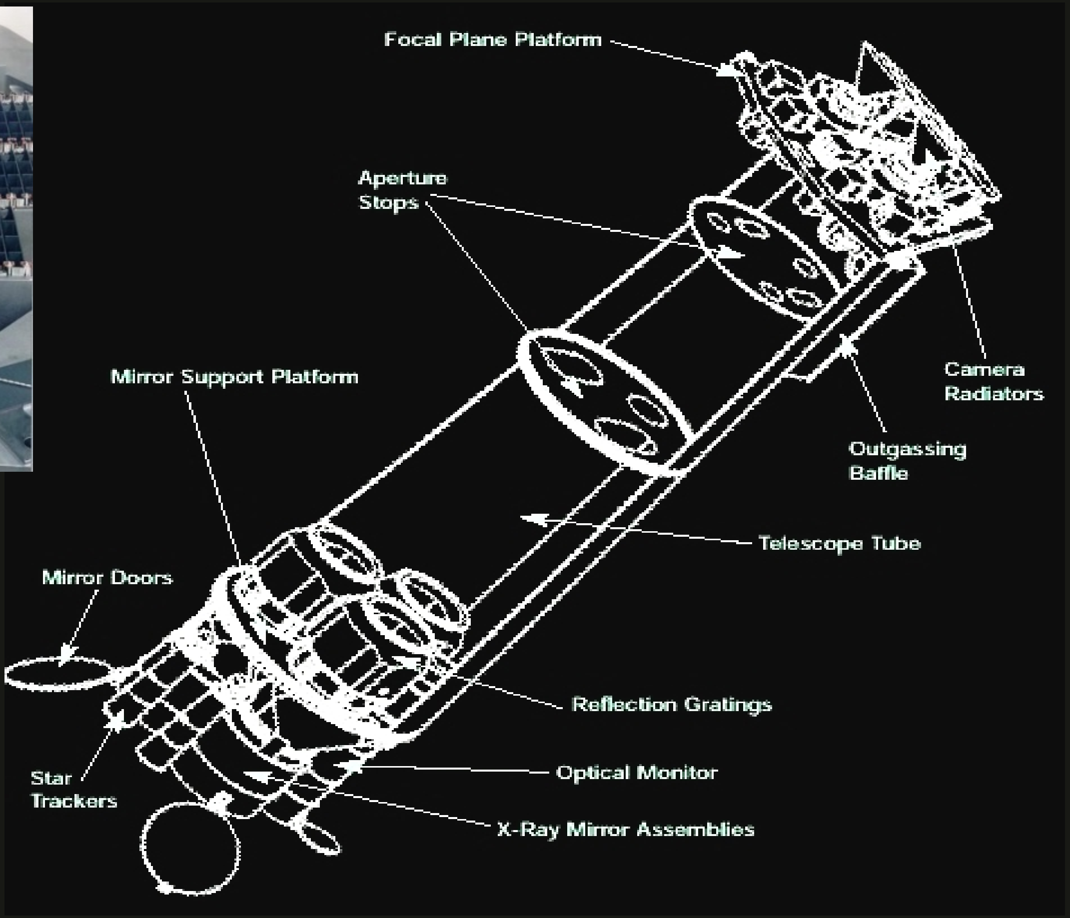
Recent highlights of XMM-Newton observations of AGN / Supermassive Black Holes

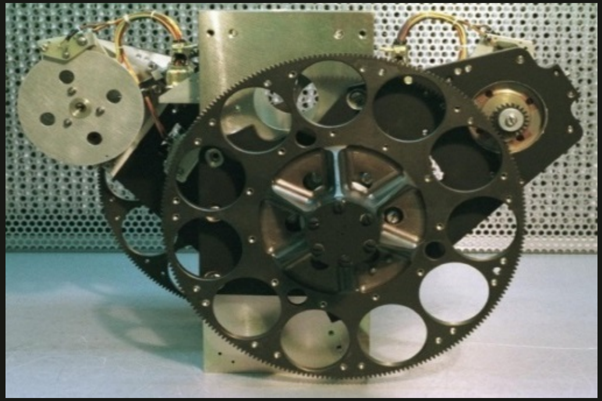
EAS 2021 / virtual
30.6.2021

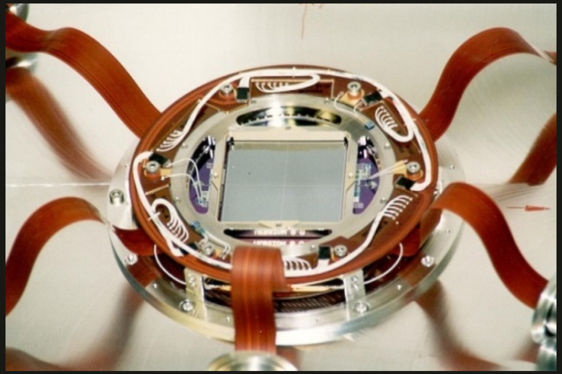
Norbert Schartel s

XMM-Newton

Instruments







XMM-Newton

- 3 Mirror Modules / highest effective collecting area ever
- Six simultaneously observing instruments:
    - 3 CCD cameras (one pn and two MOSs)
    - 2 spectrometers (RGS)
    - 1 Optical Monitor (OM)

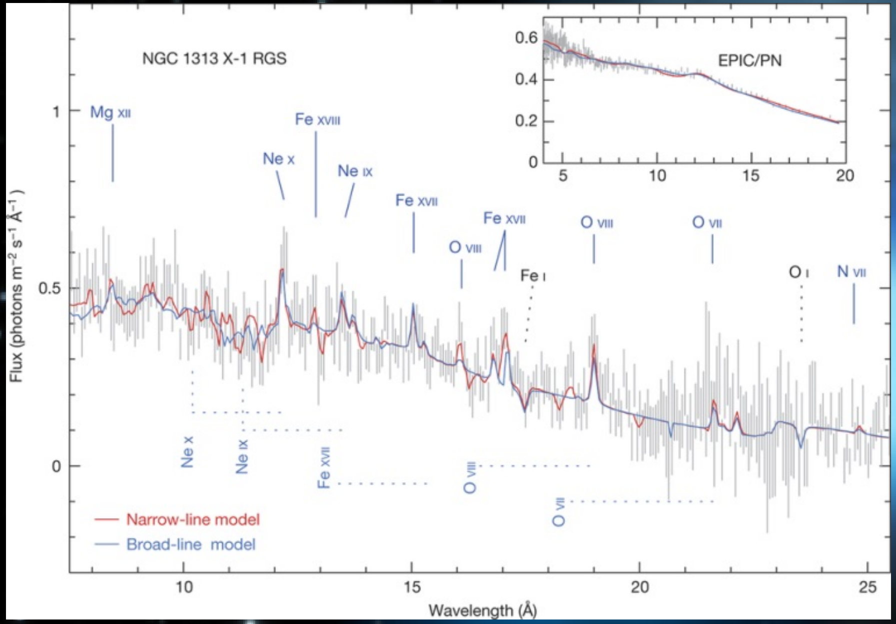
ULX

Outflows in two Ultraluminous X-ray Sources (ULX)

ULX have X-ray luminosities > 3 × 10^{39} ergs / s.
Possible explanations are accretion:

(a) onto neutron stars or stellar-mass black holes (BH) in excess of the Eddington limit

(b) onto intermediate-mass BH (10^3–10^5 solar masses)



High-resolution XMM-Newton X-ray spectra of the ULXs NGC 1313 X-1 and NGC 5408 X-1.

