論文の内容の要旨

Variability and Polarization of the Ultraviolet-optical Continuum Emission of Quasar Accretion Disks
(クエーサー降着円盤紫外可視域連続光放射の光度変動および偏光現象の研究)

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The study of the physical mechanisms driving the active galactic nuclei (AGN) activity, namely the physics of the black hole accretion disks in AGNs, is essential to better understand not only the growth of the supermassive black hole (SMBH) at the center of the galaxy but also the cosmological galaxy evolution in the Universe. However, in spite of its importance, surprisingly little has been known about the true nature of the AGN accretion disks since the first proposal of standard accretion disk model as the central engine of AGNs in 1970s. In this dissertation, we examine the ultraviolet(UV)-optical flux variability and polarization of AGNs or quasars to assess the validity of our current understandings of the quasar accretion disks and their vicinity. The flux variability and polarization are two unique observational properties of AGN/quasar UV-optical emission, enabling to disentangle the emission spectrum of the accretion disk thermal emission from the broad emission lines and the host galaxy light and consequently to examine the intrinsic accretion disk continua in AGNs/quasars.

First we review observational properties of UV-optical flux variability and polarization of AGNs/quasars from the viewpoint of standard geometrically-thin thermal accretion disk model in Chapter 1.

Then, we move on to examining the statistical properties of the spectral variability of quasars by using a large sample of multi-band light curves of quasars in the Sloan Digital Sky Survey (SDSS) Stripe 82 region in Chapter 2. It is shown that the variable component spectra of the quasars, which should reflect the spectral shape of the intrinsic accretion disk emission, are much bluer ($\alpha_\nu \sim +1/3$) than the directly-observed spectra ($\alpha_\nu \sim -0.5$) . We show that the accretion disk spectra of quasars revealed as the variable component spectra are too blue to be explained by existing geometrically-thin thermal accretion disk models.

In Chapter 3, we examine whether the “inhomogeneous accretion disk model” proposed by Dexter &

Agol (2011) can simultaneously explain the large variability amplitude and the strong correlation of the multi-band light curves through the UV-optical wavelength range observed in the SDSS Stripe 82 quasars. By comparing the intrinsic scatter $\sigma_{\rm int}$ from the linear magnitude-magnitude relation of the two-band light curves between the observational data and the inhomogeneous accretion disk model simulations, we show that the inhomogeneous accretion disk model predict systematically weaker inter-band correlation compared to the real quasars. This study demonstrates that the observed inter-band correlations in AGNs/quasars impose strong constraints on the variability models involving many localized instabilities/flares over the disk surface.

In Chapter 4, we study the relationship of the spectral shape between the variable component and the polarized flux spectra in each of the four quasars with continuum-confined polarization (B2 1208+32, Ton 202, 3C 323.1, and 4C 09.72). According to the knowledge in the previous works on the variability and polarization, both of the variable component spectra and the polarized flux spectra in these quasars should reflect the intrinsic accretion disk emission spectra. However, by comparing these two spectral components by using the archival spectro-polarimetry data and the newly obtained multi-band light curves for these quasars, we show that they have totally different spectral shape, suggesting that there are fundamental problems in the current understanding of the quasar UV-optical variability and/or polarization.

In Chapter 5, we constrain the polarization source in one of the quasars with continuum-confined polarization studied in Chapter 4, 3C 323.1, by examining the polarimetric and photometric variability of this object. It is shown that the total (unpolarized) flux and the polarized flux in 3C 323.1 show strongly correlated variability during the three epochs of the polarimetric measurements, and that the polarization position angle (PA) also show evidence of time-variability. Also, multi-epoch spectro-polarimetric data reveal that the polarized flux spectra of 3C 323.1 show variability in their broad absorption features on time-scales of several years. Taking these observational facts into account, we propose a geometrical model in which the polarized flux spectra are interpreted as the accretion disk continua with additional broad absorption features induced by the equatorial absorbing region because the observed polarized light has once passed through the absorbing region. We conclude that the polarized flux spectra of quasars do not directly reflect the spectral shape of intrinsic accretion disk continua, which is the reason why the spectral shape of the polarized flux and the variable component of quasars studied in Chapter 4 does not agree with each other. This work validates the conclusions derived in Chapter 2 and Chapter 3 on the assumption that the variable component spectra of quasars is a good tracer of the spectral shape of the intrinsic accretion disk continuum emission.

Conclusions of this dissertation and future prospects are summarized in Chapter 6. These studies clarify that the observational properties of the UV-optical variability and polarization can strongly constrain models of the accretion disk and of the inner structure of AGNs/quasars. I emphasize that we should investigate models of quasar accretion disks which can naturally account for the general properties of the years time-scale AGN/quasar variability, namely, the large variability amplitude and the tight inter-band correlation within the UV-optical wavelength range, simultaneously. It is discussed in Chapter 6 that the X-ray reprocessing model may possibly explain the observed UV-optical variability of AGNs/quasars, and further simultaneous X-ray and optical monitoring observations are needed to confirm the validity of the X-ray reprocessing model. Also, we point out that the photometric and polarimetric monitoring observations for microlensing events in gravitationally lensed quasars will enable to probe the true nature of the flux variability and polarization, and consequently of the accretion disk emission in AGNs/quasars.