Searching for String Theory with *Athena*

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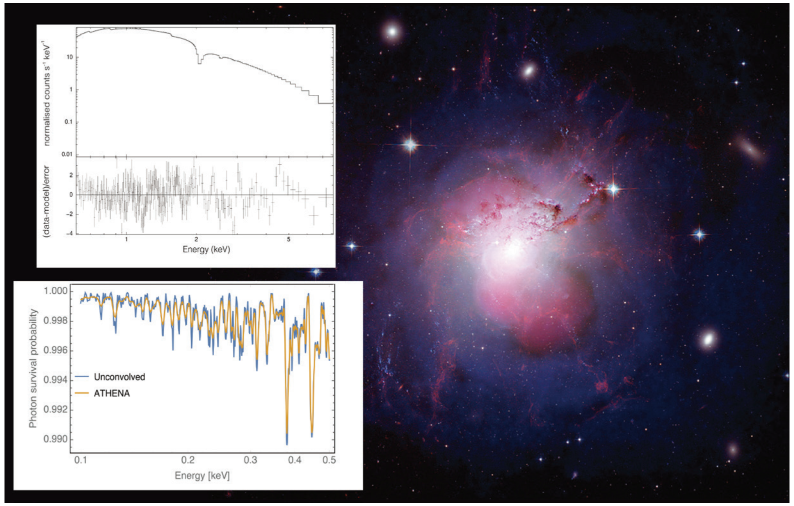

Caption: Right: The galaxy NGC1275. Bottom Left: A simulated survival probability spectrum for photons travelling from NGC1275 through the Perseus galaxy cluster assuming the existence of ALPs (blue), and this same spectrum convolved with Athena's energy resolution (yellow). Top left: A simulated Athena observation of NGC1275 including the effects of ALPs. Residuals, when this spectrum is fit with a no-ALP model, are shown in the lower panel. Credit: X-ray: NASA/CXC/IoA/A.Fabian et al.; Radio: NRAO/VLA/G. Taylor; Optical: NASA/ESA/Hubble Heritage (STScI/AURA) & Univ. of Cambridge/IoA/A. Fabian. Plots from Conlon et al. 2018, MNRAS, 473: 4932.

String theory is a theory of quantum gravity. By representing particles as different modes of vibration on one-dimensional strings, string theory can provide a unified description of quantum field theory and gravity. However, there is as yet no experimental evidence for string theory. Even worse, string theory makes very few experimental predictions. One prediction generic to many string theory scenarios is the existence of ultra-light axion-like particles (ALPs). These ALPs could be much lighter even than neutrinos and would interact only very weakly with photons and other Standard Model particles. ALPs can act as both Dark Matter and Dark Energy, depending on their mass, and may have striking astrophysical signatures. In a background magnetic field, ALPs and photons can interconvert. If ALPs exist, there is some probability that a photon travelling through a magnetic field will turn into an ALP. In this case, the magnetic fields of galaxy clusters would be powerful photon to ALP converters. Through this effect, *Athena* observations of point sources shining through galaxy clusters will give us an unprecedented opportunity to search for ALPs.

The figure shows an X-ray image of NGC1275 – the galaxy at the centre of the Perseus galaxy cluster. When we observe NGC1275 with *Athena*, if some of its photons have turned into ALPs, the resulting photon survival probability will be imprinted on the observed spectrum. The photon survival probability is shown at the bottom left of the figure. This oscillatory pattern is typical of ALP-photon interconversion. Crucially, *Athena*'s exceptional energy resolution means that all the oscillations can be resolved. The top left of the figure shows a simulation of these oscillations imprinted on a hypothetical *Athena* observation of NGC1275. If we attempt to fit the observed spectrum to a model including no ALPs, the ALP induced oscillations can be clearly seen in the residuals.

This effect has already been used to place the tightest existing bounds on the coupling between ALPs and photons via observations with other telescopes. Thanks to its unprecedented effective area and energy resolution, *Athena* will allow us to significantly improve these bounds, potentially even discovering ALPs. Such a discovery would represent a deeper understanding of the content of our universe and could even be a gateway to understanding quantum gravity.