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Dramatic emission line variations in QSO Kaz 102 and possible causes*

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Abstract. We report optical spectroscopic observations of the radio-quiet quasar Kaz 102. We find impressive variations of the Hα emission line both in shape and intensity. Hα dimms by 40%, and develops a blue asymmetry within a few years. The continuum level also decreases by a similar amount. We discuss the results in terms of the kinematics of the BLR (Broad Line Region), and consider several plausible scenarios: The association of the BLR to Supernovae Remnants evolving in a dense medium, the emission from two BLRs in a binary black hole system, emission from clouds whose motion is predominantly radial coupled with light echoes, and variations in the distribution of a small number of clouds.

Key words: quasars: emission lines – quasars: individual: Kaz 102=Q 1803+676

1. Introduction

The structure and kinematics of the BLR in Active Galactic Nuclei (AGN) is a major object of discussion and research. One of the main approaches has been the study of line variability, first detected by Dibai and Pronik (1967). High temporal frequency monitoring of AGN over extended periods has proven to be a powerful way to unravel the structure and physical conditions of the BLR in AGN (see e.g., Korista et al. (1995) for a recent example, and Peterson (1993) for a review). But also isolated discoveries of large line variations, some times by chance, may either constrain or challenge the models of the BLR. In this paper we will present and discuss variability in the continuum, as well as the Hα and Hβ emission lines in Kaz 102. Kaz 102 (1803+676) is a bright (V = 15.8), low redshift (z = 0.136), radio quiet, X-ray quasar. A multifrequency study can be found in Treves et al. (1995). Deep CFHT images (Hutchings & Neff 1992) show a very compact object surrounded by a faint disturbed outer halo.

2. Observations and data reduction

Spectra from Kaz 102 were obtained on July 17 and August 8, 1995, and on March 3, 1996, using a large-format thined CCD, coupled to the B&Ch spectrograph of the 2.1m telescope of the Observatorio Astronómico Nacional, sited at San Pedro Mártir, Baja California, México. The spectra cover both Hα and Hβ, with a resolution of 2.7 Å/pix. The data were reduced using the IRAF package. In order to search for variability, we have compared with spectra taken on July 7, 1987, and June 18-20, 1988 (Thompson 1992 and references therein). These spectra cover approximately the same range as our observations, including both Hα and Hβ, but their resolution is slightly lower.

3. Results

We can see from Fig. 1, that the 1995 and 1996 Hα lines have similar profiles and intensities, and the same may be said about the 1987 and 1988 observations (Thompson 1992), so that no changes are detectable within one year. A small variation in the continuum level of $\Delta m \simeq 0.25$, is seen mainly blueward of Hβ. The time span is seven months. This is very similar to the largest variation in the B band observed by Treves et al.(1995) during their monitoring, from February to September 1991.

When we compared the 1987/88 data with those of 1995/96, however, we found impressive variations both in intensity and shape for the Hα emission line (Fig. 2). Unfortunately, there are no spectroscopic data -to our knowledge- for Hα that may fill the gap between 1988 and 1995, thus we can only set an upper limit to the variation time-scale of seven years. For Hβ however, a blue bump is also clearly seen in our later data (particularly in the higher S/N spectrum of March 31, 1996 in Fig. 1). This blue bump was not present in the spectra taken during 1990/91 by Treves et al.(1995) around Hβ. Treves et al.(1995) compared their spectra with those taken in 1988 by Shastri et al. (1993), and found no evidence for variations. The same can be said for

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* Based on observations made at the Observatorio Astronómico Nacional at San Pedro Mártir, Baja California

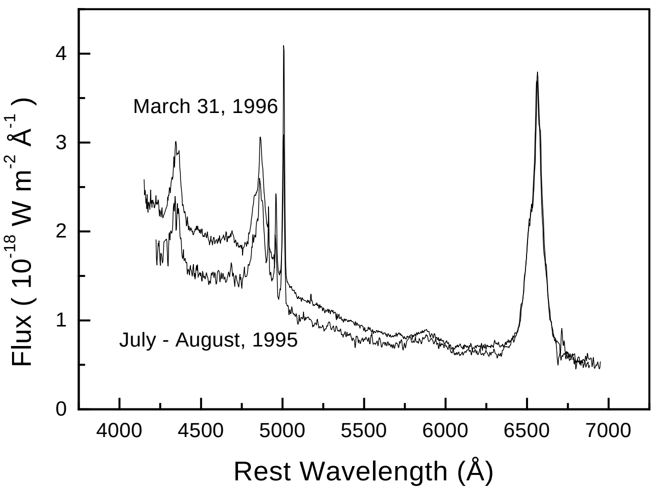

Fig. 1. Complete spectra of Kaz 102 covering the Hα and Hβ range. There is a brightening around Hβ of about Δm $\sim$0.25 mag in a time span of $\sim$ 7 months (see text).

