ANALYSES OF THE VARIABILITY ASYMMETRY OF KEPLER AGNs

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ABSTRACT

The high-quality light curves from the Kepler space telescope make it possible to analyze the optical variability of active galactic nuclei (AGNs) with unprecedented time resolution. Studying the asymmetry in variations could provide independent constraints on physical models for AGN variability. In this paper, we use Kepler observations of 19 sources to perform analyses of the variability asymmetry of AGNs. We apply smoothing correction to light curves to deduct their bias toward high-frequency variability asymmetry caused by long-term variations that have been poorly sampled due to the limited length of light curves. A parameter β based on structure functions is introduced to quantitively describe the asymmetry and its uncertainty is measured using extensive Monte Carlo simulations. Individual sources show no evidence of asymmetry at timescales of 1 ~ 20 days and there is no general trend toward positive or negative asymmetry over the whole sample. Stacking the data from all 19 AGNs, we derive an averaged $\beta$ of $0.00 \pm 0.03$ and $-0.02 \pm 0.04$ over timescales of 1 ~ 5 days and 5 ~ 20 days, respectively, which are statistically consistent with zero. Quasars and Seyfert galaxies show similar asymmetry parameters. Our results indicate that short-term optical variations in AGNs are highly symmetric.

Key words: accretion, accretion disks – galaxies: active – galaxies: Seyfert – quasars: general

1. INTRODUCTION

Aperiodic optical/ultraviolet variability is a significant property of active galactic nuclei (AGNs), but its physical origin is still unclear. Variability asymmetry describes whether a light curve favors the shape of rapid rise and gradual decay, i.e., positive asymmetry, or the shape of gradual rise and rapid decay, i.e., negative asymmetry. There are only a few observational/theoretical works in the literature which study the variability asymmetry of AGNs. Kawaguchi et al. (1998) introduced a structure function approach to estimate the variability asymmetry of AGN light curves. They adopted two structure functions, i.e., $S_{\text{dir}}(\tau)$ and $S_{\text{inc}}(\tau)$, which only include pair epochs with increasing and decreasing flux, respectively. They also discussed possible physical models that could produce asymmetry in variations. Through Monte Carlo simulations, Kawaguchi et al. (1998) showed that the disk instability model produces $S_{\text{dir}}(\tau) < S_{\text{inc}}(\tau)$ or negative asymmetry, while the starburst model, which attributes the optical variations to the random superposition of supernovae in the nuclear starburst region, yields a contrary asymmetry, i.e., $S_{\text{dir}}(\tau) > S_{\text{inc}}(\tau)$. Shortly thereafter, Hawkins (2002) added that the micro-lensing model statistically predicts $S_{\text{dir}}(\tau) = S_{\text{inc}}(\tau)$ or no asymmetry.

Observationally, Hawkins (2002) tested the three aforementioned models using the long-term optical light curves of 401 quasars and 45 Seyfert galaxies. They found that the Seyfert galaxy NGC 5548 displays negative asymmetric variations on timescales of $10 \sim 70$ days, while for quasars the variations are symmetric on timescales of a year or longer. de Vries et al. (2005) studied the long-term variations of a large sample of 41,391 quasars with SDSS and historic photometry, and showed that on timescales of years the quasar variations demonstrate positive asymmetry. Bauer et al. (2009) analyzed the optical variability of nearly 23,000 quasars in the Palomar-QUEST Survey and found no evidence of any asymmetry in variability over $\sim 10$ days to several years. Voevodkin (2011) computed the structure functions for 7562 quasars from SDSS Stripe 82 and detected significant negative asymmetry on timescales longer than 300 days. All of the above analyses were based on the structure function method introduced by Kawaguchi et al. (1998). Meanwhile, Giveon et al. (1999) used a different method to calculate the difference between the medians of the brightening phases and fading phases in the light curves of 42 PG quasars and reported a negative asymmetry in the variations. In summary, negative asymmetry is favored by more studies, but inconsistencies exist among the few observational studies in the literature.

