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The I Zw 1 type AGN: busy in X-rays but optically quiet

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A sub-class of narrow-line Seyfert 1 galaxies with exceptionally strong Fe II emission lines named after the prototype I Zw 1 show high variability in X-rays. Despite this, and in contrast with many other Seyferts, variations in the optical are comparatively small. I have collected Las Cumbres Observatory robotic telescope network BVugr photometry of 19 I Zw 1 type AGN over 2-3 years and can compare their optical variability to that of other sub-classes of AGN. The study confirms that on average the relative optical luminosity fluctuations of I Zw 1 type AGN are significantly smaller. Possible physical interpretations of this result are explored.

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1. Introduction

Active Galactic Nuclei (AGN) have long known to be highly variable (e.g. [1]). In the 1980's [2] identified a sub-class of AGN characterized by comparatively narrow (FWHM < 2000 km.s^{-1}) broad lines. Their spectra often include very strong Fe II lines and very weak [O III] and related lines associated with the narrow emission line region. A prime example of this AGN sub-type is I Zw 1, and consequently this specific AGN sub-class has been referred to as "I Zw 1 type" [3]. Another comparatively nearby object associated with the I Zw 1 type class is H 0707−495 [4].

I Zw 1 type objects are subject to sometimes dramatic short-term variations in X-rays (e.g. [5–7]). These fluctuations however do not seem to extend into the optical domain, where the variations tend to be small, even when compared to other AGN [3]. This paper reports the latest results in a long-term photometric study of AGN carried out by the author. The paper specifically examines whether the data backs the assertion that I Zw 1 type objects are less variable than more common forms of AGN.

2. Methodology

Photometric observation were carried out with either the 1.0 m or 0.4 m robotic telescopes constituting the Las Cumbres Observatory Global Telescope Network (LCOGT) [8]. Images in the Johnson BV and Sloan g′r′ filters were collected for all observation. While Sloan u′ and even some Johnson U images were also recorded in many cases, these will not be used in the current paper due to the more difficult and less accurate calibration in these other filters (see, e.g. [9]). LCOGT supplies images that have already been processed (bias, dark and flatfield corrections) and where possible sources have been identified and their fluxes within specific apertures measured using the Source Extractor procedure [10].

This paper uses the thus determined values measured through a 3 arcsec diameter circular aperture. Integration times were typically between 20 s and 40 s in most filters. For a normal observation two integration were recorded per filter to compensate for possible contamination of pixels by cosmic rays. The photometric calibration was carried out using the BVg′r′ magnitudes for other stars in the field previously determined by the AAVSO Photometric All Sky Survey (APASS) [11].

Measurements were done at roughly monthly intervals. Between 15 and 36 observations will be carried out per object. As the programme is ongoing, some targets have less observations made to date. This paper covers observations carried out up to October 2025.

The sample for study included nineteen I Zw 1 type AGN. There is no definitive complete compilation of this subclass of AGN, so these 19 objects consisted of most of the relatively few members of the subclass criteria in the $z < 0.1$ range that were bright enough for monitoring with small telescopes. The sample excluded some well known subclass representatives such as I Zw 1 itself that are currently being observed with LCO for other projects. Of these, 13 varied sufficiently to determine the host galaxy flux and hence the varying nuclear flux using the flux variation gradient method [12]. This method assumes that the observed linear relationship between flux measurements in different filters is the result of a near-constant spectral flux distribution being retained during variations (in line with models projecting a fixed spectral index in accretion disks, e.g. [13]). This then implies that the host galaxy flux in the chosen aperture is represented by the intersection of the line defining the host galaxy colours with the line fitted through the measured fluxes.

The nuclear percentage B-band variation σ_B was determined by calculating the standard deviation of the values of the total flux with the estimated host galaxy flux subtracted, specifically $f_B - f_{B,host}$.

3. Results

The thirteen I Zw 1 targets observed in this programme that varied sufficiently (see previous section for how that was determined) are listed in Table 1. That table also lists the B-band estimated host galaxy contribution to the flux in the 3 arcsec aperture determined by identifying the intersection between the lines in the B-flux vs. V-flux diagram corresponding to the host galaxy and the nucleus, i.e. through the application of the earlier described flux variation gradient technique. The table further lists the average B-band nuclear flux $f_{B,n}$ and its percentage standard deviation $\sigma_{B,n}$.

