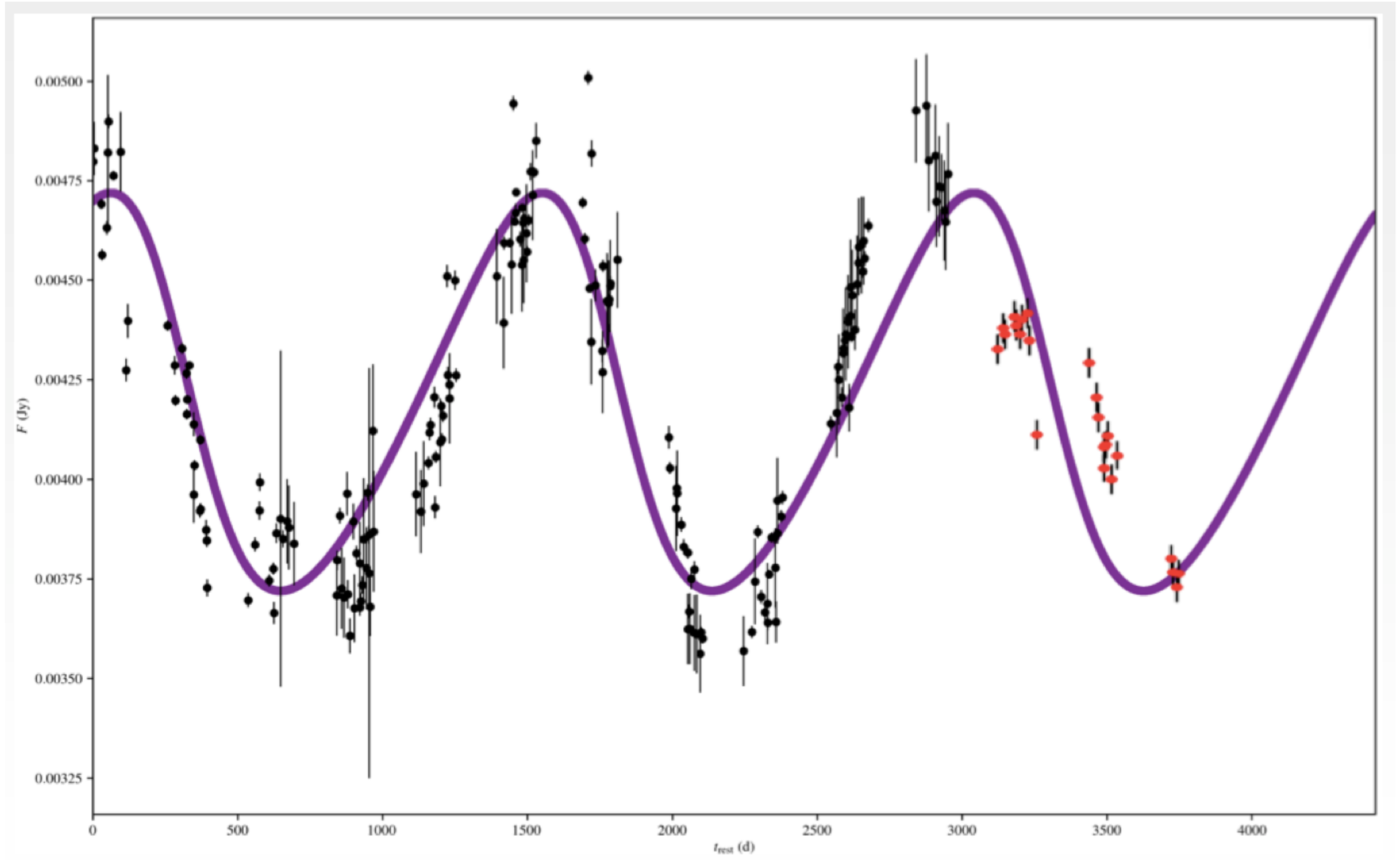
Extreme AGN Variability with Palomar/DBSP

Daniel Stern
JPL/Caltech

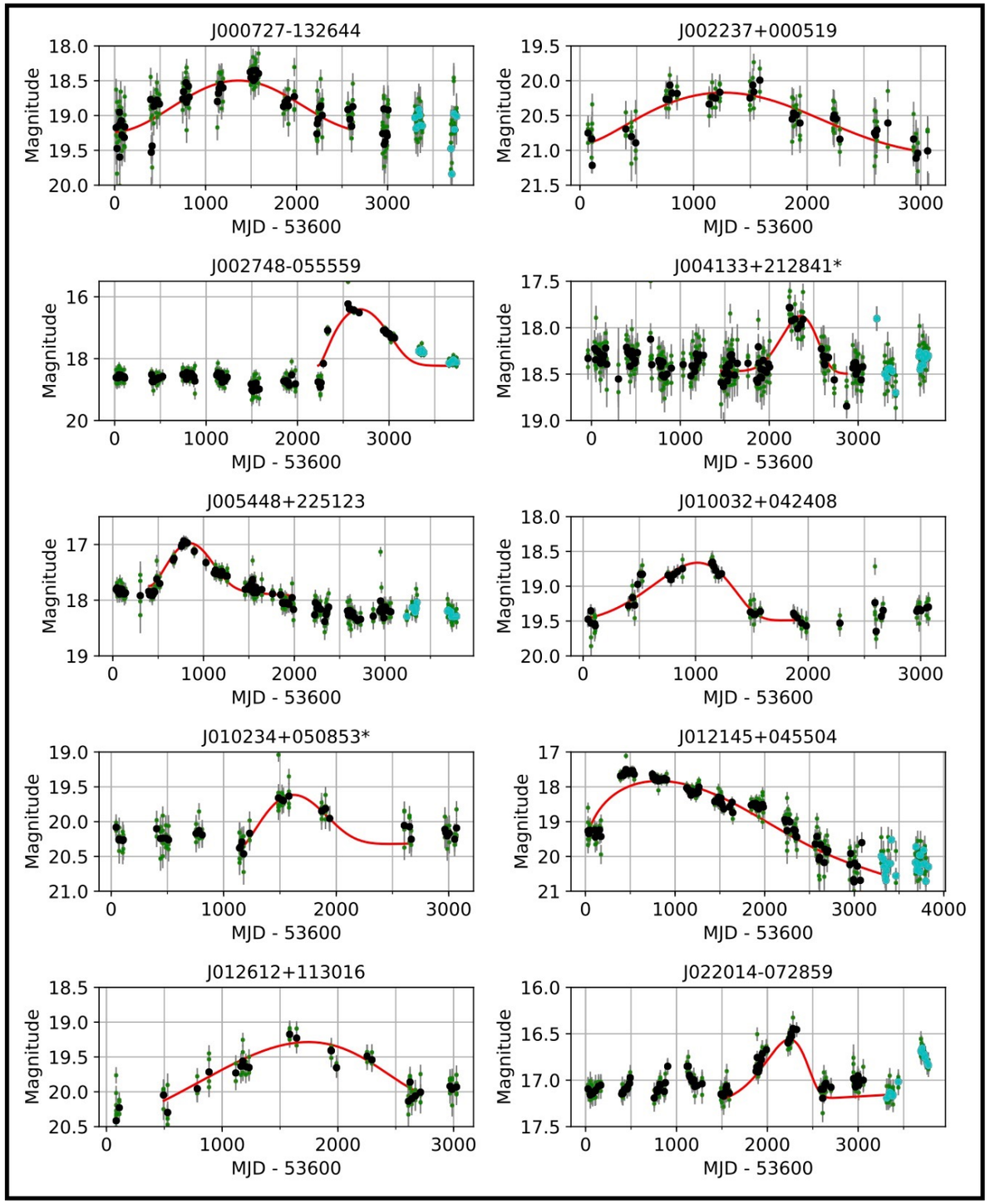
September 2019
JPL Astrophysics Colloquium

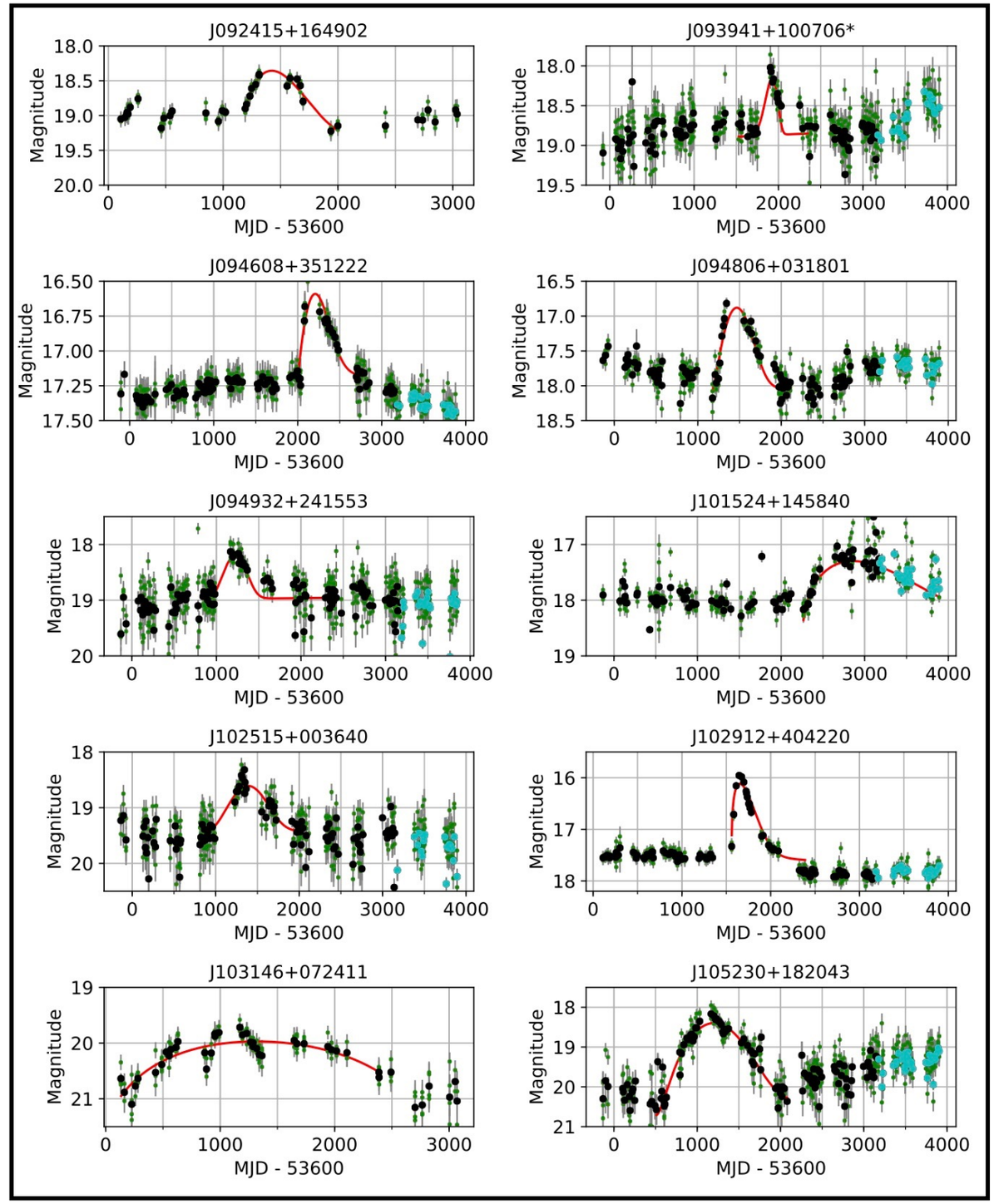
Extreme AGN Variability



Graham, Djorgovski, Stern et al. 2015a, Nature, 518, 74
Graham, Djorgovski, Stern et al. 2015b, MNRAS, 453, 1562

