Nuclear Spectroscopic Telescope Array

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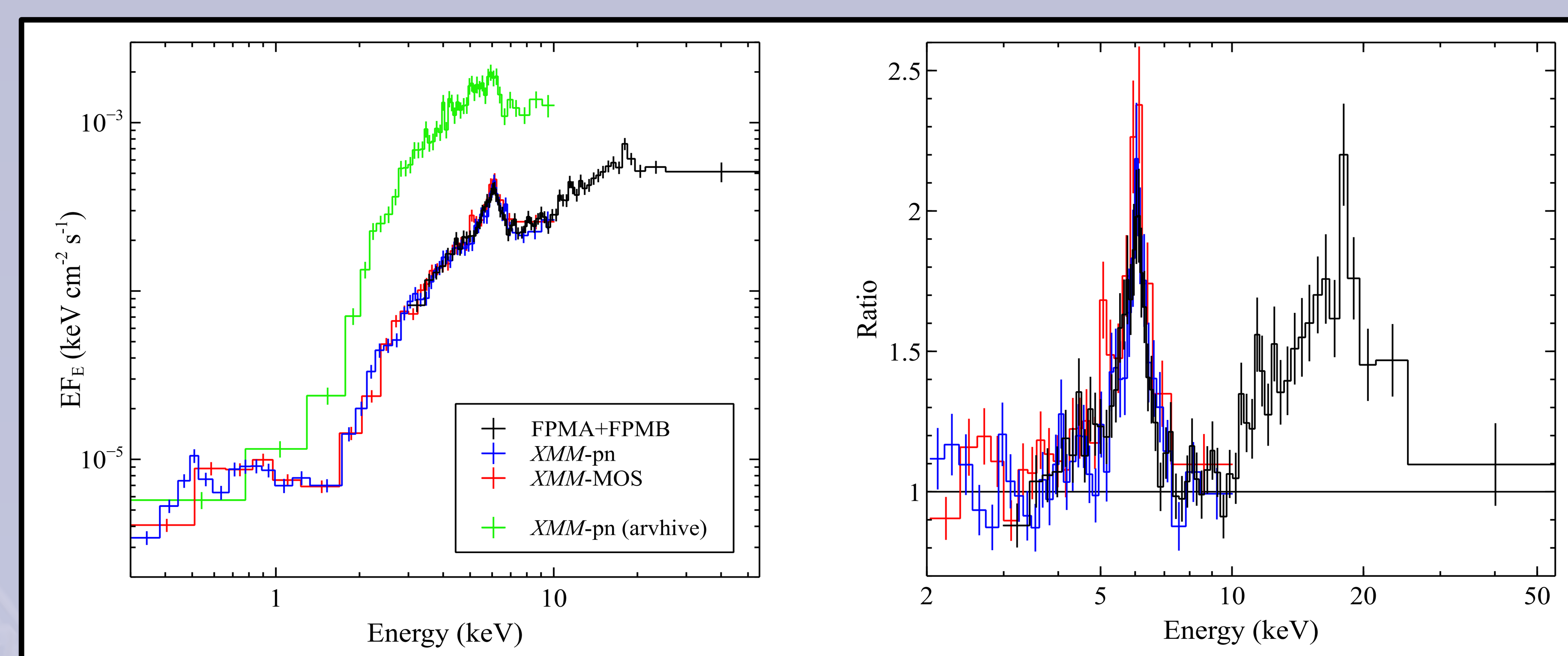
An Extreme Ultrafast Outflow in the Seyfert 2 Galaxy IRAS 00521-7054

1. IRAS 00521-7054

IRAS 00521-7054 is a moderately bright, nearby (z = 0.0689) Seyfert 2 galaxy. Previous observations of this source with both *XMM-Newton* and *Suzaku* revealed evidence for an extremely strong (equivalent width ~1 keV), relativistically broadened iron emission line (Tan et al. 2012; Ricci et al. 2014), likely implying the presence of a rapidly rotating black hole (a > 0.73, where $a = Jc/GM^2$ is the dimensionless spin parameter). The extreme equivalent width is consistent with an intrinsic spectrum that is dominated by the contribution from relativistic reflection from the innermost accretion disk, which would require an extreme accretion geometry. In order to test this possibility, we obtained a deep, coordinated observation with *XMM-Newton* and *NuSTAR* (175+400 ks, respectively), recently presented in Walton et al. (2019).

