XMM-Newton Observations of the Strong Gravitational Field and of Dark Energy

ASTRONET Symposium -
A Science Vision for European Astronomy in the Next 20 Years

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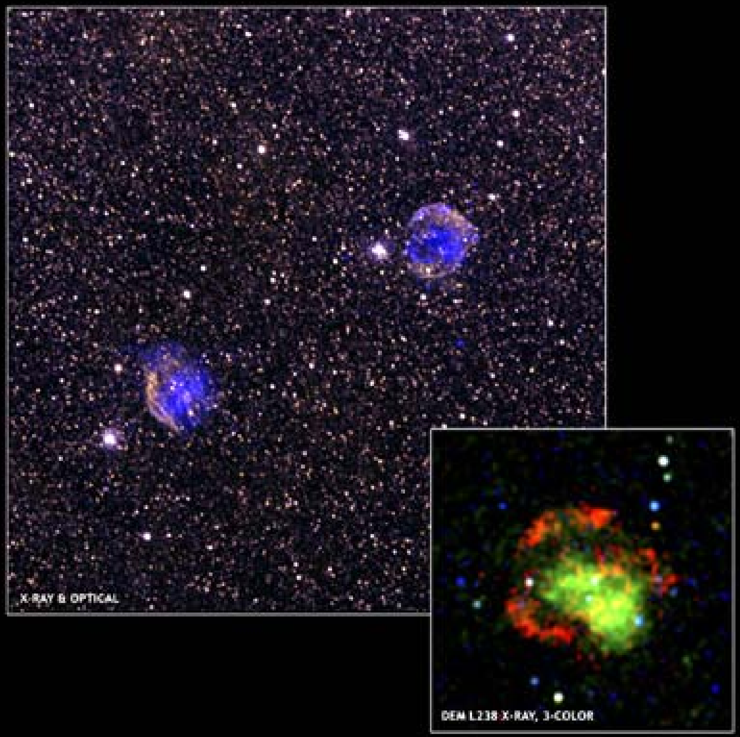
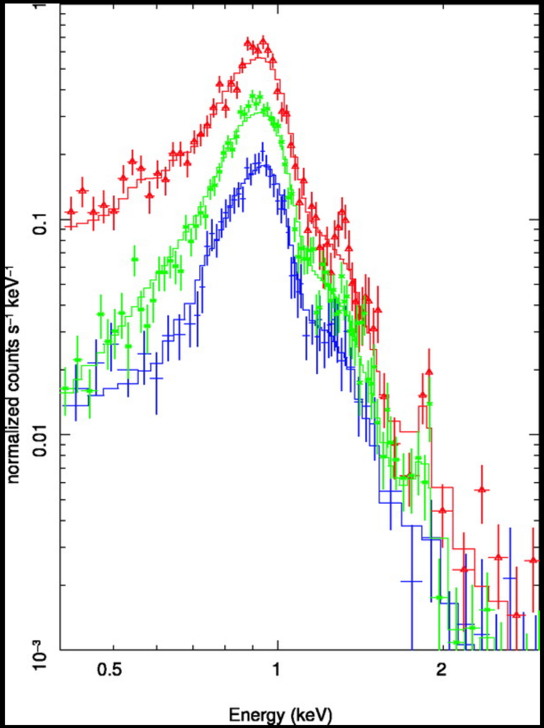
Contents

- New Class of Supernova
- Black Holes
  - New Class of Supernova
  - First black hole in Globular Star Clusters
  - How to observe black holes
  - Near the event-horizon / mass, spin and variability
  - First feedback to theory
  - Cosmological observations
- Dark Matter
  - Parameters constraints for sterile neutrino dark matter
  - COSMOS field: a dark matter map
  - Existence of dark matter
- Resumé and “Next 20 Years”

New Class of Type 1 SN



- **DEM L238**
  DEM L249
- **Thermal spectrum dominated by Fe L-shell lines**
- **Fe over-abundance ➔ Thermo-nuclear Type Ia explosions**
- **K.J. Borkowski et al. 2006, ApJ 652, 1259**



➔ Progen-itor: 50 M_{solar} ➔ Lifetime 10-15x 10^3 y ➔ Explosion: 3×10^{50} ergs

➔ New class of SN Ia, more massive and younger progenitors

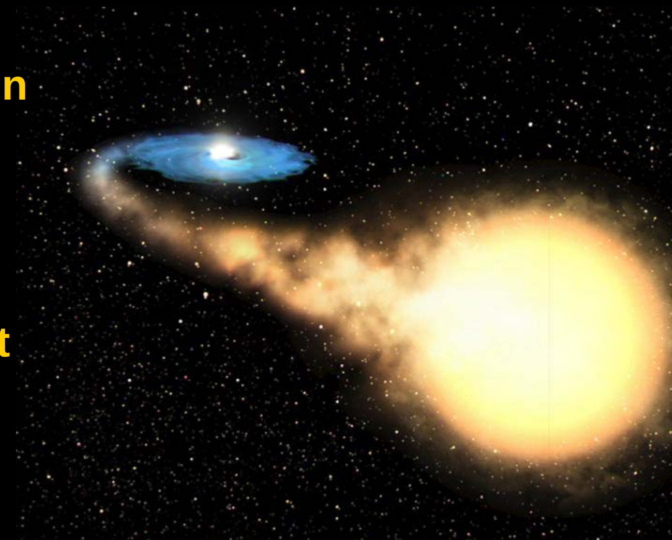
First Black Hole in Globular Star Clusters

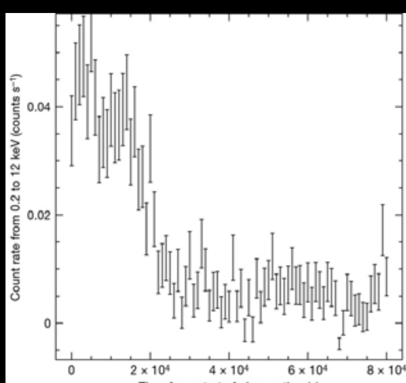
- GCs contain 10^3-10^6 old stars packed within tens of light years

➔ Formation of 10^3 solar mass BH ?

➔Interaction will eject BHs ?

T.J. Maccarone et al., 2007, Nature 445, 183





- X-ray source in GC associated with NGC 4472 (in the Virgo cluster)

- X-ray luminosity: $4x10^{39}$ erg s^{-1}

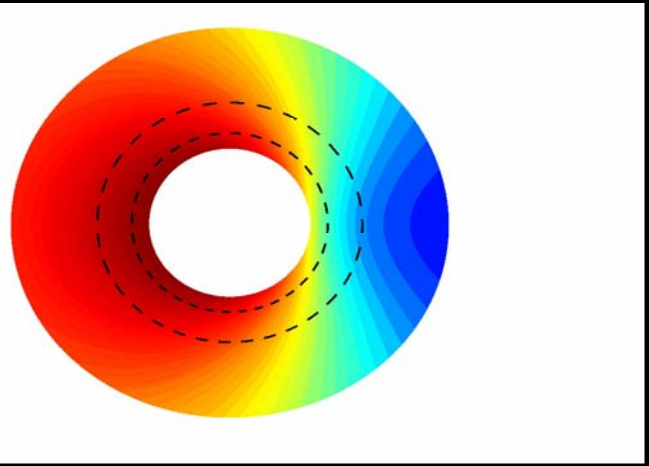
- Variability excludes composition by several objects