Name	RA(2000)	Dec(2000)	N	$f_{B,n}$	$\sigma_{B,n}$
WPVS 7	00 39 15.8	−51 17 01	34	1.04	11.8%
Ton S180	00 57 20.2	−22 22 56	28	1.28	25.9%
H 0707−495	07 08 41.5	−49 33 06	36	1.80	7.7%
RX 1007+2203	10 07 10.2	+22 03 01	24	0.59	7.6%
Mkn 648	12 07 19.8	+24 11 56	26	0.28	20.1%
MS 12235+2522	12 26 04.2	+25 06 38	23	0.35	7.8%
Q 1349−439	13 52 59.6	−44 13 25	16	0.86	9.5%
PG 1404+226	14 06 21.6	+22 23 46	11	0.94	7.3%
PG 1448+273	14 51 08.8	+27 09 27	18	1.19	10.3%
MS 15198-0633	15 22 28.7	−06 44 41	30	0.49	18.2%
Mkn 493	15 59 09.6	+35 01 47	31	1.51	11.8%
RX 1741+0348	17 41 28.3	+03 48 53	29	1.19	16.5%
Mkn 896	20 46 20.9	−02 48 45	15	0.74	15.9%

Table 1: List of I Zw 1 type AGN observed that varied sufficiently to determine reliable nuclear fluxes and quantify their fluctuations. N is the number of observations per object and the flux is given in units of mJy.

After the magnitudes were converted to fluxes, these were plotted in flux vs. flux diagrams, an example being shown here for H 0707−495 in Fig. 1.

The median for $\sigma_{B,n}$ in Table 1 is 14.7%. In addition to the observations of I Zw 1 type AGN, the programme also includes similar observations of over 100 AGN that are not I Zw 1 type AGN. In particular, these comparatively nearby and therefore easily observable Seyfert 1 galaxies do have broad lines with FWHM > 2000 km.s^{-1}. For these, the median value of $\sigma_{B,n}$ was 25.7%, which is substantially higher. That however includes a lot of AGN that have other spectral peculiarities, such as such as double-peaked broad components, abnormally strong helium lines, coronal lines, prominent LINER or starburst features, and even some BL Lac objects. If one removes all these from the analysis and only considers the 69 Seyfert 1 galaxies that do not have any unusual features in their spectra, the percentage nuclear B-band flux variation range $\sigma_{B,n}$ has a median value of 22.8%.

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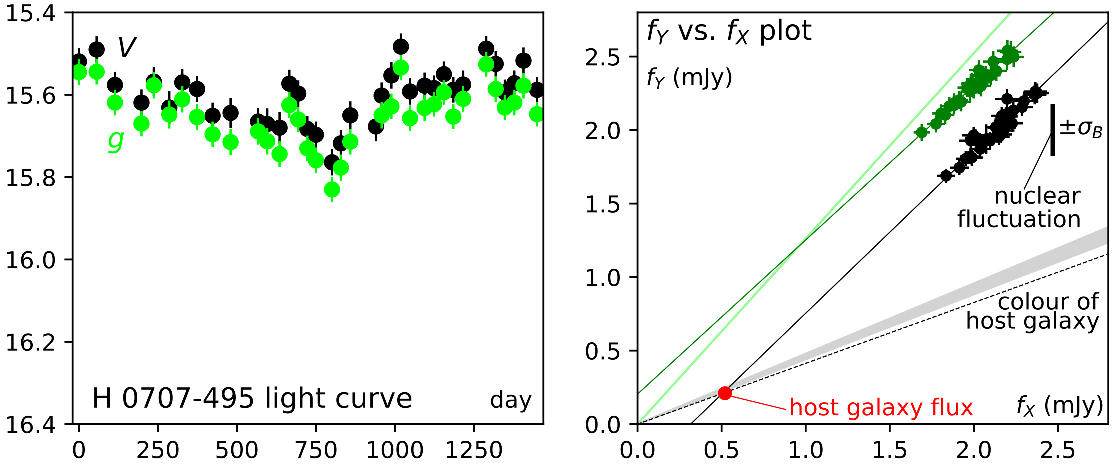

Figure 1: *Left*: The *V* and *g*' light curve of H 0707−495. *Right*: A flux vs. flux diagram of the photometrically obtained fluxes in each filter. The shaded areas correspond to the host galaxy colours.