➔ X-ray absorption lines from highly ionized iron, oxygen and neon

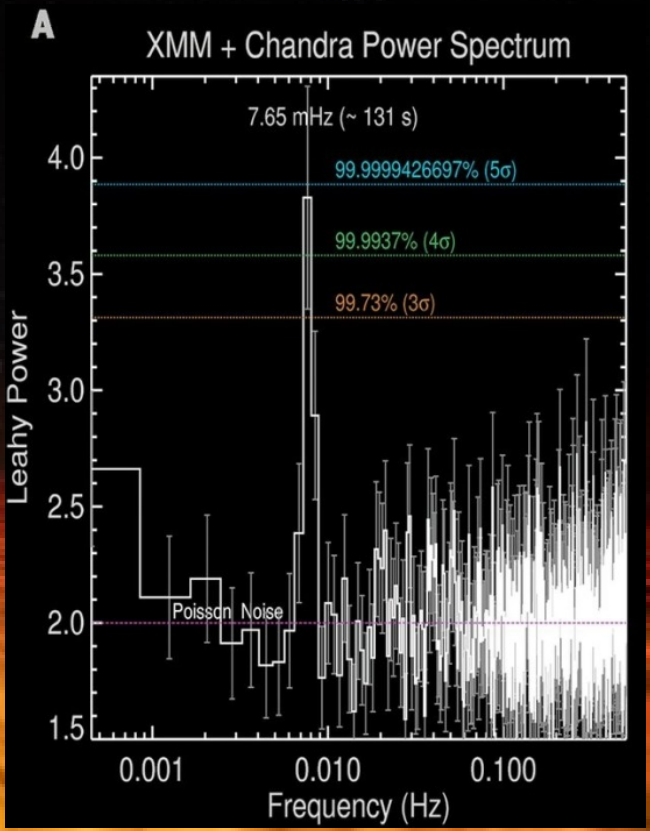
➔ Blueshift velocity ~ 0.2 c

➔ The absorption lines occur in a fast-outflowing gas, as predicted by models of hyper-accreting stellar-mass BH

C. Pinto, et al., 2016, Nature 533, 64

TDE

Quasi-Periodic Oscillations after a Star is Disrupted by a Massive Black Hole



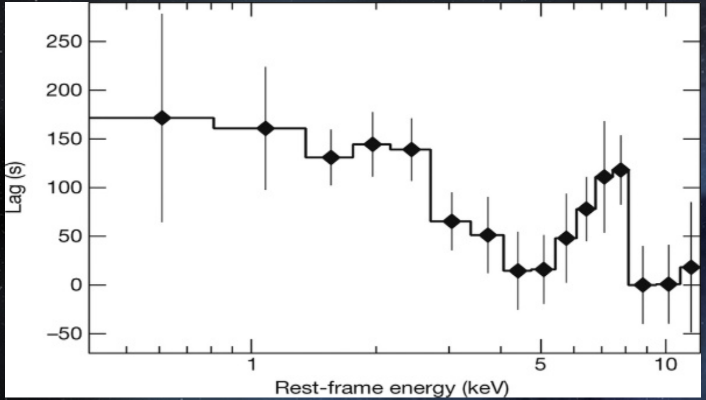
- tidal forces close to black holes can rip apart stars that come too close to them.
- stellar debris spirals toward the black hole

➔ stable 131-second x-ray quasi-periodic oscillation from the tidal disruption event ASASSN-14li

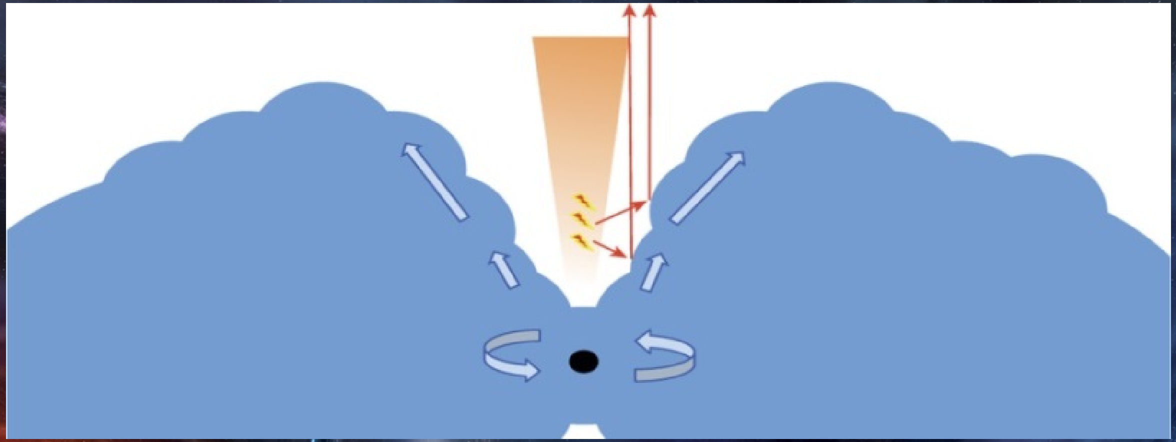
➔ periodicity originates from close to the event horizon and that the black hole is rapidly spinning

D. R. Pasham, et al., 2019, Science 363, 531

Relativistic Reverberation in the Accretion Flow of a Tidal Disruption event



The emission from ~4–5 keV and 8–13 keV (continuum) vary first, and the iron line from ~7–8 keV responds ~100 s later.



Swift J1644+57 is a super-Eddington accreting source, with a thick disk (blue) and a relativistic radio jet (orange). The blue arrows represent the dynamics in the disk: the accretion flow rotates around the central black hole and the walls of the funnel are outflowing at ~0.1c–0.5c.

Swift J1644+57 tidal disruption event

- relativistic jet pointed in line of sight

Kara et al., 2016, Nature 535, 388

- ➔ **Reverberation arising from gravitationally redshifted iron Kα photons reflected off the inner accretion flow**
- ➔ **Accretion rate of 100 times the Eddington limit**
- ➔ **X-rays do not arise from the relativistic jet**

Flows of X-ray gas reveal the disruption of a star by a massive black hole

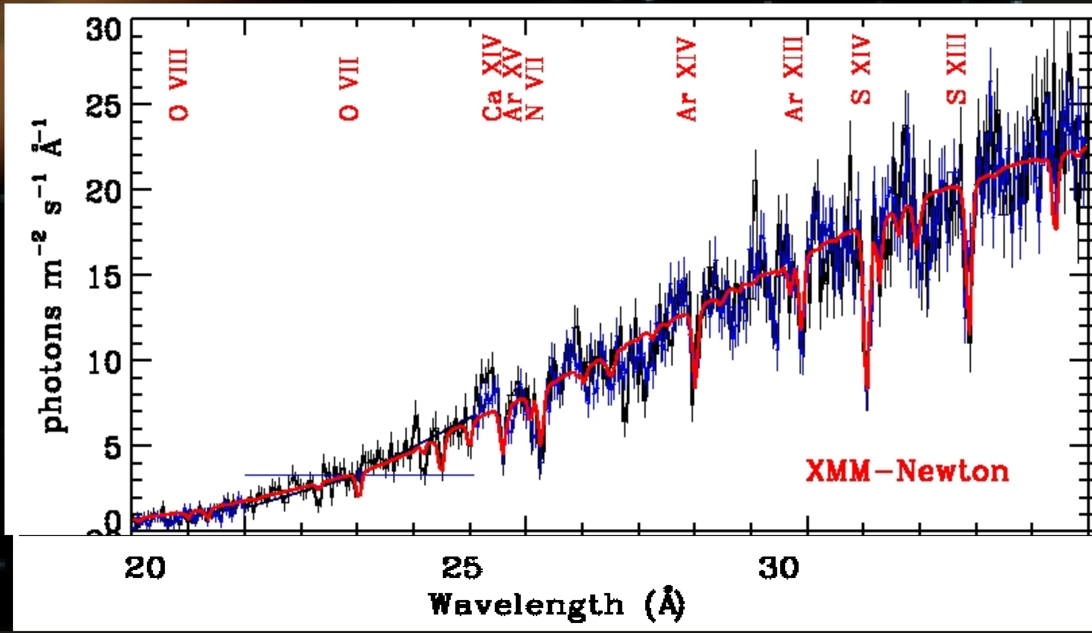
J.M. Miller et al., 2015, Nature 526, 542

- tidal disruption event ASASSN-14li
- detection of blue-shifted absorption lines of highly ionized atoms
- variability indicates that the gas is close to the black hole
- narrow line widths indicate a low volume filling factor
- outflow speeds are below the escape speed from the radius set by variability

➔ rotating wind from the inner region of a nascent accretion disk, or

➔ a filament of disrupted stellar gas near to the apocenter of an elliptical orbit

The high-resolution (RGS1 & RGS2) X-ray spectra of ASASSN-14li reveal blue-shifted absorption lines.