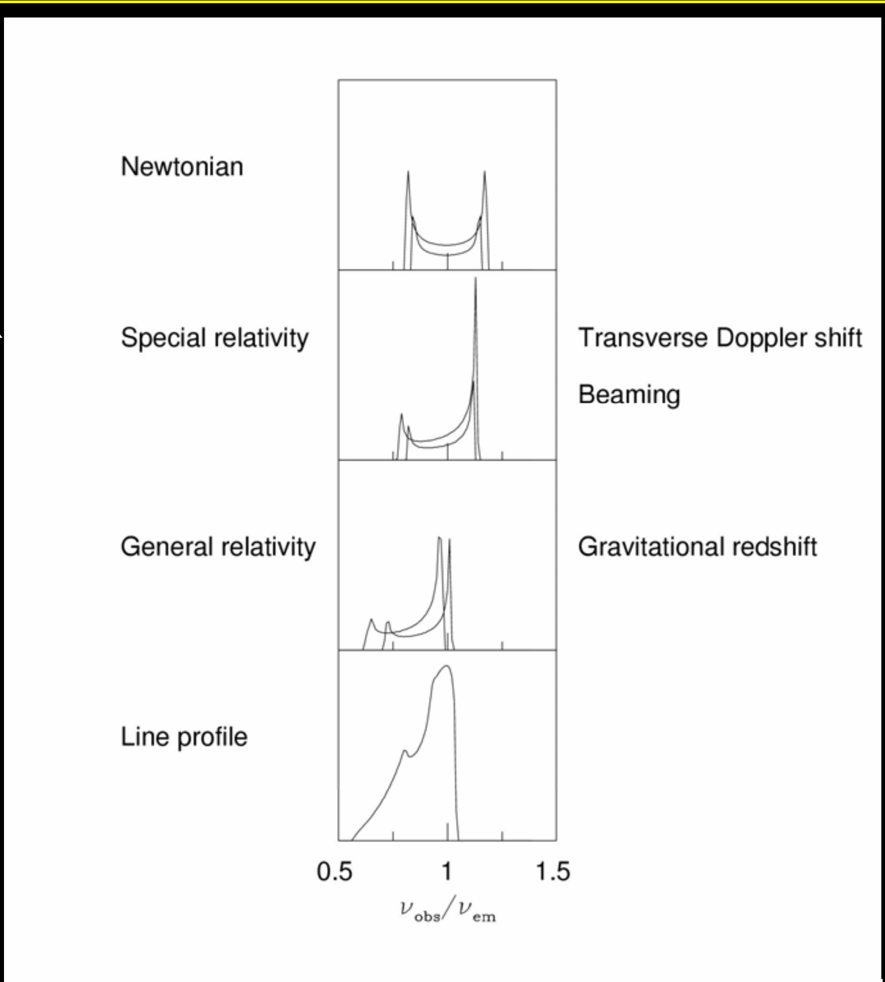
➔ Black hole (15-30 or 400 solar masses)

Contents

… how to observe black holes

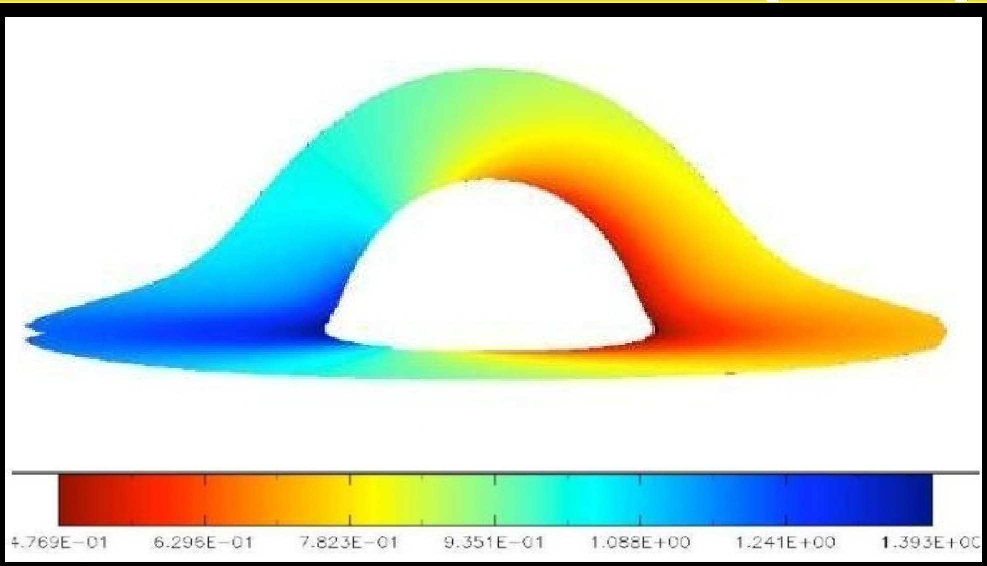
Emission in the Strong Gravitational Field of the Black Hole

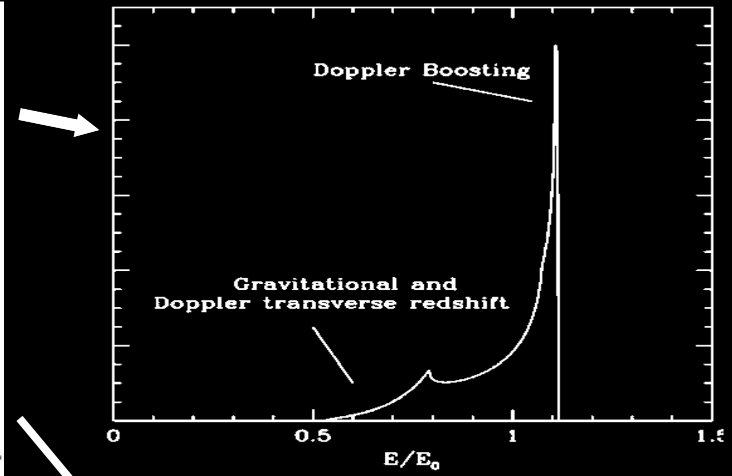


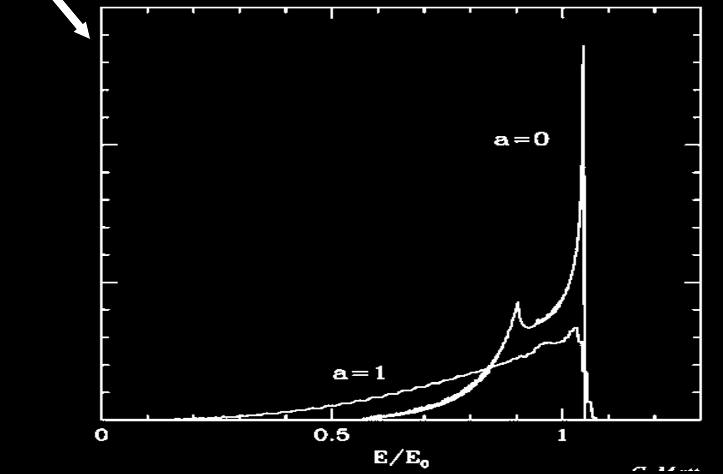


- Fabian et al. (1989); Laor et al (1990); Dovciak et al (2004); K. Beckwith & C. Done, Chris, 2005, MNRAS 359, 1217
- image courtesy A. Fabian

