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A systematic survey for $z < 0.04$ CLAGNs

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ABSTRACT

We have conducted a systematic survey for $z < 0.04$ active Galactic nuclei (AGNs) that may have changed spectral class over the past decade. We use SkyMapper, Pan-STARRS and the Véron-Cetty & Véron catalogue to search the entire sky for these 'changing-look' AGNs (CLAGNs) using a variety of selection methods, where Pan-STARRS has a coverage of 3π steradians (sky north of Declination $-30°$) and SkyMapper has coverage of $\sim$21000 deg^2 (sky south of Declination 0°). We use small aperture photometry to measure how colour and flux have changed over time, where a change may indicate a change in spectral type. Optical colour and flux are used as a proxy for changing Hα equivalent width, while *WISE* 3.4 μm flux is used to look for changes in the hot dust component. We have identified four AGNs with varying spectra selected using our optical colour selection method. Three AGNs were confirmed from recent observations with WiFeS on the 2.3 m telescope at Siding Spring and the other was identified from archival spectra alone. From this, we identify two new CLAGNs; NGC 1346 and 2MASX J20075129–1108346. We also recover Mrk 915 and Mrk 609, which are known to have varying spectra in the literature, but they do not meet our specific criteria for CLAGNs.

Key words: methods: Observational – galaxies: active – galaxies: Seyfert.

1 INTRODUCTION

The classic dichotomy of Active Galactic Nuclei (AGNs) classifies their optical spectra as having either broad or narrow emission lines, type 1 and type 2, respectively, with some intermediate classes containing both emission-line components (Seyfert 1943; Weedman 1976; Osterbrock 1977, 1981). The widely used unified model of AGNs proposes that observed AGN type/classes are a single type of object, observed at different orientations along the line of sight (Osterbrock 1989; Antonucci 1993). We can directly observe both the broad-line region (BLR) and narrow-line region (NLR) in type 1 Seyferts. Whereas, in type 2 Seyferts, the light from the BLR is absorbed by the dusty torus and is not visible in the optical [although it is observable in the infrared (IR)], while the light from the NLR is scattered. Intermediate type 1 Seyferts can have both narrow and broad emission lines, type 1.5 Seyferts have narrow lines with obvious broad Hα and Hβ components, type 1.8s have narrow lines with a broad Hα component and a recognizable broad Hβ component and type 1.9s contain narrow lines with only Hα line being broad (Osterbrock 1977, 1981).

Different wavelengths probe different regions of an AGN. The IR wavelength range is sensitive to thermal emission from warm dust, which is often attributed to the torus that can obscure the ultraviolet and optical emission (e.g. Padovani et al. 2017). The optical and ultraviolet (UV) bands probe emission from the accretion disc and fast-moving gas (1000–10 000 km sec^{-1}) in the BLR, but the UV and optical emission from these regions can be obscured by dust. The X-ray band traces the emission of the hot corona and the ionized reflection of the X-ray continuum from distant neutral material like the molecular torus, the BLR and NLR or the accretion disc (George & Fabian 1991; Antonucci 1993; Jaffe et al. 2004; Meisenheimer et al. 2007; Bianchi et al. 2008). X-rays from AGNs are believed to be a result of inverse Compton scattering of the photons in the accretion disc by the hot corona.

Changing-look AGNs (CLAGNs) are Seyferts and quasars where the spectral type changes from broad line to narrow line and vice versa. Given that the size of the torus is of the order of 1 pc and the relevant velocities are $<10^4$ km s^{-1}, one might expect CLAGNs to take $\sim10^3$ yr to change spectral class in the optical. We may expect variability on the viscous time-scale, which for AGNs is of the order of $\sim10^3$–10^5 yr (Siemiginowska, Czerny & Kostyunin 1996). However, Tohline & Osterbrock (1976), Penston & Perez (1984), Tran, Osterbrock & Martel (1992a), Storchi-Bergmann, Baldwin &

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Wilson (1993), Eracleous & Halpern (2001), Marchese et al. (2012), Marin et al. (2013), Denney et al. (2014), Shappee et al. (2014), Guo et al. (2016), Oknyansky et al. (2017), Ross et al. (2018), Noda & Done (2018) and Hon, Webster & Wolf (2020), for example, have identified CLAGNs that change spectral type in only a few years. CLAGNs may therefore be more common than previously believed.

Examples of low-redshift CLAGNs from the literature include Mrk 833 (Canelo et al. 2018), which changed from type 1.9 to type 1.8, NGC 7603 (Tohline & Osterbrock 1976), which changed from type 1 to type 1.5, Mrk 372 (Penston & Perez 1984), which changed from type 1.5 to type 1.9 and NGC 1566 (Oknyansky et al. 2018), which changed from type 1.9 to type 1.2. While there is not a strict definition in the literature, for consistency with the literature we classify objects as CLAGN if the broad-line components completely disappears, a new broad-line component appears and/or if the Osterbrock (1977) and Osterbrock (1981) spectral type changes by more than 0.1 (that is a change from type 1.8 to 1.9 and 1.9 to 2.0 and vice versa is not significant enough to be classified as a CLAGN). Some objects in our sample do show interesting spectral variability while falling below our CLAGN thresholds, and we retain them in this work while not classifying them as CLAGNs. AGNs such as Mrk 883, which change type by only 0.1 do not meet our CLAGN criteria, however, it is considered a CLAGN by Canelo et al. (2018).

1.1 Why CLAGN change spectral type

There are two main reasons why AGNs change their spectral type. One scenario is an obscuring cloud crosses the line of sight, causing changes in observed light curves. Goodrich (1989) and Guo et al. (2016) have found AGNs which vary due to obscuring clouds. In this case, light from the inner disc and BLR is obscured by the dusty cloud, causing broad lines to disappear from the spectra. IR emission is sensitive to thermal emission from warm dust, which is often attributed to the torus, as the change in spectral type in this scenario is caused by obscuration of the BLR, we do not expect to measure a change in IR. Thus, the spectra of the AGNs should return to their original state after a period of time. A likely example of such a CLAGN is quasar SDSS J231742.60+000535.1 (Guo et al. 2016), where the change in its spectral type was caused by rapid outflow or inflow with an obscuring cloud passing along the line of sight. This scenario is in agreement with the unified model as changes in the spectral type are due to changes along the line of sight.

The second and more complex cause for change in spectral type is due to changes in accretion rate of the central black hole, changes in accretion disc structure, or tidal disruptions (Dexter & Agol 2011; Kelly, Sobolewska & Siemiginowska 2011; Kokubo 2015; Merloni et al. 2015; MacLeod et al. 2016). Ross et al. (2018) use models of the innermost stable circular orbit around a black hole to determine if this is a possible driver for changes in the spectra of SDSS J1100-0053, where the different models have combinations of zero torque, non-zero torque, spectral hardening factor[1] and radii. Ross et al. (2018) attributed the change in spectral type to mass flow rate switching from cold, high-mass flow rate to hot, low-mass flow rate. Unlike the previous scenario, the change in spectral type is caused by changes in accretion. Thus, it does not agree with the unified model as the spectral type change is not caused by changes along the line of sight.

[1]The spectral hardening factor, also referred to as the colour correction, is used to interpret multitemperature blackbody fitting results (Davis & El-Abd 2019). Where for a canonical blackbody spectral, the spectral hardening factor is 1.

1.2 Known CLAGNs

Until recently, the most common method by which studies have identified CLAGNs is by serendipity. For example, NGC 2617 is a CLAGN that was identified by Shappee et al. (2014) after an outburst triggered a transient source alert, and the corresponding changing optical spectra are displayed in Fig. 1. NGC 2992 was identified by Gilli et al. (2000) using *Beppo*SAX observations (Scarsi 1997) which caught a rise in nuclear emission from the AGN, and there was a corresponding change in the optical classification from type 1.9 to type 2.

It is only recently that targeted searches for CLAGNs such as LaMassa et al. (2015), MacLeod et al. (2016), Ruan et al. (2016), Runnoe et al. (2016), Gezari et al. (2017), Yang et al. (2018), Stern et al. (2018), and MacLeod et al. (2019) have been conducted. This is because there is now more readily available archival data and multi-epoch photometry such as NEOWISE (Mainzer et al. 2014), Pan-STARRS (Chambers et al. 2019), SDSS (Eisenstein et al. 2011), SkyMapper (Wolf et al. 2018), and GAIA (Gaia Collaboration et al. 2016). These targeted searches are focused mainly on detecting changing-look quasars that are well beyond $z \sim 0$. That said, a number of changing-look Seyferts have been identified in the $z < 0.04$ Universe, and these and their key details including previous and current type are summarized in Table 1. The CLAGNs in Table 1 were identified by serendipity or X-ray monitoring of known AGNs.

Motivated by the frequency of ad hoc nearby CLAGN identifications, we have conducted a systematic search for $z < 0.04$ CLAGNs. Our redshift limit is chosen to keep Hα within the r band and increases availability of archival photometry and spectroscopy. We use the comprehensive Véron-Cetty & Véron (2010) catalogue to identify $z < 0.04$ AGNs using SkyMapper (Wolf et al. 2018), the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS, Chambers et al. 2019; Flewelling et al. 2020), the Wide-field Infrared Survey Explorer (*WISE*, Wright et al. 2010) and Sloan Digital Sky Survey (*SDSS*, Abazajian et al. 2004). We select CLAGN candidates meeting our colour and flux criteria, and then follow-up these candidates with archival and new spectroscopy. In Section 2, we discuss the methods by which we selected CLAGN candidates and the effectiveness of each method. In Section 3, we discuss what objects were observed. In Section 4 we discuss the new CLAGNs we identified, including NGC 1346 which we also discuss in Senarath et al. (2019). We also discuss the possible reasons why these AGNs changed spectral type in Section 4.