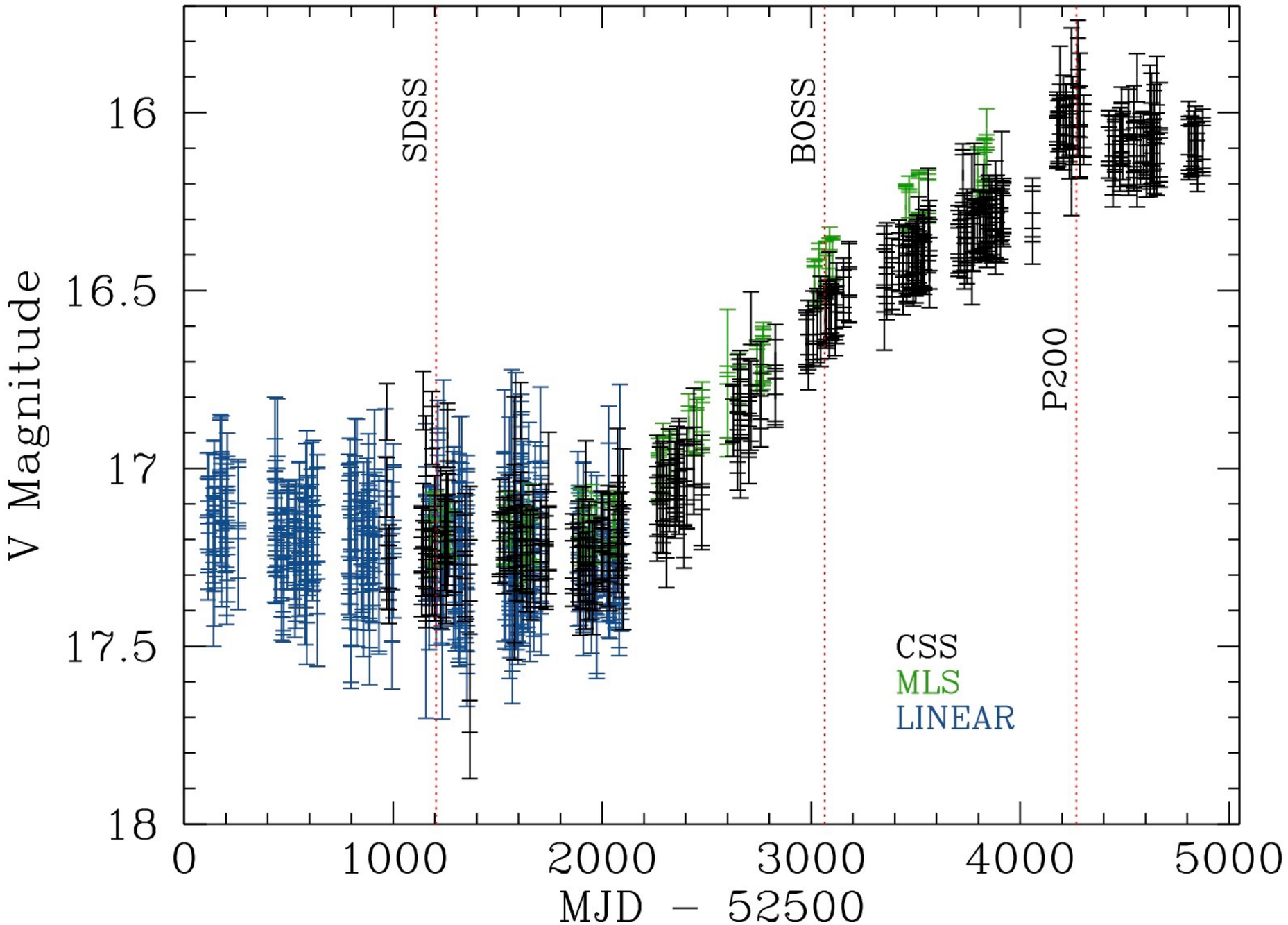
Extreme AGN Variability





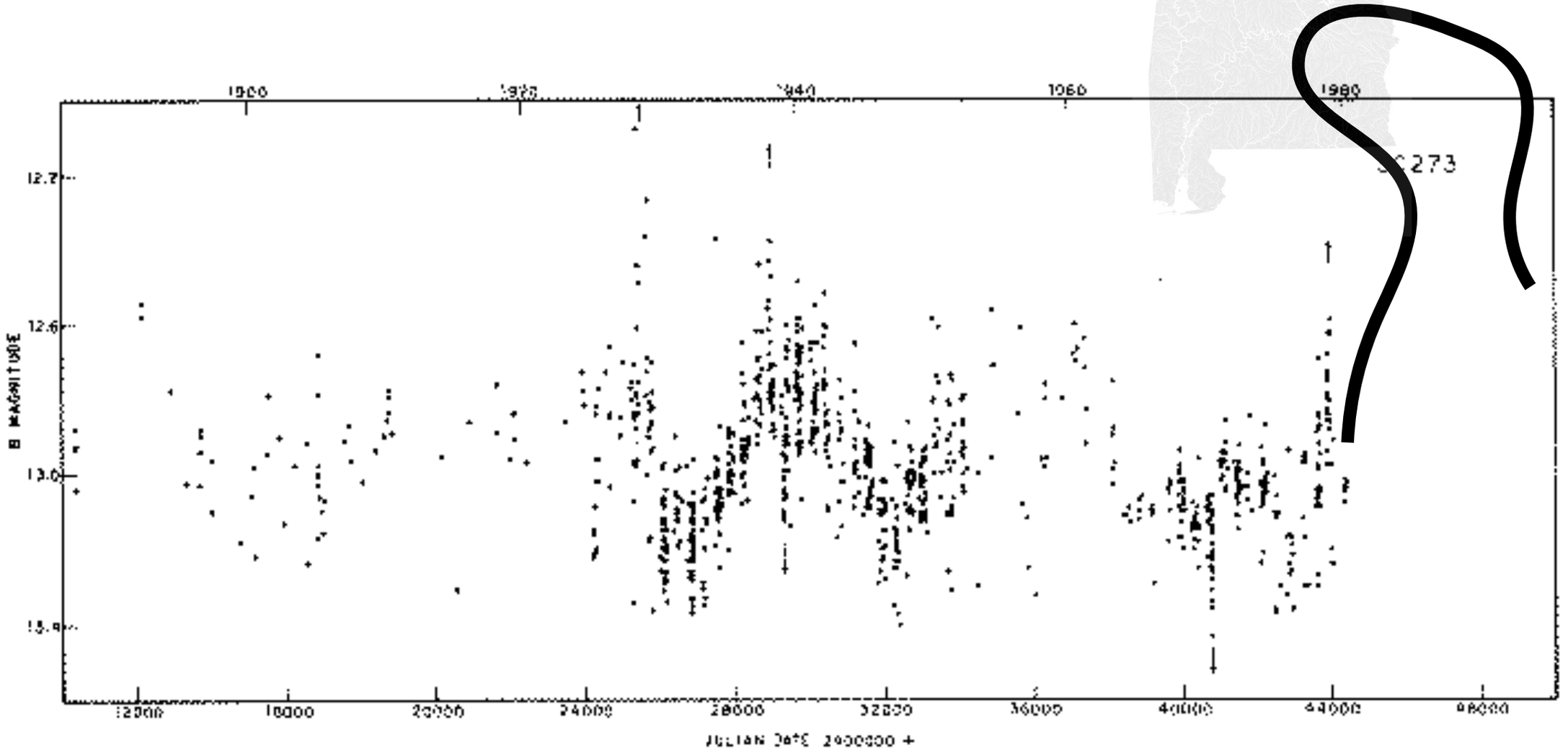
Graham, Djorgovski, Drake, Stern et al. 2017, MNRAS, 2017, 470, 4112
Drake, Djorgovski, Graham, Stern et al. 2019, MNRAS, 482, 98

Extreme AGN Variability



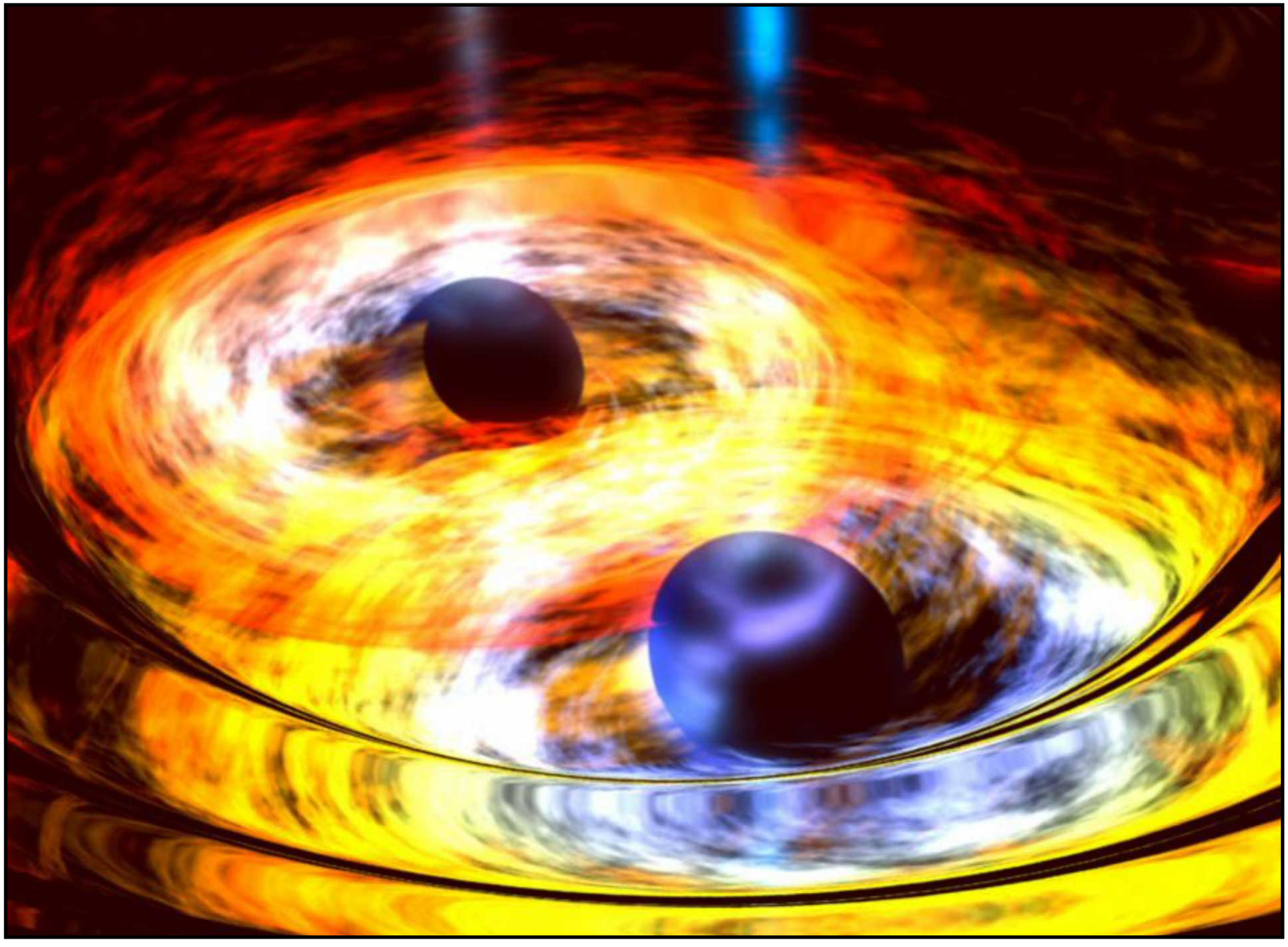
Stern et al., 2018 ApJ, 864, 27
Ross et al. 2018, MNRAS, 480, 4468

Extreme AGN Variability



Birmingham, Tuscaloosa, Huntsville et al., submitted

Periodic Quasars



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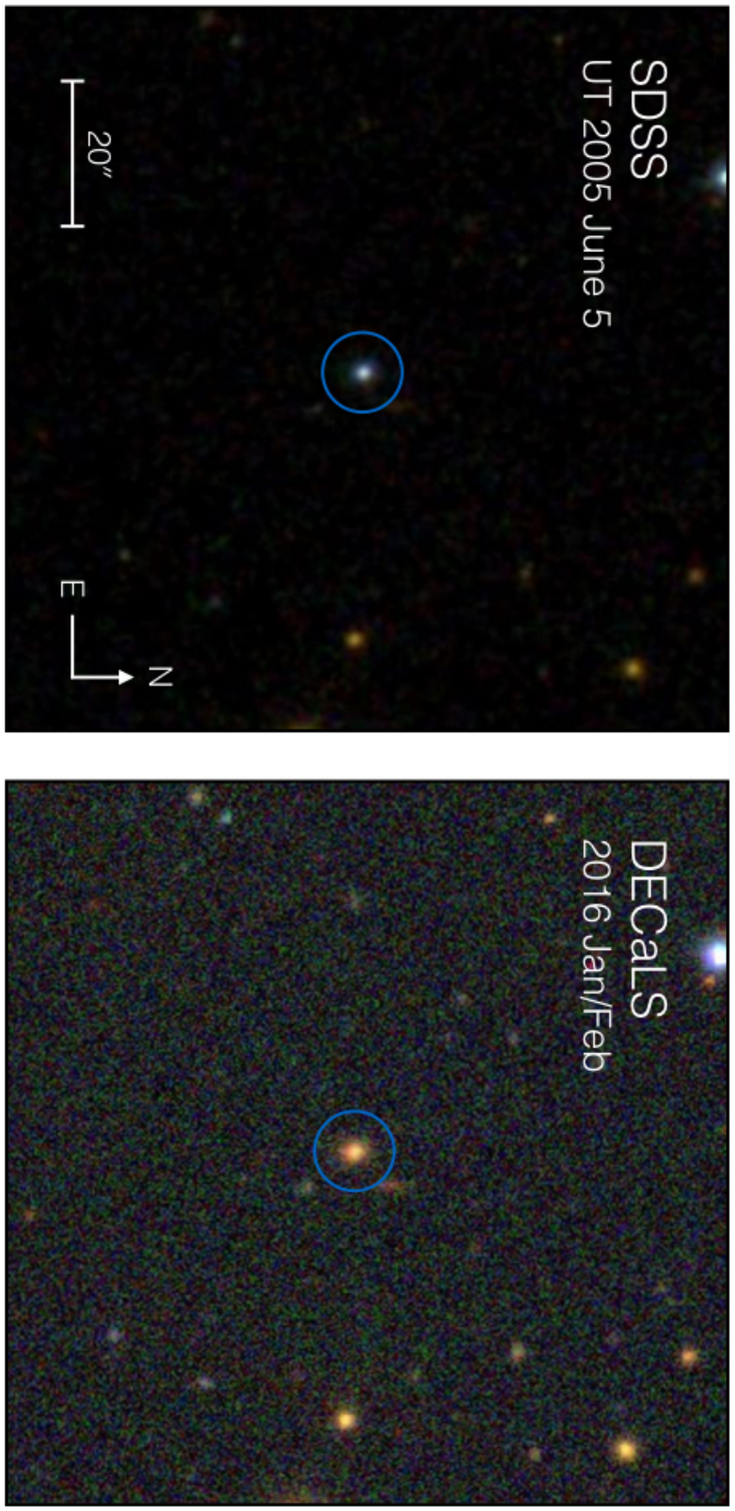
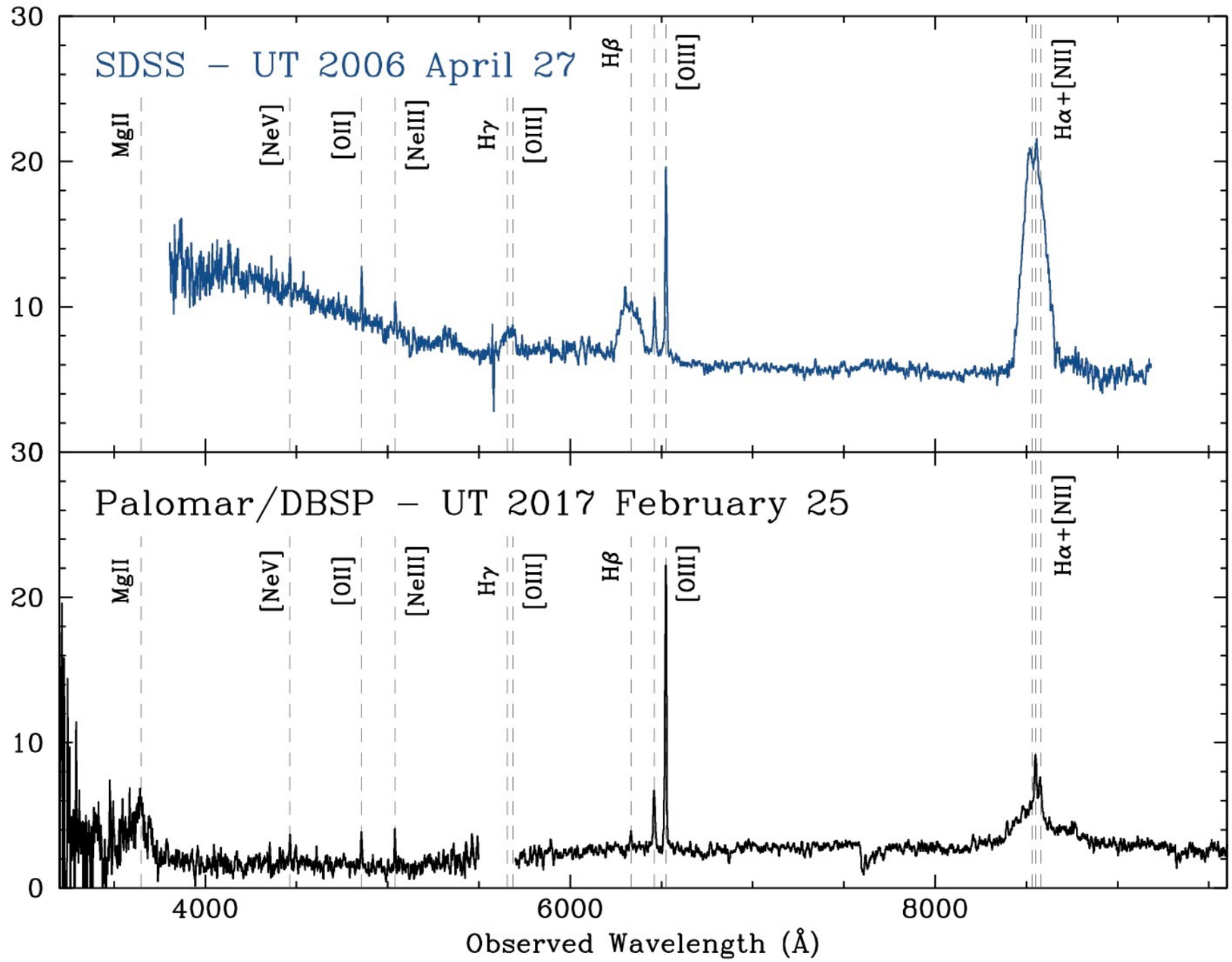
Changing-Look Quasars