Emission in the Strong Gravitational Field of the (Kerr) Black Hole





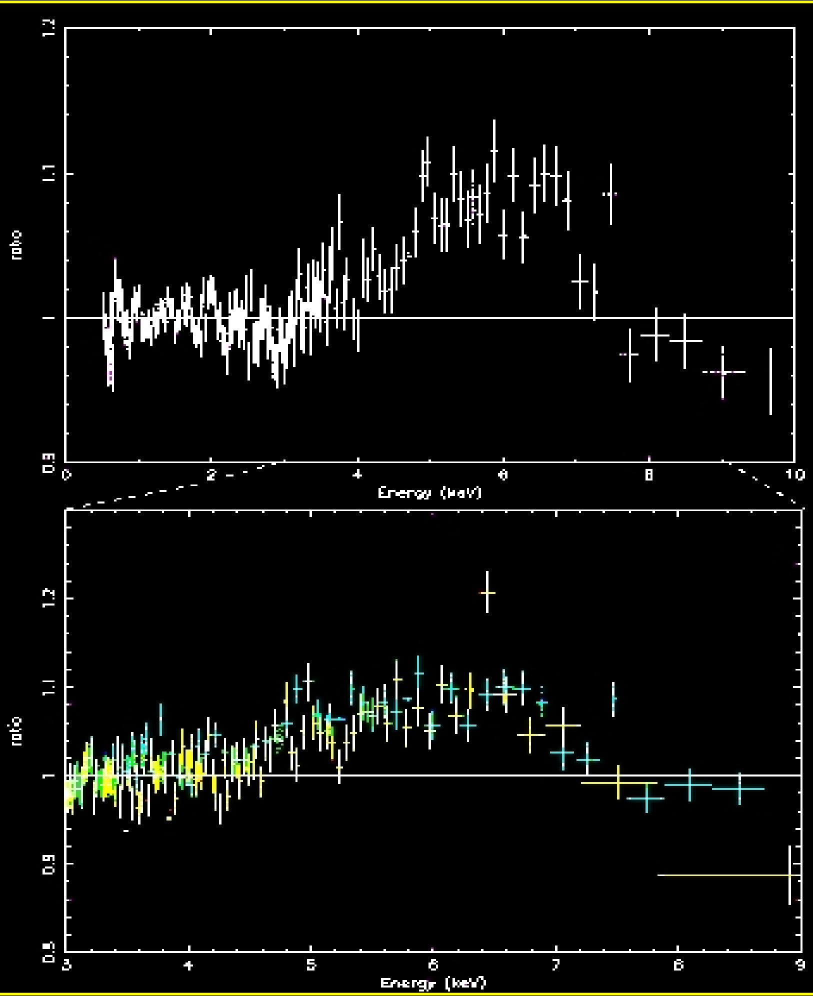


- image courtesy G. Matt and K. Beckwith
- K. Beckwith & C. Done, Chris, 2005, MNRAS 359, 1217

Contents

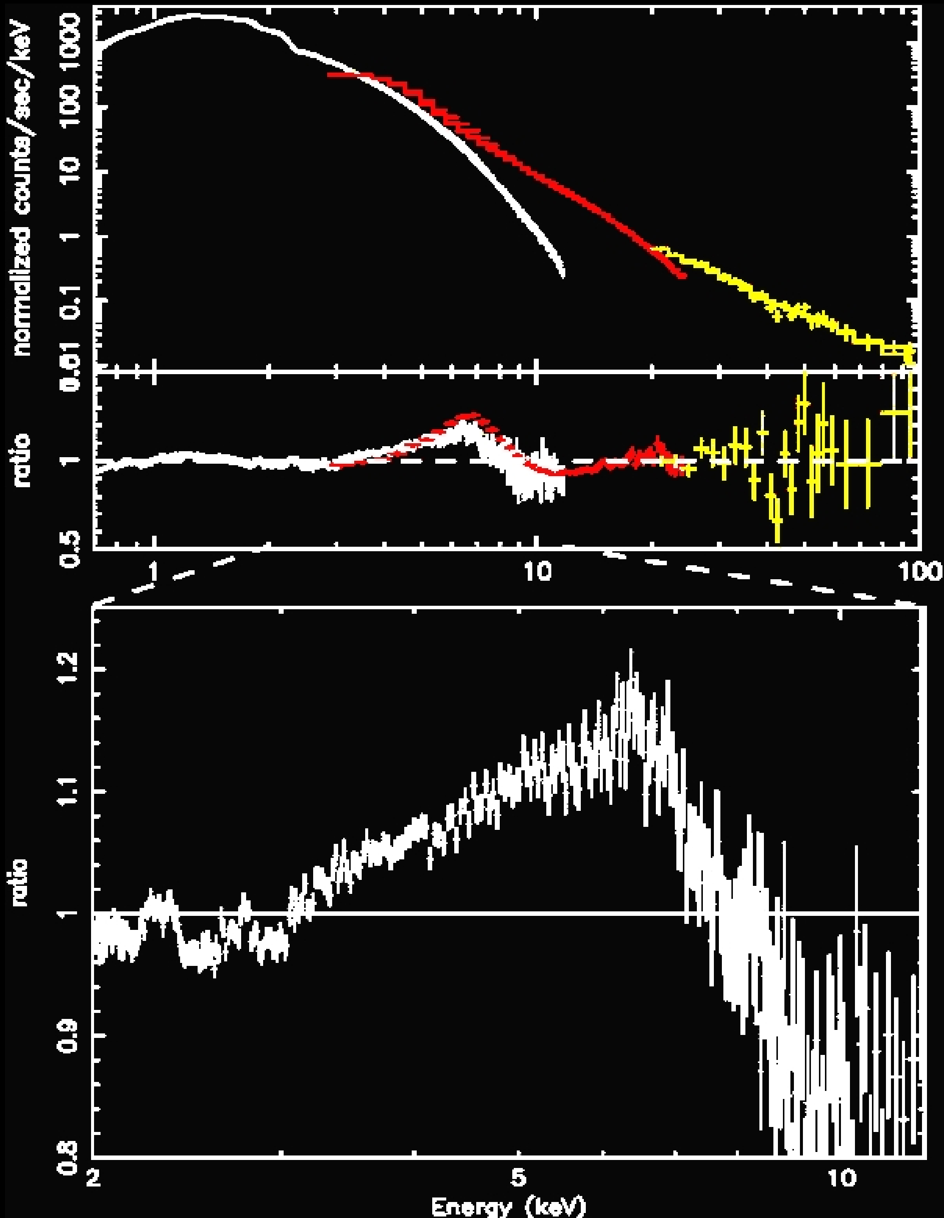
… near the event-horizon: mass & spin

XTE J1650-500 in its 2001 Outburst



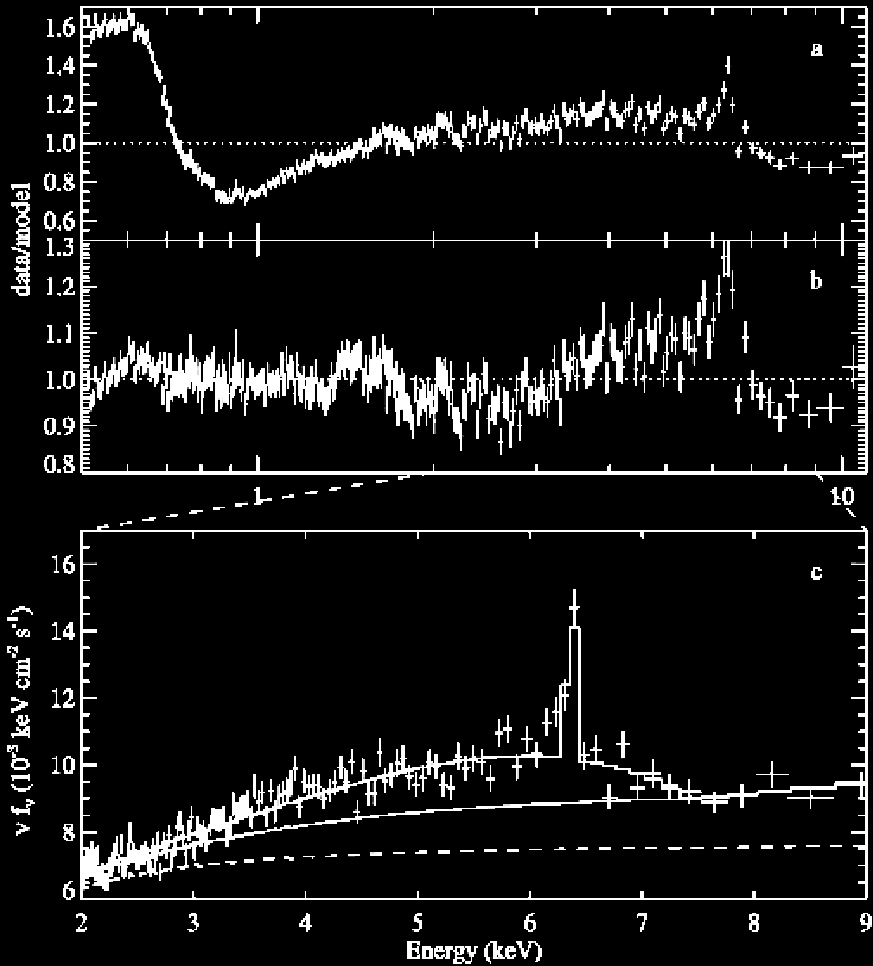
- broad, skewed Fe Kα emission line suggests the primary in this system may be a Kerr black hole
- steep disk emissivity profile that is hard to explain in terms of a standard accretion disk model
- ➔ may be explained by the extraction and dissipation of rotational energy from a black hole with nearly maximal angular momentum
- J. M. Miller, et al. 2002, ApJ 570, L69