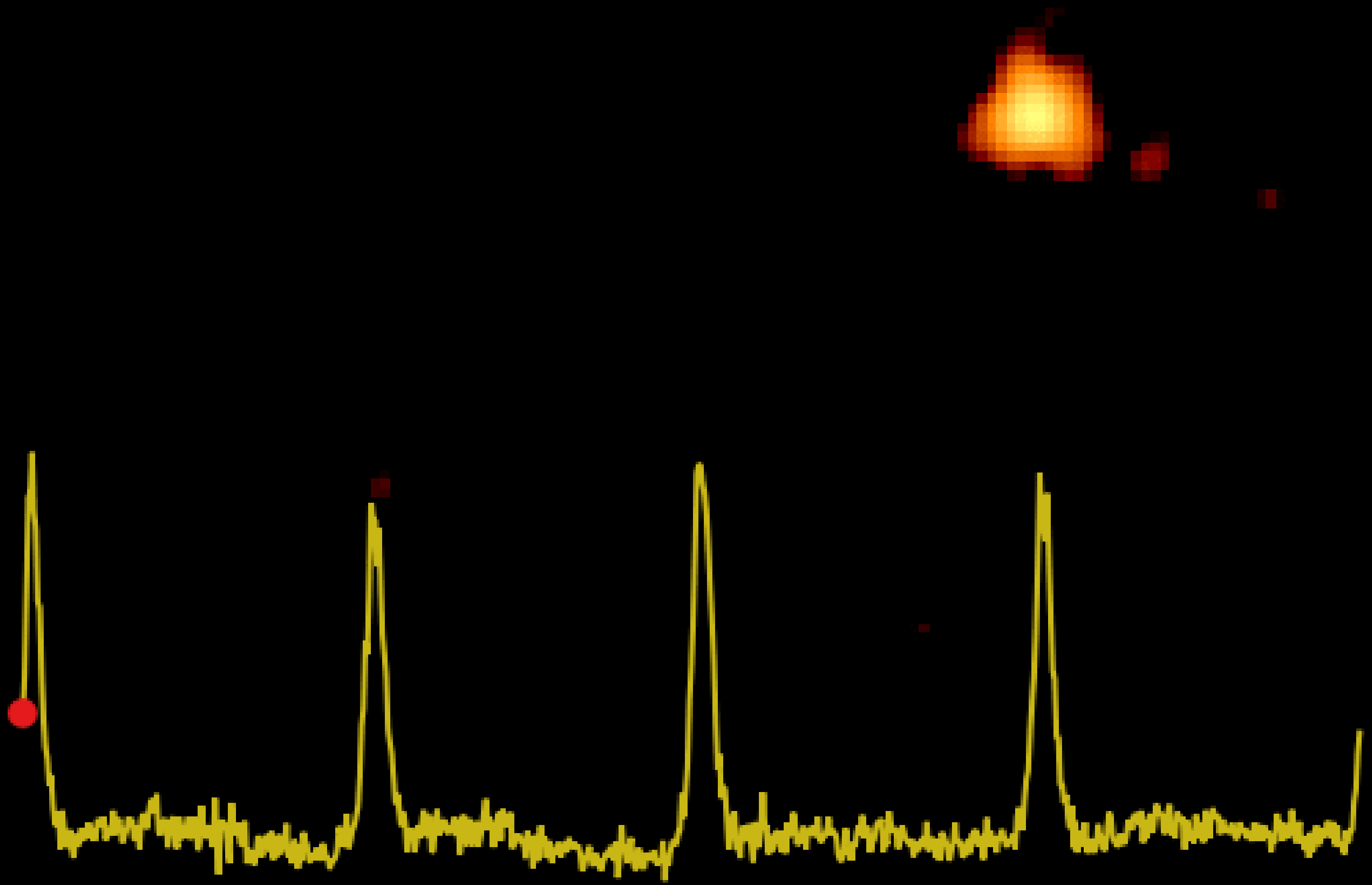
Nine-hour X-ray quasi-periodic eruptions from a low-mass black hole galactic nucleus

