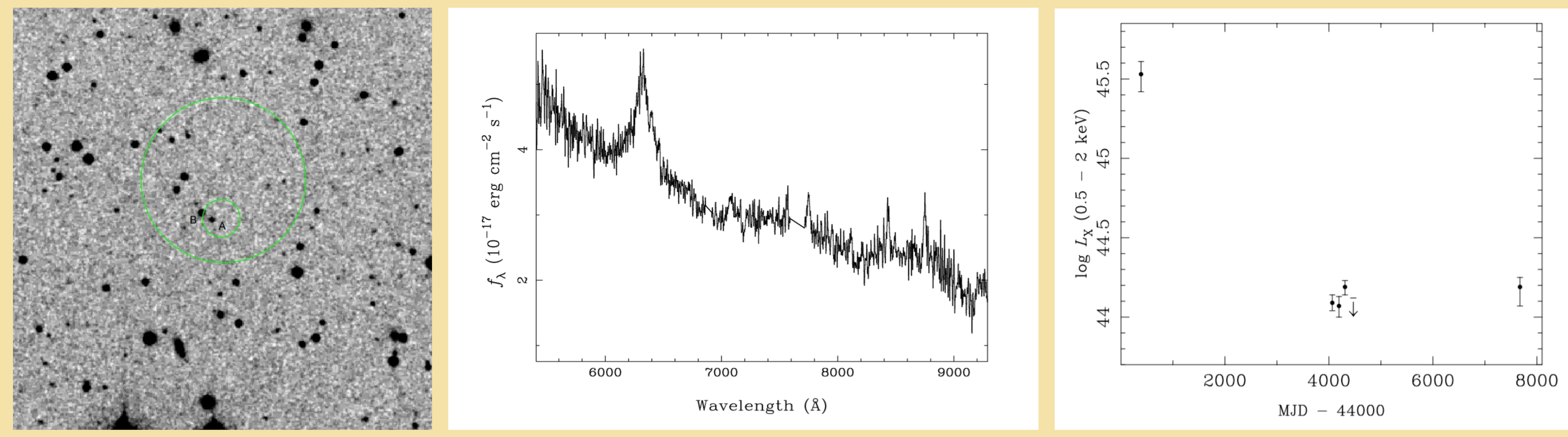

Figure 1: The optical field (left) around J1801+6624 (object A) is shown with the Einstein (large) and ROSAT (small) position error circles. The broad Mg II line in J1801+6624's optical spectrum (middle) indicates a redshift of z = 1.26 for the radio-quiet quasar. In addition to Einstein, the source was detected in the ROSAT All-Sky Survey, in several pointed ROSAT observations, and by Chandra. The soft X-ray light curve demonstrates a factor of ~ 30 decrease in luminosity post-1980.