Outburst of the Galactic Black Hole GX 339-4



- extremely skewed, relativistic Fe Kα emission line and ionized disk reflection spectrum
- inner disk radius is not compatible with a Schwarzschild black hole
- ➔ black hole with a>0.8-0.9 (where rg=GM/C^2 and a=cJ/GM^2)
- J.M Miller et at., 2004, ApJ 606, L131

MCG-6-30-15: Extraction of Energy from the Spinning Black Hole



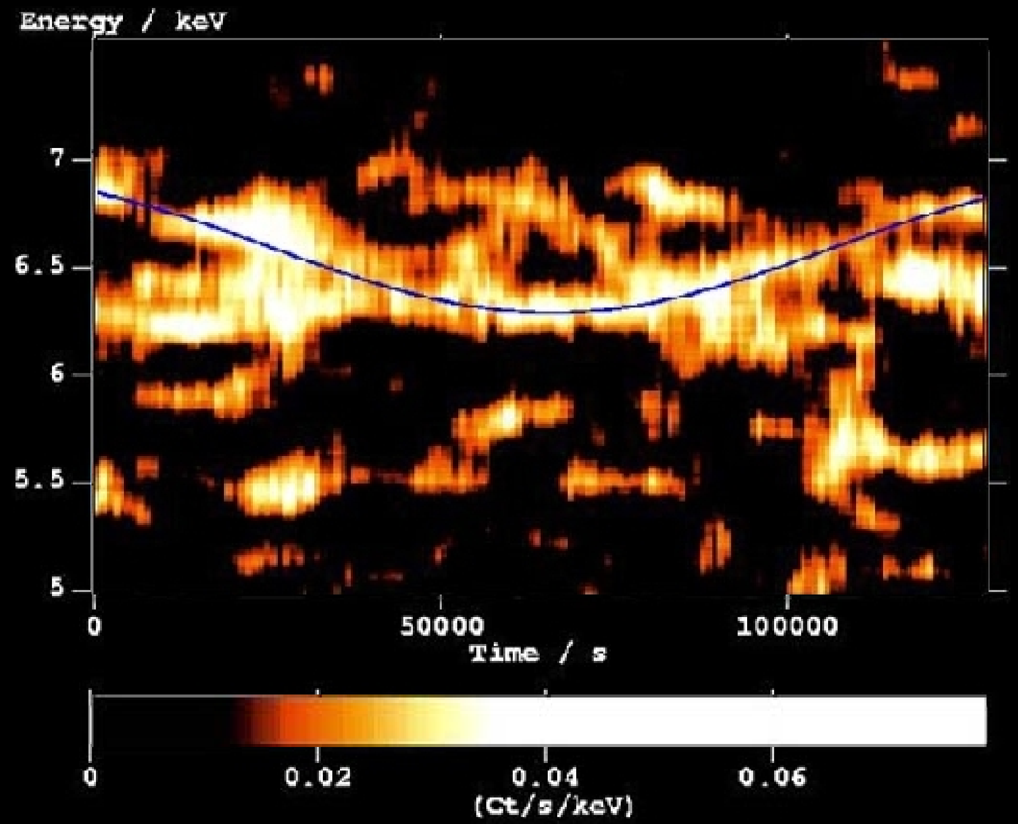
- `deep minimum' state
- difficult to understand in any pure accretion disc model
- extraction and dissipation of rotational energy from a spinning black hole
- J. Wilms et al., 2001, MNRAS 328, L27

Contents

… **near the event-horizon: variability**

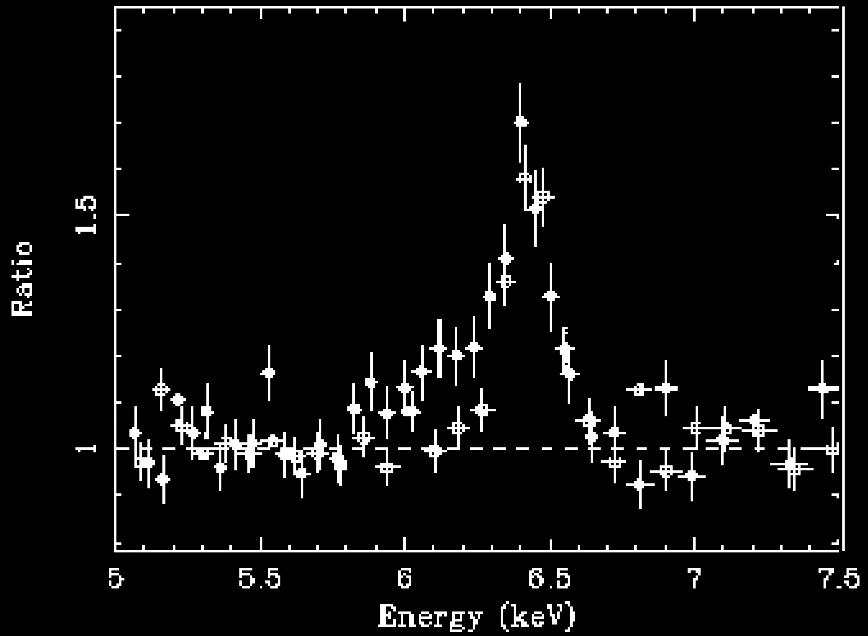
Orbital Motion Close to the Central Black Hole of Mrk 766

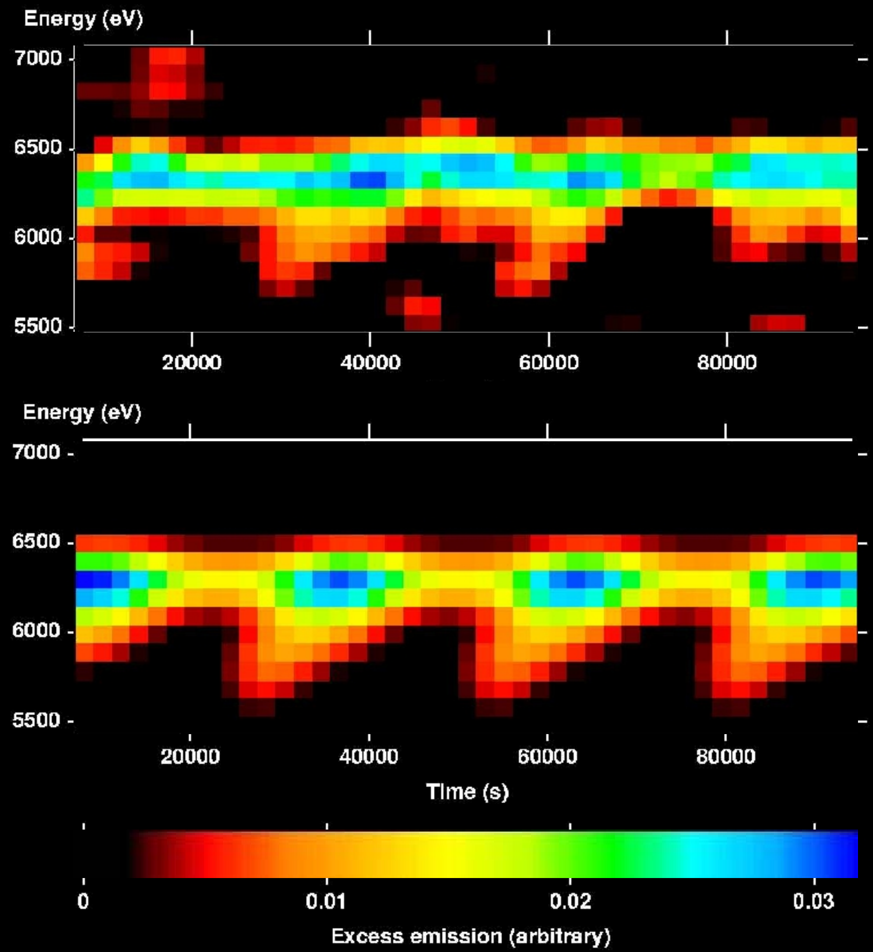
- **energy-time plane of EPIC pn data in the 4-8 keV band**
- **Fe Kα emission shows a variation of photon energy with time consistent with sinusoidal variation**
- **orbit has a period ~165 ks and a line-of-sight velocity ~13,500 km/s**
- **$4.9 \times 10^5 < M_{BH} < 4.5 \times 10^7$**