2 CANDIDATE SELECTION

To select CLAGN candidates, we use photometry from PanSTARRS, SkyMapper, and the *WISE* (Wright et al. 2010). Our methods use optical and MIR fluxes and colours to search for variability in the optical continuum. Our first approach uses optical colours as a proxy of Hα equivalent widths. Our second and third approaches use variability of optical and MIR fluxes to search for changes in accretion disc and hot dust component respectively.

We use the MIR to identify changes in the dust near the accretion disc of the AGNs (presumably not associated with the larger torus). The optical and UV continuum probes emission from the disc while the optical and UV spectral lines probe ionized gas above the disc, and changes in the optical flux and colour may indicate changes in spectral type resulting from changes in accretion or changing obscuration along the line of sight. We use optical colour and IR fluxes and colours as prox-

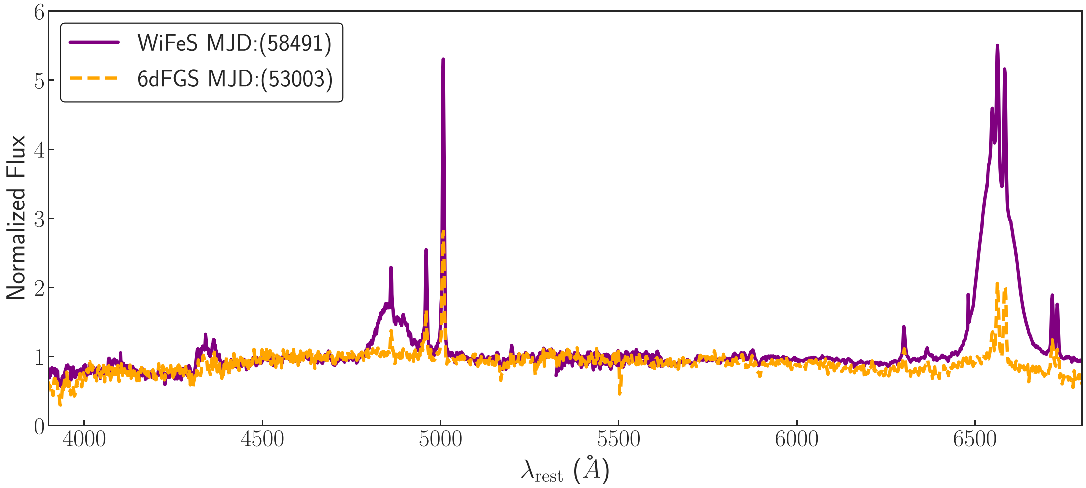

Figure 1. Spectra of NGC 2617, a previously identified CLAGN with still evolving spectra from type 1.8 to type 1 Seyfert (Oknyansky et al. 2017). Véron-Cetty & Véron (2010) identify the 6dFGS spectrum as type 1.8, while our WiFeS 2019 January shows NGC 2617 is currently a type 1, which agrees with observations from Oknyansky et al. (2017).

Table 1. Known $z < 0.04$ CLAGNs and their respective types and references.

ID	RA (J2000)	Dec. (J2000)	Redshift	Previous type(s)	Current type	Reference
NGC 7603	$23^{h}18^{m}56^{s}.65$	$+00^{d}14^{m}37^{s}.9$	0.030	1	1.5	Tohline & Osterbrock (1976)
NGC 4151	$12^{h}10^{m}32^{s}.65$	$+39^{d}24^{m}20^{s}.7$	0.003	1, 2	1.5	Penston & Perez (1984)
NGC 2622	$08^{h}38^{m}10^{s}.943$	$+24^{d}53^{m}43^{s}.02$	0.029	1.8	1	Goodrich (1989)
Mrk 372	$03^{h}02^{m}13^{s}.18$	$-23^{d}35^{m}19^{s}.8$	0.035	1.5	1.9	Gregory, Tifft & Cocke (1991)
Mrk 993	$01^{h}25^{m}31^{s}.47$	$+32^{d}08^{m}10^{s}.5$	0.016	1	1.9	Tran et al. (1992a)
NGC 1097	$02^{h}46^{m}19^{s}.05$	$-30^{d}16^{m}29^{s}.6$	0.004	2	1	Storchi-Bergmann et al. (1993)
NGC 3065	$10^{h}01^{m}55^{s}.30$	$+72^{d}10^{m}13^{s}.0$	0.007	2	1.2[a]	Eracleous and Halpern (2001)
NGC 2992	$09^{h}45^{m}42^{s}.04$	$-14^{d}19^{m}34^{s}.8$	0.008	1.9, 1.5	2	Gilli et al. (2000) and Trippe et al. (2008)
NGC 454E	$01^{h}14^{m}22^{s}.50$	$-55^{d}23^{m}55^{s}.0$	0.012		2[b]	Marchese et al. (2012)
NGC 1365	$03^{h}33^{m}36^{s}.45$	$-36^{d}08^{m}26^{s}.3$	0.005		1.8[b]	Marin et al. (2013)
Mrk 590	$02^{h}14^{m}33^{s}.57$	$-00^{d}46^{m}00^{s}.2$	0.026	1	1.9–2	Denney et al. (2014)
Mrk 6	$06^{h}52^{m}12^{s}.251$	$+74^{d}25^{m}37^{s}.46$	0.019	2	1.5	Khachikian & Weedman (1971), Khachikian, Asatrian & Burenkov (2011), and Afanasiev et al. (2014)
ESO 362-G018	$05^{h}19^{m}35^{s}.80$	$-32^{d}39^{m}27^{s}.0$	0.012	1.5	2	Agís-González et al. (2017)
NGC 7582	$23^{h}18^{m}23^{s}.62$	$-42^{d}22^{m}14^{s}.0$	0.005	1	2	Braito et al. (2017)
NGC 2617	$08^{h}35^{m}38^{s}.77$	$-04^{d}05^{m}17^{s}.2$	0.014	1.8	1	Oknyansky et al. (2017)
NGC 1566	$04^{h}20^{m}00^{s}.41$	$-54^{d}56^{m}16^{s}.1$	0.005	1.9	1.2	Oknyansky et al. (2018)
Mrk 883	$16^{h}29^{m}52^{s}.84$	$+24^{d}26^{m}37^{s}.4$	0.037	1.9	1.8	Canelo et al. (2018)
HE 1136-2304	$11^{h}38^{m}51^{s}.00$	−23d21m32.0d	0.027	2	1.5	Zetzl et al. (2018)
NGC 3516	$11^{h}06^{m}47^{s}.490$	$+72^{d}34^{m}06^{s}.88$	0.009	1	2	Shapovalova et al. (2019)
1ES 1927+654	$19^{h}27^{m}19^{s}.54$	$+65^{d}33^{m}54^{s}.2$	0.017	2	1	Trakhtenbrot et al. (2019)
NGC 1346	$03^{h}30^{m}13^{s}.27$	$-05^{d}32^{m}36^{s}.3$	0.014	1.8	2	Senarath et al. (2019) and this work
2MASX J20075129-1108346	$20^{h}07^{m}51^{s}.29$	$-11^{d}08^{m}34^{s}.6$	0.030	2	1.8	This work

[a]While Eracleous & Halpern (2001) do not explicitly state the spectral types of the changes, they do state that NGC 3065 went from lacking broad Balmer lines to containing broad Balmer lines. [b]NGC 1365 is an X-ray CLAGN. X-ray CLAGNs are characterized by rapid transitions between Compton-thick to Compton-thin, where this transition can be due to absorption by gas clouds passing along the line of sight or relativistic reflection on to the accretion disc (Marin et al. 2013). In the case of NGC 1365, the CLAGN classification is due to the reflection-dominated scenario.

ies for Hα emission and hot disc emission, respectively, where variations would indicate the presence of a CLAGN. Therefore, we require photometry of known AGNs (the specifics of this are explained in Section 2.1). Following the photometric selection of CLAGN candidates, we obtained follow-up spectroscopy.

2.1 Imaging surveys and catalogues

We select known $z < 0.04$ AGNs from Véron-Cetty & Véron (2010), an extensive compilation of AGNs (particularly at low redshift). We then measure optical and IR photometry of these AGNs with SkyMapper, Pan-STARRS, and *WISE*. Possible CLAGNs are then selected with the colour and flux criteria described Sections 2.2–

2.4. The SkyMapper survey (with passbands *uvgriz*) contains ≈280 million objects and has a coverage area of almost the entire Southern sky. Pan-STARRS, on the other hand, surveys the sky north of Declination -30° (passbands *grizy*). Together the two surveys provide data for the entire sky.

The depth of the optical catalogues are $r \sim 21.7$ mag for SkyMapper and $r \sim 23.2$ mag for Pan-STARRS, which is more than sufficient to detect all the $z < 0.04$ Véron-Cetty & Véron (2010) AGNs. For our analysis, we use small aperture photometry. For Pan-STARRS (PS1) we measure photometry in 3 arcsec diameter apertures on stack images. For SkyMapper we use the DR1 5 arcsec diameter aperture photometry. For SDSS, we use the fibre magnitudes (3 arcsec in diameter). To photometrically identify AGNs that may have a varying hot dust component, we use photometry drawn from the *WISE* and NEOWISE surveys (Mainzer et al. 2014). NEOWISE measures photometry in the W1 and W2 bands and surveys the entire sky at a cadence of 6 months, and has been doing so since *WISE* was brought out of hibernation in late 2013. We present a subset of our CLAGN candidate catalogues in Tables 2 and 3 for SkyMapper and Pan-STARRS, respectively, which contain all the $z < 0.04$ AGN with information on the selection criteria and whether or not each galaxy meets the criteria. They also contain archival spectra references for the Seyferts that meet the CLAGN candidate criteria.

