Literature Review on Changing-Looking Quasars(CLQs)

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October 27, 2020

Abstract

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1 Overview

Quasars are thought to be Active Galactic Nucleus(AGNs) at a stage where rapid accretion is on and the luminosity is extremely high. The quasar phases are relatively short in the life of AGNs, generally last 10^{7-8}years.

In previous study, AGNs have been observed to undergo spectra transition in X-ray binarys, which always show large changes in the X-ray absorption continuum. As a diffferent phenomenon, optical changing-looking AGNs are also observed, with characteristic large changes in Balmer broad line emissions(BLEs), showing the AGNs have transitioned from Type 1 to Type 1.8-2.0. With the discovery of Changing-looking quasar(CLQ) first by LaMassa et al.[1] from the SDSS Stripe 82X survey, this kind of AGN transition is extended to high luminosity and redshift regime.

In recent studies, CLQs are identified as Active Galactic Nuclei (AGN) with high luminosity $L_{bol} > 10^{44} erg\ s^{-1}$ that show strong variability in their optical/UV continuum and Broad Emission Line(BEL) flux, over rest-frame timescale $\sim$ 10years. Systematic search for CLQs in archival repeat spectra of quasars(Ruan et al.[3]) as well as follow-up spectroscopic search (Macleod et al.[2]) have revealed more CLQs and CLQ candidates. Macleod et al.[2] find a confirmation rate of CLQ among highly variable quasars of 20%.

2 Observational facts

Overall the CLQs have undergon a dramatic brightening or dimming in the light curve, accompanied by emerging or disappearing Balmer BELs. It's also observed that when dimming, if the Balmer BELs dim but still appear, their widths are broadened. A few CLQ examples are shown in Figure 1. We see an overall dimming in the continuum, as well as strong dimming in broad emission lines.

In most cases observed, CLQs dim rather than flare. The dimming type is also called "turn-off" type while the contrast is "turn-on" type. As an example, Wang et al. in [7] presented a turn-on CLQ transition, with non-detectable Hβ broad lines at early epoch but strong Balmer emission lines at later epoch.

In [2], the author studied whether the continuum change and BEL change are correlated. With limited sample sizes, it looks like the luminosity and flux change of the continuum at 3240A is proportional to those of Hβ, stronger Balmer line variability happens with stronger variation in continuum. Whether this tend holds for lager sample is to be studied. If that is confirmed, it means the spectral energy distribution keeps constant during the transition.

There are CLQ samples that show other behavior, such as strong variability in other elements' broad emission lines like He II, Fe II; flickering in the light curves; asymmetric broad Balmer lines, etc. These behavior may reveal interesting physical condition of the sources that are worth studying.

3 Physical Origin

The physical origin of CLQ variability is uncertain. Many efforts have been put on determining whether the CLQ variability is due to intrinsic or extrinsic origin. The instrinsic argument, especially changes in accretion rate or accrection disk structure appears to be more likely than extrinsic argument such as changes in obscuration.

3.1 Instrinsic? Dependence upon luminosity, black hole mass and the Eddington ratio

Wihlite et al. [5] and LaMassa et al.[1] both pointed out that their CL quasars, when dimming in broad line luminosity, the broad line widths are broadening such that the derived black hole masses are preserved. This phenomenon is consistent with change in the Eddington ratio.

The Eddington ratio is defined as L_{bol}/L_{Edd}. For variable quasars, it is well known that the amplitude of variability is anti-correlated to luminosity. An example is givin in [4] Figure 11. I put it here as Figure 2.

In [5] Wihlite et al studied repeat spectra of $\sim$ 8000 quasars from SDSS and derived their black hole masses, then studied the correlation between luminosity, variability and black hole masses. They reproduced the anti-correlation between luminosity and variability, , which is independent of the black hole masses. They also probed relation between variability and central black hole mass. Combined both, they pointed out that the Eddington ration is anti-correlated to the amplitude of optical variability further meaning the the Eddington ratio could be driving the quasar variability.