T. J. Turner, et al., 2005, A&A accepted

Flux and Energy Modulation of Iron Emission in NGC 3516





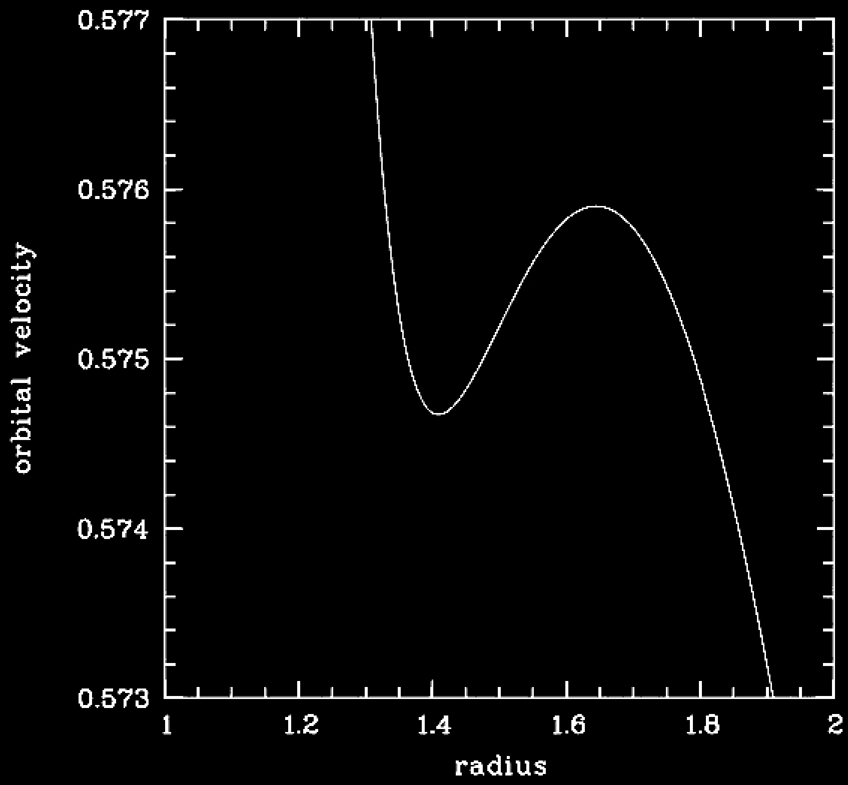
- K. Iwasawa, G. Miniutti, A.C. Fabian, 2004, MNRAS 355, 1073
- "corotating" flare at a (3.5-8) r_{Sch}
- mass of the BH: (1-5) × $10^7 M_o$

Contents

… first feedback to theory

Microquasars / Galactic Center BH

- GRO J1655-40, XTE J1550-564 and GRS 1915+105 show twin high frequency quasi-periodic oscillations with a ratio of 3:2 and/or 3:1
- resonance between vertical and radial epicyclic oscillations and Kepler orbits
- ➔new topological structure
- ➔ a = 0.99616
- ➔ Galactic Center BH:
  M = (3.28±0.13) $10^6 M_{\odot}$

