Nuclear Spectroscopic Telescope Array

Absorption Variability in NGC 1365 seen with *XMM-Newton* and *NuSTAR*

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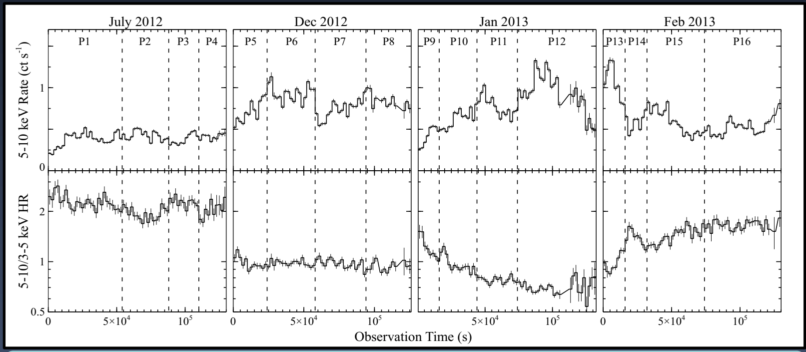


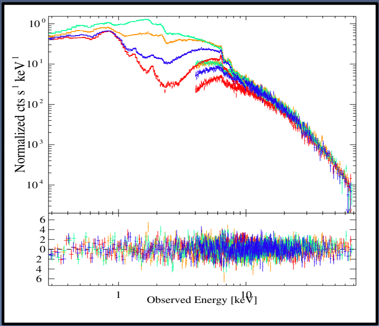
Light curves and hardness ratios (HR) for the four observations and showing the 16 time-resolved analysis intervals

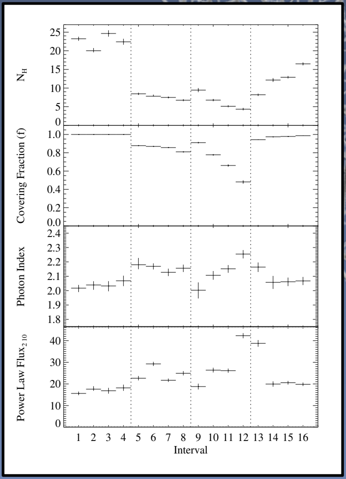
Introduction

Following up the investigations of Risaliti et al. (2013) and Walton et al. (2014) we have performed time-resolved spectral analysis of 4 observations of NGC 1365 made simultaneously with *XMM-Newton* and *NuSTAR* covering the energy range 0.3-70 keV, revealing extreme variability both in the level of absorption and the covering factor of the dominant absorber in this source.

Goals

1. Characterize the variability of the dominant partial covering absorber in NGC 1365
2. Investigate other sources of absorption and soft X-ray variability





Above: PN+FPMA spectra for all four observations with residuals to the best fit model.
Right: Best fit spectral parameters for all 16 intervals.

Spectral Analysis

In order to get the best possible handle on the continuum level we used the fully spectral energy range from 0.3 to 70 keV. This necessitated modeling the near and distant reflectors (Walton '14), the Fe K shell absorption lines, and the extended two-temperature plasma seen previously by Chandra (Zhang '00).

We also modeled a highly variable partial-covering absorber and an additional low column density full-covering absorber ($N_H \sim 1 \times 10^{22}$ cm^{-2}). Our final model had the form:

APEC[×2] + ZGAUSS[×5] + SCATTERED POWER LAW + ZPHABS × ZPCFABS × GAUABS[×4] × (POWER LAW + RELCONV × XILLVER) + XILLVER.

The partial covering absorber had a range of values for the column density of $\mathbf{N_H \sim 5–25 \times 10^{22}}$ **cm^{-2}** and covering fraction from $\boldsymbol{f \sim}$ **0.5–1** over the course of the four observations.

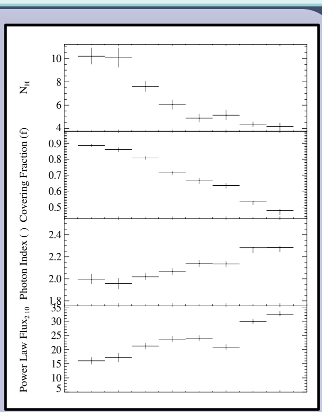
The Uncovering of NGC 1365

The uncovering of the continuum seen from 2012 December to 2013 January is an unusual event, particularly the extreme uncovering witnessed in Obs 3 (January), where both the column density and covering fraction dropped dramatically. Even if the uncovering and recovering of the source seen from December to February are not all part of the same event, it is clear that the drop in N_H and *f* lasted at least ~days, up to a timescale of months if all three observations were part of a single event.

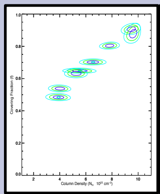
If we are seeing gaps in a clumpy torus, then the drop in covering fraction could be explained by a cloud with a sharpening tail, the opposite of a comet-like tail which fans out (Maiolino '10).

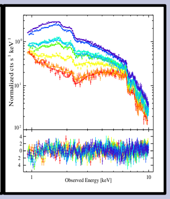
Alternatively, it could be that the rate of material infall into the nucleus was temporarily reduced. This would be the more likely scenario if all three observations were part of the same overall event. The attenuation of material reduced the number of clumps in the line of sight, leading to a drop in N_H but with the covering fraction remaining very close to 1. Then as the number of clumps declined to a sufficiently low number, *f* began to decline as well, seen to some extent in Obs. 2 and to a much greater extent in Obs. 3.

The rapid decrease in both N_H and *f* could plausibly be due to parameter degeneracy, however the error bars are very small. Contour plots of *f* vs N_H for the eight half intervals verify that no parameter degeneracy is apparent.



Above: Parameters for 8 half intervals of Obs 3. *Below (left):* Confidence contours for $\boldsymbol{f}$ vs $\mathbf{N_H}$. *(right):* Overlaid PN spectra of the 8 half intervals.





Summary

We find evidence for a variable, likely clumpy, partial-covering absorber in addition to a low density constant absorber which may be distant or else a diffuse medium co-spatial with the clumpy absorber. An uncovering of the source lasting ~ days to months indicates that these clumps are not the close-up BLR clouds, but rather must be at a distance from the nucleus.

Spectral variability

- Partial Covering $N_H \sim 5–25 \times 10^{22}$ cm^{-2}
- Covering factor $f \sim 0.5–1$
- Photon Index $\Gamma \sim 2.0$-2.3
- Intrinsic 2-10 keV Power Law Flux ~ 15-40 x 10^{-12} erg cm^{-2} s^{-1}

Acknowledgements

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NuSTAR

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