Absorption at the Dust Sublimation Radius and the Dichotomy between X-ray and Optical Classification in the Seyfert Galaxy H0557-385

D. Coffey, A. L. Longinotti, A. Rodríguez-Ardila, M. Guainazzi, G. Miniutti, S. Bianchi, I. de la Calle, E. Piconcelli, L. Ballo, M. Linares

Presenting Author

Damien Coffey

School of Physics, Trinity College Dublin
ESAC,ESA

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X-ray Absorption Variability in AGN

A significant fraction of local Seyfert galaxies show evidence for continuum absorption in their X-ray spectra.

Measurements of variability timescales can be used to infer the distance to the absorbing medium.

Short timescale variability is often attributed to BLR clouds. (e.g. NGC 1365; Maiolino et al. 2010, Risaliti et al. 2007).

Longer variability timescales are associated with the circumnuclear torus (e.g. NGC 7582; Piconcelli et al. 2007).

Figure: Urry & Padovani 1995 (adapted)
Extensive *XMM-Newton* observation campaigns have revealed extreme X-ray variability on a time scale of several years.

| Obs. # | Mission     | Date          |
|--------|-------------|---------------|
| 1      | ASCA        | 1995-03-23    |
| 2      | BeppoSAX    | 2001-01-26    |
| 3      | XMM         | 2002-04-04    |
| 4      | XMM         | 2002-09-17    |
| 5      | XMM         | 2006-08-11    |
| 6      | XMM         | 2006-11-03    |
| 7      | XMM         | 2010-10-15    |
| 8      | XMM         | 2010-10-19    |
| 9      | XMM         | 2010-10-31    |

Less dramatic variability observed among the low-state spectra on a time scale of weeks/months.
H0557-385: Previous Work

Ashton et al. (2006)

- Presented the 2002 XMM-Newton observations.
- Investigated the warm absorption present in the soft X-ray spectrum.
- Used a model consisting of a two-phase warm absorber, along with a neutral gas component.

Longinotti et al. (2009)

- Presented the low-state data which showed a drop in flux by a factor of $\sim 10$.
- Low-state model included a partial covering absorption component.
- Showed that transitions between the two states can be attributed to a neutral absorber attenuating the primary emission.
Designing the Spectral Model

- Intrinsic AGN power law
- Warm absorption (ZXIPCF)
- Compton reflection (PEXMON)
- Collisionally ionised emission (APEC)
- Transition between states due to variable neutral absorber (ZPCFABS)
Results From the Spectral Model

Transition between states require a Compton-thin ($N_H \sim 10^{23} \text{ cm}^{-2}$) neutral absorber covering more than 80% of the X-ray source.
**Swift XRT Data**

Search for short (days/weeks) timescale variability: *Swift* monitoring, 2010 March - 2011 November.

\[ \text{Swift XRT Flux} \ 0.4-5 \text{ keV (cgs)} \]

\[ 10^{-11} \]

\[ 10^{-12} \]

\[ 10^{-13} \]

\[ 0 \quad 100 \quad 200 \quad 300 \quad 400 \quad 500 \quad 600 \]

\[ \text{Day from 2010-04-03} \]

*H0557-385 is not observed to revert back to its high-state on short timescales*
Origin of the X-ray Variability

Multiple observations provide upper limit on variability time scale $\Delta T$.

Cloud velocity estimates;

- Velocity of BLR clouds estimated from FWHM of emission lines.
- Distance to dust sublimation radius: $R_d \propto L^{0.5}$
- Calculate velocity of material at $R_d$ assuming Keplerian motion.
Cloud diameter, \( D_c \), found from

\[
D_c \geq V_c \Delta T + D_s
\]

(Miniutti et al. 2014) where \( D_s \sim 10R_g \) is the X-ray source size.

Cloud number density (\( \text{cm}^{-3} \)) found from cloud column density, \( N_H \),

\[
N_e = \frac{N_H}{D_c}
\]
Properties of the Absorbing Material

Obscuring clouds can be associated with material at the dust sublimation radius, a distance \( R_d \approx 2 \times 10^{18} \) cm from the X-ray source.

| Cloud Properties |
|-------------------|
| \( N_H \) (cm\(^{-2}\)) | 7.4 \times 10^{23} |
| \( V_c \) (km s\(^{-1}\)) | 650 |
| \( D_c \) (cm) | 3 \times 10^{15} |
| \( N_e \) (cm\(^{-3}\)) | 2 \times 10^{8} |
Optical Spectroscopy Measurements

SOAR/Goodman optical spectroscopic observations, November 2010 - January 2011.

- Optical observations concurrent with 2010 *XMM-Newton* observations.
- Broad emission lines detected during an X-ray absorption event.
Dramatic X-ray variability attributed to absorption by a neutral Compton-thin absorber.

Variability timescales suggest that absorber forms part of the inner torus.

Observation of broad optical emission lines suggests that the absorber must be dust-free.

H0557-385 does not fit in to the traditional Unification Model for AGN.

Unusual, but not unique; X-ray and Optical Classification may give contrasting results for ∼30% of AGN. (Merloni et al. 2014).