2.2 Optical colour selection

CLAGNs should change colour due to varying Hα strength, thus we use $r - i$ as a proxy for Hα equivalent width. Our optical colour selection assumes that type 1 and type 2 AGNs have relatively blue and red $r - i$ colours, respectively, resulting from the equivalent width of the Hα emission line. As the Pan-STARRS and SkyMapper bands differ from each other, the $r - i$ colours they measure for individual AGNs will differ. As a consequence, we compare $z < 0.04$ AGNs that appear in both catalogues, we find a linear relation as a function of $r - i$ colour. We apply this relation when determining our $r - i$ colour criteria for our Pan-STARRS and SkyMapper catalogues.

For our SkyMapper catalogue, we select blue Seyfert type 2s with $r - i < 0.35$ mag and red type 1s with $r - i > 0.53$ mag (after removing flagged objects with spurious photometry). For our Pan-STARRS sample, we select blue type 2s with $r - i < 0.25$ mag and red type 1s with $r - i > 0.43$ mag (after removing flagged objects with spurious photometry). This selects a total of 109 candidates where we select 40 and 69 AGNs in SkyMapper and Pan-STARRS, respectively. These candidates are displayed in Figs 2 and 3.

We further refine this candidate list by inspecting the archival images and spectra, including identifying changes in the Hα and Hβ emission lines. We select candidates to observe on the basis that they have more than one archival spectra and there is variation in emission linewidths that appear to be changing in the last 10 yr (after 2008), these archival spectra are referenced in Tables 2 and 3. It should be noted that 46 per cent of the candidates selected using the mentioned colour criteria have no readily available archival spectra or have just one readily available spectrum. Also 26 per cent of candidates did not have archival spectra taken in the last 10 yr. AGNs that fall into these categories are not selected for observations.

Of the 22 known $z < 0.04$ changing-look Seyferts, 10 are known to have changed optical spectral class between 1998 and 2015, where 2015 is defined by the end of the SkyMapper observations for the data release we are using (DR1) (Wolf et al. 2018) and 1998 is defined by the beginning of the SDSS imaging we are using (Eisenstein et al. 2011), while Pan-STARRS PS1 data was obtained between 2009 and 2014 (Chambers et al. 2016). Our photometric selection has recovered five of these known CLAGNs; Mrk 883, Mrk 590, NGC 4151, NGC 7282, and NGC 2617 (further information on these CLAGNs appear in Table 1).

2.3 Optical flux variability selection

As with $r - i$ colour selection, we utilize the r-band flux variability to detect the changing Hα emission of CLAGNs. As, by definition this requires multiple *r*-band epochs, we have measured the variability of the Véron-Cetty & Véron (2010) $z < 0.04$ AGNs in the ≈14 055 deg^2 that have both SDSS and Pan-STARRS photometry. It should also be noted that the time between SDSS and Pan-STARRS observations can be as little as a few years or longer than a decade, while changes in Seyfert spectra can take decades to occur, or in some cases can be limited to just a few years (i.e, tidal disruptions, Guo et al. 2016).

We found that type 1.8s, 1.9s, and type 2s typically showed variability $\Delta m_r < 0.2$ mag, and these are plotted in Fig. 4. However, type 1s showed a greater variability making it impractical to select type 1s fading into type 2 on the basis of *r*-band flux variability alone. Of the 335 type 1.8s, 1.9s, and type 2s with both SDSS and Pan-STARRS photometry, we identified 22 potential CLAGNs using $\Delta m_r > 0.2$ mag. It should be noted that as these objects are relatively bright, the photon shot noise is relatively small and the scatter is dominated by PSF differences, zero-point errors, filter curve differences and AGN variability. The dominant source of error is systematic errors rather than easily quantifiable errors, and thus we have not included individual error bars into Fig. 4.

After further investigation of the 22 potential CLAGNs, four CLAGN candidates were removed as their measurement of variability resulted from centroid errors, where two of these AGNs were in galaxy pairs. We also recover the known CLAGNs NGC 2617 (Oknyansky et al. 2017) and Mrk 883. Further inspection into archival spectra of the AGNs with $\Delta m_r > 0.2$ (NGC 1048A, SDSSJ03205-0020, Zw497.016, NPM1G-16.0109, MCG+08.15.009, NGC 4565, Mrk 1392, Mrk 673, Mrk 609, UGC 4145, Zw098.038, HS1656+3927, NGC 6264, Mrk 248, and IC1725) showed all had archival spectra. Inspecting these archival spectra, we found no evidence of variation. As such, we did not undertake spectroscopic follow up of these AGNs.

2.4 IR flux variability selection

We use NEOWISE variability to search for $z < 0.04$, Véron-Cetty & Véron (2010) AGNs where the contribution of hot dust to the SEDs may be changing. Unlike optical flux variability selection where we measure the difference between SDSS and Pan-STARRS photometry, in this scenario, we measure the change in magnitude over time using different epochs of NEOWISE. Each NEOWISE epoch has multiple photometry measurements, so we use the median photometry measurement for each epoch and measure the difference between the highest and lowest magnitude epochs, we present this in Fig. 5.

Most of the AGNs that display a high change are type 1 Seyferts which naturally vary over time. Variability on the time-scale of months or a few years indicated some emission is occurring close to the central engine (de Ruiter & Lub 1986; Burtscher et al. 2015), and the varying MIR emission is attributed to a dusty wind in the AGNs polar region (Hönig et al. 2013). As with the previous CLAGN candidate selection methods, we inspect the archival spectra of AGNs where 1.8s, 1.9s, and type 2s had $\Delta W1 > 0.3$ mag. In all instances, where we identified a type 2 with *WISE* variability and spectra more recent than 2017, we found that the recent spectra still exhibited

Table 2. Sample taken from our SkyMapper catalogue used to select CLAGN candidates. Note that the full table is available online.

RA	Dec.	Name	z	VCV	SkyMapper			MJD	SDSS			MJD	Pan-STARRS[a]			Flag[b]	Spectra	Spectral
(°)	(°)			Spectral type	r (mag)	i (mag)	z (mag)		r (mag)	i (mag)	z (mag)		r (°)	i (°)	z (°)		notes[c]	sources[d]
0.8839	– 10.7446	NGC7808	0.03	1	15.11	14.62	14.39	51792	15.92	15.48	15.13	55866	15.85	15.38	15.09	0	3	2, 3
2.7260	– 21.0675	ESO538-G25	0.03	2	15.77	15.32	14.93	53353	16.67	16.20	15.78	56028	16.56	16.08	15.78	0	2	2
2.7776	– 12.1079	MARK938	0.02	2	14.48	13.95	13.69	0	0.00	0.00	0.00	56170	15.44	15.03	14.56	0	2	2
6.8176	– 1.7802	NGC118	0.04	2	14.52	14.16	13.90	54769	15.29	14.90	14.65	55618	15.26	14.89	14.69	0	0	0
8.5568	– 21.4386	ESO540-G01	0.03	1.8	14.61	14.32	14.08	53995	15.38	15.07	14.79	55913	15.33	15.03	14.84	2	0	0
8.9533	– 13.6106	NGC166	0.02	2	15.43	15.04	14.55	0	0.00	0.00	0.00	56123	16.34	15.94	15.54	0	0	0
9.3992	0.2807	MARK955	0.04	2	15.14	14.72	14.46	52231	15.94	15.56	15.26	55541	15.87	15.43	15.22	0	2	3
10.7200	– 23.5410	NGC235	0.02	1	14.50	14.04	13.66	53995	15.07	14.73	14.42	55937	14.99	14.65	14.35	0	2	5
11.0909	– 17.3512	ESO540-G17	0.03	2	16.52	16.10	15.73	0	0.00	0.00	0.00	56026	17.41	16.99	16.66	0	2	2
13.3747	– 8.7677	NGC291	0.02	2	15.55	14.88	14.74	51814	16.38	15.98	15.57	55768	16.32	15.96	15.59	0	3	2,3
13.7271	– 32.0317	ESO411-G029	0.03	2	15.60	15.01	14.75	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	2	2
14.5930	– 36.6601	ESO351-G025	0.04	2	16.20	15.77	15.45	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	2	2
16.3203	– 58.4375	ESO113-G10	0.03	1.8	14.89	14.53	14.29	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	0	0
18.0802	– 32.0612	NGC427	0.03	1.2	15.52	15.22	14.99	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	2	2
18.2025	– 0.2902	SDSSJ01128-0017	0.02	2	14.44	13.95	13.63	52963	15.16	14.74	14.35	55635	15.11	14.65	14.42	0	2	3
18.5293	– 32.6509	IC1657	0.01	2	15.39	14.68	14.55	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	3	2,4
18.7029	– 0.4961	UGC793	0.03	1.5	16.09	15.59	15.30	53272	16.91	16.54	16.23	55834	16.81	16.46	16.27	0	3	3,32
18.9802	– 50.1894	ESO195-G35	0.02	2	14.84	14.43	14.16	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	2	2
20.0821	– 44.1287	ESO244-G17	0.02	1.5	15.47	15.13	14.84	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	0	0
20.8383	– 1.9766	UM319	0.02	2	16.19	15.73	15.43	54770	17.08	16.74	16.35	55913	17.03	16.65	16.38	0	2	2
20.9766	– 35.0654	NGC526A	0.02	1.9	14.93	14.42	14.00	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	3	2, 5
23.4906	– 36.4932	NGC612	0.03	2	15.27	14.64	14.25	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	3	2, 5
25.9065	– 33.7054	ESO353-G38	0.03	2	15.11	14.64	14.40	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	0	0
25.9907	2.3499	MARK573	0.02	1	14.46	14.12	13.89	54742	15.12	14.95	14.62	56011	15.03	14.88	14.57	0	2	4
27.9245	– 36.1878	ESO354-G04	0.03	1	15.13	14.64	14.37	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	2	2
28.2042	– 3.4468	MCG-01.05.047	0.02	2	15.94	15.43	15.10	54770	16.92	16.44	16.02	56294	17.50	16.79	16.28	0	3	2,5
29.9634	– 6.8404	IC184	0.02	2	15.55	15.15	14.78	54832	16.48	16.10	15.78	56178	16.41	15.96	15.74	0	3	2,15
30.2769	– 6.8159	NGC788	0.01	1	14.39	13.99	13.70	54832	15.28	14.93	14.57	56178	15.19	14.78	14.57	0	2	5
32.3525	– 10.1359	NGC835	0.01	2	13.84	13.37	13.07	51813	14.68	14.25	13.93	56091	14.50	14.12	13.85	0	3	2,4
33.4098	– 0.7173	SDSSJ02136-0043	0.02	1	15.21	14.87	14.71	52963	16.17	15.79	15.45	56254	16.06	15.65	15.46	0	2	3
33.6399	– 0.7667	MARK590	0.03	1	14.58	14.08	13.77	52963	15.33	14.94	14.60	56311	15.26	14.83	14.58	0	2	3