Although the physical process causing the variability is unknown, there is a damped random walk model that can explain the observed light curves of quasars pretty well, thus this model can be a nice tool. In [6] Macleod et al. applied this model on $\sim$9000 confirmed quasars in SDSS Stripe 82 and found correlations between some variability parameters and physical parameters. Their modelling once again confirmed the anti-correlation between variability and the Eddington ratio, once again supported the scenario that quasar optical variability is tied to accretion process.

Macleod et al. in [2] have confirmed the trend also in their CLQs that CLQs in general are at lower Eddington ratios than the control sample. This trend is consistent with the anti-correlation between Eddington ration and variability, favoring a instrinsic origin related to dramatic change in the accretion flow of the AGN.

In a word, many evidences shown that quasar variability might be driven by the Eddington ratio change, which in fact represents changes either in the accretion rate or in the accretion disk structure.

3.2 Extrinsic?

3.2.1 Dust extinction

LaMassa et al.[1] argue that obscuration by a dust cloud outside the Broad Line Region is unlikely, because the timescale for light to across the BLR is would be much longer than the observed transition timescale.

LaMassa et al.[1] and Ruan et al.[3] have both analyzed whether the extinction model could explain the variability. They dereddenned the decomposed quasar spectrum and fitted E(B-V) such that the dimming of the continuum could match the early epoch and found that the change by extinction could not reproduce observed spectrum in the Hα emission. Ruan et al.[3] also argue that the broadening of Hα component could not be explained by dust extinction, because that implies less emission from the outer part of BLR than from the inner part, which could not due to dust.

3.2.2 TDEs

Tidal Disruption Event(TDE) was suggested to be an explanation. Ruan et al.[3] ruled out this possibility for their CLQ samples by analyzing narrow emission lines. The oberseved narrow lines, if produced by TDE, it would take 10^{3-4} years for light to travel through the narrow line region, order of magnitude longer than the timescale of CLQ dimming or flaring. Also, the BPT diagram of the three CLQs in their paper showed they are AGN-like ionizing continuum, disfavoring a TDE scenario. The BPT diagram is shown in Figure3.

3.2.3 Other

Rumbaugh et al.[4] pointed out that the effect of orientation should not be the reason. Macleod et al. pointed out the samples in [2] lack foreground spectral features, their variability were unlikely to be due to lensing by foreground galaxies or micro-lensing by foreground stars.

4 Key questions

The changing-looking quasar phenomenon is quite a new area, awaiting more identified samples with more informative data as well as satisfying explanations for the nature of the variability. Here are some of the key issues to be solved.

1. There is no standard quantitative definition for CLQs. So far CLQs are mostly selected by searching in quasars with specific conditions, for example $\Delta g > 1$, then selected by visual inspection.
2. Are CLQs merely tail of some continuous distribution of quasar properties? Or are they standing out as a distinct population?
3. A satisfying explanation of the physical origin of CLQ transition is needed.
4. No good theoretical timescale can be applied to explain the observed CLQ transition timescale. The viscous timescale in the optical-emitting region of the disk is orders of magnitude longer than the observed CLQ transition timescale, while he dynamical time is too short. Whether the calculation of viscous timescale is wrong or a better timescale is needed is to be studied.
5. Multi-wavelength observations are needed, more samples of CLQ are needed, larger data set of repeat quasar spectroscopy is needed.
6. So far most CLQs are ”turn-off” CLQs, more ”turn-on” CLQs are needed.
7. Why the Mg II BEL is not showing as significant response to changes in continuum as the Balmer lines, as Mg II line is formed at a similar ionization energy as the Balmer lines?

5 Summary

Add your summary here.

References

[1] LaMassa et al. “The Discovery of the First Changing look quasar: New Insights into the Pjysics Phenomenology of AGN”. In: *ApJ* 800.144 (2015). DOI: `http://dx.doi.org/10.1088/0004-637X/800/2/144`.

[2] MacLeod et al. “Changing-look quasar candidates: first results from follow-up spectroscopy of highly optically variable quasars”. In: *ApJ* 874.1 (2019). DOI: `http://dx.doi.org/10.3847/1538-4357/ab05e2`.