Stern et al., 2018 ApJ, 864, 27
Ross et al. 2018, MNRAS, 480, 4468

Changing-Look Quasars

Physical models for abrupt quasar fading

1. obscuration
   - obscuration by a cloud in a Keplerian orbit
   - obscuration by an infalling cloud
2. changes to the inner accretion disk

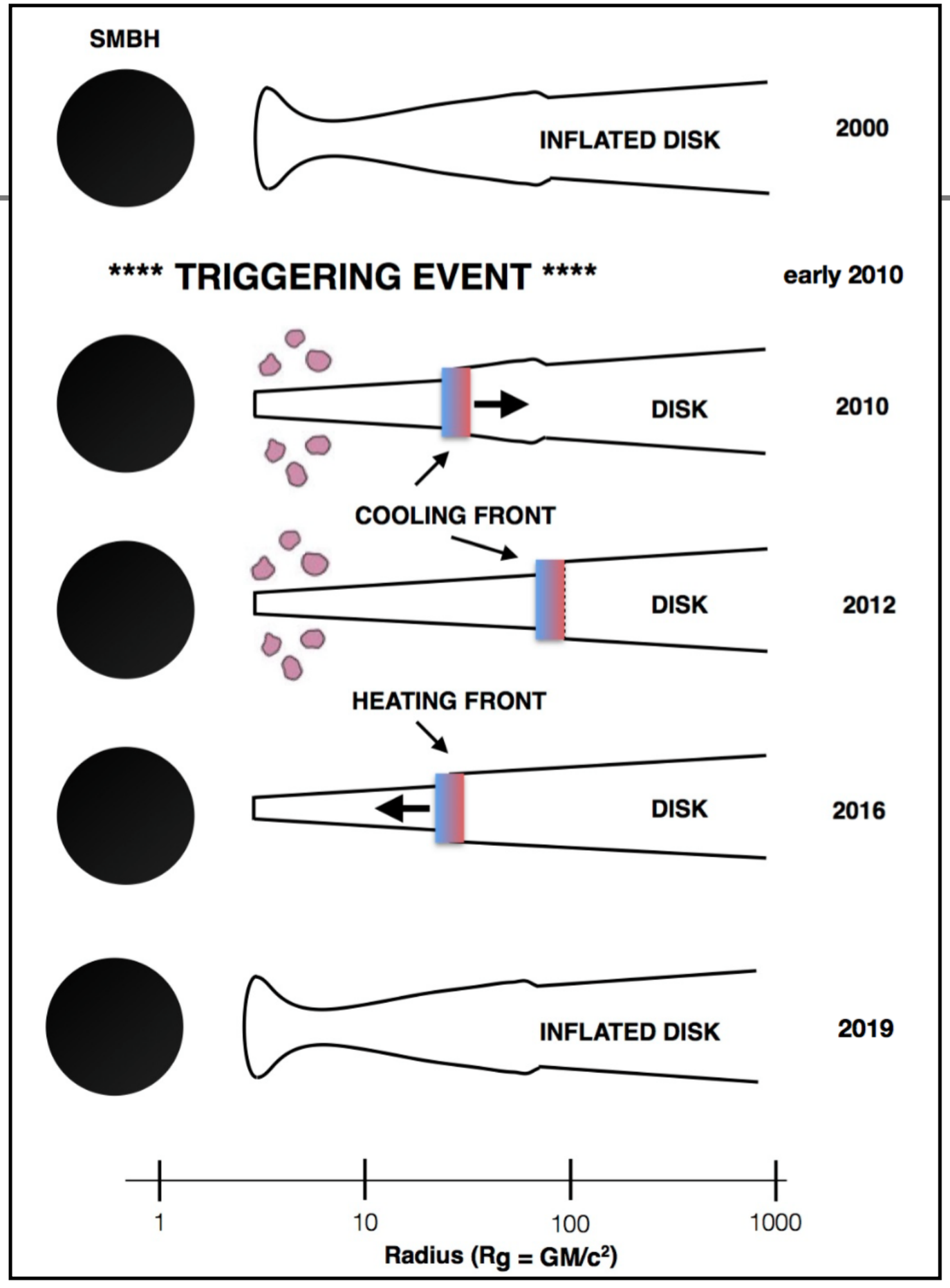
$$t_{\rm orb} \sim 10\,{\rm day} \left(\frac{M_{\rm BH}}{10^8 M_\odot}\right) \left(\frac{R}{150 r_g}\right)^{3/2}$$

$$t_{\rm th} \sim 1\,{\rm yr} \left(\frac{\alpha}{0.03}\right)^{-1} \left(\frac{M_{\rm BH}}{10^8 M_\odot}\right) \left(\frac{R}{150 r_g}\right)^{3/2}$$

$$t_{\rm front} \sim 20\,{\rm yr} \left(\frac{h/R}{0.05}\right)^{-1} \left(\frac{\alpha}{0.03}\right)^{-1} \left(\frac{M_{\rm BH}}{10^8 M_\odot}\right) \left(\frac{R}{150 r_g}\right)^{3/2}$$

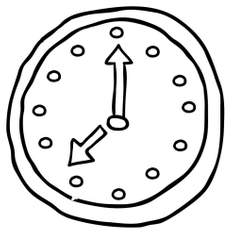
$$t_{\nu} \sim 400\,{\rm yr} \left(\frac{h/R}{0.05}\right)^{-2} \left(\frac{\alpha}{0.03}\right)^{-1} \left(\frac{M_{\rm BH}}{10^8 M_\odot}\right) \left(\frac{R}{150 r_g}\right)^{3/2}$$

Stern et al., 2018 ApJ, 864, 27
Ross et al. 2018, MNRAS, 480, 4468



- cartoon picture of situation for one of the UV-collapse quasars
- predicts major events in innermost accretion disk, which is the source of the UV emission

Ross et al. 2018, MNRAS, 480, 4468



Changing-Look LINERs

SCI-TECH

New type of black hole activity discovered in dramatic galaxy transformation

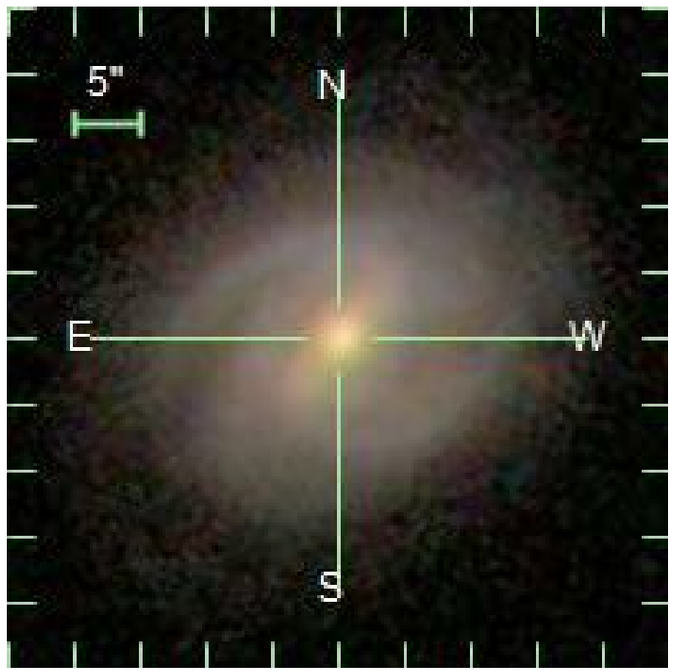
Astronomers are surprised by the speed of this wimpy galaxy glow-up.

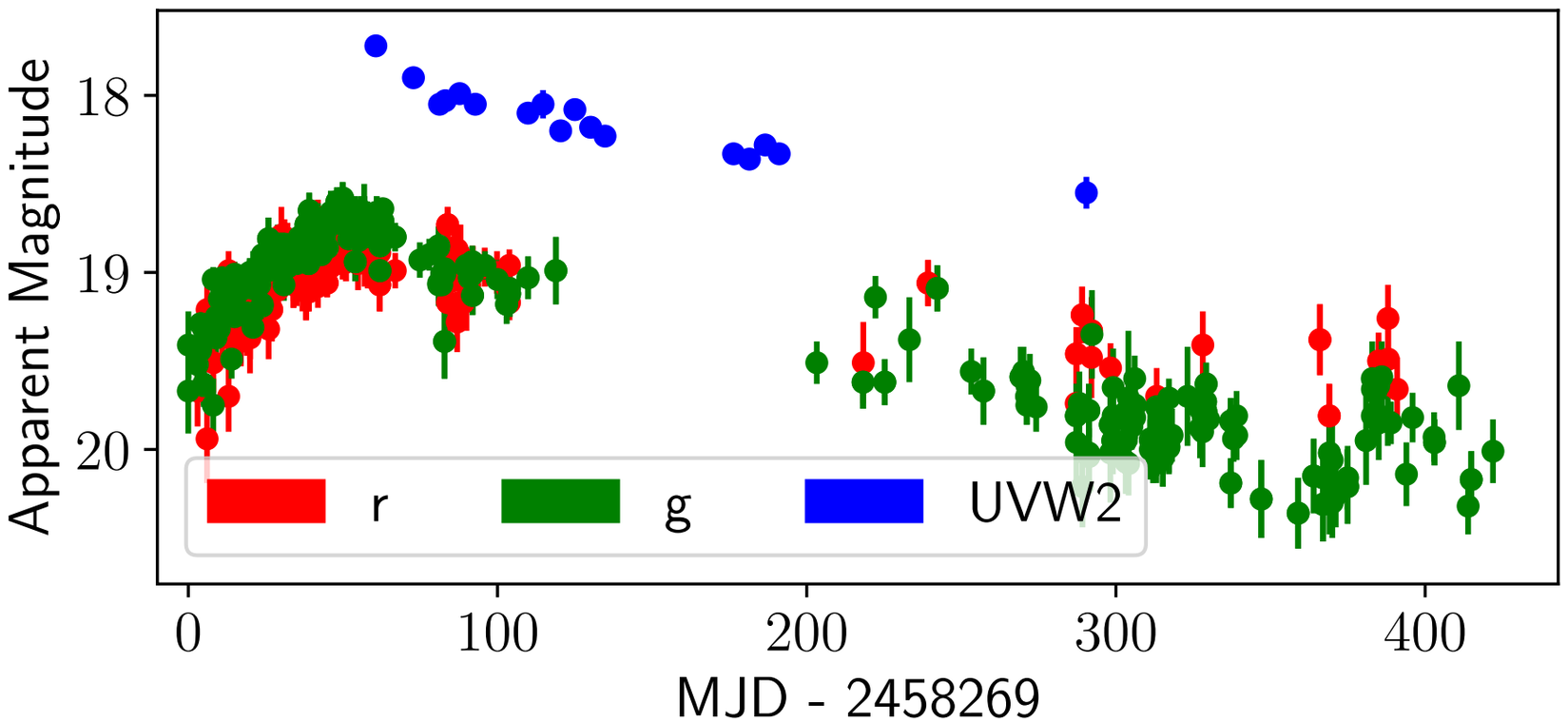
BY JACKSON RYAN | SEPTEMBER 18, 2019 7:04 PM PDT

Frederick et al. (incl. DS) 2019, ApJ, 883, 1

Changing-Look LINERs

• Reports 6 narrow-lined, weak LINERs identified as nuclear transients by the Zwicky Transient Factory (ZTF) that brightened dramatically, turning into luminous, broad-lined AGN





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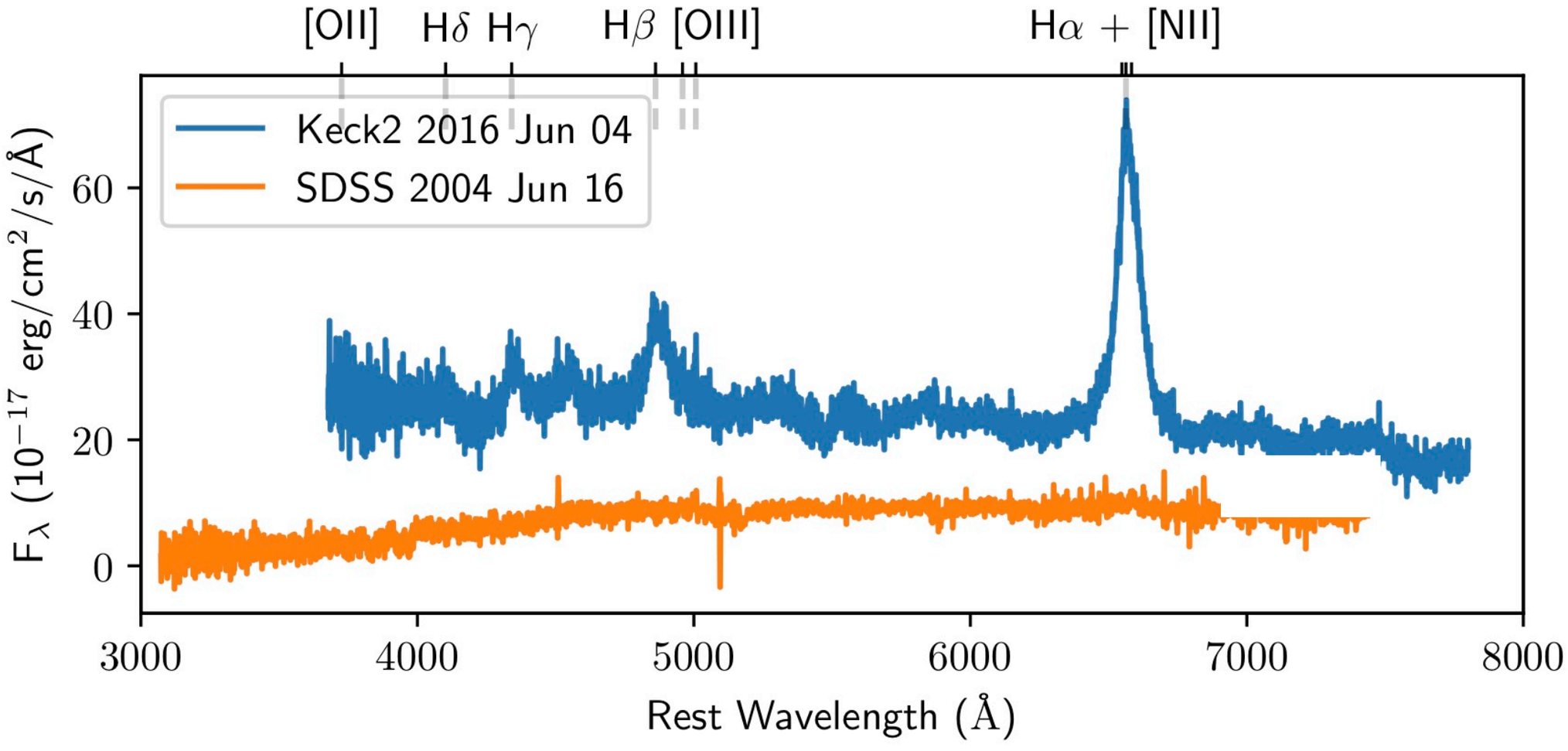