Table 2 – *continued*

RA (°)	Dec. (°)	Name	z	VCV Spectral type	SkyMapper r (mag)	SkyMapper i (mag)	SkyMapper z (mag)	MJD	SDSS r (mag)	SDSS i (mag)	SDSS z (mag)	MJD	Pan-STARRS[a] r (°)	Pan-STARRS[a] i (°)	Pan-STARRS[a] z (°)	Flag[b]	Spectra notes[c]	Spectral sources[d]
37.5230	– 8.9982	MARK1044	0.02	1	14.49	14.37	14.08	54057	14.72	14.75	14.57	56170	14.71	14.59	14.34	0	3	2,5
37.9625	– 36.6721	IC1816	0.02	2	14.81	14.42	14.14	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	3	2,4,5,20
38.2552	0.4208	UGC2024	0.02	2	14.96	14.59	14.30	0	0.00	0.00	0.00	56284	15.43	15.09	14.92	0	3	2,3
38.4651	1.1371	SDSSJ02338+0108	0.02	1	15.24	14.79	14.54	54715	15.92	15.52	15.17	56262	15.83	15.41	15.21	0	2	3

[a]The Pan-STARRS photometry in this table has been measured by us using the Pan-STARRS cutouts (where available) with a 3 arcsec diameter aperture for the AGNs in our Skymapper catalogue. [b]Optical colour selection flag where 1 indicates possible narrowing spectra and 2 indicates possible broadening spectra. [c]CLAGN spectra flag where 0 indicates no archival spectra online, 1 indicates varying in archival and/or WiFeS spectra, 2 indicates only one archival spectrum found and no WiFeS, 3 indicates two or more archival spectra, not varying in WiFeS and archival spectra, 4 indicates no archival spectra found from the last 10 yr, but shows signs of varying before then and 5 indicates no archival spectra found from the past 10 yr, does not show signs of varying before then. [d]If Spectra Notes is 0, then this is also 0. 1 – WiFeS; 2 – 6dFGS; 3 – SDSS; 4 – S7; 5 – BASS; 6 – 2dFGRS; 7 – Ho, Filippenko & Sargent (1995); 8 – MaNGA; 9 – Fosbury et al. (1982); 10 – Phillips, Charles & Baldwin (1983); 11 – Kennicutt & Keel (1984); 12 – Bergvall, Johansson & Olofsson (1986); 13 – Veron-Cetty & Veron (1986a); 14 – Veron-Cetty & Veron (1986b); 15 – Kollatschny & Fricke (1987); 16 – Maia et al. (1987); 17 – Rudy, Cohen & Ake (1988); 18 Morris & Ward (1988); 19 – Storchi Bergmann, Bica & Pastoriza (1990); 20 – Winkler (1992); 21 – de Grijp et al. (1992); 22 – Moran, Halpern & Helfand (1994); 23 – Cruz-Gonzalez et al. (1994); 24 – Goodrich (1995); 25 – Maia et al. (1996); 26 – Moran, Halpern & Helfand (1996); 27 – Reimers, Koehler & Wisotzki (1996); 28 – Scarpa, Falomo & Pesce (1996); 29 – Coziol et al. (1997); 30 – Pietsch et al. (1998); 31 – Fraquelli, Storchi-Bergmann & Binette (2000); 32 – Jansen et al. (2000); 33 – Kewley et al. (2001); 34 – Reunanen, Kotilainen & Prieto (2003); 35 – Márquez et al. (2004); 36 – Georgantopoulos et al. (2004); 37 – Masetti et al. (2006a); 38 – Masetti et al. (2006b); 39 – Moustakas & Kennicutt (2006); 40 – Ho & Kim (2009); 41 – Trippe et al. (2010); 42 – Dopita et al. (2014); 43 – Schmidt et al. (2016); 44 – Ramos Almeida et al. (2016); 45 – Thomas et al. (2017)

Table 3. Sample taken from our Pan-STARRS (PS1) catalogue used to select CLAGN candidates. Note that the full table is available online.

RA	Dec.	Name	z	VCV	Pan-STARRS (PS1)			MJD	SDSS			Flag[a]	Spectra	Spectral
(°)	(°)			Spectral type	*r* (mag)	*i* (mag)	*z* (mag)		*r* (mag)	*i* (mag)	*z* (mag)		notes[b]	sources[c]
0.4933	36.6489	Zw517.014	0.032	2	16.13	15.78	15.53	0	0.00	0.00	0.00	0	0	0
0.6100	3.3517	MARK543	0.026	1.5	15.75	15.64	15.38	54742	15.76	15.58	15.31	0	0	0
0.7900	21.9600	MARK334	0.022	1.8	15.51	15.27	14.89	54849	15.54	15.27	14.86	0	0	0
0.8837	− 10.7447	NGC7808	0.029	1	15.86	15.38	15.10	51792	15.92	15.48	15.13	1	3	2,3
1.5813	20.2031	MARK335	0.026	1	14.35	14.45	14.21	55119	14.43	14.90	14.45	0	2	5
2.7262	− 21.0675	ESO538-G25	0.026	2	16.54	16.07	15.77	53353	16.67	16.20	15.78	0	2	2
2.7775	− 12.1075	MARK938	0.019	2	15.23	14.80	14.32	0	0.00	0.00	0.00	0	2	2
4.5979	30.0631	NGC71	0.022	2	15.95	15.48	15.18	55122	16.02	15.59	15.21	0	0	0
6.8175	− 1.7797	NGC118	0.037	2	15.28	14.90	14.71	54769	15.29	14.90	14.65	0	0	0
8.5575	− 21.4389	ESO540-G01	0.027	1.8	15.33	15.03	14.84	53995	15.38	15.07	14.79	0	0	0
8.9533	− 13.6103	NGC166	0.020	2	16.33	15.94	15.54	0	0.00	0.00	0.00	0	0	0
9.3992	0.2808	MARK955	0.035	2	15.89	15.47	15.25	52231	15.94	15.56	15.26	0	2	3
9.7392	48.3372	NGC185	0.000	2	17.34	16.99	16.76	0	0.00	0.00	0.00	0	2	7
10.6846	41.2694	M31	0.000	2	12.52	100.00	12.21	0	0.00	0.00	0.00	2	3	7,39,50
10.7200	− 23.5411	NGC235	0.022	1	15.00	14.67	14.37	53995	15.07	14.73	14.42	0	2	5
11.0908	− 17.3517	ESO540-G17	0.031	2	17.34	16.94	16.62	0	0.00	0.00	0.00	0	2	2
11.8308	14.7033	MARK1146	0.039	1	16.77	16.25	15.95	51878	16.51	16.12	15.82	1	2	3
12.1967	31.9569	MARK348	0.014	1	15.63	15.36	15.08	55121	15.78	15.52	15.13	0	2	5
12.8958	29.4011	UGC524	0.036	1	15.77	15.18	14.94	55122	15.75	15.36	15.05	1	0	0
13.3742	− 8.7678	NGC291	0.019	2	16.31	15.95	15.60	51814	16.38	15.98	15.57	0	3	2,3
13.7608	− 19.0047	ESO541-G001	0.021	2	16.20	15.83	15.57	0	0.00	0.00	0.00	0	0	0
14.9171	15.3308	UGC615	0.018	2	15.63	15.19	14.90	51464	15.68	15.20	14.94	0	2	3
14.9721	31.8269	MARK352	0.015	1	15.87	15.47	15.52	55121	15.76	15.69	15.48	0	2	5
17.1983	− 15.8425	IC78	0.040	2	16.04	15.57	15.12	0	0.00	0.00	0.00	0	0	0
18.2025	− 0.2900	SDSSJ01128-0017	0.018	2	15.12	14.66	14.43	52963	15.16	14.74	14.35	0	2	3
18.7025	− 0.4958	UGC793	0.034	1.5	16.83	16.48	16.28	53272	16.91	16.54	16.23	0	2	3
19.0300	33.0894	MARK1	0.016	2	15.92	15.95	15.78	0	0.00	0.00	0.00	2	2	41
20.8383	− 1.9767	UM319	0.016	2	17.01	16.63	16.37	54770	17.08	16.74	16.35	0	2	2
21.1117	33.7994	NGC513	0.019	1	15.61	15.16	14.85	53263	15.71	15.26	14.85	1	2	5
21.3808	32.1364	MARK993	0.017	1.5	15.50	15.10	14.81	53263	15.63	15.21	14.82	0	0	0
21.8854	19.1789	MARK359	0.017	1	15.27	15.02	14.86	54848	15.37	15.17	14.85	0	2	5
22.2146	2.4464	UM105	0.030	2	16.44	16.09	15.72	54742	16.56	16.10	15.73	0	0	0
23.3800	35.6681	MARK1157	0.015	1	15.56	15.38	15.02	0	0.00	0.00	0.00	0	0	0
25.9908	2.3497	MARK573	0.017	1	15.05	14.90	14.60	54742	15.12	14.95	14.62	0	2	4
26.1267	17.1025	IIIZw35	0.027	2	16.25	15.83	15.51	54741	16.37	15.95	15.58	0	0	0