The Kepler space telescope was designed to search for exoplanets (Borucki et al. 2010) and could produce nearly continuous optical light curves for targets within its field of view, including AGNs. There are several works in the literature which report high-frequency variability analyses of Kepler AGNs. Mushotzky et al. (2011) calculated the power spectral density (PSD) functions for four Seyfert 1 galaxies in the Kepler field and obtained best-fit PSD power-law slopes of $-2.6 \sim -3.3$, which are considerably steeper than those of quasars at timescales of months to years which could be described by the damped random walk process (e.g., Kelly et al. 2009). Complemented by ground-based observations, Carini & Ryle (2012) presented a further analysis of the Kepler light curve of Zw 229-15. Wehrle et al. (2013) and Revalski et al. (2013) reported four radio-loud Kepler AGNs and calculated their PSD functions using light curves stitched by a normalization method. Edelson et al. (2013) reported the variability analyses of a BL Lac object, i.e., W2R 1926+42, in the Kepler field.

Meanwhile, the Kepler data provide the first ever opportunity to study the short-term variability asymmetry of AGNs, which is the aim of this work. We describe the adopted Kepler AGN sample and light curve stitching process in Section 2. The methods of asymmetry analysis and smoothing correction are introduced in Section 3. In Section 4, we report our major results. A discussion is provided in Section 5 and we present our conclusions in Section 6.
2. DATA REDUCTION

2.1. Kepler AGN Sources

There are only a few cataloged AGNs in Kepler’s field of view. The 19 AGNs we used in this work (listed in Table 1) are collected from the literature (Mushotzky et al. 2011; Edelson et al. 2012; Wehrle et al. 2013). Following Hawkins (2002), we divide the AGNs into two subsamples, including nine quasars with $M_f < -23.6$ and nine Seyfert galaxies with $M_f > -23.6$. The rest source (W2R 1926+42) in Table 1 is a BL Lac object.

We adopt the SAP FLUX in the Kepler light curve files since PDCSAP FLUX (calibrated for systematic effects, e.g., pointing and focus changes) may have masked out the intrinsic AGN variations (Carini & Ryle 2012).

2.2. Stitching Light Curves

As a result of the differential velocity aberration effect of the Kepler telescope, the target flux is continuously redistributed among neighboring pixels, appearing as artificial long-term variations in the electron counts within the fixed optimal aperture and discontinuous light curves between adjacent quarters (Van Cleve & Caldwell 2009; Kinemuchi et al. 2012). Carini & Ryle (2012) rescaled the Kepler light curves with coordinated ground-based observations to connect different quarters, however, this is not a generally used approach. Kinemuchi et al. (2012) provided another method which increases the number of pixels in the target mask for photometry using the PyKE tasks kepmask and kepextract. Using the reset target mask, a new light curve can be extracted from the counterpart target pixel file. The latter method could reduce the target flux losses out of the aperture, but it might also cause contamination from nearby sources.

Following Kinemuchi et al. (2012), we perform the pixel re-extraction process as illustrated in Figure 1. Since not all of the sources have enough observational quarters and since clear surroundings and, during the process, sufficient “halo” pixels surrounding the target are needed, only four sources, i.e., Zw 229-15, W2 1925+50, W2R 1904+37, and CGRaBS J1918 +4937, can be stitched. The results are shown in Section 4.1.

3. ANALYSIS METHODS

3.1. Structure Function and Asymmetry Parameter

The general definition of the structure function and its properties were provided by Simonetti et al. (1985). The first-order structure function $SF(\tau)$ is defined as

\[
SF^2(\tau) = \frac{1}{N(\tau)} \sum_{\tau} [f(t+\tau) - f(\tau)]^2, \tag{1}
\]

where $N(\tau)$ is the number of data pairs for a certain time lag $\tau$, and $f$ is the observed source flux. To quantify variability asymmetry, an asymmetry parameter $\beta(\tau)$ is defined as (see Kawaguchi et al. 1998)

\[
\beta(\tau) = \frac{SF_{ic}(\tau) - SF_{dc}(\tau)}{SF_{ic}(\tau)}, \tag{2}
\]

where the subscripts “ic” and “dc” denote data pairs with increasing and decreasing flux, respectively, and “tot” stands for the total data pairs. $\beta(\tau)$ quantifies the normalized difference between the increasing and decreasing variability. A positive $\beta(\tau)$ indicates that the light curve favors a rapid rise and gradual decay, i.e., positive asymmetry, while a negative $\beta(\tau)$ characterizes the opposite situation.