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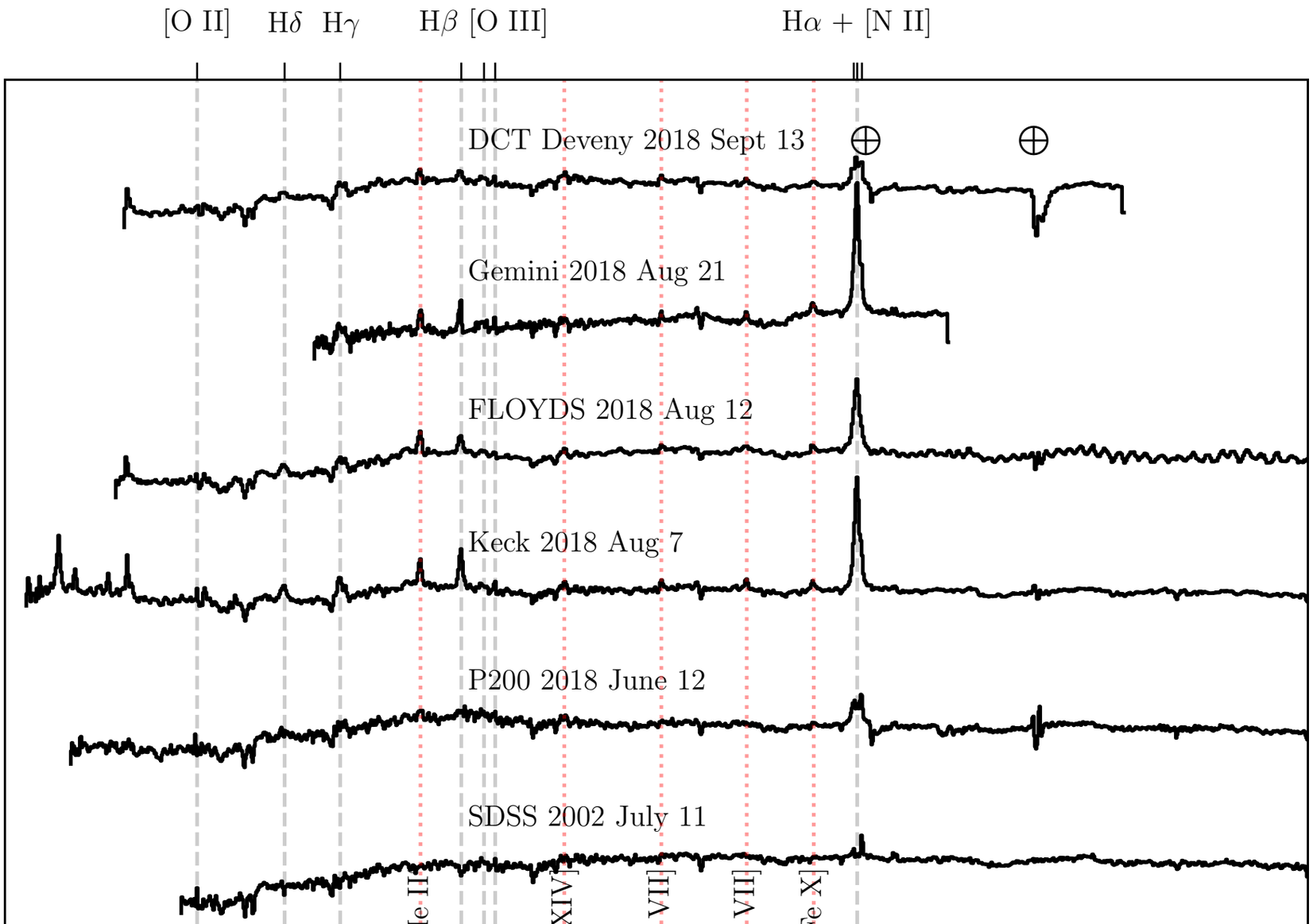

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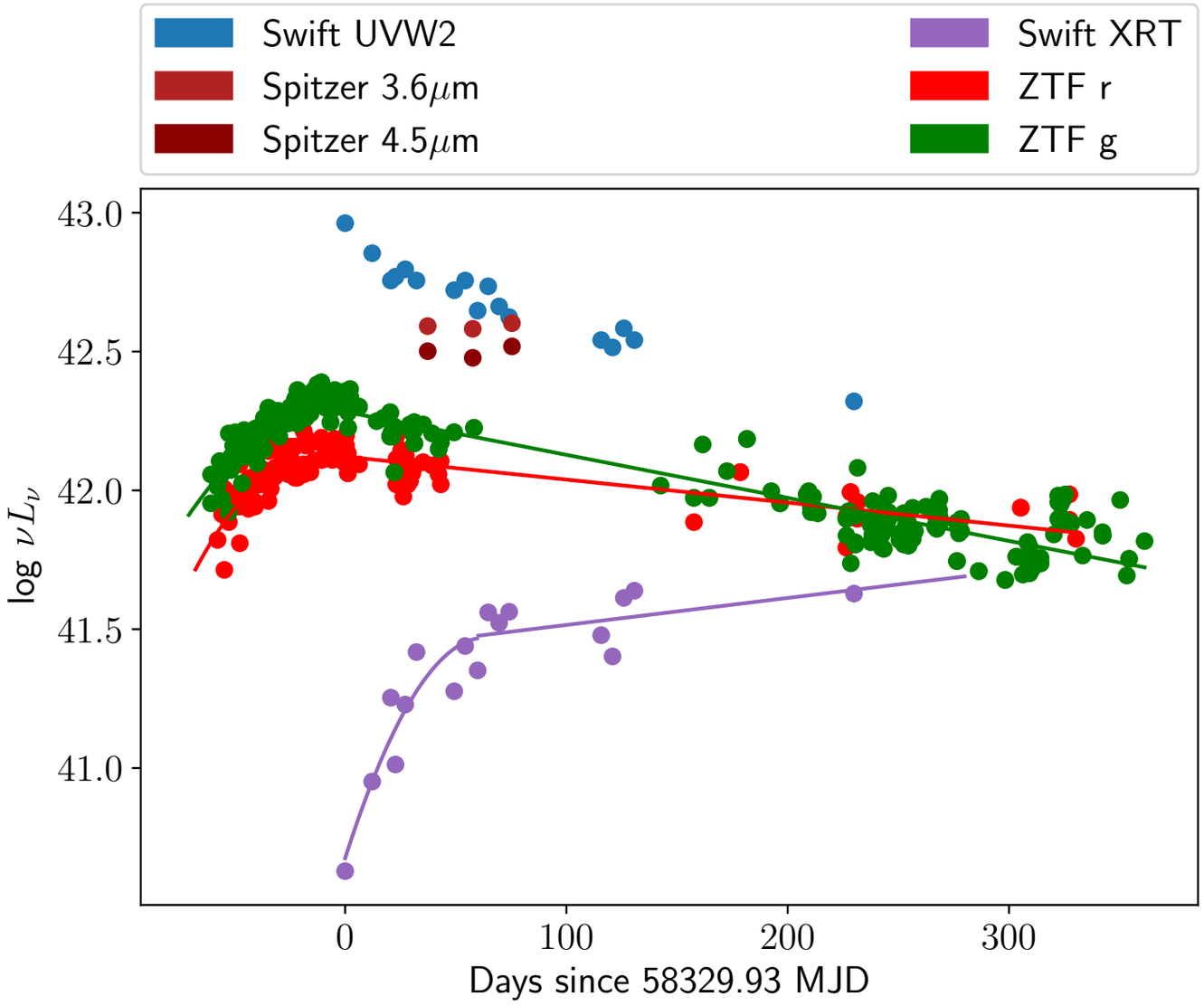

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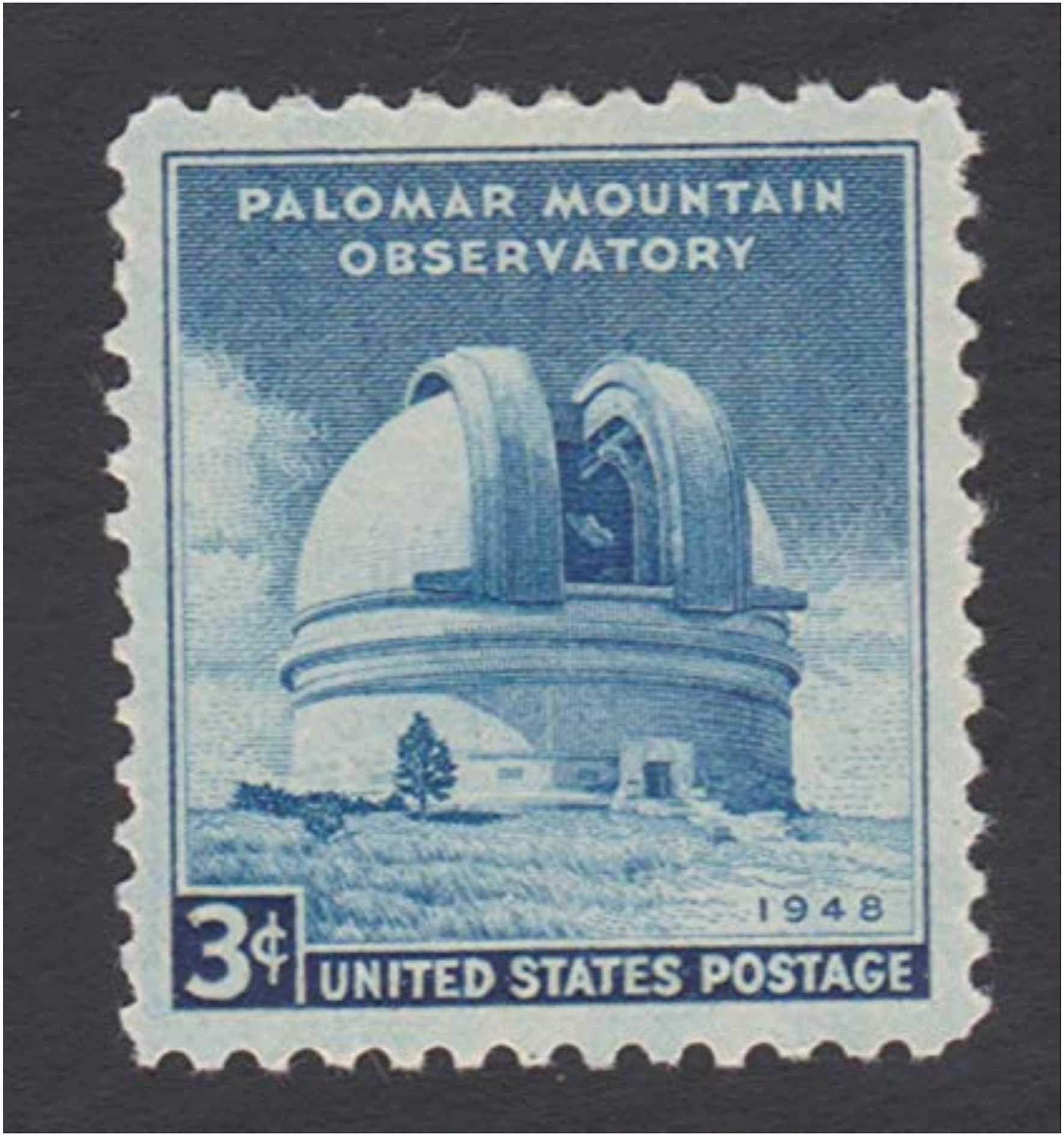
PALOMAR MOUNTAIN
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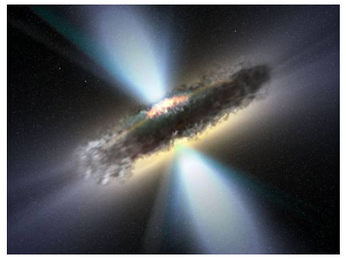
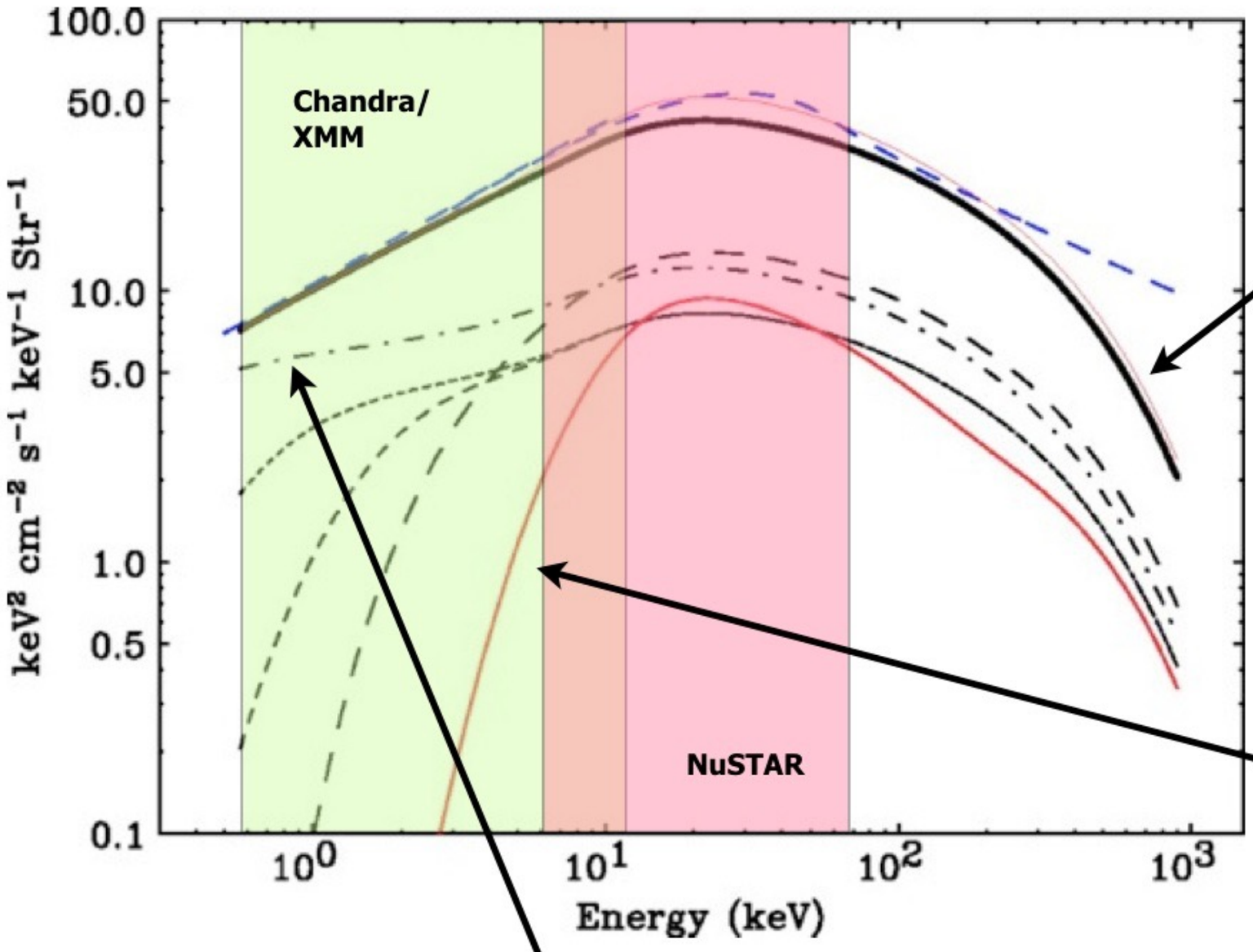