[a]Optical colour selection flag where 1 indicates possible narrowing spectra and 2 indicates possible broadening spectra. [b]CLAGN spectra flag where 0 indicates no archival spectra online, 1 indicates varying in archival and/or WiFeS spectra, 2 indicates only one archival spectrum found and no WiFeS, 3 indicates two or more archival spectra, not varying in WiFeS and archival spectra, 4 indicates no archival spectra found from the last 10 yr, but shows signs of varying before then and 5 indicates no archival spectra found from the past 10 yr, does not show signs of varying before then. [c]If Spectra Notes is 0 , then this is also 0. 1 – WiFeS; 2 – 6dFGS; 3 – SDSS; 4 – S7; 5 – BASS; 6 – 2dFGRS; 7 – Ho et al. (1995); 8 – MaNGA; 9 – MUSE; 10 – Phillips et al. (1983); 11 – Goodrich & Osterbrock (1983); 12 – Penston & Perez (1984); 13 – Osterbrock (1985); 14 – Bergvall et al. (1986); 15 – Veron-Cetty & Veron (1986a); 16 – Rudy et al. (1988); 17 – Morris & Ward (1988); 18 – Sabbadin et al. (1989); 19 – Gregory et al. (1991); 20 – Kennicutt (1992); 21 – Tran, Miller & Kay (1992b); 22 – de Grijp et al. (1992); 23 – Durret (1994); 24 – Kim et al. (1995); 25 – Goodrich (1995); 26 – Moran et al. (1996); 27 – Owen, Ledlow & Keel (1996); 28 – Scarpa et al. (1996); 29 – Coziol et al. (1997); 30 – Pietsch et al. (1998); 31 – Wei et al. (1999); 32 – Gonçalves, Véron-Cetty & Véron (1999); 33 – White et al. (2000); 34 – 2000UZC...C......0F; 35 – Reichardt, Jimenez & Heavens (2001); 36 – Stepanian et al. (2002); 37 – Rossa et al. (2006); 38 Moustakas & Kennicutt (2006); 39 – Lira et al. (2007); 40 – Buttiglione et al. (2009); 41 – Stoklasová et al. (2009); 42 – Tsalmantza et al. (2009); 43 – Trippe et al. (2010); 44 – Gavazzi et al. (2013): 45 – Barth et al. (2015); 46 – Dopita et al. (2015); 47 – Schmidt et al. (2016); 48 – Ramos Almeida et al. (2016); 49 – Thomas et al. (2017); and 50 – Greenawalt, Walterbos & Braun (1997)

narrow lines (i.e. NGC 4135, NGC 6230, IC 1495 and Mrk 670). Thus, we did not undertake any spectroscopic follow up of AGNs on the basis of IR variability alone.

2.5 AGNs with 2 or more archival spectra

To measure the completeness of our colour and flux selection criteria, we inspected AGNs that have 2 or more archival spectra. Our main sources of spectra are WiFeS Siding Spring Southern Seyfert Spectroscopic Snapshot Survey (S7; Dopita et al. 2015), SDSS, 6dFGS and Ho et al. (1995). The date ranges for these spectra sources are as follows: S7 spectra were observed from 2013 to 2016, SDSS spectra were observed between 2000 and 2019 (where DR16 spectra were observed through 2019), 6dFGS spectra were observed from 2001 to 2009 and Ho et al. (1995) spectra were observed between 1984 and 1990. Of all the z <0.04 AGNs in our sample, 21 per cent do not have readily available spectra online and 52 per cent have only one available spectrum and 27 per cent have multiple archival spectra. As we are refining our CLAGN candidates by selecting candidates where the archival spectra already show some signs of change, there is the potential to miss CLAGNs where the spectra have changed after the last archival spectra was taken and this will decrease our completeness. Of the AGNs that were not identified by our CLAGN candidate selection methods and have multiple

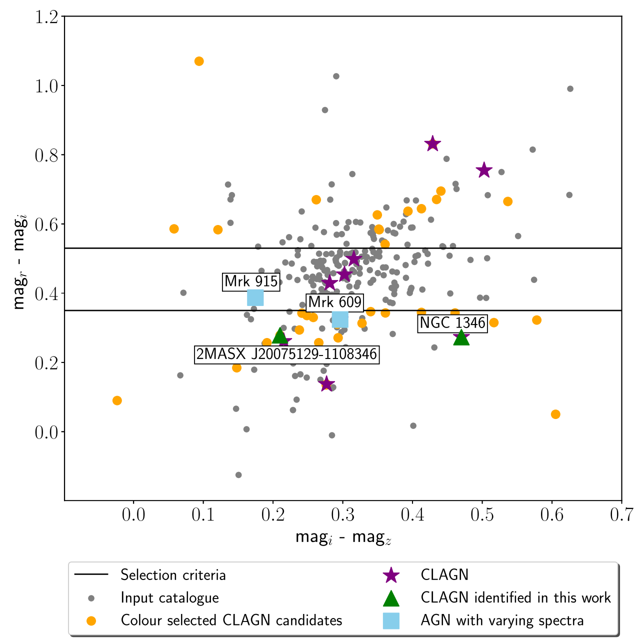

Figure 2. Skymapper *riz* colours for our CLAGN candidates with the other $z < 0.04$ AGNs displayed in the background. We select Véron-Cetty & Véron (2010) type 1s with $r - i > 0.53$ mag and type 2s with $r - i < 0.35$ mag as possible CLAGN candidates, these are indicated in orange.

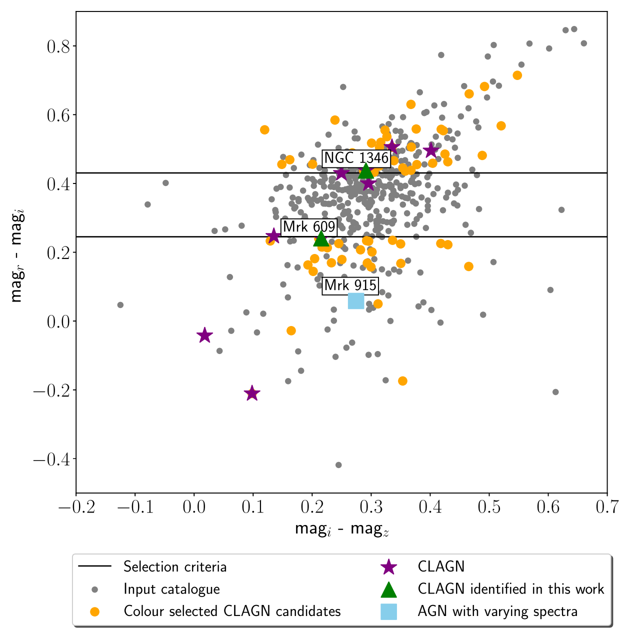

Figure 3. Pan-STARRS catalogue *riz* colours for our CLAGN candidates with the other $z < 0.04$ AGNs displayed in the background. We select Véron-Cetty & Véron (2010) type 1s with $r - i > 0.43$ mag and Véron-Cetty & Véron (2010) type 2, type 1.8, and type 1.9 with $r - i < 0.25$ mag as potential CLAGN candidates, these are indicated in orange.

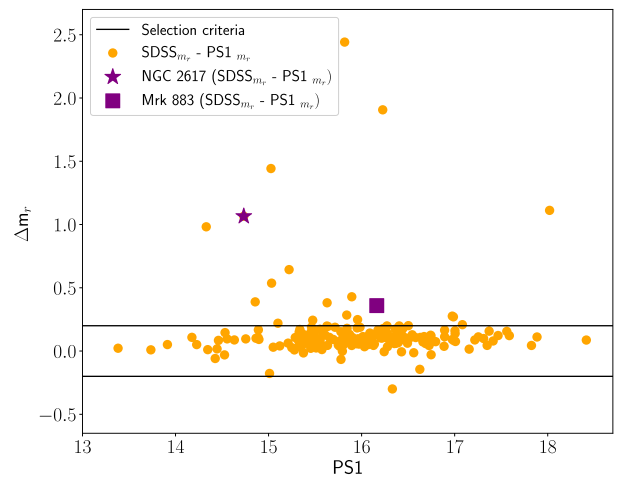

Figure 4. The *r*-band magnitude as a function of apparent magnitude for Véron-Cetty & Véron (2010) type 1.8s, type 1.9s, and type 2s, measured with SDSS and Pan-STARRS 3-arcsec aperture photometry. Known CLAGNs NGC 2617 and Mrk 883 are highlighted, NGC 2617 became 1 mag brighter in *r* band between the SDSS and Pan-STARRS imaging surveys.