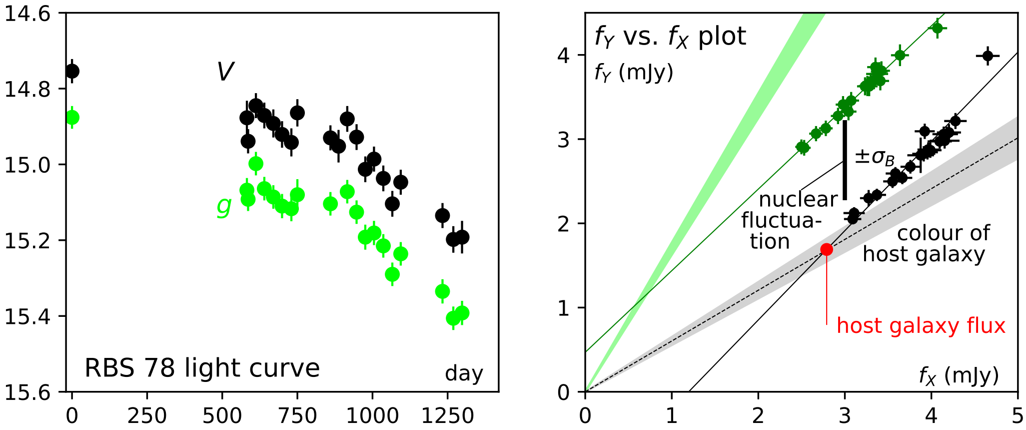

Figure 2: As in Fig. 1, but this time for the ordinary Seyfert 1 galaxy RBS 78.

This is still substantially higher than the quantity determined for the I Zw 1 sample, confirming that the nuclear flux variations in this sub-type is significantly smaller.

Fig. 2 is a similar plot to Fig. 1, but for the RBS 78, an example of an AGN from the ordinary (not I Zw 1, and no other spectral peculiarities) Seyfert 1 sample. Fig. 3 displays histograms comparing the $\sigma_{B,n}$ of I Zw 1 type objects to that of ordinary Seyfert 1's.

Regardless on how one defines the comparison sample, the I Zw 1 type AGN have with $\sigma_{B,n}$ = 14.7% a significantly smaller percentage variability than Seyfert 1 galaxies as a whole.

4. Discussion and Conclusion

The results of this study confirms that I Zw 1 type AGN have a smaller variability range in the optical than the broader Seyfert 1 category.

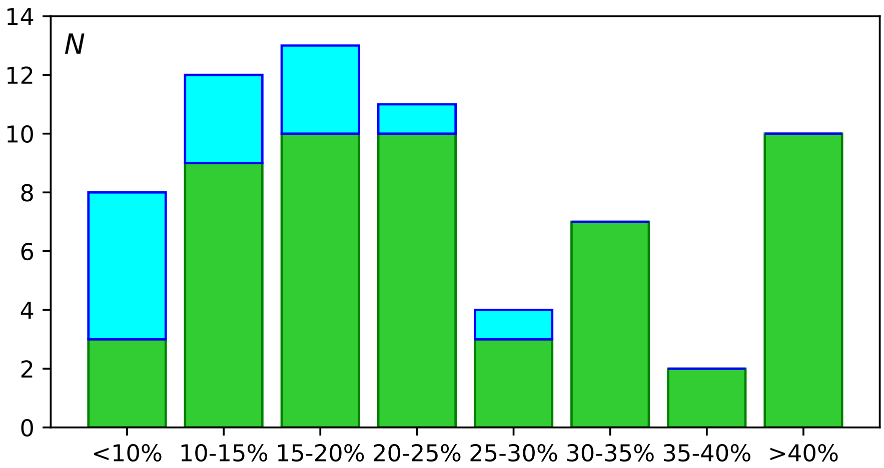

Figure 3: Histogram showing the distribution (in terms of the nuclear B-filter flux standard deviation σ_B) of the I Zw 1 type AGN from Table 1 (in blue) and the ordinary Seyfert 1 galaxies (in green).

This may be due to AGN with strong Fe II emission being regarded as having higher Eddington ratios [14]. The overall stronger emission this entails may mean that episodes with low emission are much rarer, so that the consistently high emission rate also entails overall smaller $\sigma_{B,n}$.

Another possibility is that the host galaxy contribution used to determine the variability measure excludes one or more components that are constant or vary on much longer time scales. In particular, the region of the AGN in which the Fe II lines are formed, sometimes referred to as the intermediate line region, is believed to be located further from the black hole than where the broad lines are formed. Suggested locations include the inner edge of the narrow line region or the inner parts of the dust torus (see [3] for a discussion of this). This intermediate line region may also be radiating at an overall more constant rate in view of this region's larger volume. In that case the flux from the accretion zone close to the black hole would be proportionally smaller than assumed in the flux variation gradient methodology, and the actual nuclear variations would then be larger and more closely aligned to the range observed in other Seyferts.

It is unlikely that the smaller $\sigma_{B,n}$ is due to an incorrect estimation of the host galaxy colours. While seeing would affect the point spread function and exaggerate the flux recorded in the annulus used to estimate the galaxy colours, this effect is most pronounced for shorter wavelengths. The end effect would be to yield bluer host galaxy colour estimates. That would increase rather than decrease $\sigma_{B,n}$.

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