the comparison with our spectra from the epoch 1987/88. Hence, from the Hβ data we can infer that the blue bump developed in a time span of no more than four years. We do want to stress, however, that no intensity variations are detectable in Hβ from 1987 to 1996 *within errors*, which are quite large for Hβ. For this reason, and because of the much higher S/N ratio, in all that follows, we prefer to center our discussion on Hα.

From Fig. 2, we can see that Hα has dimmed by about 40% in seven years. The continuum level has also dimmed by a similar ammount. We have fitted the observed symmetric profile of 1987/88 (Fig. 1a) using two components: a narrow (FWHM = 27 Å; EW = 35 Å) Gaussian component, plus a broad (FWHM = 103 Å; EW = 550 Å) Lorentzian component. In Fig. 2b, the components are: a narrow Gaussian core similar to the one in Fig. 1a (FWHM = 24 Å; EW = 59 Å); a second Gaussian component centered at 6583 Å (which could correspond to the contribution from the [NII] 6583 Å line) with FWHM = 26 Å; EW = 31 Å, and a broad (FWHM = 132 Å; EW = 570 Å) component fitted by a Voigt profile, blueshifted by nearly 470 km/sec, with respect to the narrow core. In Fig. 2c, we show the best fit in shape that we were able to achieve (by means of three Lorentzian components; notice that the continuum has been subtracted in 2c). A major inconvenience of this procedure, is that the combination of shapes and intensities of the fitted components is not unique. The question whether the fittings show real components or they are simply a convenient mathematical method to reproduce the line profiles, which are a consequence of hidden, unknown superposing processes, cannot be answered here. What we can assert, however, is that in order to reproduce the 1995/96 profile, the fit requires at least three components.

4. Interpretation

Sulentic et al. (1995) and Marziani et al. (1996), found a statistical trend for a large sample of AGN in the sense that most