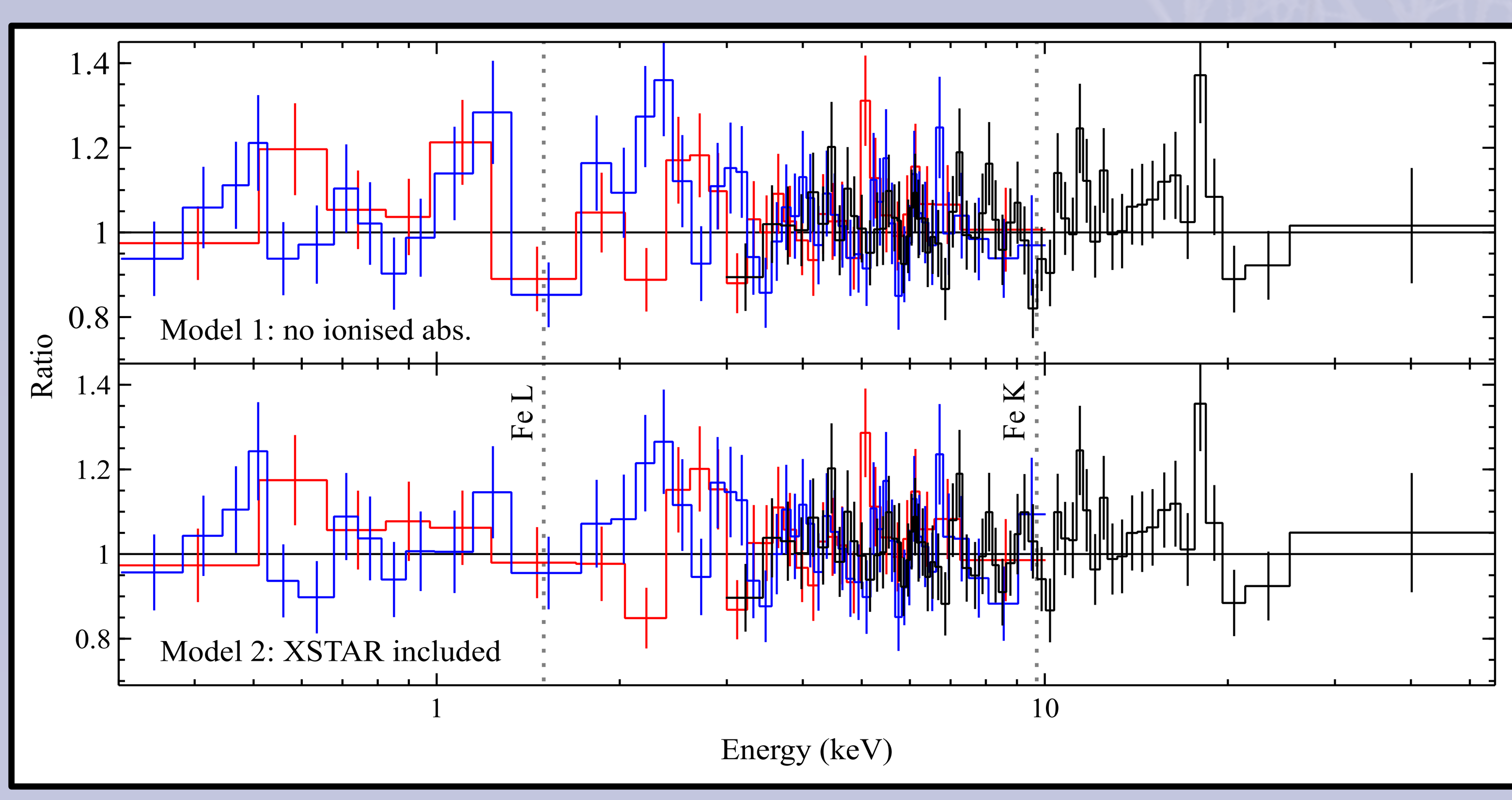
2. Broadband Spectroscopy

The broadband *XMM-Newton+NuSTAR* spectrum obtained with our deep observation is shown below, comparison to the *XMM-Newton* data available in the archive (which is also representative of the archival *Suzaku* data). The new data caught IRAS 00521-7054 in an unusually low-flux state, a factor of ~6 fainter than previous X-ray observations. Nevertheless, fits with a standard AGN contiuum (absorbed powerlaw) still revealed the classic signatures of relativistic disk reflection (a relativistically broadened iron emission line at ~6 keV, and a strong Compton hump at ~20 keV), even after allowing for partially covering neutral absorption. The broad iron line seen in these data is similar to the that reported by Tan et al. (2012) and Ricci et al. (2014). These simple fits also found the drop in flux could not be related to changes in line-of-sight absorption (which remained at the same level as seen in the archival data; $N_H \sim 7\times10^{22}$ cm^{-2}), and so must be an intrinsic to the source.



3. An Extreme Ultrafast Outflow