3.2. Smoothing Correction

Since the light curves have limited durations, the long-term variations are poorly sampled and will yield a large, unphysical scatter in the measurement of the asymmetry parameter. In other words, for individual light curves, asymmetry analyses could only be performed for short-term variations (the ratio of the duration of the light curve to the concerned timescale of variations $\gg 1$) which have been well sampled. Furthermore, the long-term trend in the light curves could also introduce biases into the short-term asymmetry analyses. Such an effect can be reduced by using smoothing correction method, in which the corrected light curve is produced by the inverse Fourier transform of the power spectrum with the low-frequency portion set to zero. The cutoff frequency in the power spectrum is set to $2 \times 10^{-4}$ Hz, which corresponds to about 60 days and is shorter than the duration of the light curves for each quarter of all the sources. An example is illustrated in Figure 2 and Section 4 presents the results of our asymmetry analysis for both the original and the smoothing-corrected light curves.

3.3. Uncertainty Estimation

Estimating the uncertainties in $SF(\tau)$ and $\beta(\tau)$ is not straightforward (see Emmanoulopoulos et al. 2010). The $\{f(t+\tau) - f(\tau)\}$ series (in Equation (1)) of a single light curve are not mutually independent, and thus the uncertainties in $SF(\tau)$ and $\beta(\tau)$ at a given $\tau$ would be significantly underestimated using the standard deviation definition. Furthermore, the values of $SF(\tau)$ and $\beta(\tau)$ at different timescales $\tau$ are not independent either. Therefore, following Emmanoulopoulos et al. (2010), we estimate the uncertainties through extensive Monte Carlo simulations.

We adopt the algorithm from Timmer & Koenig (1995) to generate artificial light curves for a given power spectrum. In order to have the simulated light curves possess a power spectrum shape and noise level similar to those observed, we use the original periodogram, calculated from the original observed (and not the smoothing-corrected) light curves, as the input spectrum, instead of using the power spectrum with a specific fixed power-law slope. The observed light curve is end-matched before the periodogram calculation to reduce the contamination caused by the mismatch between the beginning and end points (e.g., Mushotzky et al. 2011; Wehrle et al. 2013; Edelson et al. 2014). To simulate the effect of a red noise leak in the short light curves, the artificial light curves should be made much longer than the observed ones by

\[2\]

\[\text{Without end-matching, the high-frequency components of the power spectrum will be spuriously enhanced, and then the spectrum slope will be flatter than in reality (Fougere 1985; González-Martín & Vaughan 2012). The simulated light curves, based on such an input power spectrum, will be significantly biased against the observed one. Note that in this work the end-matching was only adopted to calculate the power spectrum. No end-matching is performed for calculations of structure function and asymmetry parameter.}\]
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Table 1
The Time Mean $\bar{R}$ of All AGNs

| Source Name | Kepler ID | R.A.        | Decl.   | $z$     | $n(q)^d$ | Original $\bar{R}_{1.5}$ | Smoothing-corrected $\bar{R}_{1.5}$ | Type |
|-------------|-----------|-------------|---------|---------|----------|--------------------------|-------------------------------------|------|
| Zw 229-15‘a | 6932990   | 19 05 26.0  | +42 27 40 | 0.028  | 13       | -0.04 ± 0.07             | -0.10 ± 0.11                        | Sy1  |
| W2R 1925+50‘a | 12158940  | 19 25 02.2  | +50 43 14 | 0.067  | 11       | -0.04 ± 0.10             | -0.04 ± 0.12                        | Sy1  |
| W2R 1856+48  | 11178007  | 18 56 01.1  | +48 50 23 | 0.079  | 8        | -0.23 ± 0.09             | -0.24 ± 0.12                        | Sy1  |
| W2R 1904+37‘a | 2694186   | 19 04 58.7  | +37 55 41 | 0.089  | 10       | -0.03 ± 0.08             | -0.09 ± 0.13                        | Sy1  |
| W2R 1914+42  | 6595745   | 19 14 15.5  | +42 04 59 | 0.502  | 6        | -0.03 ± 0.08             | -0.06 ± 0.15                        | QSO‘b |
| W2R 1920+38  | 3337670   | 19 20 47.7  | +38 26 36 | 0.368  | 6        | -0.10 ± 0.10             | -0.18 ± 0.17                        | QSO‘b,c|
| W2R 1931+43  | 7610713   | 19 31 12.5  | +31 13 27 | 0.439  | 7        | -0.00 ± 0.12             | -0.00 ± 0.18                        | QSO‘c |
| W2R 1910+38  | 2837332   | 19 10 02.5  | +30 00 09 | 0.130  | 6        | -0.04 ± 0.10             | -0.08 ± 0.16                        | Sy1  |
| W2R 1853+40  | 5597763   | 18 53 19.2  | +40 53 36 | 0.625  | 5        | -0.01 ± 0.12             | -0.07 ± 0.19                        | QSO‘b |
| W2R 1845+48  | 10841941  | 18 45 59.5  | +48 16 47 | 0.152  | 6        | -0.05 ± 0.08             | -0.11 ± 0.15                        | QSO‘b |
| W2R 1931+38  | 3347632   | 19 31 15.4  | +38 28 17 | 0.158  | 6        | -0.11 ± 0.11             | -0.02 ± 0.17                        | Sy1  |
| W2R 1926+42  | 6690887   | 19 26 31.0  | +42 09 59 | 0.154  | 6        | -0.00 ± 0.04             | -0.03 ± 0.07                        | QSO‘c |
| KA 1915+41   | 5781475   | 19 15 09.1  | +41 02 39 | 0.220  | 3        | -0.27 ± 0.20             | -0.37 ± 0.28                        | QSO‘c |
| KA 1922+45   | 9215110   | 19 22 11.2  | +45 38 06 | 0.115  | 7        | -0.07 ± 0.06             | -0.09 ± 0.11                        | Sy1 9 |
| IRXS J192949.7+462231 | 9650715 | 19 29 50.5  | +46 22 24 | 0.127  | 4        | -0.10 ± 0.16             | -0.14 ± 0.21                        | Sy1  |
| MG4 J192325.4+4754 | 10663134 | 19 23 27.2  | +47 54 17 | 1.520 | 11       | -0.01 ± 0.04             | -0.06 ± 0.09                        | QSO  |
| MG4 J190945.4+4833 | 11021406 | 19 09 46.5  | +48 34 32 | 0.513  | 8        | -0.15 ± 0.05             | -0.32 ± 0.11                        | QSO  |
| CGRaBS J1918+4937‘a | 11606854 | 19 18 45.6  | +49 37 55 | 0.926  | 11       | -0.04 ± 0.06             | -0.14 ± 0.11                        | QSO  |
| [889] 1924+507 | 12208602 | 19 26 06.3  | +50 52 57 | 1.098  | 11       | -0.15 ± 0.03             | -0.35 ± 0.08                        | Sy1 5 |