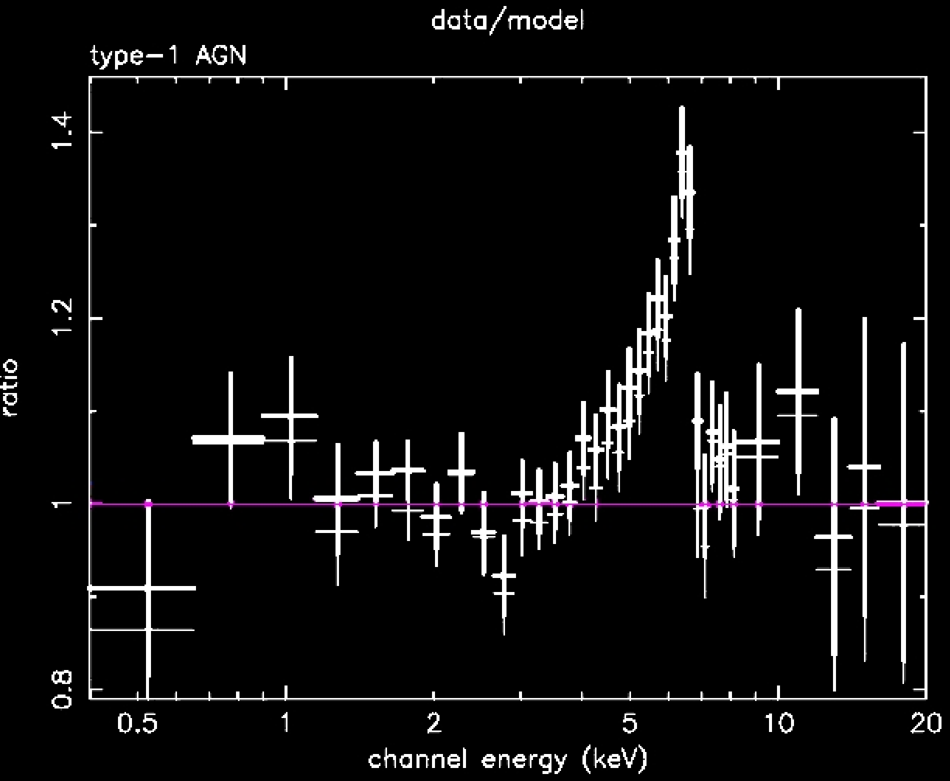


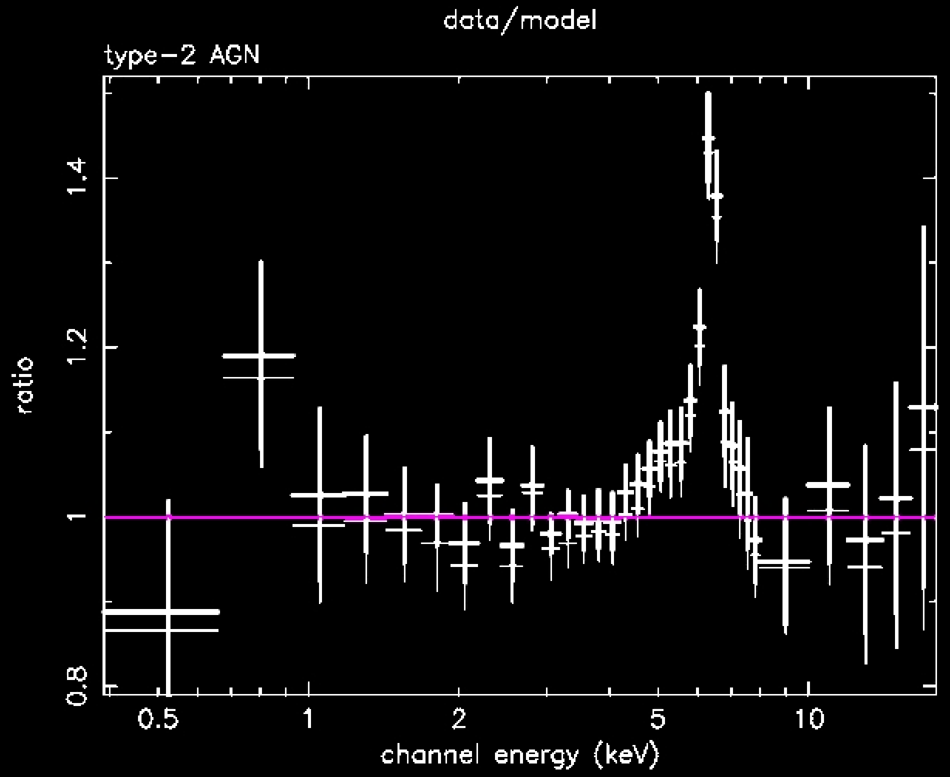
- B. Aschenbach, 2004, A&A 425, 1075

Contents

… cosmological observations

Stacked Spectra of the Lockman Hole AGNs





- **A. Streblyanska, et al., 2005, A&A 432, 395**

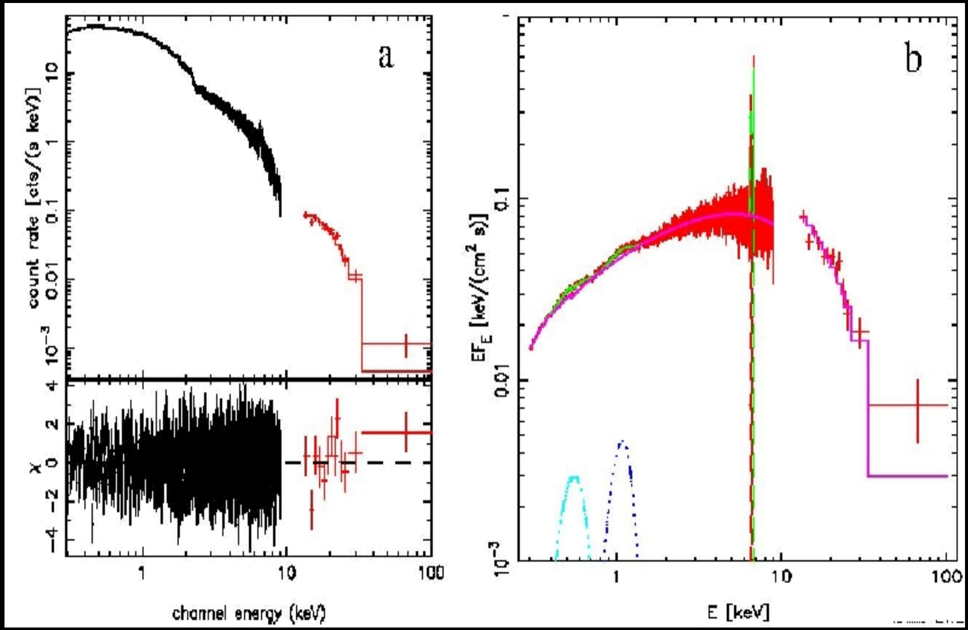
- **770 ks exposure time**
- **53 type 1 and 41 type 2 AGNs**

Contents

Dark Matter

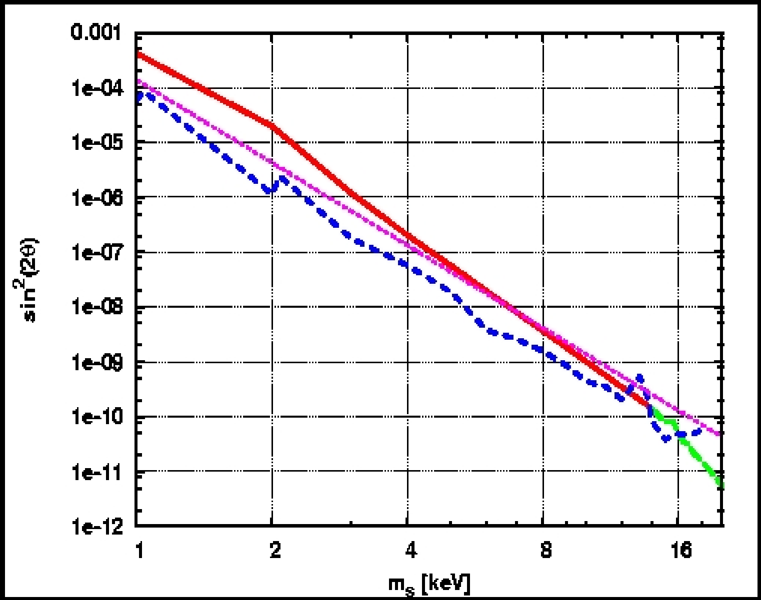
… sterile neutrino dark matter

Restrictions on Parameters of Sterile Neutrino Dark Matter



- XMM-Newton and BeppoSax spectra of Coma

- A. Boyarsky et al., 2006, Phys Rev D 74, 3506

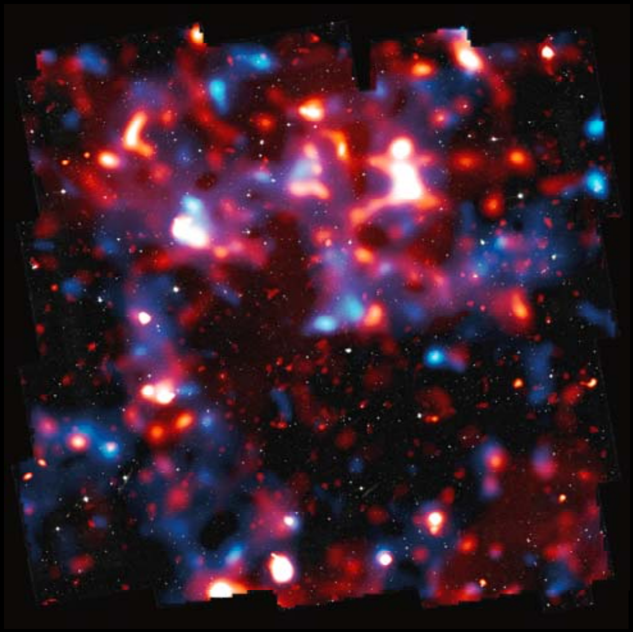


Contents

Dark Matter

… map

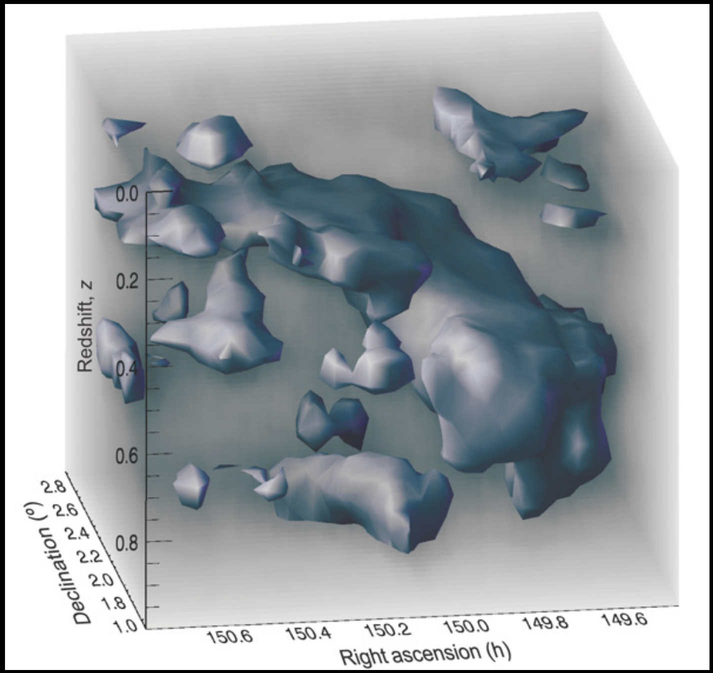
Dark Matter Maps reveal Cosmic Scaffolding