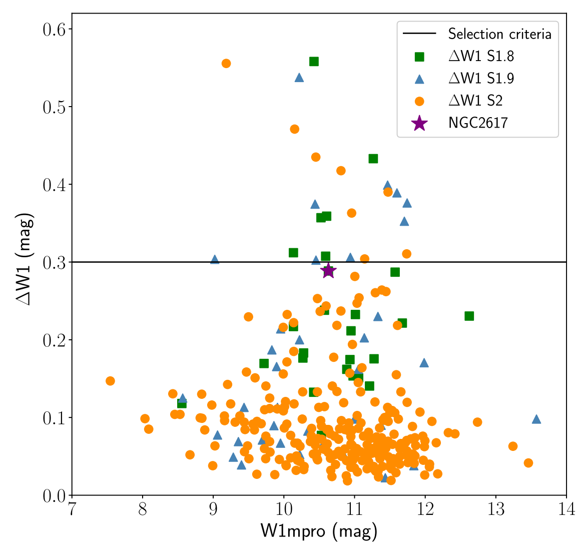

Figure 5. Change in NEOWISE W1 photometry as a function of W1 photometry. As type 1s vary at $\sim$3.5 μm without changing spectral type, we can only plot and draw CLAGN candidates from AGNs classes type 1.8s, 1.9s, and type 2.0s. The purple star is NGC 2617, a known CLAGN.

archival spectra, we identified AGNs that appeared to have some small variations in the spectra, however, these variations were not significant enough to require further investigation (i.e. changes in spectral class were 0.1 or less). Thus, while our three candidate selection criteria select many AGNs that are not CLAGNs, our selection criteria are not missing a large number of nearby CLAGNs.

3 SPECTROSCOPIC FOLLOW-UP

Once candidates were identified using the colour and flux criteria discussed in Sections 2.2–2.4, we inspected the archival spectra of these objects in order to identify potential CLAGNs without obtaining new spectra. It should be noted that we did not follow up candidates where archival spectra from the past two decades showed no variability (irrespective of the selection criteria).

We used the Wide Field Spectrograph (WiFeS, Dopita et al. 2010) integral field unit (IFU) on the Australian National University's 2.3-m telescope at Siding Spring to obtain new spectra of our candidates

Table 4. CLAGN candidates that were observed with WiFeS between 2018 July and 2019 March.

2MASX ID	Name	Redshift	Initial type	WiFeS classification	MJD
J03252538–0608380	Mrk 609	0.0345	1.9, 2	1.9	58375
J03301327–0532363[a]	NGC 1346	0.0135	1.8	2	58457
J05521140–0727222	NGC 2110	0.0078	1	1	58491
J08044636+1046363	UGC 04211	0.0344	1	1	58548
J08353877–0405172[b]	NGC 2617	0.0142	1.8	1	58491
J10445172+0635488	NGC 3362	0.0277	2	2	58491
J13254405–2950012	NGC 5135	0.0137	2	2	58549
J13311382–2524096	ESO 509-G 038	0.0260	1	1	58548
J13352457+0124376	NGC 5227	0.0175	2	2	58548
J15461637+0224558	NGC 5990	0.0128	2	2	58549
J20075129–1108346[a]		0.03	2	1.8	58308
J21141259+0210406	IC 1368	0.0130	2	2	58310
J21522605–0810248		0.0348	2	2	58375
J22590139–2531423	ESO 535-G 001	0.0303	2	2	58309
J22364648–1232426	Mrk 915	0.0241	2	1.9	58724

[a]New CLAGN that we have identified.
[b]Known CLAGN.

to confirm that they are indeed CLAGN. WiFeS has a field of view of 25 × 38 arcsec^2, divided into 950 spaxels. The advantage of using an IFU for follow-up observations of candidates is that extraction aperture size can be matched to previous observations (e.g. the 7-arcsec fibre of 6dF, Jones et al. 2009). The wavelength coverage is 3800–9200 Å, which spans the Hα, Hβ, and O III lines at $z < 0.04$, and we expect Hα to show the most clear signs of change in CLAGNs.

We observed in nod-and-shuffle mode taking at least three frames with 60s on object, 60s on sky, and 10 cycles per frame. This results in 40 min on object, 40 min on sky, and ∼15 min on overheads including telescope nod time, guide star re-acquisition and CCD readout. In total we allow ∼100 min per galaxy. Our observations were taken between 2018 July and 2019 March. We reduced our data with PyWiFeS, Python-based pipeline (Childress et al. 2014). We observed 15 CLAGN candidates over multiple observing sessions, the AGNs are presented in Table 4.

4 SPECTRAL VARIABILITY AND NEW CLAGNS

We next present the spectra of the new CLAGNs that we have identified using the selection criteria mentioned in Sections 2.2–2.4, where we compare archival spectra of the galaxies with spectra taken using WiFeS. We plot archival spectra, where available, with the spectra taken using WiFeS to display the change. Multiplicative scaling has been applied so that the continuum spectra agree, highlighting changes in the emission lines. We match apertures of the multiple spectra of the new CLAGNs and AGNs with varying spectra below (where possible). It should be noted, however, that the features in our observed WiFeS spectra displayed their respective broad-line and narrow-line features irrespective of the extraction aperture used.

4.1 2MASX J20075129–1108346

2MASX J20075129-1108346 was classified as a type 1.9 by Véron-Cetty & Véron (2010), however, it has SkyMapper $r - i < 0.35$ mag, which according to the optical colour selection criteria, we adopt in Section 2.2, suggests that the spectra of this AGN may have broadened. The 6dFGS spectrum in Fig. 6 is consistent with a type 2 as the spectra contain only narrow-line components. Our 2018 WiFeS spectrum shows broad-line components (irrespective of the extraction aperture used) and we classify it as a type 1.8. As 2MASX J20075129-1108346 changes from type 2 to type 1.8. This change meets our criteria for a CLAGN.

4.2 Mrk 609

Mrk 609 is classified by Véron-Cetty & Véron (2010) as a type 1.8 using the spectra from Rudy et al. (1988), but has $r - i < 0.35$ mag in SkyMapper, indicating according to our colour selection criteria that it may have broad-line components. Mrk 609 was one of the first Seyferts to be classified as an intermediate type. Mrk 609 was classified as a type 1.8 by Osterbrock (1981). Rudy et al. (1988) note that the spectral lines were inconsistent with a type 1 Seyfert, i.e. it lacks broad lines. Trippe et al. (2010) report small variability in Mrk 609 spectra. They note the absence of broad-line components in their observed spectra which they classified as type 2, although prior observations of Mrk 609, including Osterbrock (1981), note broad Hα components. As the Rudy et al. (1988) spectral classification is inconclusive, we use the SDSS and 6dFGS spectra in Fig. 7 as the baseline for determining whether Mrk 609 is changing spectral type. We classify the SDSS and 6dFGS spectra as type 1.9 and type 2, respectively, in accordance with the criteria outlined by Osterbrock (1981). Our WiFeS spectra are consistent with that of a type 1.9 and is similar to that of SDSS indicating that Mrk 609 changed spectral type between 2001 and 2018 to a type 2, and has returned to being a type 1.9. This small variation in spectra is not consistent with our CLAGN criterion, but additional spectroscopy may reveal further changes in the spectral class of Mrk 609.

4.3 Mrk 915

Mrk 915 was classified as a type 1.8 by Véron-Cetty & Véron (2010) using the Dahari & De Robertis (1988) spectrum, but has Pan-STARRS $r - i < 0.25$ mag. This colour, according to our Pan-STARRS colour selection criteria, suggests that the spectra of