[3] Ruan et al. “Towards an understanding of changing-look quasars: an archival spectroscopic search in SDSS”. In: *ApJ* 826.2 (2016). DOI: `http://dx.doi.org/10.3847/0004-637X/826/2/188`.

[4] Rumbaugh et al. “Extreme variability quasars from the Sloan Digital Sky Survey and the Dark Energy Survey”. In: *ApJ* 854.2 (2018).

[5] Wilhite et al. “On the variability of quasars: A link between Eddington ratio and optical variability”. In: *MNRAS* 383.1232 (2008).

[6] Chelsea Macleod et al. “Modeling the Time Variability of SDSS Stripe 82 Quasars as a Damped Random Walk”. In: *The Astrophysical Journal* 721 (Apr. 2010). DOI: `10.1088/0004-637X/721/2/1014`.

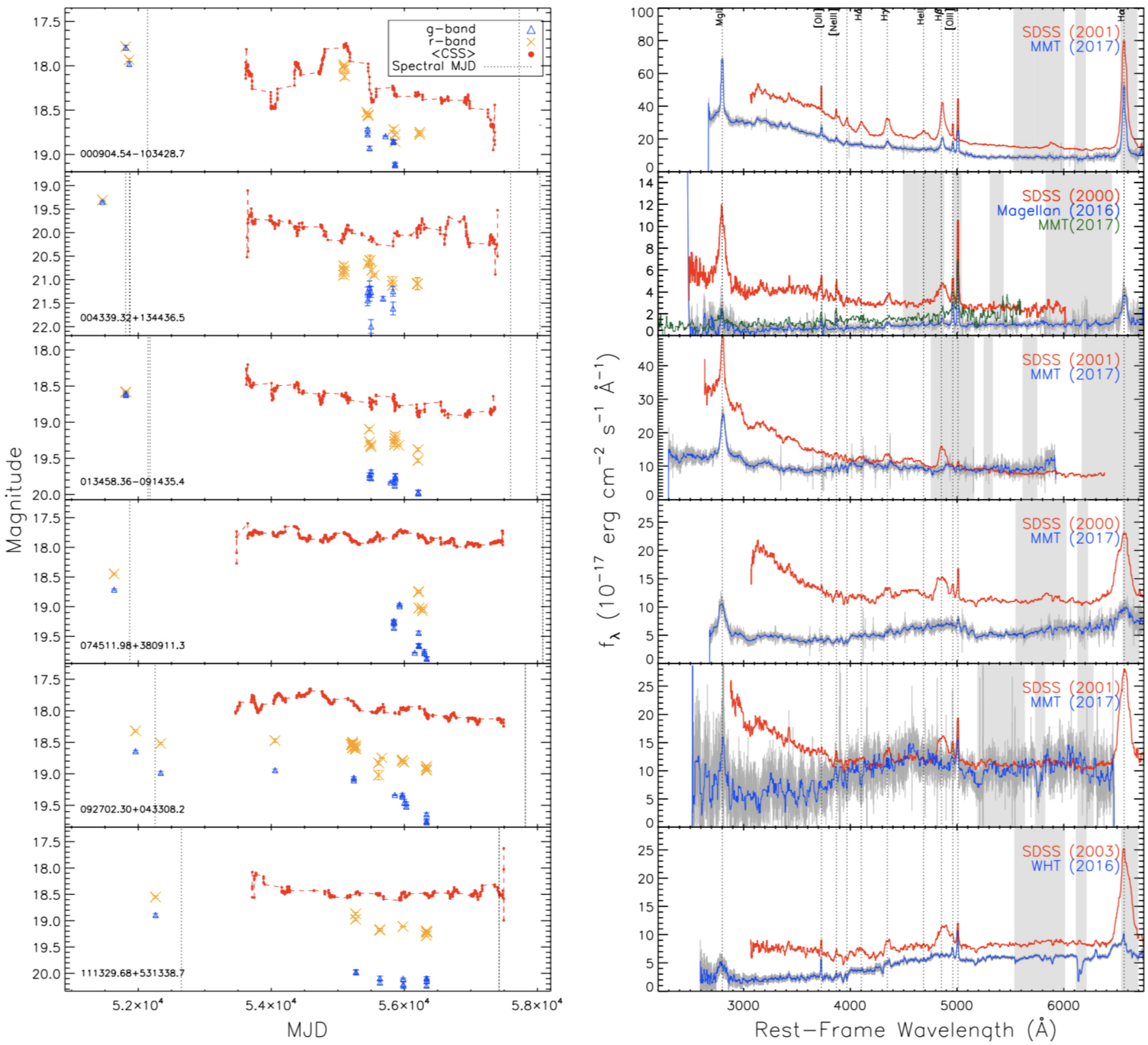

Fig. 2*a*