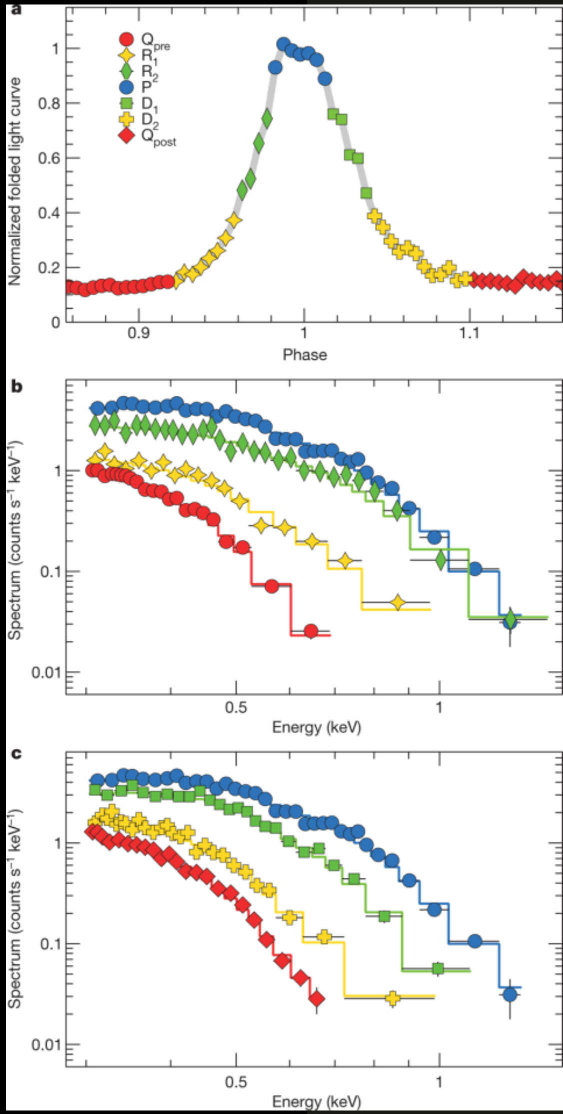
Seyfert 2 galaxy GSN 069

z = 0.0189

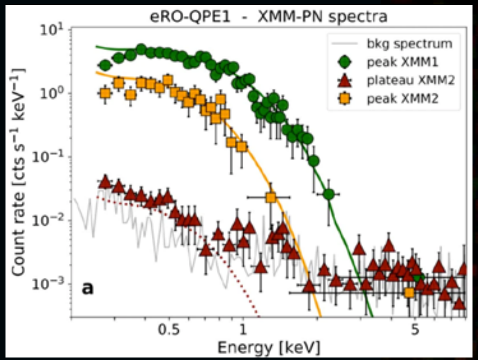
$M_{BH} \approx 2 \times 10^6 M_\odot$

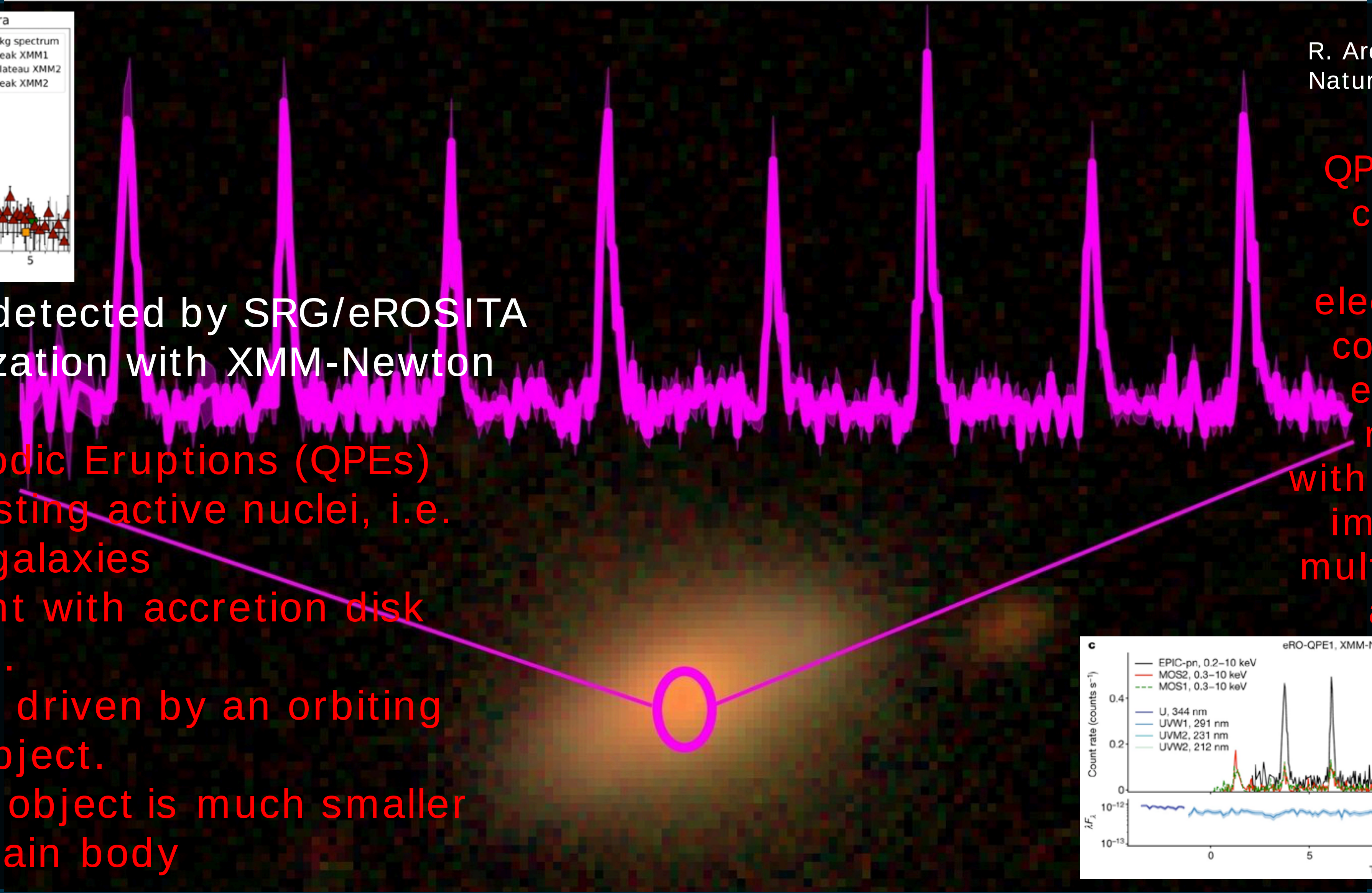
Miniutti et al., 2019, Nature 573, 381





Quasi-Periodic Eruptions from Quiescent Galaxies

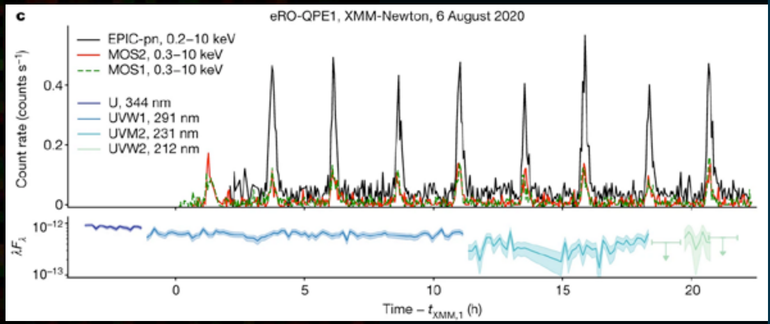




R. Arcodia et al. (2021, Nature 592, 704)

- ❑ 2 sources detected by SRG/eROSITA
- ❑ Characterization with XMM-Newton and NICER
- ➢ Quasi-Periodic Eruptions (QPEs)
- ➢ No pre-existing active nuclei, i.e. quiescent galaxies
- ➢ Inconsistent with accretion disk instabilities.
- ➢ QPEs likely driven by an orbiting compact object.
- ➢ Secondary object is much smaller than the main body

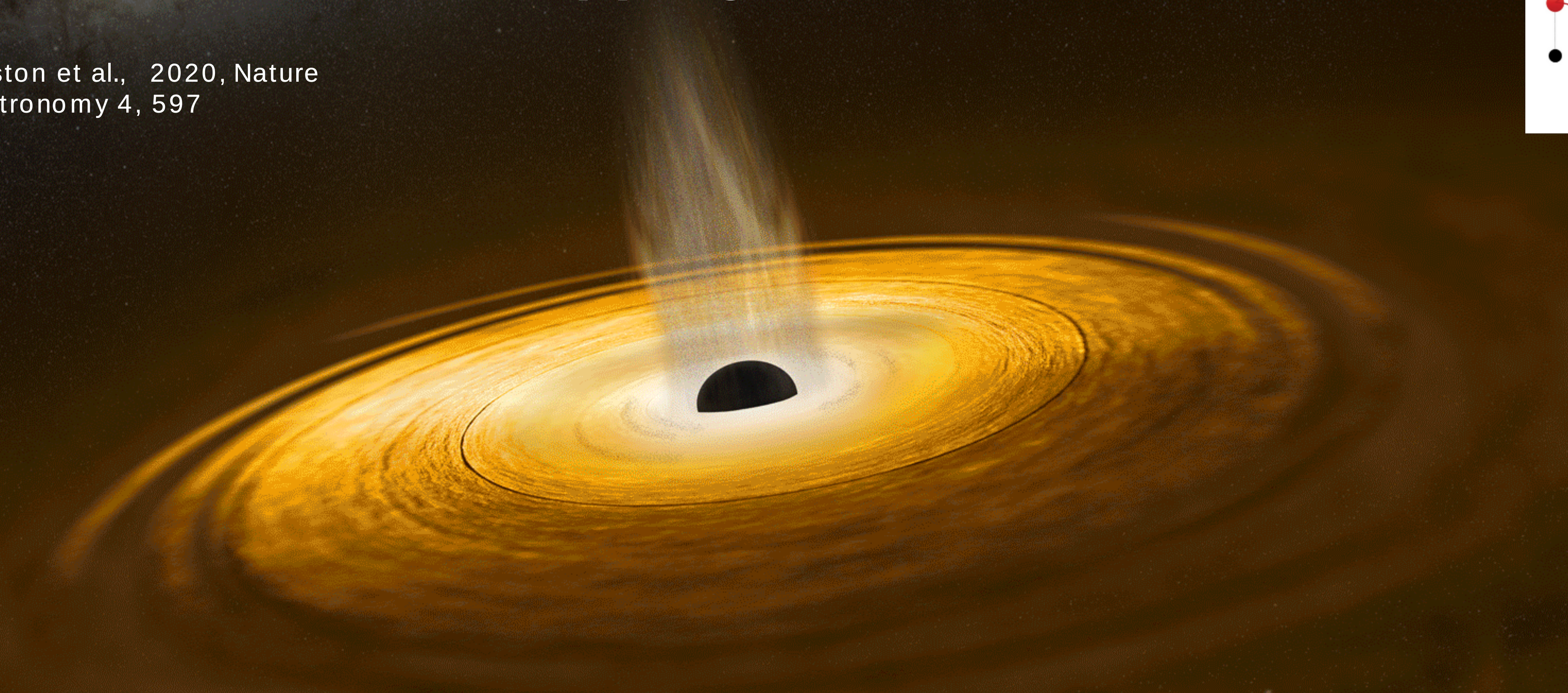
QPEs are viable candidates for the electromagnetic counterparts of extreme mass ratio inspirals with considerable implications for multi-messenger astrophysics.