NuSTAR Extragalactic Surveys: Resolving the Cosmic X-Ray Background

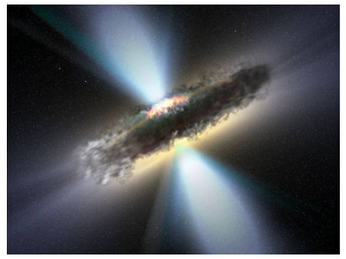


cosmic X-ray background

heavily obscured sources

unobscured sources

Ueda et al. 2003, ApJ, 598, 886



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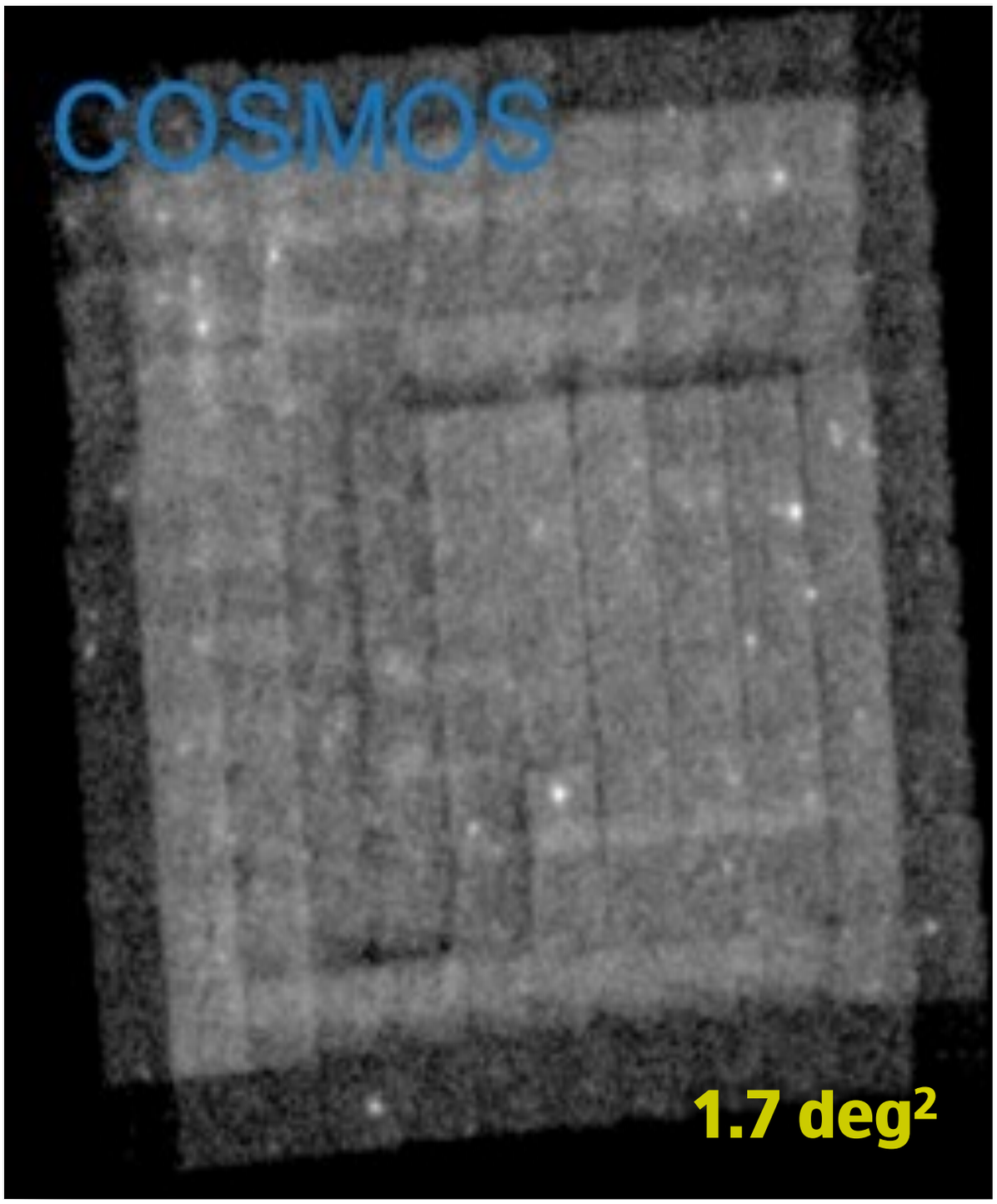
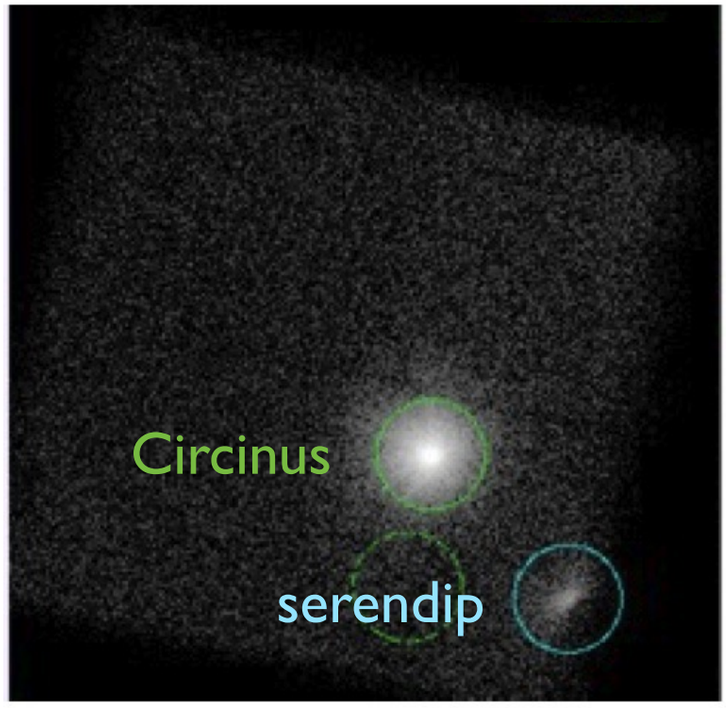
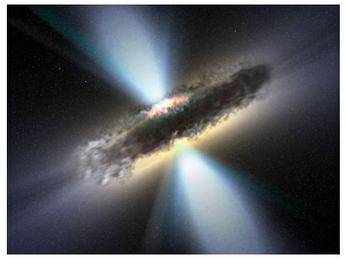


- 3-tiered survey:
  - CANDELS - deep
  - COSMOS - medium
  - serendipitous survey of ~all NuSTAR fields - "shallow"





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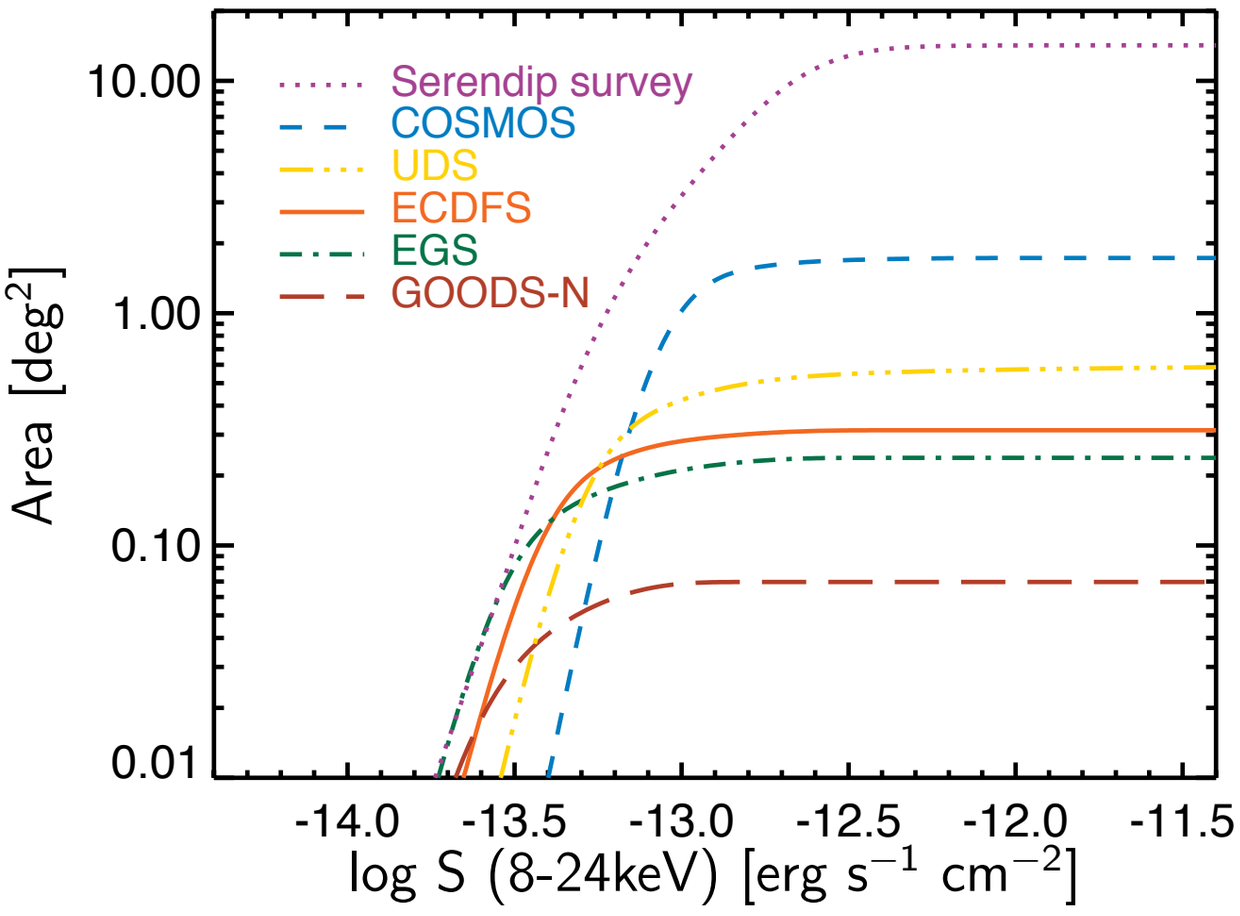
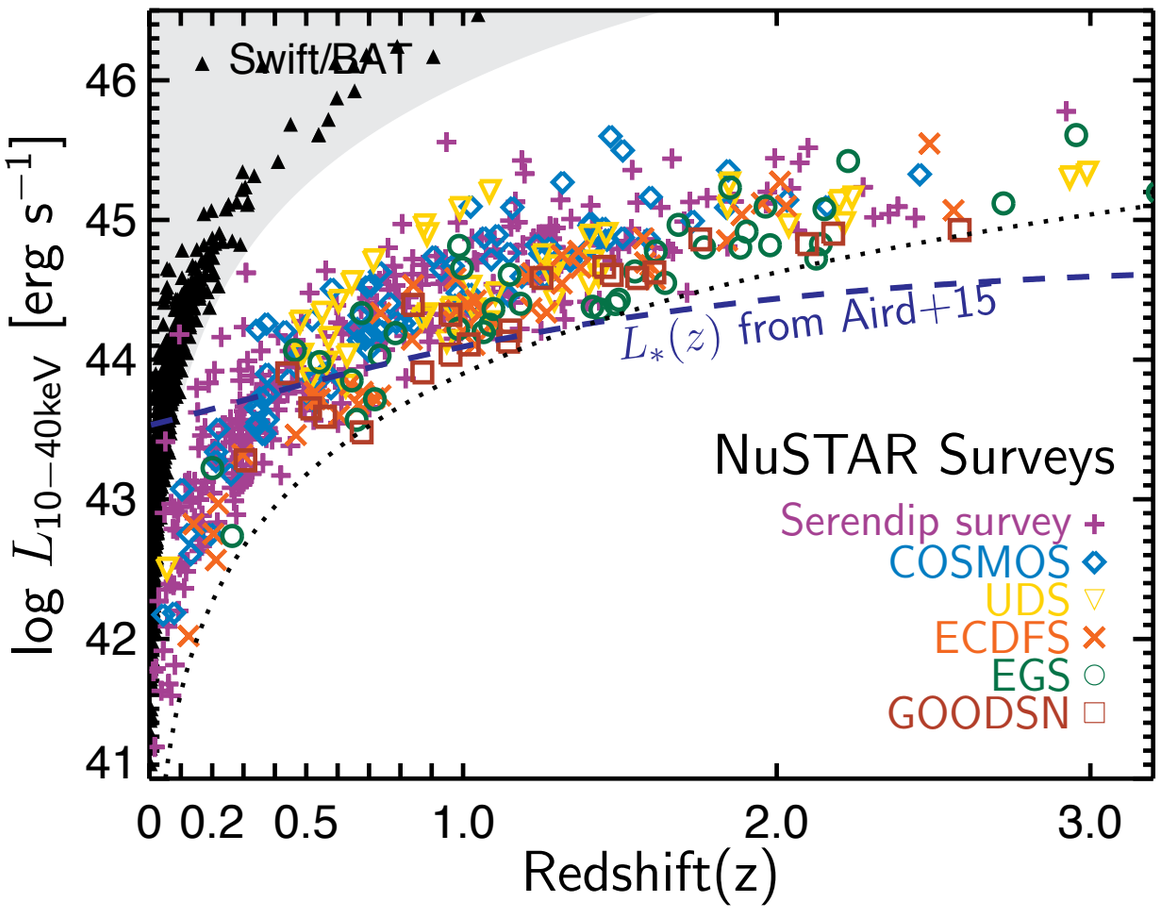
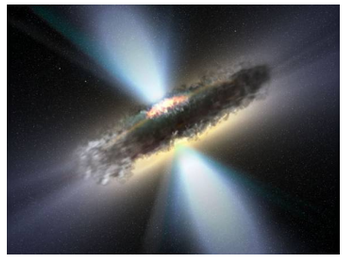




Measuring Black Hole Growth Over Cosmic Time

- median redshift of Swift/BAT hard X-ray sources: z=0.03
- median redshift of NuSTAR hard X-ray sources: z=0.63
- Palomar plays a key role in getting the redshifts (and ancillary information, when possible from the spectra — e.g., black hole mass, line diagnostics, optical obscuration)