Figure 1: Left: variation of g-band magnitude with time. Right: Corresponding spectra at two epochs. The figure is from [2],Figure 2a.

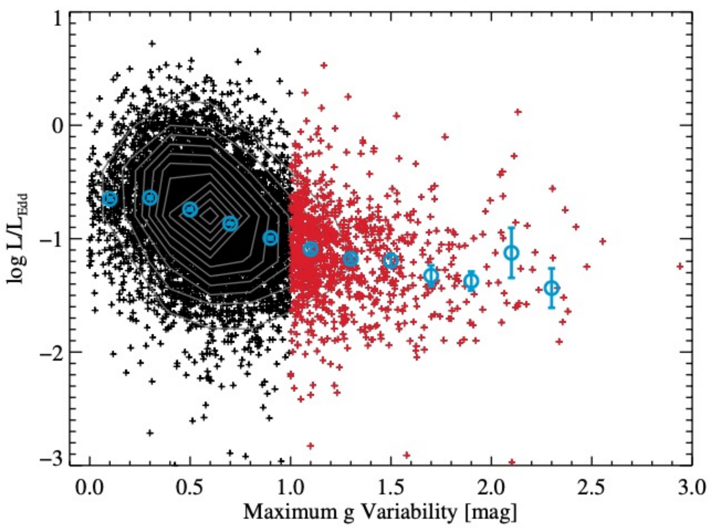

Figure 2: Anti-correlation between maixmum g-band variability and the Eddington ratio estimated from SDSS spectrum. A decreasing trend is observed.

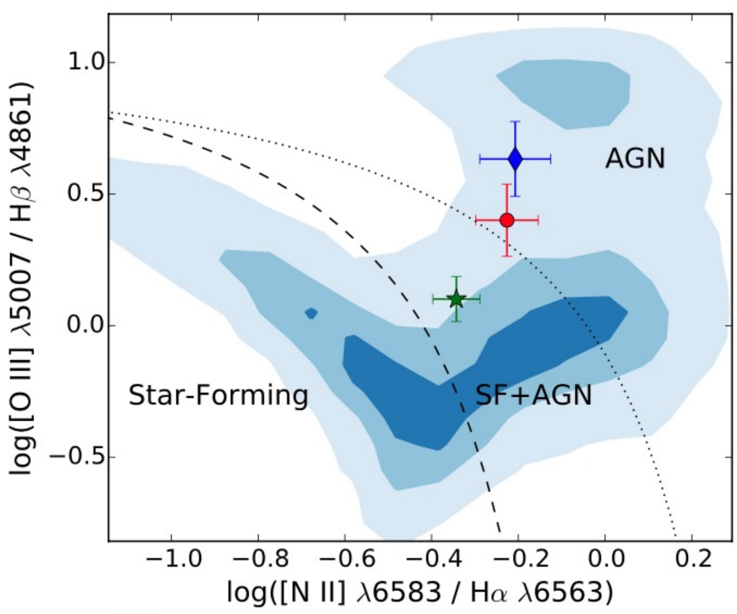

Figure 3: BTP diagram of the three CLQs in [3], showing the narrow emission lines of these CLQs are AGN-like, disfavoring TDE scenario

[7] J. Wang, D. Xu, and Jianyan Wei. "Identification of SDSS J141324.27+530527.0 as a New "Changing-look" Quasar with a "Turn-on" Transition". In: *The Astrophysical Journal* 858 (Mar. 2018). DOI: `10.3847/1538-4357/aab88b`.