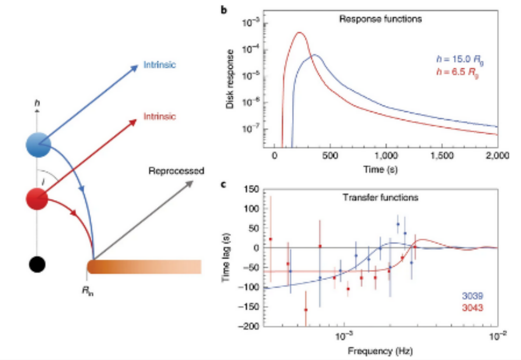


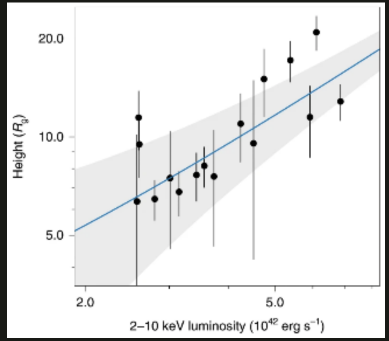
AGN

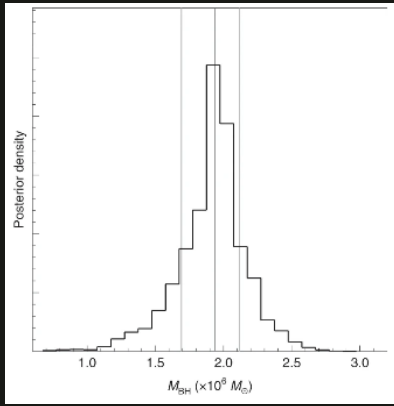
Dynamic Black Hole Corona in an AGN through X-ray Reverberation Mapping

Alston et al., 2020, Nature Astronomy 4, 597





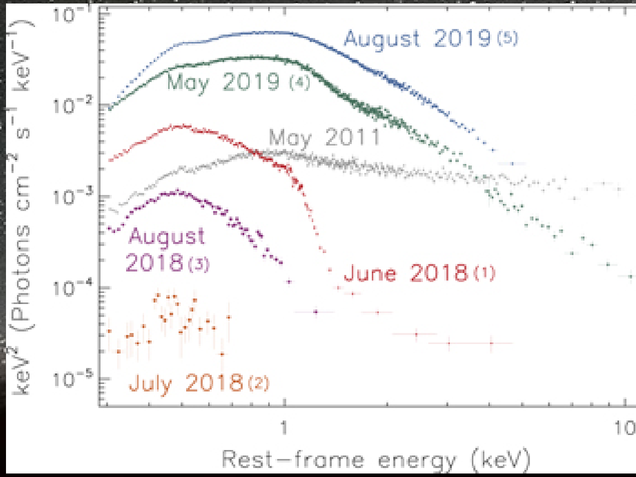




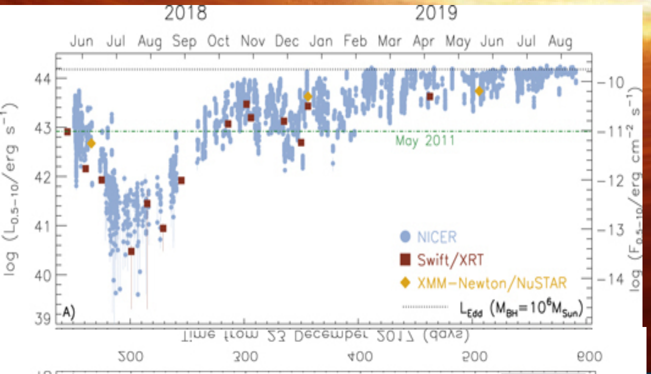
X-ray reverberation based on a long XMM-Newton observation of the IRAS 13224−3809

- ➔ X-ray corona increases with increasing luminosity
- ➔ break inherent degeneracy between black hole mass, inner disk radius and height of corona
- ➔ $M_{BH} = 1.9 \pm 0.2 \times 10^6 M_{\odot}$
- ➔ spin value a = 0.97

Destruction and Recreation of the X-Ray Corona in a Changing-look AGN 1ES 1927+65



Ricci et al. 2020, ApJ 898, L1



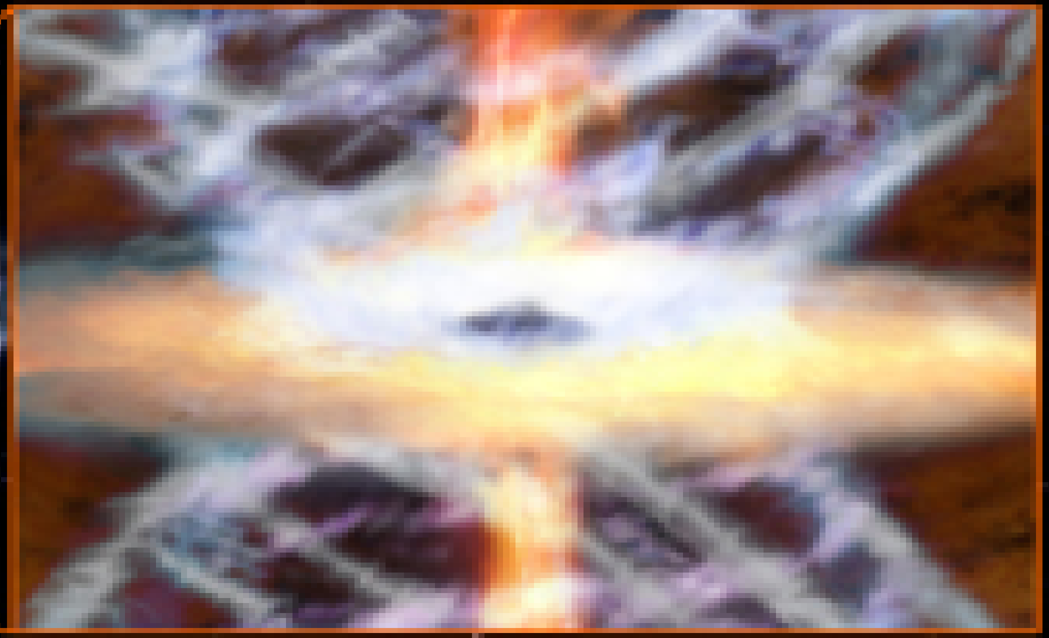
- after optical/ultraviolet outburst the power-law component disappeared
➔ corona was destroyed
- increase in luminosity to levels exceeding the pre-outburst level ≳300 days
➔ X-ray corona is recreated

Ultra-fast Outflows in Radio-quiet Active Galactic Nuclei

F. Tombesi et al., 2012, MNRAS 422, L1

F. Tombesi, et al., 2011, ApJ 742, 44

F. Tombesi, et al., 2010, A&A 521, 57

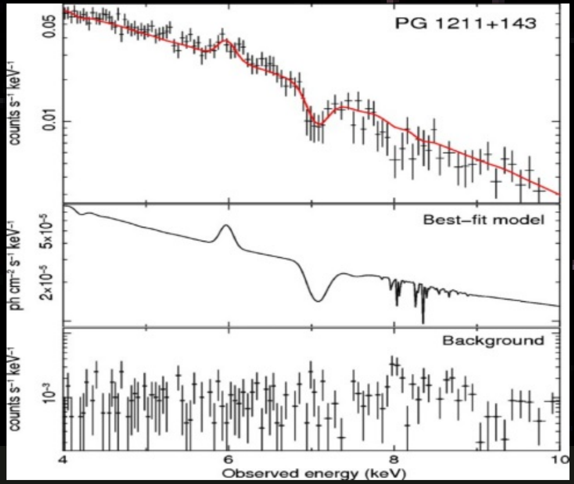


Ultra-fast outflows (UFOs) are detected through blueshifted Fe XXV/XXVI K-shell transitions.