(2) 124551.03+032128.4

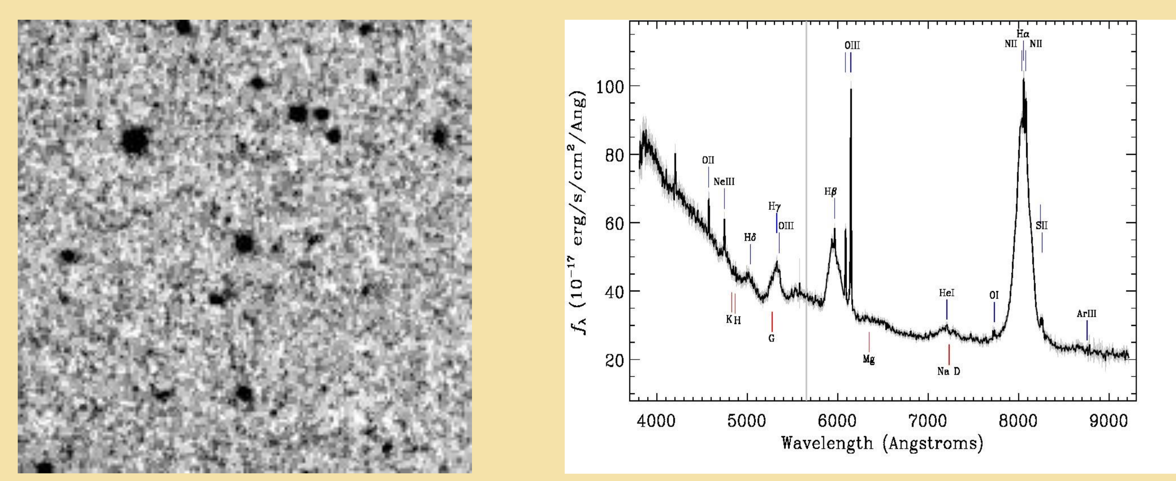

Figure 2: J1245+0321 is a radio-quiet type 1 AGN at z = 0.227. Its soft X-ray flux dropped by a factor of ~ 13 between the Einstein and Chandra observations.

(3) 083052.21+241059

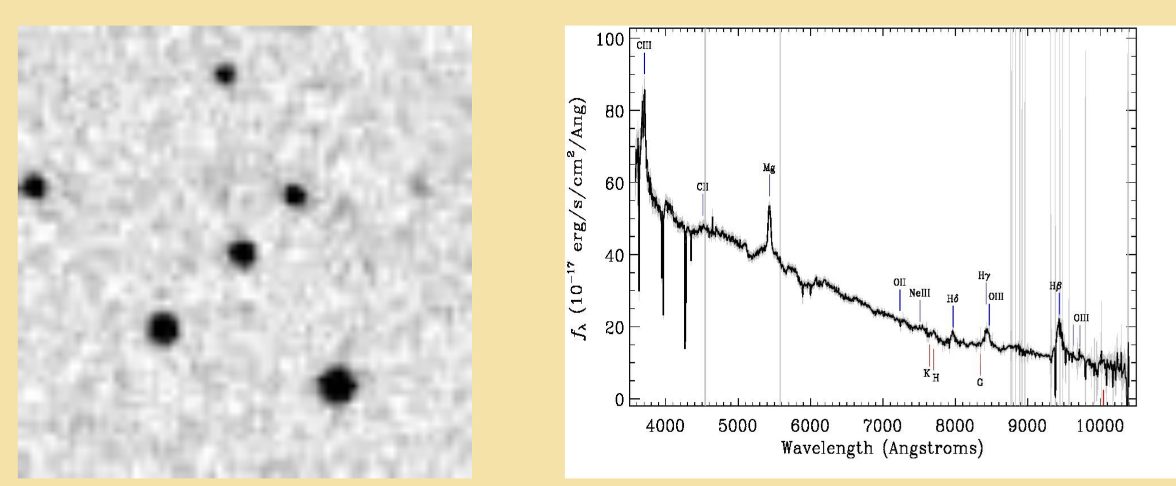

Figure 3: Figure 3: J0830+2410 (a.k.a. OJ 248, z = 0.94) is a well-studied gamma ray-bright blazar whose X-ray variability (factor of 12) is likely due to beaming effects associated with a relativistic jet rather than changes in accretion.

Results

- Only abut 120 ETS sources appear to display dramatic, long term X-ray variability in excess of a factor of 10, which implies that this type of variability is rare.
- Optical identifications of about one-third of the variable sources have been made using data from the Sloan Digital Sky Survey.
- We have identifies several radio-quiet quasars that may have experienced changes in accretion. But even at their weakest, they are very luminous X-ray sources, which likely explains why they continue to appear optically as broad-line objects, and not CLAGN.
- Other strongly variable sources include radio-loud quasars and bright Galactic stars.

Future Work

- Find optical data for variable sources in catalogs like the Sloan Digital Sky Survey (SDSS).
- Conduct up-to-date optical and X-ray observations for the variable sources to verify them as CLAGN candidates.
- Focus on the north ecliptic pole (NEP) region in preparation for eROSITA's X-ray mission.

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Results

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