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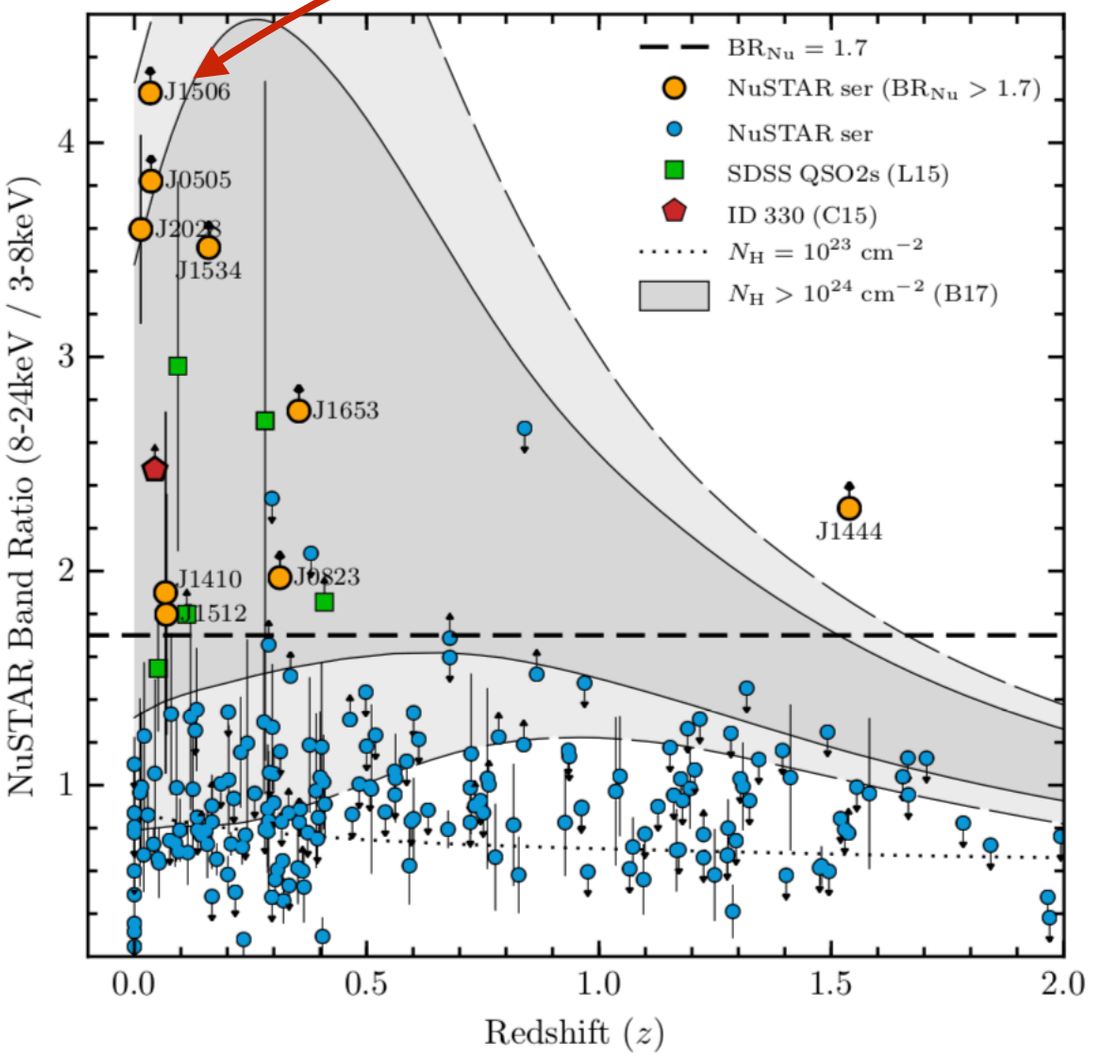
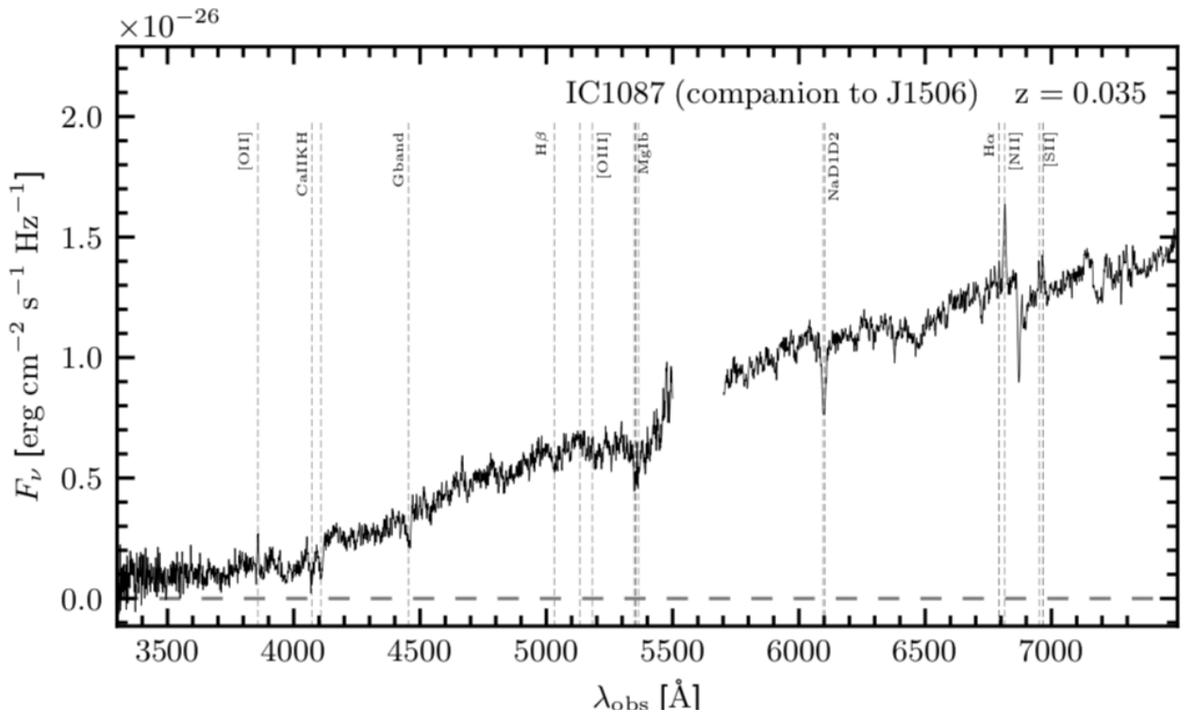
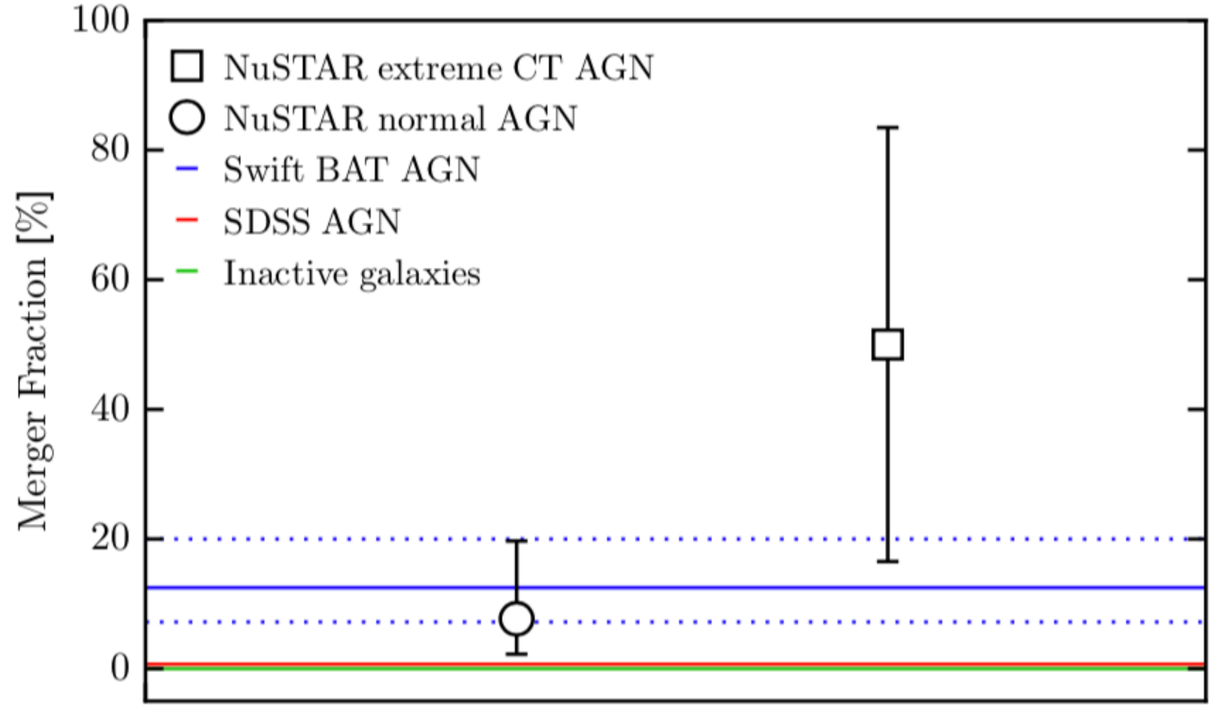
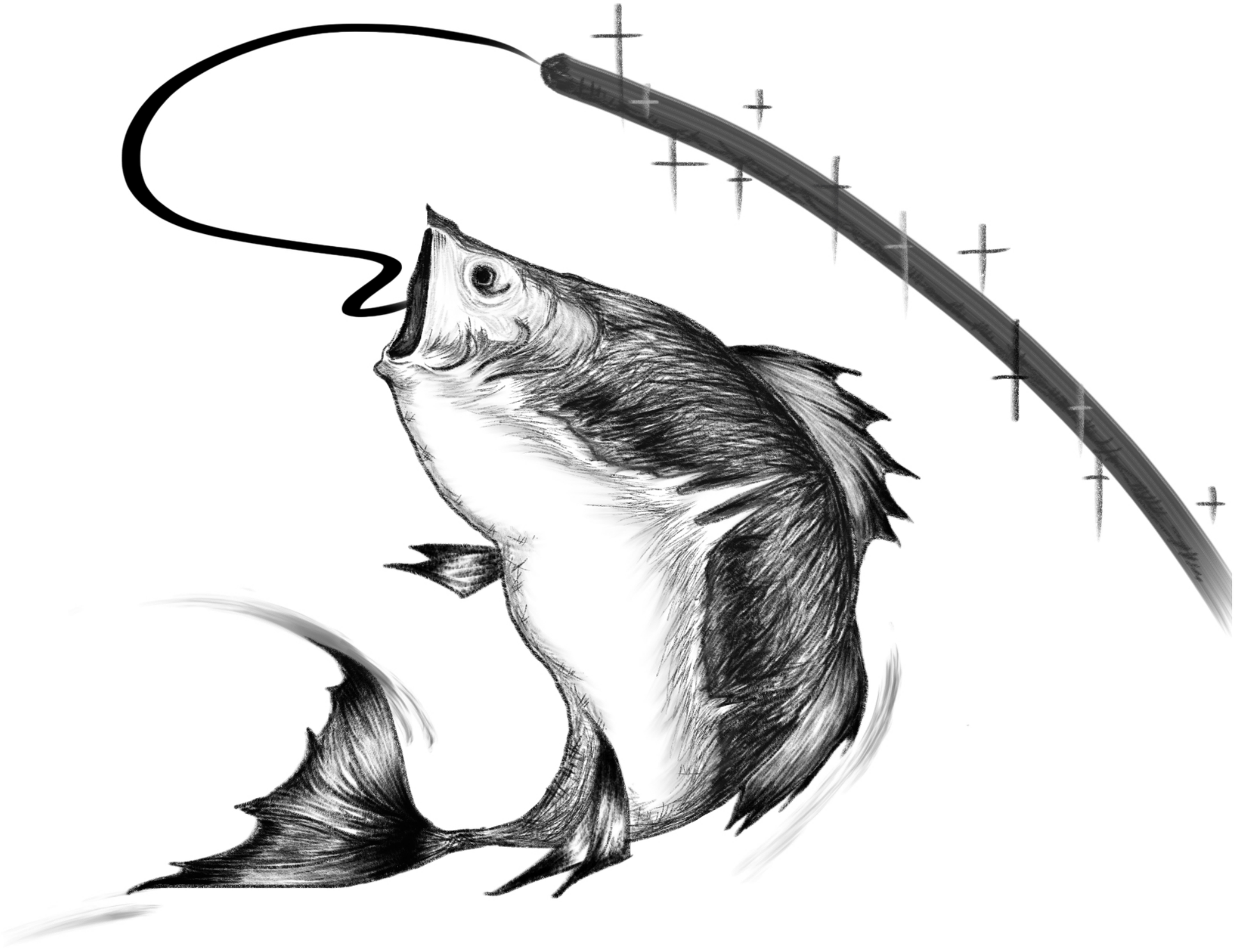




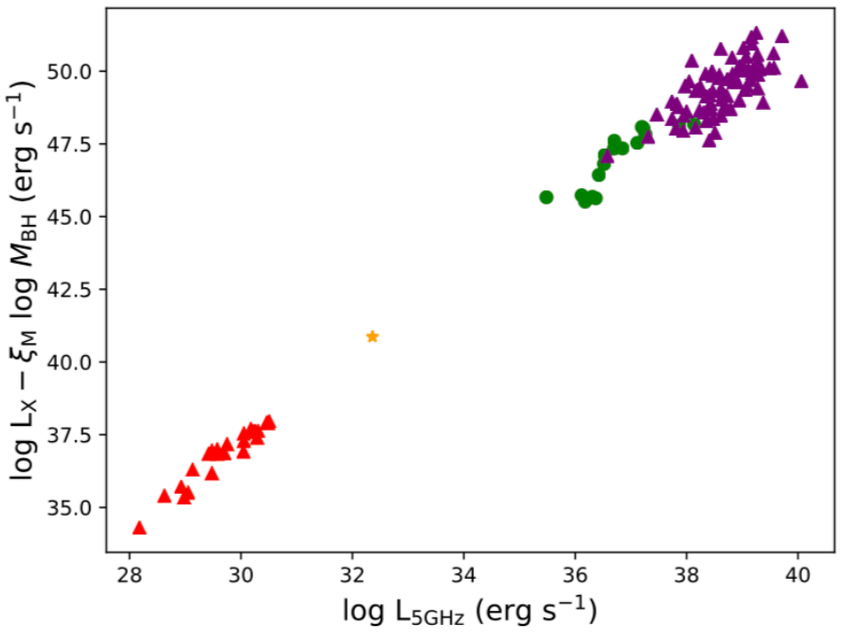


- high merger fraction in NuSTAR sources
- very high merger fraction in most heavily obscured ("Compton thick", CT) sources



BASS: BAT AGN Spectroscopic Survey

BAT AGN Spectroscopic Survey - I: Spectral measurements, derivied quantities, and AGN demographics	Koss et al. (2017)
BAT AGN Spectroscopic Survey - II: X-ray emission and high-ionization optical emission lines	Berney et al. (2015)
BAT AGN Spectroscopic Survey - III. An observed link between AGN Eddington ratio and narrow-emission-line ratios	Oh et al. (2017)
BAT AGN Spectroscopic Survey - IV: Near-Infrared Coronal Lines, Hidden Broad Lines, and Correlation with Hard X-ray Emission	Lamperti et al. (2017)
BAT AGN Spectroscopic Survey - V: X-ray Properties of the Swift/BAT 70-month AGN Catalog	Ricci et al. (2017)
BAT AGN Spectroscopic Survey - VI. The Γ_X-L/L_{Edd} relation	Trakhtenbrot et al. (2017)
BAT AGN Spectroscopic Survey - VII. The close environments of accreting massive black holes are shaped by radiative feedback	Ricci et al. (2017)
BAT AGN Spectroscopic Survey - VIII. Type 1 AGN with massive absorbing columns	Shimizu et al. (2018)
BAT AGN Spectroscopic Survey - IX. The clustering environments of an unbiased sample of local AGN	Powell et al. (2018)
BAT AGN Spectroscopic Survey - X. The 105-month *Swift*-BAT all-sky hard X-ray survey	Oh et al. (2018)
BAT AGN Spectroscopic Survey - XI. The Covering Factor of Dust and Gas in *Swift*/BAT Active Galactic Nuclei	Ichikawa et al. (2018)
BAT AGN Spectroscopic Survey - XII. The relation between coronal properties of active galactic nuclei and the Eddington ratio	Ricci et al. (2018)