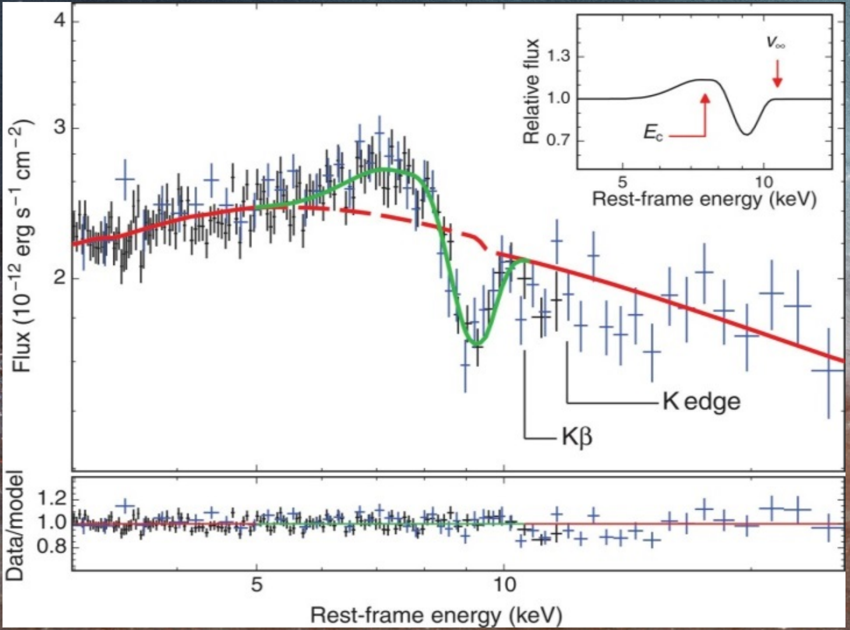
- 42 local radio-quiet AGNs

- ➔ **>35% are showing UFOs**
- ➔ **v ~ 0.03c -0.3c, mean ~0.14c**
- ➔ **Ionization parameter is very high**
- ➔ **Column densities are N_H~10^{22}-10^{24} cm^{-2}**

- ➔ **Location: ~10^2-10^4 r_s from the central black hole**
- ➔ **Outflow rates: ~0.01-1 Mo y^{-1} / 5-10% of the accretion rates**
- ➔ **mechanical power ~42.6-44.6 erg s^{-1}**
- ➔ **significant contribution to the AGN cosmological feedback**



Black hole feedback in the luminous quasar PDS 456



XMM-Newton pn (black) and NuSTAR (blue) data are shown. The green curve shows a model where the emission and absorption residuals characterizing the Fe-K band are described through a self-consistent P-Cygni profile from a spherically symmetric outflow.

- XMM-Newton and NuSTAR simultaneously observed PDS 456 on four occasions in 2013

- The emission and absorption residuals of the Fe-K band are described through a self-consistent P-Cygni profile

➔ Nearly spherical symmetric outflow of highly ionized gas

➔ This wind is expelled at relativistic speeds from the inner accretion disk

➔ The outflow's kinetic power $>10^{46}$ ergs/s

➔ Enough to provide the feedback required by models of black hole and host galaxy coevolution.

E. Nardini, et al., 2015, Science 347, 860

The response of relativistic outflowing gas to the inner accretion disk of a black hole

Gas outflows from AGNs release huge quantities of energy into the interstellar medium, potentially moderating the growth of their host galaxy.

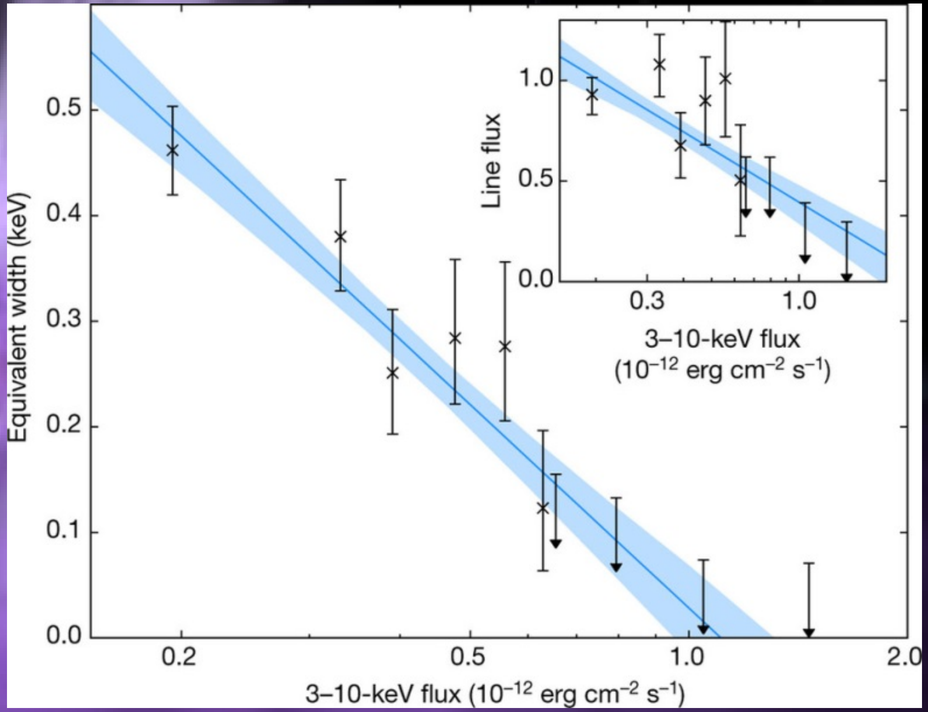
XMM-Newton observations of the narrow line Seyfert-1 galaxy IRAS 13224-3809:

➔ extreme ultrafast gas flow in the X-ray spectrum

➔ 0.236 ± 0.006 times the speed of light (71,000 km/s)

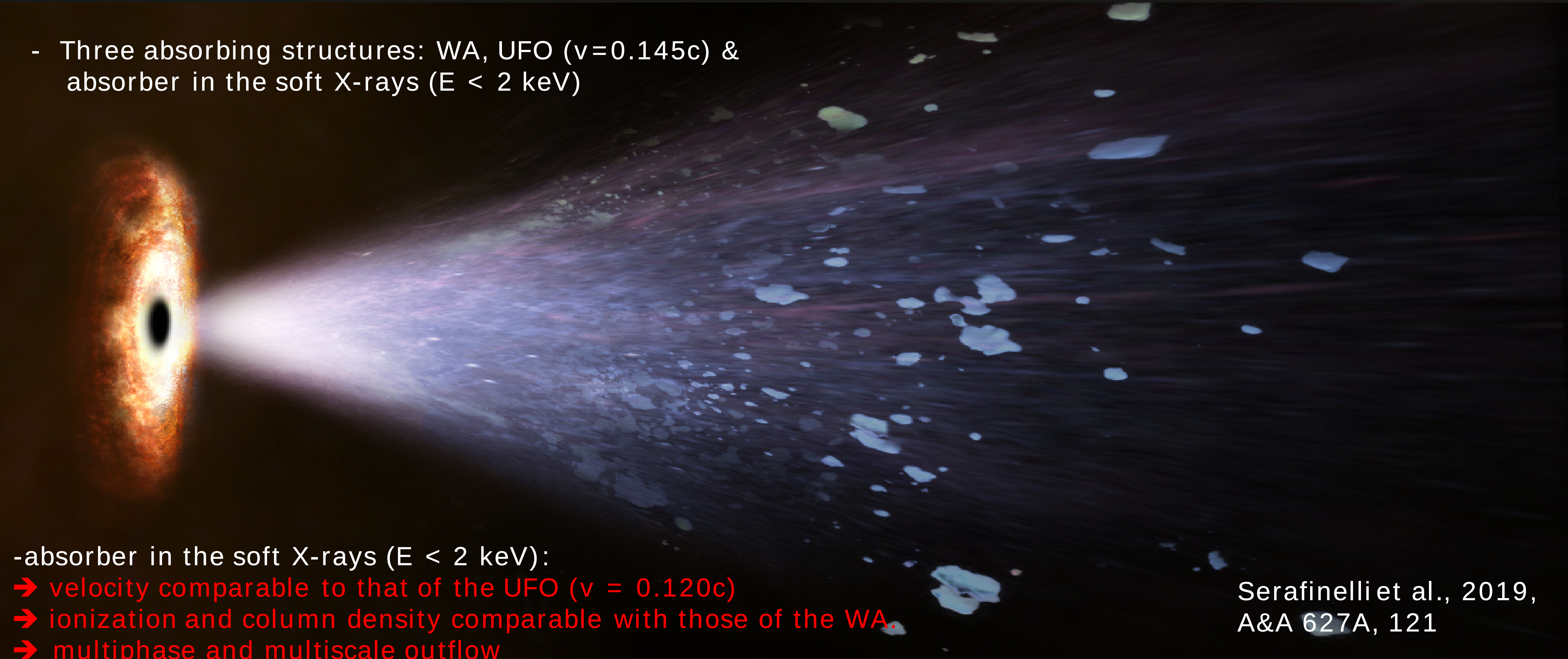
➔ absorption is strongly anti-correlated with the emission of X-ray

➔ X-ray emission from within a few gravitational radii of the black hole is ionizing the disk wind hundreds of gravitational radii further away as the X-ray flux rises.