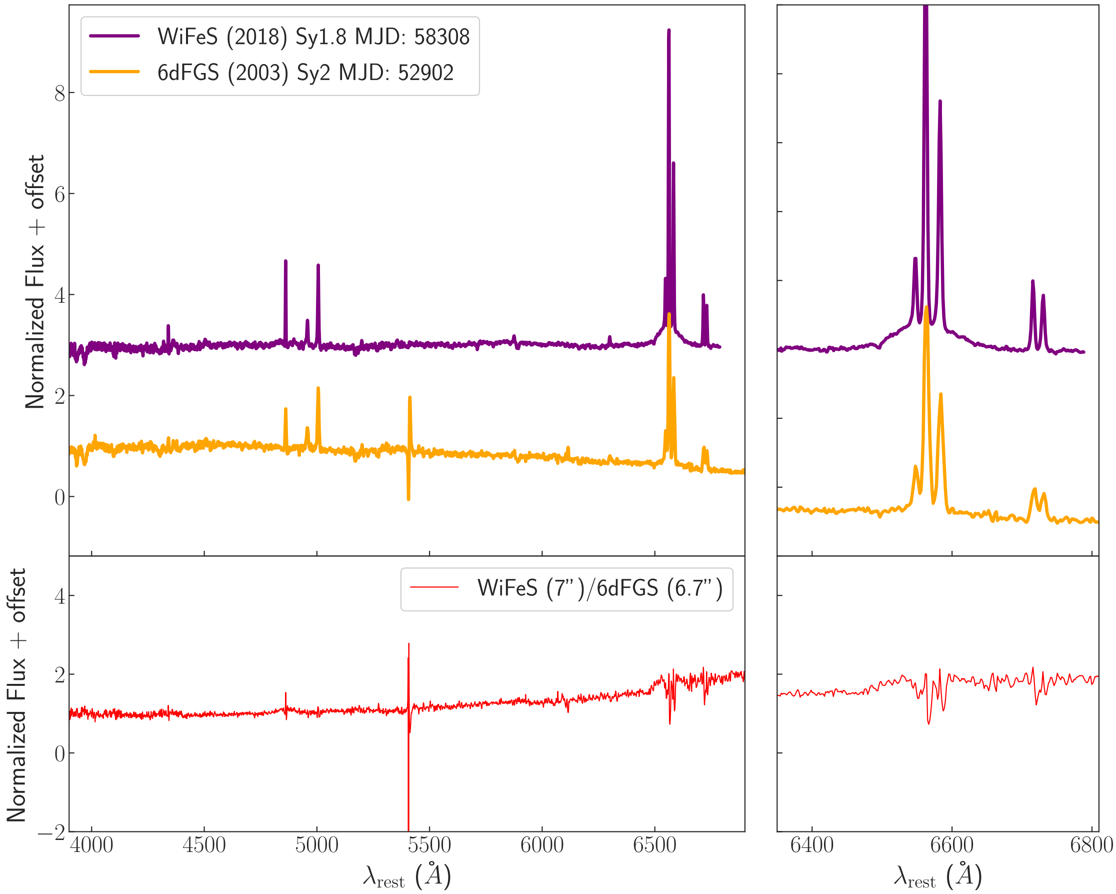

Figure 6. 2MASX J20075129-1108346 is a new CLAGN, which was a type 2 in the 6dFGS spectrum observed in 2003, and was determined to be a broad type 1.8 in the WiFeS spectrum taken in 2018. These classifications were made in accordance to the descriptions in Osterbrock (1981).

Mrk 915 has broadened. Goodrich (1995) first reported the varying spectrum of Mrk 915, with a narrowing of emission lines between 1984 to 1993. Giannuzzo & Stirpe (1996) also note a variation in the spectrum of Mrk 915, where they observed a broadening of the Hα line between 1993 and 1994. While the 1993 spectrum in Fig. 8 is of relatively poor quality, it does not show the broad-line component of subsequent spectra, and we conclude Mrk 915 as a type 2 Seyfert at the time. We classify the *BAT AGN Spectroscopic Survey* (BASS: Koss et al. 2017) spectrum as type 1.9; the 2019 WiFeS spectrum in Fig. 8 is also consistent with a type 1.9. The Hα line begins to broaden in the 2008 and 2010 spectrum (note: both spectra are from the same survey) and is broader still in the WiFeS 2019 spectrum. This variation in spectra from type 2 to type 1.9 does not meet our criteria for CLAGN. Although this may be the case, it is a good candidate CLAGN and further observations are needed.

4.4 NGC 1346

NGC 1346 is a newly discovered CLAGN. We identified NGC 1346 as a broad-line AGN with unusually red colours with the SDSS and Pan-STARRS photometry and we designated it as a CLAGN via visual inspection of spectra from SDSS, 6dFGS, and S7. NGC 1346 was classified as a Seyfert 1 galaxy by Véron-Cetty & Véron (2003) using the SDSS spectra in Fig. 9. We classify this spectrum as a type 1.8 according to the definitions outlined by Osterbrock (1981). The spectrum from SDSS (taken in 2001) showed a significant broad-line component, however, the 2004 December 6dFGS (Jones et al. 2009) spectrum contains only narrow emission lines. The S7 spectrum of NGC 1346 and the WiFeS 2018 spectrum showed only narrow lines. Therefore, NGC 1346 was a type 2 prior to 2004 and it changed spectral type between 2001 and 2004. We use IR photometry to investigate why this AGN is changing spectral type.

To determine if a varying hot dust component of NGC 1346 could be responsible for the change in spectral type, we use NEOWISE photometry and compared 2MASS photometry with recent targeted InfraRed Survey Facility (IRSF; Nagayama 2012) photometry. The NEOWISE photometry was taken between 2014 and 2018 with a cadence of 6 months, and was thus taken after the change in spectral type. We measure a change in NEOWISE photometry of 0.11 mag; this is not a significant change and is not considered high enough to suggest a change in spectral type. This is because the NEOWISE survey has data from 2014 onward, and as suggested by the spectra, NGC 1346 had already changed spectral types by then.

We find that NGC 1346 has faded by 0.82 mag in the K_s band between 1998 and 2018, where we measure photometry from 2MASS and IRSF, respectively. IR wavelength is sensitive to emission from warm dust attributed to the torus, as we measure a change in the IR photometry, this indicates that the change in spectral type we measure is a result of changes in the torus and not due to a simple obscuring cloud crossing the line of sight.

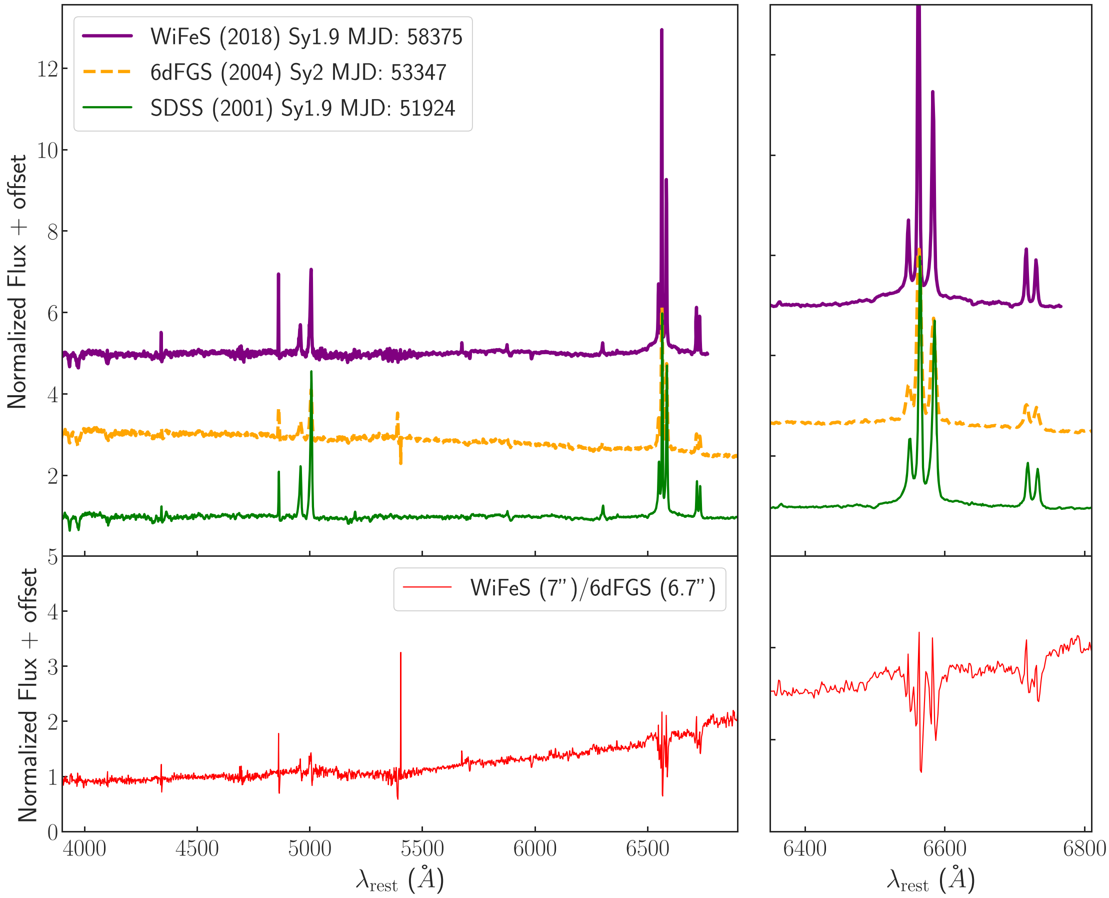

Figure 7. Mrk 609 has varying spectra and was identified using optical colour selection. The SDSS spectrum is consistent with a type 1.9 where the 6dFGS spectrum is completely narrow indicating it is a type 2. We classify Mrk 609 as type 1.9 using our WiFeS spectrum, and thus the changes in spectral class are insufficient to meet our CLAGN criterion.

5 CONCLUSIONS

We have conducted a systematic survey for CLAGNs by identifying candidates using optical and IR photometry from SkyMapper, Pan-STARRS, SDSS, and NEOWISE. Using SkyMapper, we select type 1s with $r - i > 0.53$ mag and type 2s with r-$i < 0.35$ mag and using Pan-STARRS we select type 1s with $r - i > 0.43$ mag and type 2s with $r - i < 0.25$ mag. We also select candidates with optical r-band flux where type 1.8s, 1.9s and type 2s had $\Delta m_r > 0.2$, and search for AGNs with variability in *WISE* W1(3.4 μm) (type 1.8s, 1.9s and type 2s where ΔW1 > 0.3 mag). Identifying candidates using optical colour selection provided the largest number of plausible candidates, with our new CLAGNs being selected in this manner. While this is the case, this selection criteria also produced the largest number of contaminants. The optical flux variability selection did not identify any new candidates, however, it identified NGC 2617 as a candidate, showing it is a plausible method to identify CLAGNs.

Using NEOWISE W1 (3.4 μm) photometry, we find majority of type 1s and type 2s have exhibited > 0.3 mag and < 0.3 mag, respectively, of variability during 2014–2018. While this allowed us to select type 2s displaying variability of > 0.3 mag as CLAGN candidates, in practice all of the candidates selected appear to be (on the basis of archival spectra) misclassified broad line AGN. Thus *WISE* W1 variability did not prove useful for identifying changing-look Seyferts, but it could work with cleaner input catalogues and it has been used to identify changing-look quasars (e.g. Guo et al. 2016; Ross et al. 2018; Stern et al. 2018).