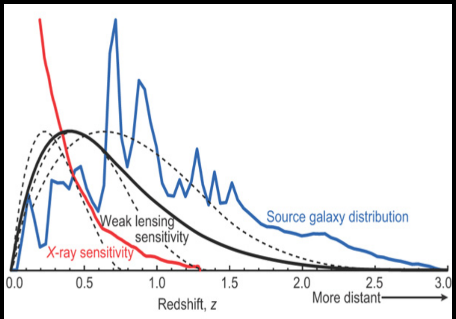
COSMOS Field:
- 1.637 degree^2
- 1000 h (HST)
- 400 h (XMM)

Matter:
- 1/6 baryonic (hot and cold)
- 5/6 dark

Gravitational lensing: total amount of matter (hot and cold)



R. Massey et al., 2007, Nature 445, 286



Optical & infrared: cold baryonic matter

XMM-Newton: hot matter (red in picture

➔ Maps of the large-scale distribution of dark matter, resolved in both angle and depth.

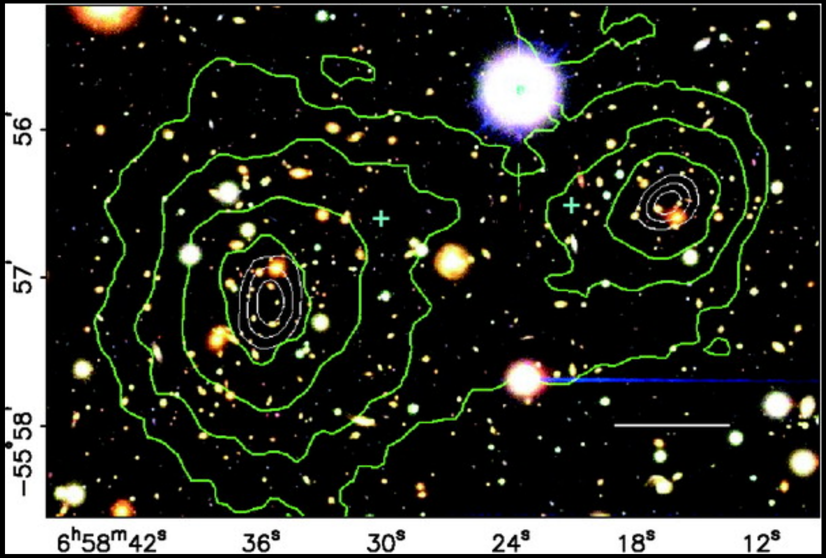
➔ Loose network of filaments, growing over time, which intersect in massive structures at the locations of clusters of galaxies

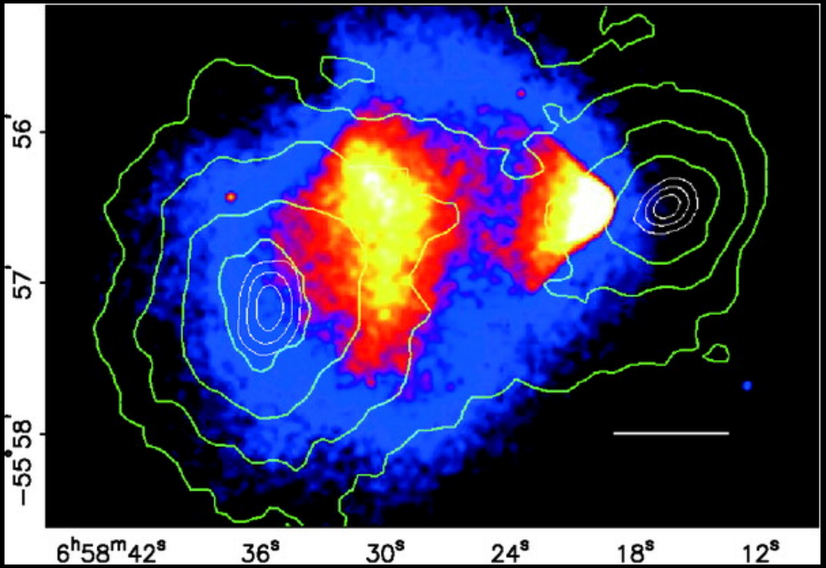
➔ Consistent with predictions of gravitationally induced structure formation

Contents

… **existence of dark matter**

Direct Empirical Proof of the Existence of Dark Matter





- D. Clowe et al., 2006, ApJ 648, L109
- weak-lensing observations of cluster merger 1E 0657-558 (z = 0.296)

- gravitational potential does not trace the plasma, the dominant baryonic mass component

➔ detection of dark matter, independent of assumptions regarding the nature of the gravitational force law.

Resumé

- **new areas of observational astrophysics:**
  - the strong, rotating gravitational field
  - dark matter
- **but, we are only making the first steps!**

Next 20 Years

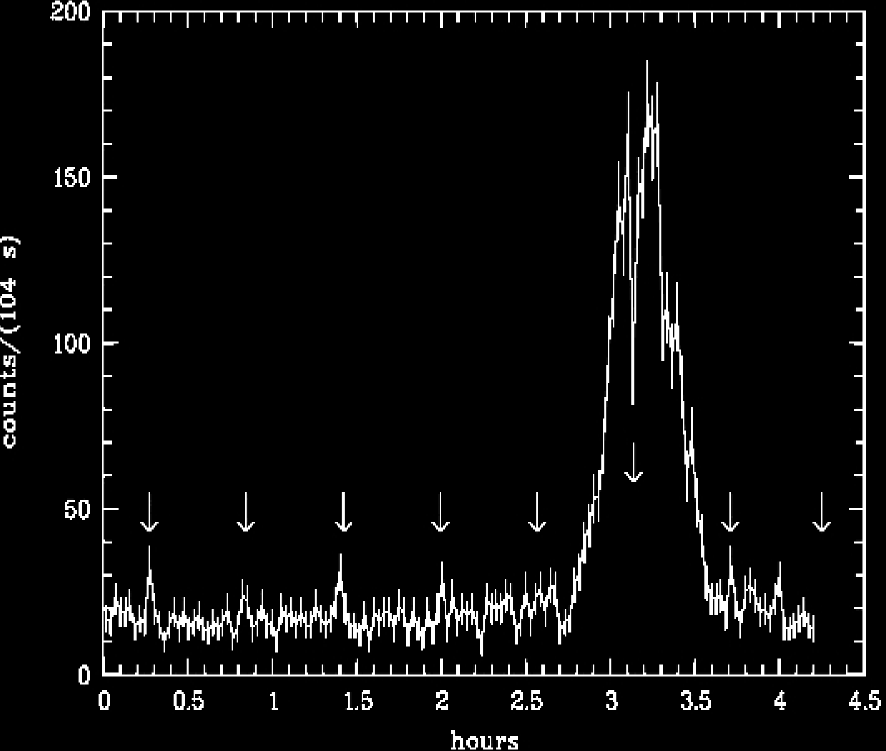
- X-ray observations made major contributions to all questions & topics listed in 6.2 recommendations: “Do we understand the extremes of the universe”!
  - Why are only “small” but dedicated projects classed as principal facilities?
  - Why not an X-ray mission, which can address each topic, as a principal facility?
  - Is it wise to split the resources from the beginning?