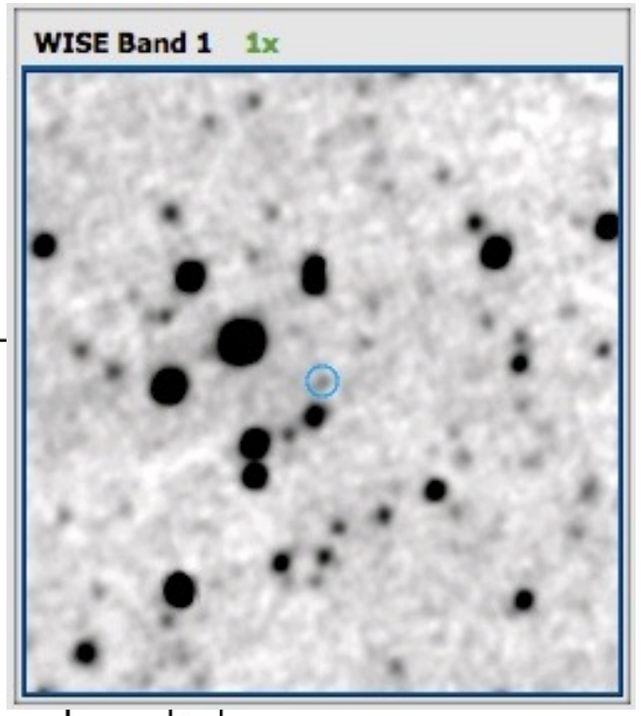


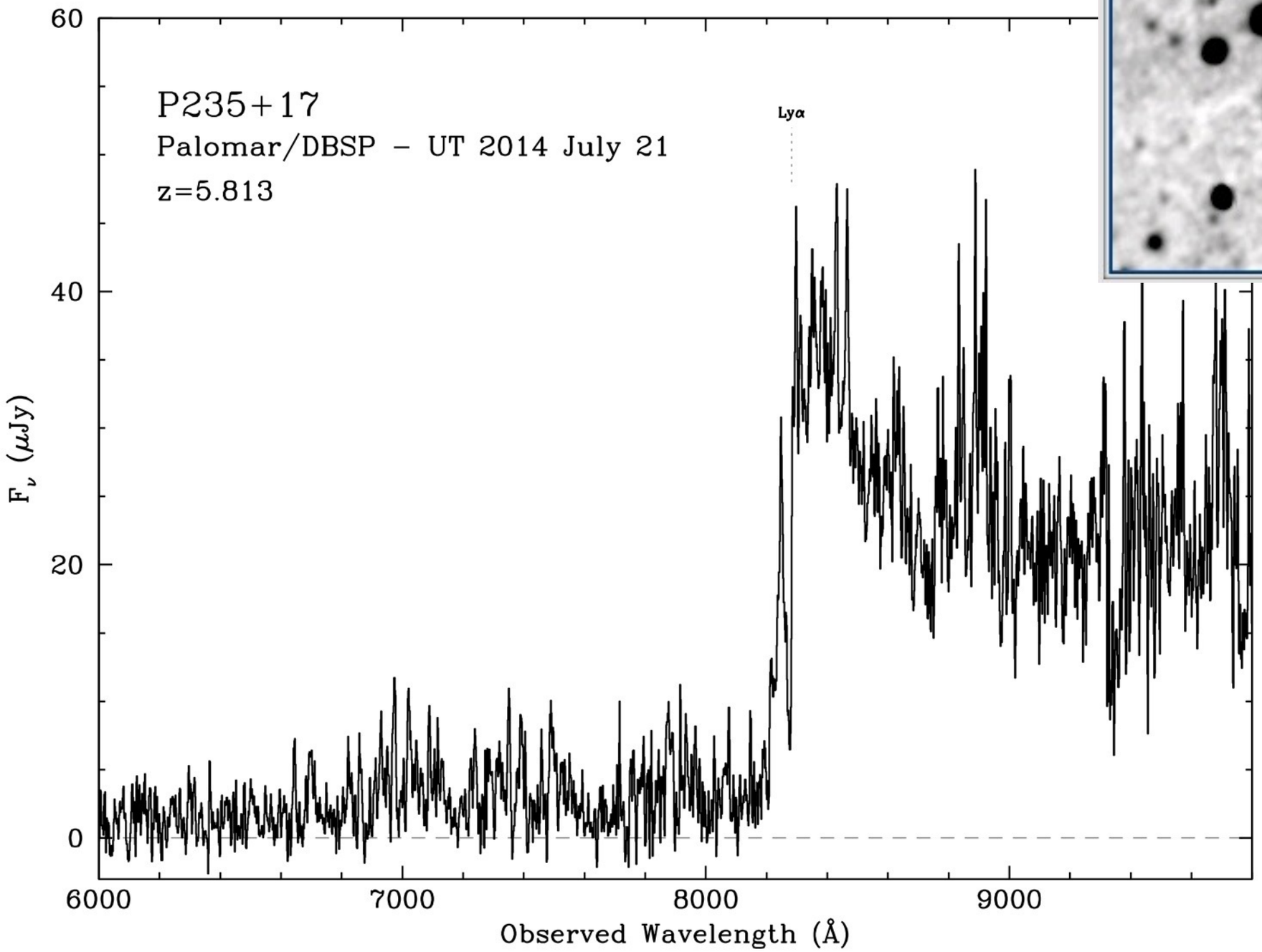
One result, at random (Smith et al., in prep.):

- the "fundamental plane of black holes" — tight correlation between black hole mass, X-ray luminosity, and radio core luminosity, from Galactic stellar mass black holes to SMBHs in (BASS) AGN

z~6 Quasars

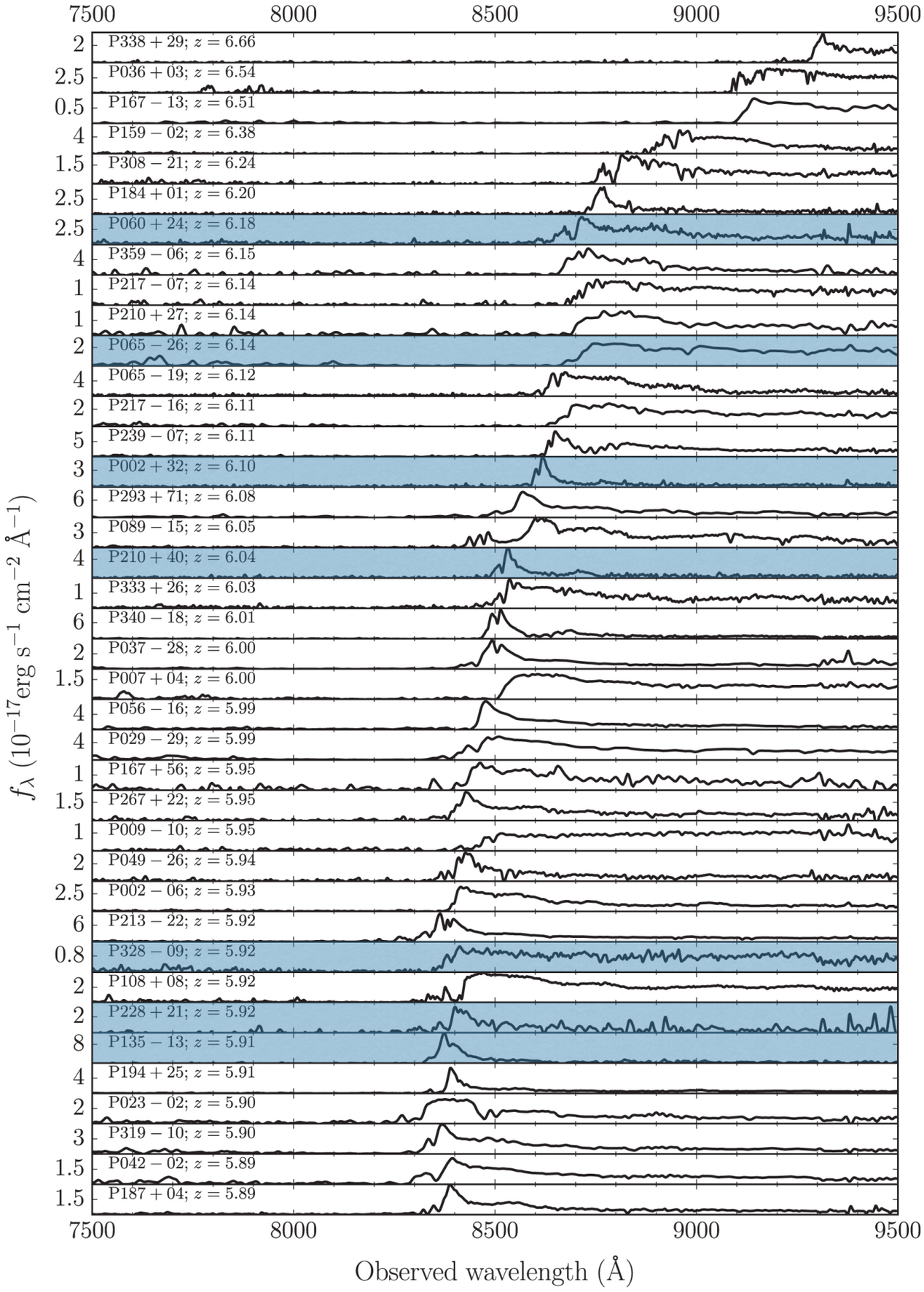
- pushing the redshift limits with PanSTARRs + WISE

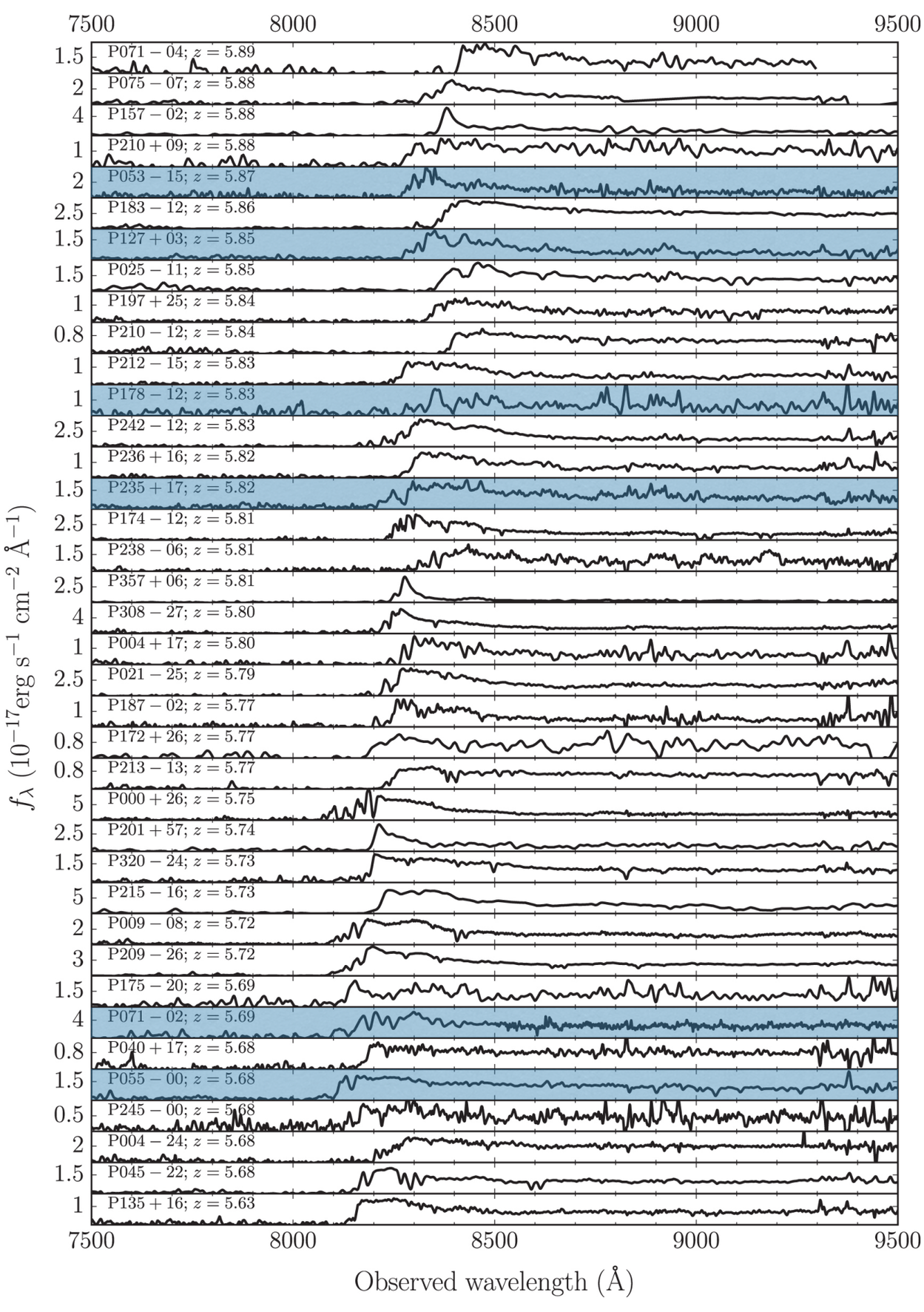




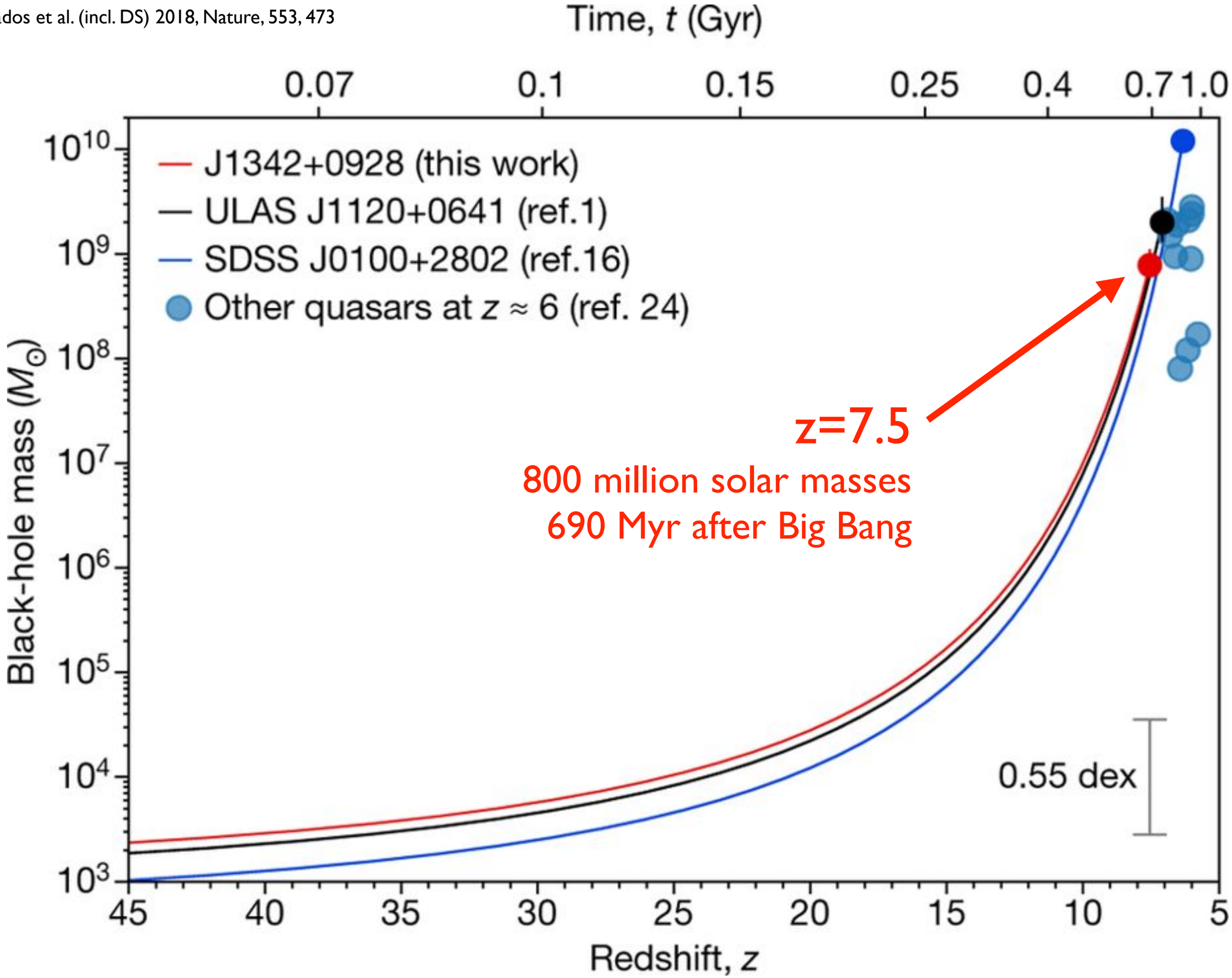
Bañados et al. (incl. DS) 2016, ApJ, 227, 11:
THE PAN-STARRS1 DISTANT $z > 5.6$ QUASAR SURVEY: MORE THAN 100 QUASARS WITHIN THE FIRST GYR OF THE UNIVERSE