Fits to the broadband spectrum with self-consistent disk reflection models (i.e. RELXILL; Garcia et al. 2014) reproduce the continuum emission very well, and confirm that the observed spectrum is largely dominated by reflection from the inner accretion disk. However, these fits left a potential narrow absorption residual at ~9.5 keV. If associated with blueshifted iron K absorption, this would imply an extreme ('ultrafast') outflow velocity.



Although the significance of the ~9.5 keV feature is reasonable by itself (98% confidence, assessed via extensive Monte Carlo simulations), modeling this feature with a physical photoionised absorption model (XSTAR; Kallman et al. 2001) picks up a second feature at ~1.5 keV, associated with Fe XXI-XXIV L-shell absorption ***at the same blueshift*** as the ~9.5 keV Fe XXV Kα feature (see above), confirming the presence of this ultrafast outflow at greater than ***4-σ significance***.

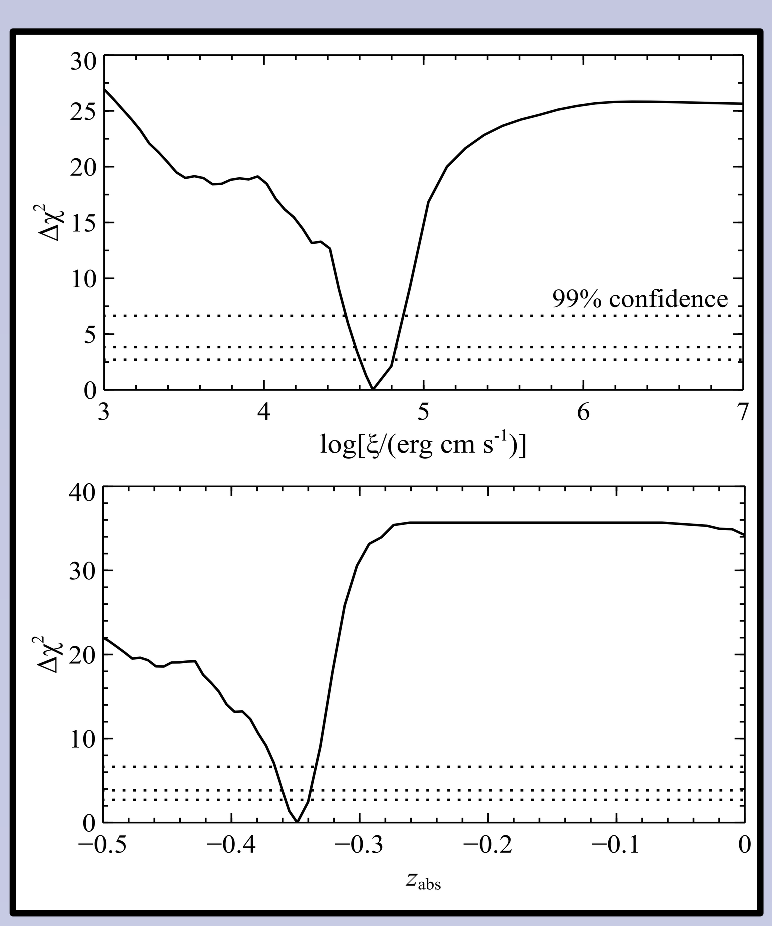
The large blueshift (z_{abs} = -0.349 ± 0.009) of this wind implies a remarkable outflow velocity of v_{out} = -0.405 ± 0.012 c! Only PDS 456 is reported to have a faster wind (Reeves et al. 2018).