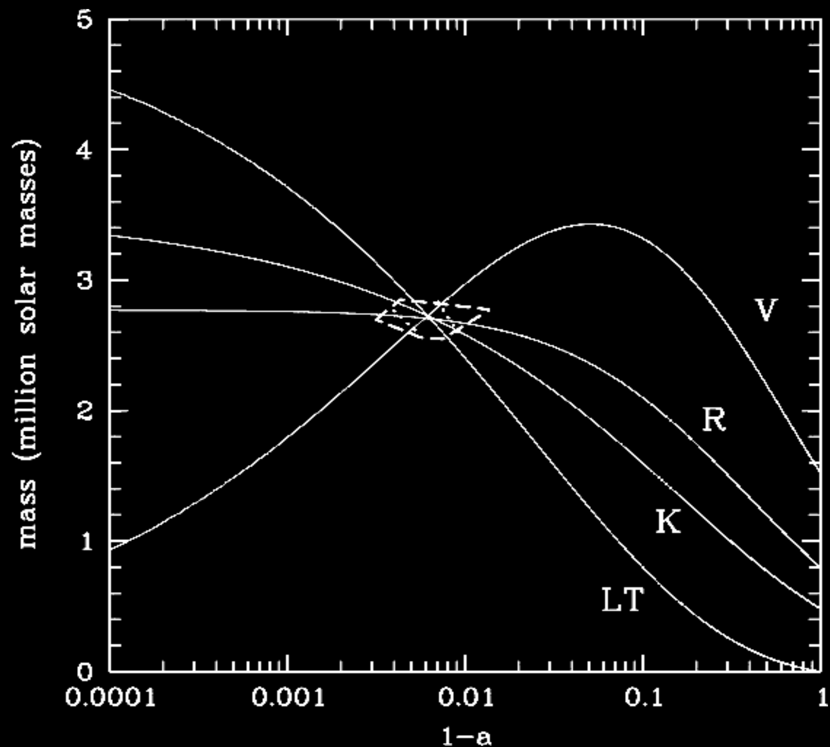
- Does Europe need access to the X-ray sky during the next 20 years?

- A time-frame of “20 years” is a short time-frame for satellites!
  - Next large European X-ray mission is possible 2023-25
  - XMM-Newton funded up to 2010
  - Gap of 15 years!
  - Is cover through US & Japanese missions sufficient for Europe?
  - On the other side:
    - From technical / instrumental side XMM-Newton can run up to 2018
    - Running costs?

- If we speak from the next 20 years, then it is important to take current satellites into account

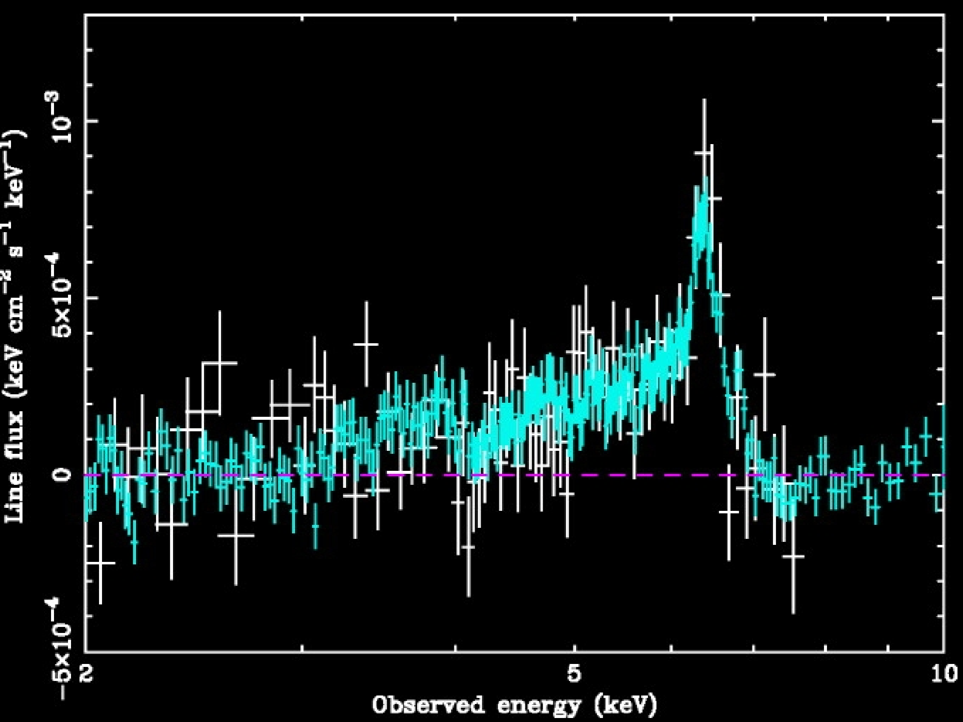
X-Ray Flare of the Galactic Center BH

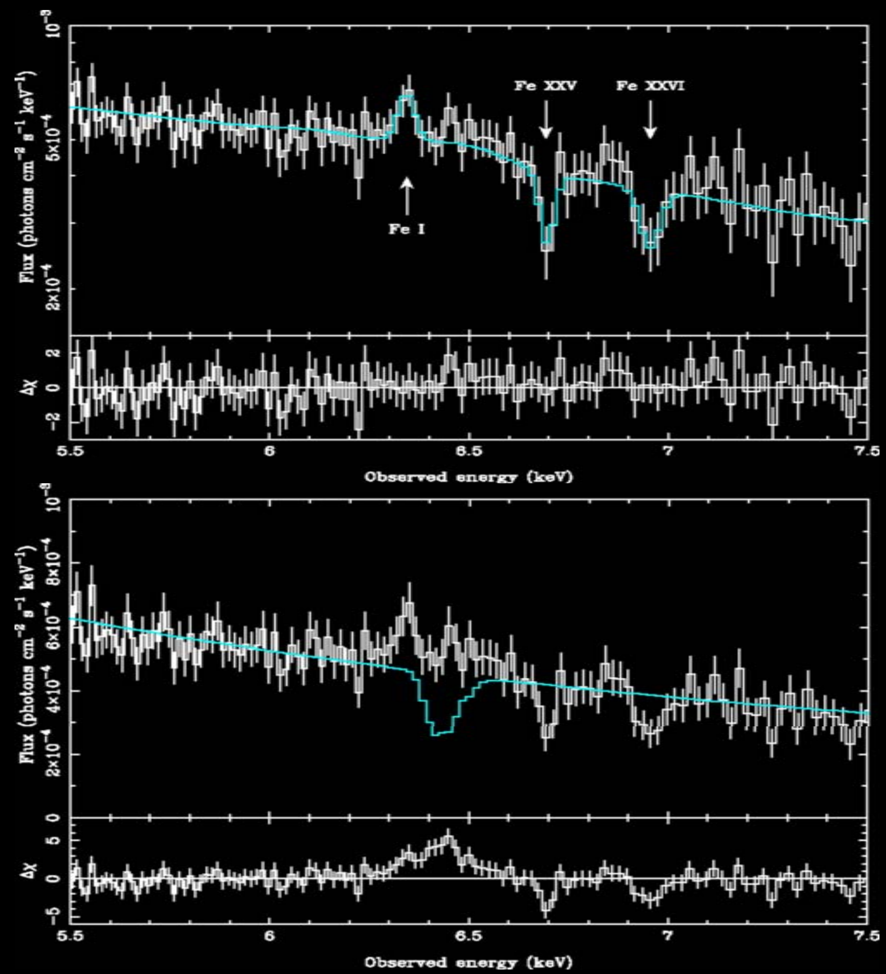




- B. Aschenbach et al., 2004, A&A 417, 71
- power density spectrum peaks at periods of 100s, 219s, 700s, 1150s and 2250s

MCG-6-30-15: Relativistic Line Versus (Warm) Absorption





- A. J. Young et al, 2005, ApJ 631, 733
- 522 ks High Energy Transmission Grating Spectrometer (HETGS)