‘a The four AGNs have stitched light curves which are analyzed in Section 4.1.
‘b The eight AGNs are classified as QSOs or Seyfert galaxies according to their $M_J$.
‘c Edelson et al. (2013) classified W2R 1931+43 as a Seyfert 1 galaxy.
‘d The column shows number of observational quarters for each Kepler AGN (the same in Table 2).
Figure 1. Original and stitched light curves with a bin size of 30 minutes (hereafter the same) of Zw 229-15. Vertical axis denotes the flux (count rate). The original data are shown in red, while the re-extracted light curves are shown in yellow, green, blue, and pink. Four reset target masks are adopted (plotted with different colors in the light curves) and duplicated for four quarters in each year. The four masks are shown at the bottom for demonstration.

Figure 2. Example showing the smoothing correction applied to the tenth quarter of Zw 229-15. The left two panels show light curves with the vertical axis denoting the flux (count rate), where the original (gray) and smoothing-corrected high-frequency (red) light curves are shown in the upper and lower panels, respectively. The low-frequency curve (green) in the upper left panel is the difference between the original and the high-frequency curves. The right two panels show the corresponding structure functions. $\tau_{SF}\text{tot}$ is shown in gray. Strong positive asymmetry, i.e., $\tau_{SFic} > \tau_{SFdc}$, is visible at timescales above a couple of days in the original light curve. Weak positive asymmetry is also visible at shorter timescales in the original structure function (upper right panel), but disappears after smoothing correction (lower right panel).
extending the input power spectrum to lower frequencies (e.g., Uttley et al. 2002; Vaughan et al. 2003; Emmanoulopoulos et al. 2010). We fit the low-frequency part of the original power spectrum to measure the low-frequency extending slope. If the best-fit slope is steeper than −2, then we adopt a fixed value of −2 as seen in the observed (lower frequency compared with Kepler) power spectrum of quasars (e.g., Kelly et al. 2009).  

For each observed Kepler light curve, we generate a single, 3000 times longer light curve, which is then split into 3000 segments. We then randomly select 1000 of these segments to calculate the corresponding SF(τ) and β(τ), following exactly the same procedures as we applied to the observed light curves, and we then take their scatters as the uncertainties of the observed SF(τ) and β(τ), respectively. Note that during the simulations, it has been assumed that the variations are intrinsically symmetric, and thus the output mean of the simulated β(τ) equals zero, and its scatter represents the uncertainty of the observed β(τ) if not severely different from zero.