M. L. Parker, et al., 2017
Nature 543, 83

Multiphase quasar-driven outflows in PG 1114+445



- Three absorbing structures: WA, UFO (v=0.145c) & absorber in the soft X-rays (E < 2 keV)

-absorber in the soft X-rays (E < 2 keV):

➔ velocity comparable to that of the UFO (v = 0.120c)

➔ ionization and column density comparable with those of the WA.

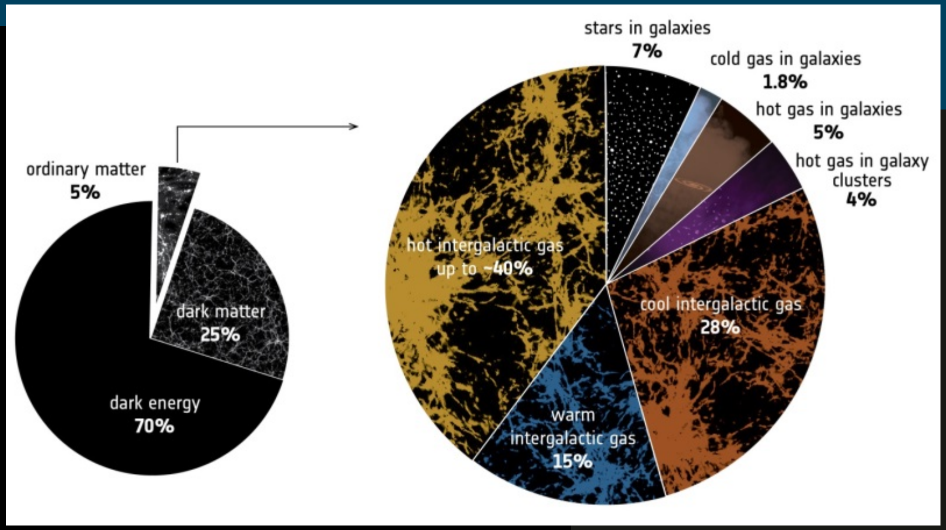
➔ multiphase and multiscale outflow

➔ entrainment of the clumpy ISM by an inner UFO producing an entrained ultra-fast outflow

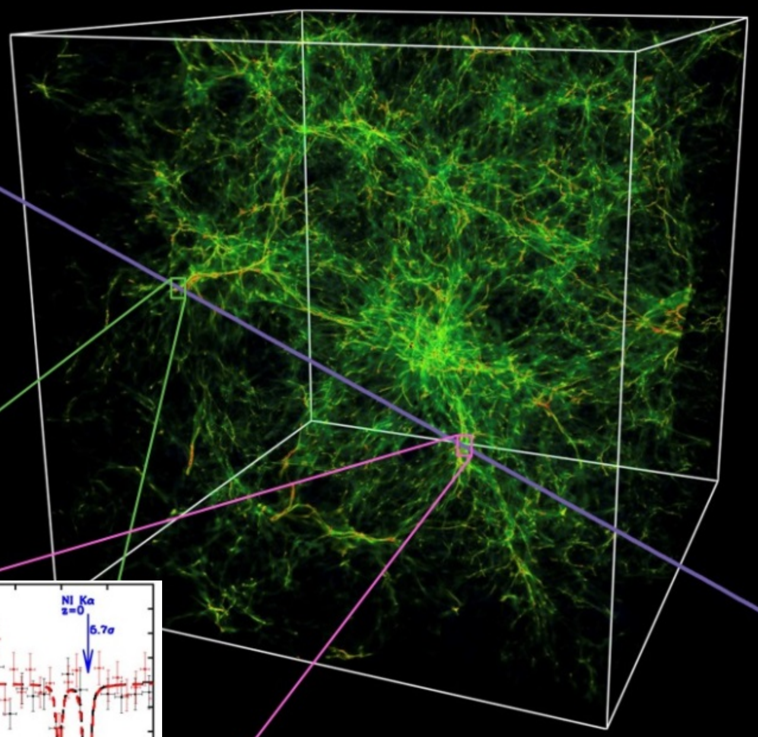
Serafinelli et al., 2019, A&A 627A, 121

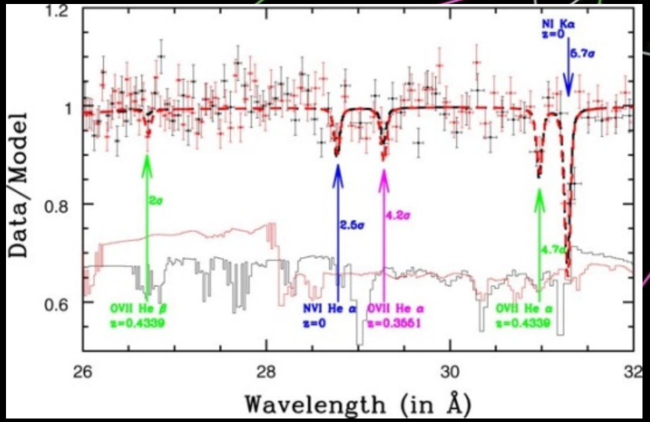
Cosmology

Observations of the missing baryons in the warm–hot intergalactic medium



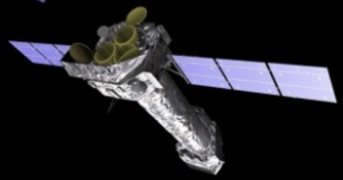
-- observed number of baryons in the local universe falls short (30-40%) of the total baryons predicted by Big-Bang Nucleosynthesis
-- from z ≈ 2 onwards the baryons condense into a filamentary web and undergo shocks heat up to T ≈ 10^5–10^7 K