Bañados et al. (incl. DS) 2016, ApJ, 227, 11

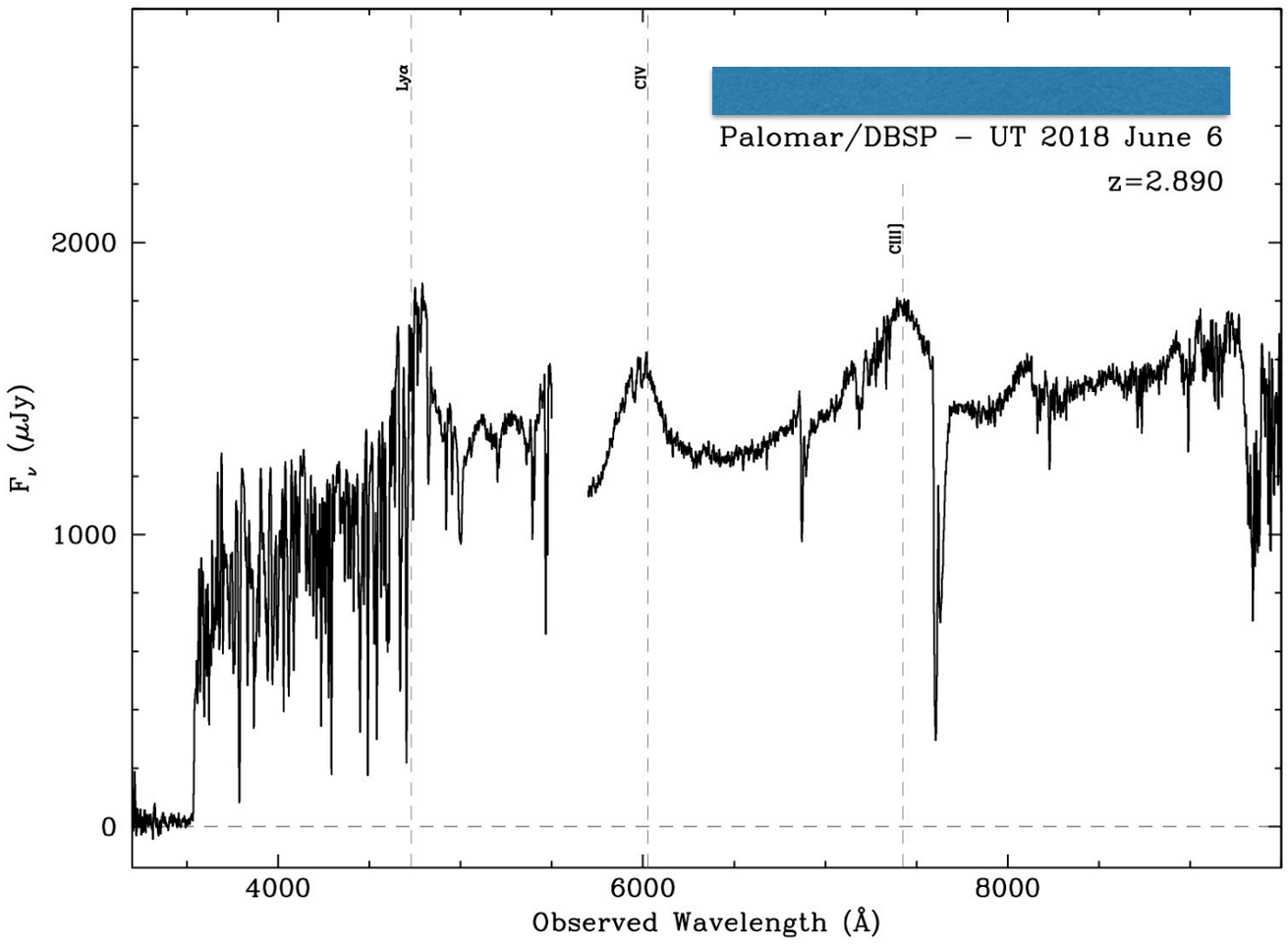


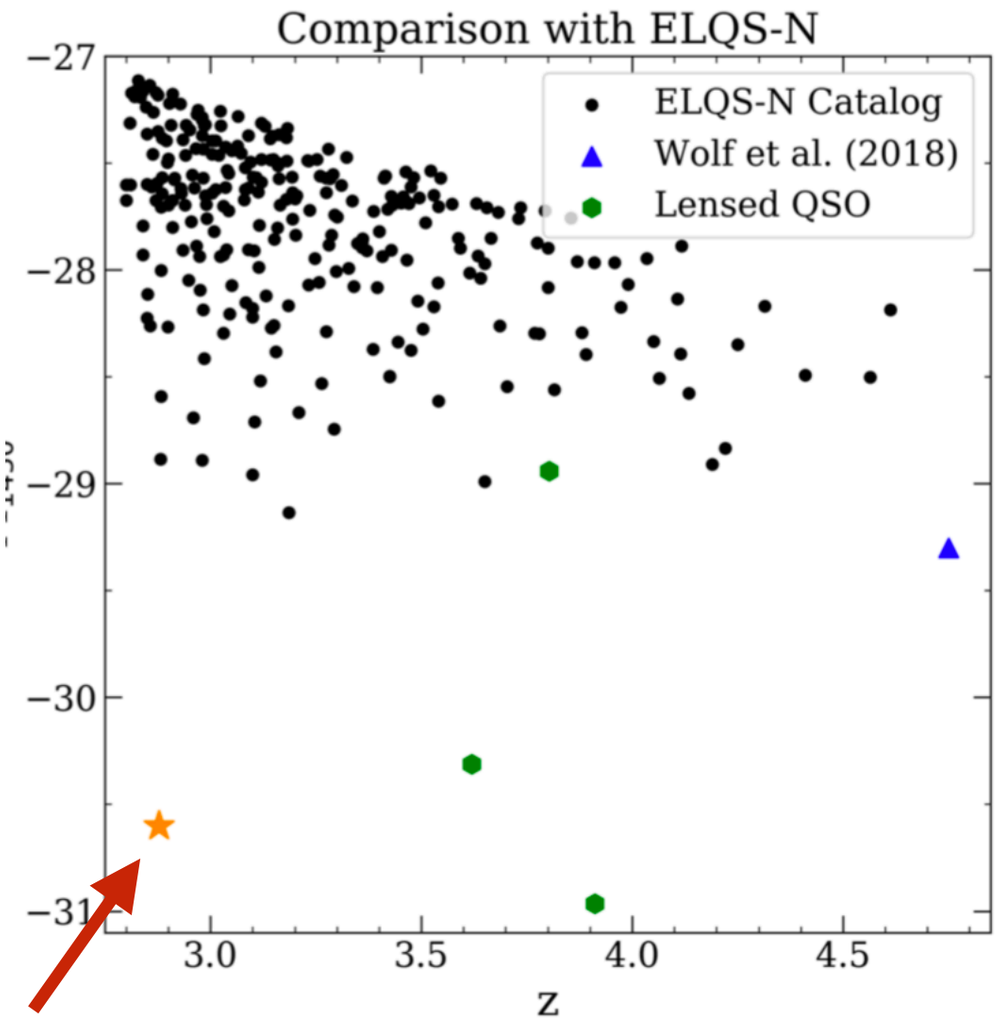


Bañados et al. (incl. DS) 2018, Nature, 553, 473



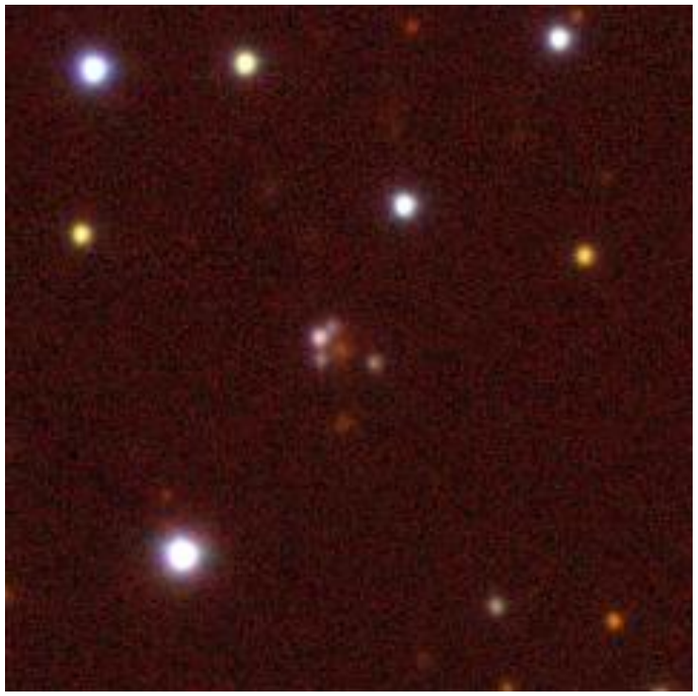
Extremely bright QSO selected from Gaia



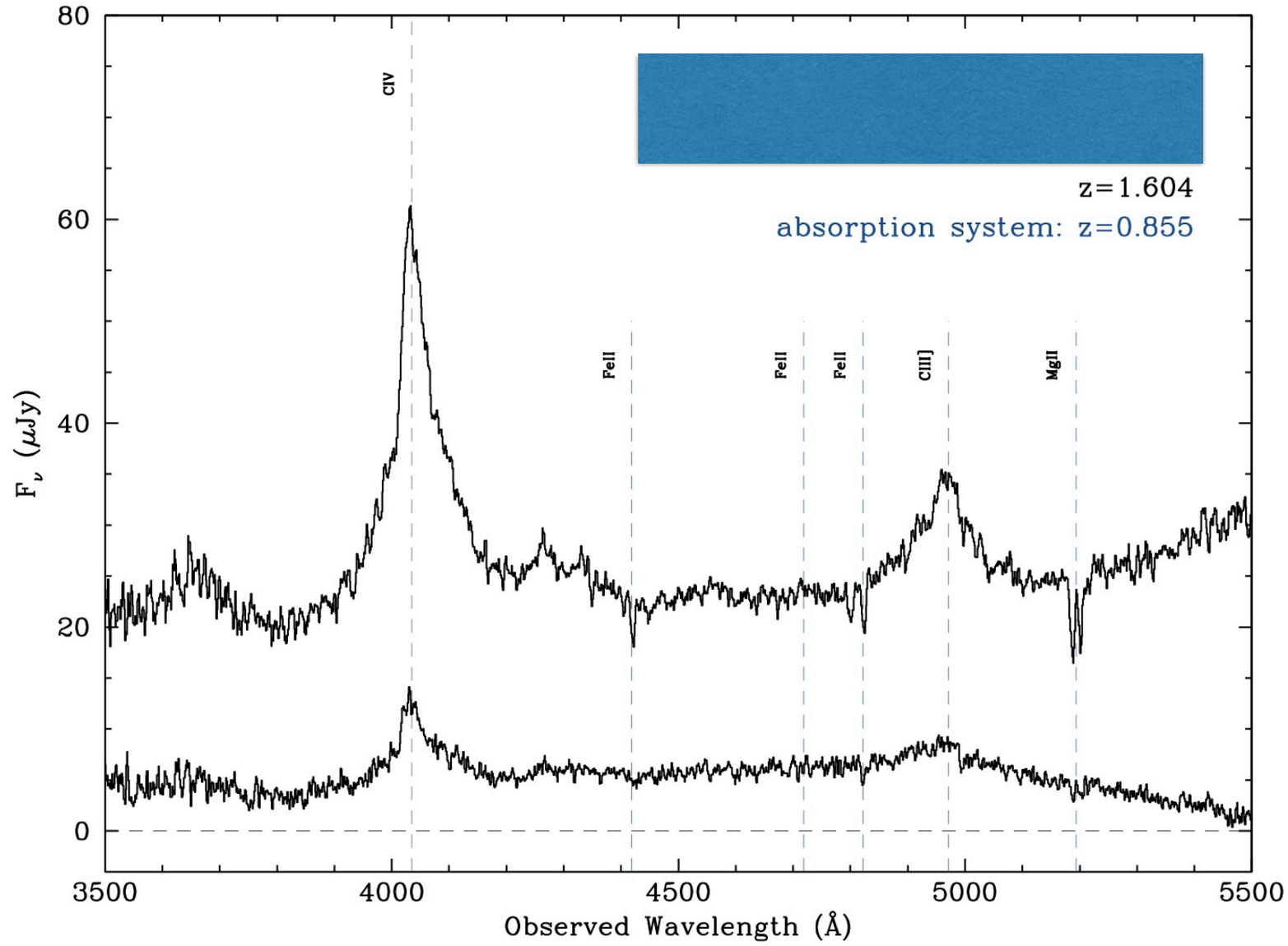


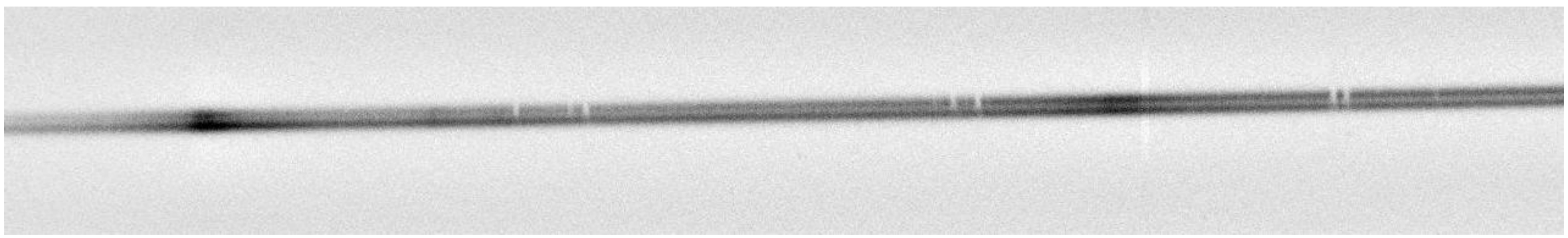
Jeram, Gonzalez et al. (incl. DS), submitted

Strong lenses selected from GAIA + WISE



"Orion's Crossbow"





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