Key Outflow Parameters:

$N_H = 2.8^{+1.7}_{-1.1} \times 10^{22}$ cm^{-2}

log[ξ/(erg cm s^{-1})] = 4.7 ± 0.1

v_{out} = -0.405 ± 0.012 c



Assuming a similar geometry for the wind as PDS 456 (see Nardini et al. 2015), we can estimate the kinetic luminosity of this outflow, $L_{kin} = \frac{1}{2}\dot{M}c^2$ relative to the total radiative output of IRAS 00521-7054, L_{bol}:

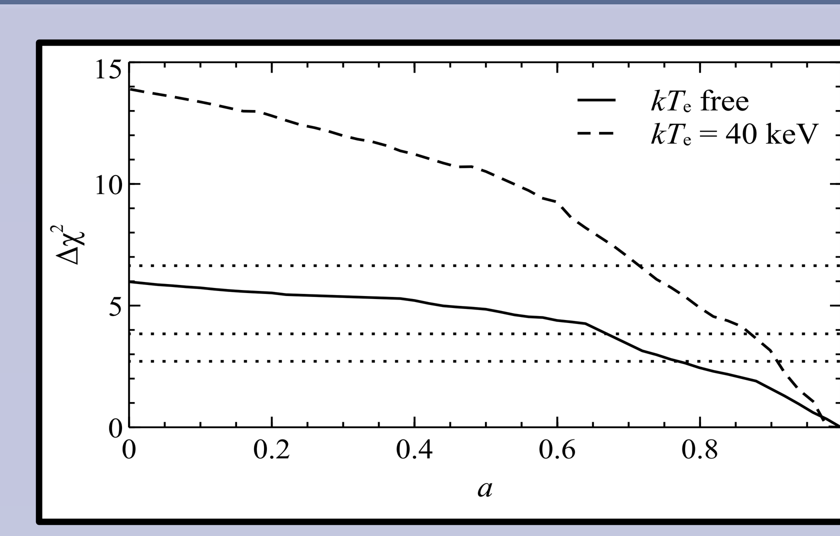
$L_{kin}/L_{bol} \sim 0.6\ C_V$

Although C_V, the volume filling factor, is not well known, this outflow is likely easily sufficient to power significant galaxy-scale AGN feedback.

XRISM* Simulations:** we simulated a standard *XRISM* observation (100 ks exposure, SXS+SXI) of IRAS 00521-7054 at its peak flux (~6x brighter), assuming the that ionisation of the wind scales with luminosity (as now seen in several other well-studied ultrafast outflows, e.g. Parker et al. 2017). Even though the increase in ξ means only the Fe K line (~9.5 keV) is observable, we find that *XRISM* should be able to independently detect the outflow at >4-σ significance. The key outflow parameters are also well constrained, thanks in large part to the excellent spectral resolution of the *XRISM* SXS, for example v_{out} should be constrained to ± 0.01 ***c.

4. Black Hole Spin

Even after allowing for partially covering neutral absorption and a highly-ionised, ultrafast outflow, the broadband spectrum still prefers a large reflection fraction (R > 1.7; see Dauser et al. 2016). This requires gravitational light bending, and implies that the corona is compact (< 5 R_G) and the black hole is rapidly rotating, consistent with Tan et al. (2012) and Ricci et al. (2014): we find ***a* > 0.77** (90% confidence; (see right for constraints with different assumptions for the coronal electron temperature, kT_e, which has some degeneracy with R).



5. Conclusions

Through broadband spectroscopic analysis of our recent, deep *XMM-Newton+NuSTAR* observation of the Seyfert 2 galaxy IRAS 00521-7054, we find evidence for:

- Strong relativistic reflection from the innermost accretion disk, implying the presence of a rapidly rotating black hole (***a* > 0.77**; 90% confidence).
- An extreme, ultrafast outflow, with $\boldsymbol{v_{out} \sim 0.4c}$. Under reasonable assumptions, we find this outflow is likely sufficiently energetic to drive significant galaxy-scale feedback.
- Simulations with the latest response files suggest that IRAS 00521-7054 should be a promising target for *XRISM* observations to further study its extreme outflow

References

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