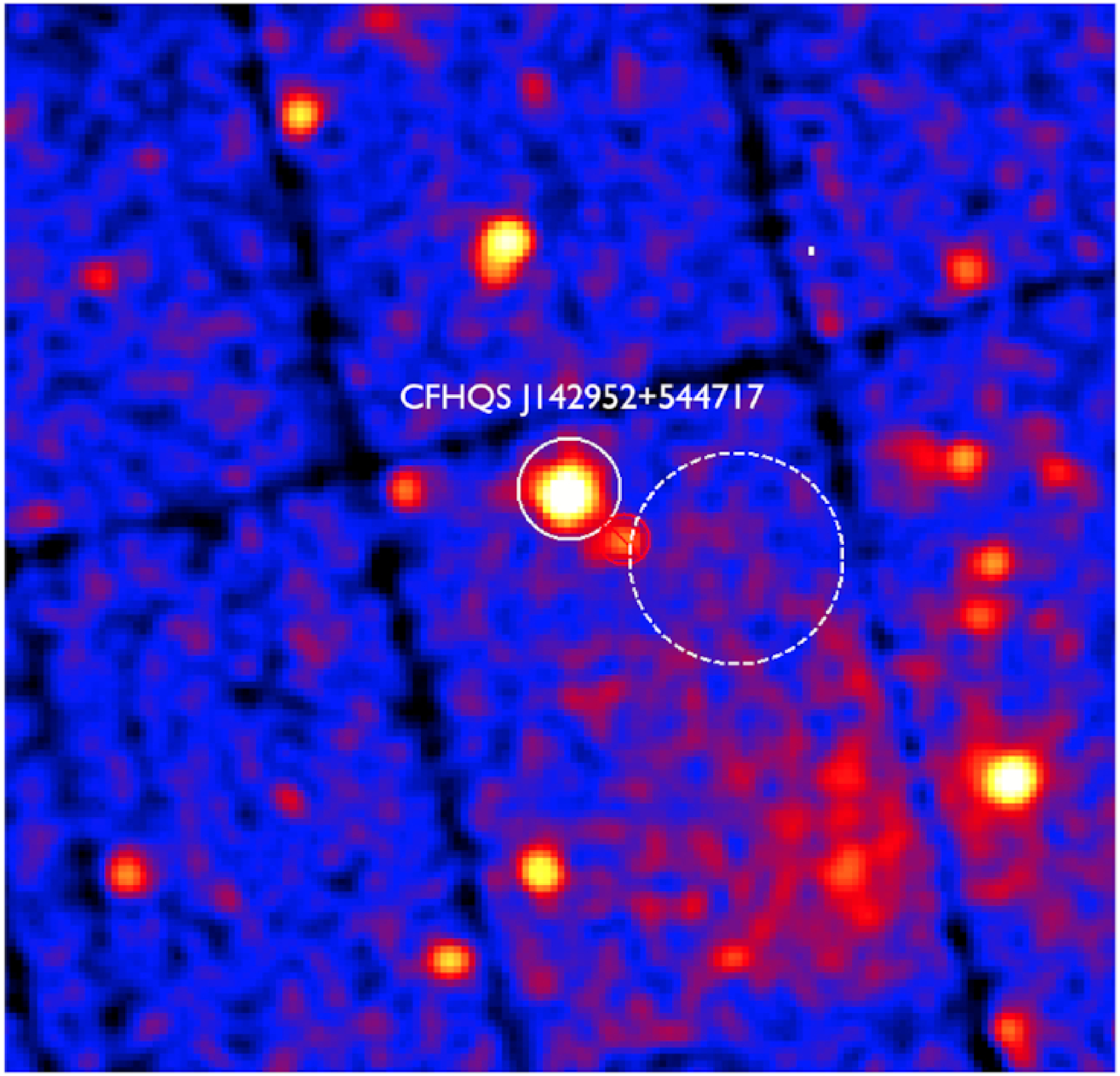
Nicastro et al., 2018, Nature 558, 406

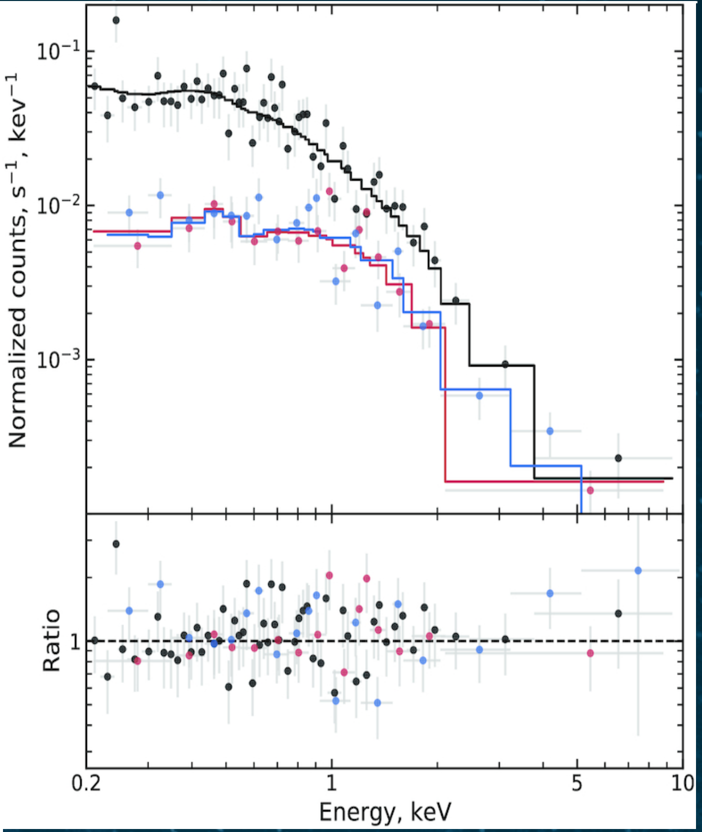
- 1.5 Ms XMM-Newton RGS spectrum on the X-ray brightest blazar 1ES 1553+113, with z > 0.4
  - two absorbers of highly ionized oxygen (O vii)
  - no associated cold absorption
  - associated galaxy overdensities



An extremely X-ray luminous quasar at z = 6.18

- 20 ks XMM–Newton observation of the radio-loud quasar CFHQS J142952+544717 at z=6.18
  - ~1400 net counts in the 0.2–10 keV energy band (1.4–72 keV in rest frame)
  - absorbed power-law with Γ= 2.5 ± 0.2.
  - extreme properties due to inverse Compton scattering of cosmic microwave background (CMB) photons in the relativistic jets
  - CMB ~ (z+1)^4

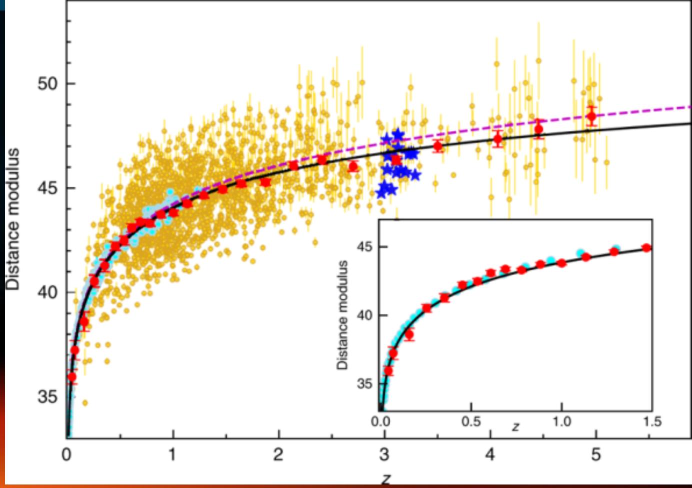




EPIC-PN (black) and EPIC-MOS (red and blue) spectra of CFHQS J142952 + 544717. The solid lines show an absorbed power-law model.

P. Medvedev, et al., 2021, MNRAS 504, 576

Cosmological Constraints from the Hubble Diagram of Quasars at High Redshifts

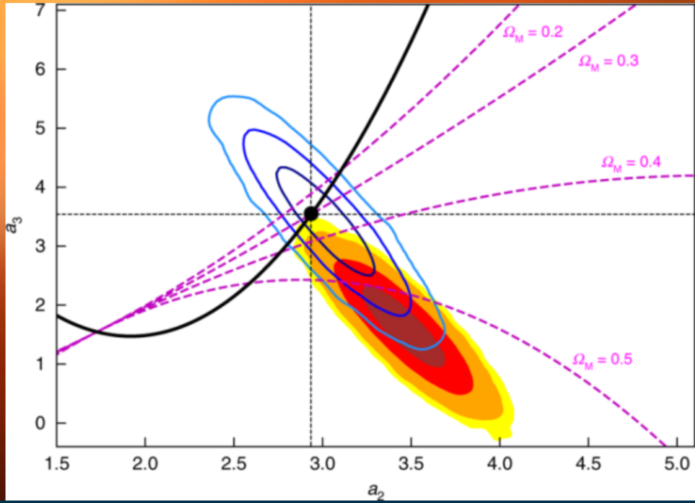


- distances based on the X-ray and ultraviolet emission of the quasars
- z < 1.4 agreement with supernovae and concordance ΛCDM model

➔ **z > 1.4 derivations of ~4σ**

➔ **does dark energy density increasing with time?**

G. Risaliti & E. Lusso, 2019, Nature Astronomy 3, 272



https://www.cosmos.esa.int/web/xmm-newton

XMM-NEWTON TWENTY-FIRST ANNOUNCEMENT OF OPPORTUNITY (AO-21) ANTICIPATED TIMELINE

THE TWENTY-FIRST ANNOUNCEMENT OF OPPORTUNITY (AO-21) IS NOT YET OPEN

The planned key milestones for the Twenty-first XMM-Newton "Announcement of Opportunity" have been established. Within this AO-21 a new call to submit proposals for observations to be performed with the XMM-Newton observatory will be issued.

To be prepared for this, please find below the anticipated timeline:

The planned key milestones for AO-21 are:

Announcement of Opportunity	17 August 2021
Due date for Proposals	8 October 2021 (12:00 UT)
Final OTAC approved programme	mid December 2021

Thank you very much,