4. VARIABILITY ASYMMETRY RESULTS

4.1. Results of Quarterly Stitched Light Curves

In this section, we present the results from our asymmetry analysis of the stitched light curves constructed for the four sources listed in Section 2.2 (i.e., Zw 229-15, W2 1925+50, W2R 1904+37, and CGRaBS J1918+4937). The stitched light curve of Zw 229-15, spanning ∼3.3 years with a time resolution of 30 minutes, is presented in Figure 3. Zw 229-15 is a narrow-line Seyfert 1 galaxy observed by Kepler over 13 quarters (Q4 ~ Q16, the most among Kepler AGNs).

Figure 4 shows the structure functions of both the original and smoothing-corrected light curves of Zw 229-15. The original SF(τ) shows a rise toward longer timescales with a gradually decreasing slope. At timescales above 200 days, SF_{ic}(τ) is significantly larger than SF_{dc}(τ), consistent with the general increasing trend in the original light curve. At very short timescales, SF(τ) reaches a plateau due to the photometric uncertainty of the light curve with a value of √2σ_{m}, where σ_{m} is the photometric uncertainty. On the long-term end, SF(τ) converges to √2σ_{l}, where σ_{l} is the standard deviation of whole light curve. As a result of the smoothing correction, the corrected SF(τ) becomes remarkably flat at long timescales and equals √2σ_{l} at timescales longer than ∼20 days, which appears as an “ideal” SF(τ) where the related light curve is long enough that edge effects and aliasing are negligible (Hughes et al. 1992). From the smoothing-corrected SF(τ), we see no clear asymmetry in the variations.

We plot the β(τ) curves for both light curves in Figure 5. The original β(τ) curve has a positive excess at long timescales, while the smoothing-corrected β(τ) curve appears approximately with |β(τ)| < 0.1 at the whole range. The β(τ) curves of the other three stitched sources are shown in Figure 6, all of which appear similar to Zw 229-15, and we find no evidence of asymmetry after smoothing correction.

4.2. Averaged Asymmetry Parameter of the Sample

We have analyzed 19 Kepler AGNs, each of which has 3 ~ 13 observational quarters. For each AGN, we derive the β(τ) curve for each observational quarter, and average them to get $\bar{\beta}(τ)$ for each source. There is an alternative process, in which we first average the structure functions of the different quarters and then derive $\bar{\beta}(τ)$ from SF(τ) with Equation (2).
However, in the second approach, the averaged asymmetry could be dominated by those quarter(s) with larger variation amplitudes, while with the first method the asymmetry parameter is simply averaged over time. For the same reason, no weight is introduced during averaging.

The mean $\beta$ over timescales of $1 \sim 5$ days and $5 \sim 20$ days are also derived and listed in Table 1. The uncertainties of $\bar{\beta}_{1-5}$ and $\bar{\beta}_{12-20}$ for individual sources are also calculated through simulations. Again, after smoothing correction, most of the sources show very small asymmetry parameters (both positive and negative values are seen with $|\beta| < 0.1$), consistent with zero within the statistical uncertainties. For the whole sample there is no general trend toward positive or negative asymmetry. This indicates that there is no, or at most very weak, variability asymmetry in Kepler AGNs.

To derive a better constraint on the asymmetry parameter, we average $\beta(\tau)$ from all quarters of all sources. The uncertainties in $\bar{\beta}(\tau)$ are also derived from simulations. The co-added $\bar{\beta}(\tau)$ averaged over all of the sources and its uncertainty are plotted in Figure 7. There is little difference between the original and smoothing-corrected $\bar{\beta}(\tau)$ curves in Figure 7, which implies that the bias due to long-term variations with limited duration of the light curves has been extensively reduced after averaging a large number (145) of quarters. However, we note that the smoothing-corrected co-added $\bar{\beta}(\tau)$ has considerably smaller scatter (Figure 7), as the scatter due to long-term variations has been reduced.

The $\bar{\beta}(\tau)$ averaged over timescales of $1 \sim 5$ days and $5 \sim 20$ days of the whole sample and two subsamples (quasars and Seyfert galaxies) are listed in Table 2. We see that the values of the co-added $\bar{\beta}(\tau)$ on timescales of $1 \sim 20$ days are all consistent with zero within the small statistical uncertainties (again derived with simulations), suggesting that the variations are highly symmetric.