Using our optical colour selection method we were able to identify four AGNs with varying spectra. 2MASX J20075129-110834 and NGC 1346 are new CLAGNs that were identified in this work using optical colour selection. Mrk 915 and Mrk 609 have varying spectra which do not meet our criteria for CLAGN and only have a small change from type 2 to type 1.9 and type 1.9 to type 2, respectively. These AGNs remain CLAGN candidates and additional followup spectroscopy may reveal further changes in their spectral types. 46 per cent of candidates selected using this method either did not have archival spectra at all, did not have archival spectra from the last 10 yr or only had one archival spectrum. Extrapolating this, we can estimate that we have only identified 54 per cent of possible CLAGNs in this sample due to lack of spectra. The optical colour selection method also only identifies ≈50 per cent of known CLAGN.

We note that as we refined our CLAGN candidates by selecting candidates where the archival spectra already showed signs of change, we may have missed CLAGNs that may have changed after the last archival spectra was taken and/or changed type relatively briefly (i.e. < 2 yr). To estimate the number of CLAGN candidates that could have changed spectral type rapidly or briefly, we need an estimate of the numbers of CLAGNs as a function of the time-scale of variability. 1ES 1927+654 ($z = 0.017$) is a CLAGN that changed from type 2 to type 1, where the change lasted for 11 months (Trakhtenbrot et al. 2019). For our candidates selected via optical and IR flux changes the variability is on time-scales of a decade to six months, respectively. Optical flux variability will miss CLAGNs that

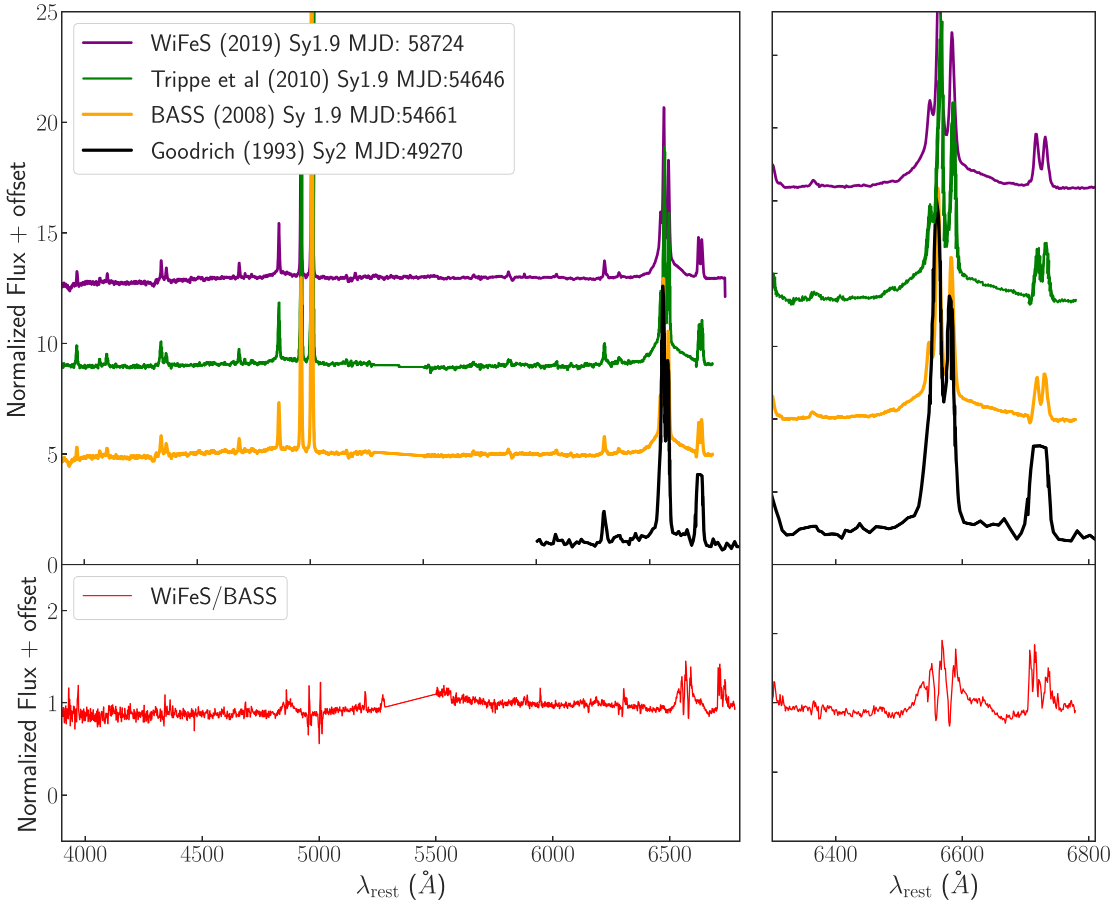

Figure 8. Mrk 915 is a varying AGN that was identified using optical colour selection. We classify the 1993 (Goodrich 1995) spectrum as a type 2 as it contains only narrow lines and the BASS 2008 spectrum is consistent with a type 1.9. The WiFeS 2019 spectra is that of a type 1.9. However, this change from type 2 to type 1.9 is not significant enough to meet out CLAGN criteria. Although this is the case, it is a good CLAGN candidate that will require further investigation.

vary only briefly from their usual state, and while NEOWISE has the cadence to detect such candidates the NEOWISE variability of 1ES 1927+654 remained < 0.2 mag (although the TDE produced $\sim$2 mags brightening in the optical) and thus it was not flagged as a WISE selected CLAGN candidate. We also note that clouds of dust moving across the line of sight may not significantly impact the NEOWISE photometry as this can occur on relatively short-time scales (Guo et al. 2016), thus this subclass of CLAGN could be underrepresented in our sample. As such we have a lower limit of $\approx$18 CLAGN as $z < 0.04$, which includes 2 new CLAGNS discovered in this work, 10 previously known CLAGNs that have varied between 1998 and 2015, and as many as 6 CLAGNs that missed our candidate selection methods or did not have archival spectra.

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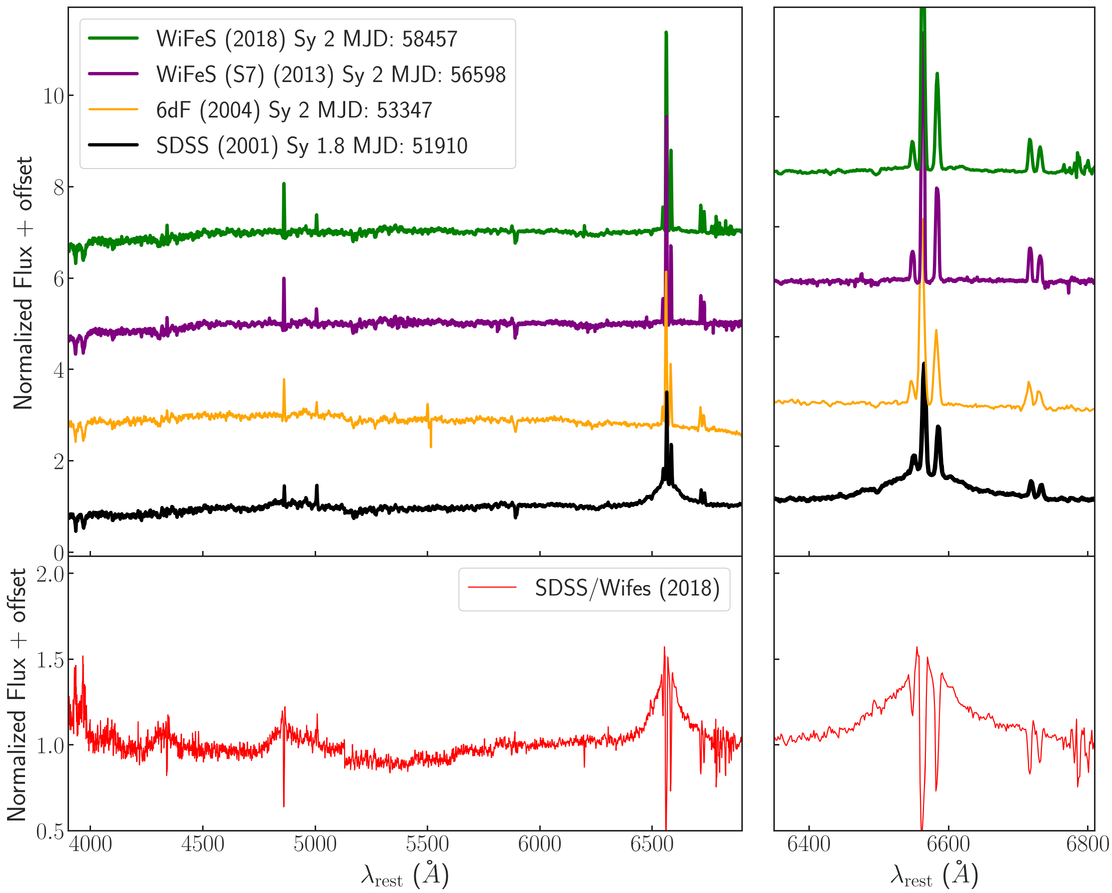

Figure 9. Spectra of CLAGN NGC 1346, with the SDSS spectrum revealing broad Hα consistent with a type 1.8, while subsequent archival 6dFGS and WiFeS spectra, and our new WiFeS spectra, indicate a Seyfert 2 (Senarath et al. 2019).

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DATA AVAILABILITY

The data underlying this paper are available in the paper and in its online supplementary material.

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