5. DISCUSSION

Using all of the *Kepler* light curves of 19 AGNs, we find that the variability asymmetry on timescales of $1 \sim 20$ days is rather weak. The averaged $\bar{\beta}$ is $0.00 \pm 0.03$ and $-0.02 \pm 0.04$ over timescales of $1 \sim 5$ days and $5 \sim 20$ days, respectively, which is statistically consistent with zero.

It is convenient to interpret the asymmetry parameter in terms of a shot-noise model in which the variations in the AGNs are attributed to the stochastic superposition of independent discrete flares (e.g., Negoro et al. 1995). Such a model provides a mathematical framework for a series of physical models (Cid Fernandes et al. 2000; Favre et al. 2005), including starburst and micro-lensing (Kawaguchi et al. 1998; Hawkins 2002). Generally, a positive asymmetry parameter $\beta$ indicates that the flare rises rapidly and decays gradually, such as expected is in the starburst model which attributes the variations in AGNs to the random superpositioning of

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4 Since there is a large number (145) of *Kepler* quarters (real data), we can measure the intrinsic scatter of $\beta(\tau)$ from different quarters and derive the uncertainties in the averaged $\bar{\beta}(\tau)$. The uncertainties in $\bar{\beta}(\tau)$ derived with this approach are slightly smaller than those from simulations, by a factor of $1.5 \sim 2.0$. In this work, we adopt the more conservative measurements from simulations. Nevertheless, our conclusions are not affected by the selection.
supernovae in the nuclear starburst region. Clearly, our detection of highly symmetric variations in Kepler AGNs does not favor the starburst model. The micro-lensing model does not predict symmetric variations (Hawkins 2002), however, for our low-redshift sample, the probability of micro-lensing would be insignificant (Hawkins 2002). Actually, independent of variability asymmetry studies, these two models (starburst and micro-lensing) are disfavored by observations which show that variations in the emission lines in AGNs closely correlate with but lag continuum variations (e.g., Peterson et al. 2004).

In the disk instability (hereafter DI) model of Kawaguchi et al. (1998), optical variability is ascribed to instabilities of the accretion disk as matter flows, and the asymmetry is due to single large-scale avalanches. By considering a disk atmosphere emitting a power-law X-ray spectrum that fluctuates in time and assuming optical variations simply follows X-ray with little delay. Kawaguchi et al. (1998) made Monte Carlo simulations adopting the cellular-automaton model of Mineshige et al. (1994) and treated the atmosphere as an advection-dominated accretion flow. The simulated light curve shows a negative asymmetry with slow rise and rapid decline on timescales of one to several hundred days. As simulated by Kawaguchi et al. (1998), in the DI model, \( \beta(\tau) = -0.1 \) corresponds approximately to the ratio of the diffusion mass to infall mass of 0.1 \( \sim 0.5 \) (see their Figure 7) with the ratio of the outer to inner disk radii fixed at 20. Our strong constraints on the asymmetry parameter from the co-added sample therefore request an even higher ratio of diffusion mass to infall mass based on this model.

Theoretical calculations on the variability asymmetry parameter for more specific physical models are required to perform a comparison with observations. Nevertheless, the result of this work indicates that the variations in AGNs rise and decay highly symmetrically. If we attribute AGN variations to perturbations in the accretion disk, then such perturbations must also behave symmetrically in both directions of time.

6. CONCLUSIONS

In this paper, we use the high-quality light curves from the Kepler space telescope to analyze the variability asymmetry of 19 AGNs. An asymmetry parameter \( \beta(\tau) \) is introduced for the quantitative description. We perform extensive Monte Carlo simulations to derive the statistical uncertainties in \( \beta(\tau) \), which cannot be obtained through the standard error analysis approach. After correction for observational bias due to long-term trends in the light curves, we find no evidence of asymmetry in the individual sources at timescales below 20 days. For the whole sample, there is no general trend toward a positive or negative asymmetry. Co-adding data for all 19 AGNs, we derive an averaged \( \beta \) of 0.00 \( \pm 0.03 \) and \(-0.02 \pm 0.04 \) over timescales of 1 \( \sim 5 \) days and 5 \( \sim 20 \) days, respectively, statistically consistent with zero. Quasars and Seyfert galaxies tend to show a similar asymmetry parameter at the observed timescales. The constraint on longer-timescale variability asymmetry is weaker as it requires much larger samples or much longer light curves which could better sample the long-term variations. The fact that the short-term optical variations in quasars and Seyfert galaxies are highly symmetric could place independent constraints on the physical models of AGN variations.

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