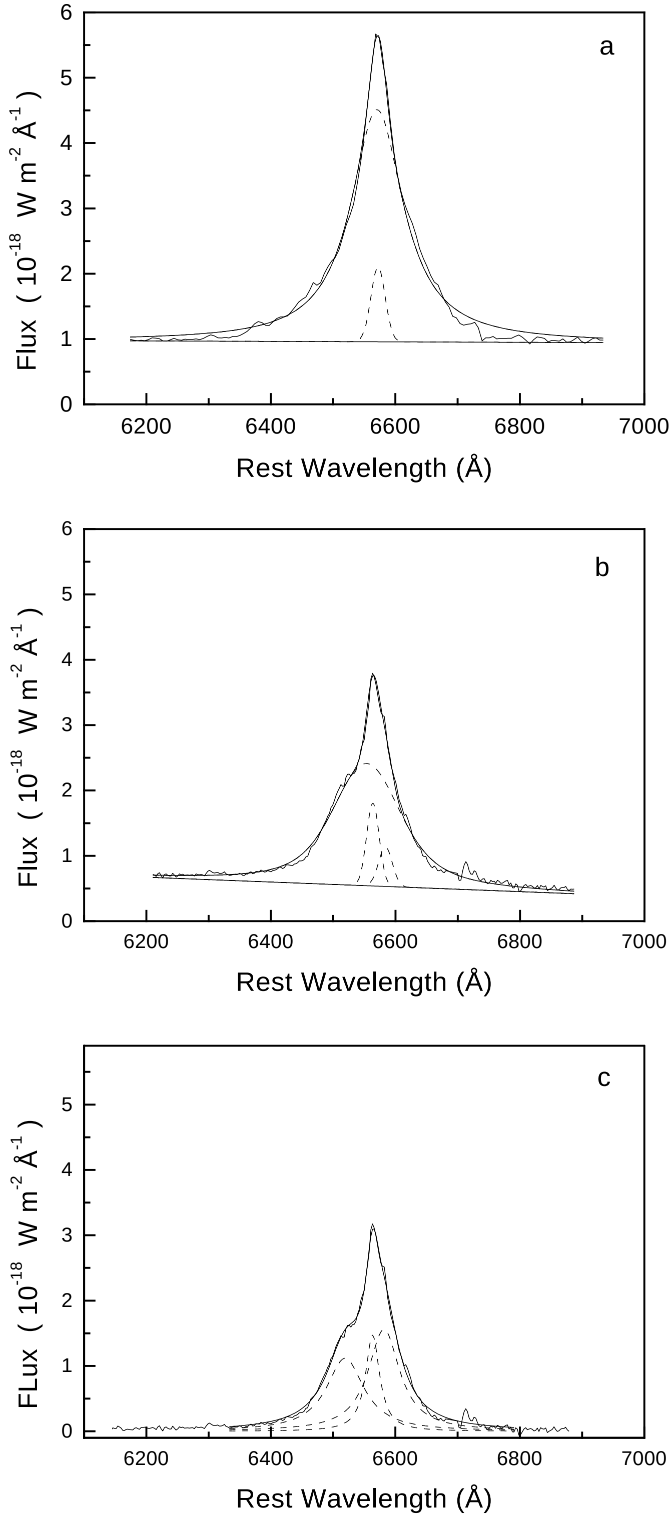

Fig. 2a–c. The Hα emission line of Kaz 102. **a** average 1987/88 spectrum; the dashed curves represent a two-component fit with the characteristics described in the text. **b** and **c** show the same average 1995/96 spectrum; the dashed curves are two different three-component fits (see text). Notice that the flux is given in the same (vertical) scale for all spectra, but the continuum level has been subtracted in (**c**).

radio quiet AGN show symmetric Balmer profiles (as opposed to radio loud AGN). This is basically true for the 1987/88 spectra, but within a few years the line profile has evolved from a nearly symmetric shape into a clearly asymmetric one.

The time scales mentioned above, are compatible with the evolution of supernovae remnants (SNR) in a dense medium such as expected near the center of an Active Nucleus. In these media, the SNR time scales of evolution are roughly 6 yr (Franco et al. 1993; 1994). This model, in which the BLR is associated to SNR, allows large variations in the intensity of the continuum, Balmer emission lines, and the profiles as well. Moreover, as long as the dense medium decelerates the expanding remnant, one expects the line to become narrower as it dimms, which is what we observe. Unfortunately, the specific predictions of this model are focussed mainly to the X-ray and Ultraviolet emission. Although the extrapolation to the optical continuum is in qualitative agreement with the observations, more quantitative estimates are not possible. Also, the non-uniquess of the solution for the 3 component fitting to the data, prevents us from making accurate calculations. Nevertheless, we can say that in order to produce the observed luminosities of about $10^9 L_\odot$, the medium should have a number density of the order of 10^8 cm^{-3}. Zheng, Burbidge and Smith (1990) found evidence for large amounts of gas at densities 10^{8-9} cm^{-3} in the vicinity of the central source of Kaz 102, from the study of the variability of the [NIII] lines. We want to stress however, that even if the above scenario could explain this case, it cannot be easily generalized. If the BLR of all NAG were associated with SNR *only*, we can find no explanation to the statistical trend found by Sulentic et al. (1995) and Marziani et al. (1996) towards a segregation of profile shapes between radio loud and radio quiet objects.

Binary black holes have also been invoked as a possible cause of this type of large spectral variations. Gaskell (1996) showed that a model consisting of a nuclear binary black hole with a mass ratio of 2:1, and a period of about 200 yr, reproduces extremely acurately the observed spectral line variations in 3C 390.3. Moreover, he found evidence for binary orbital motion. It is important to stress that BLR clouds in this model are not necessarily gravitationally bound, although there is strong evidence suggesting that they are confined to a flattened geometry, particularly for the case of radio-quiet quasars (Marziani et al. 1996). This consideration is important, because it solves the apparent dilemma posed by Penston (see Gaskell 1966 and references therein), with respect to the velocity dispersions being lower than the orbital velocity for gas bound to each black hole in a binary system. BLR clouds can be easily influenced by nongravitational forces such as radiation and wind pressures. Radiation and wind pressure in some cases may even exceed gravity (Gaskell 1966), since at least some gas is being seen to be expelled at high velocities from quasars: certainly the broad absorption line gas, and possibly the blue-shifted high ionization component observed mainly in radio-quiet quasars (Sulentic et al. 1995). A model invoking both radiation pressure and gravity can be found in Mathews (1993). An independent line of evidence for binary black holes is the case of the blazar OJ 287, which has cyclical outbursts every 11.6 years. This behaviour has been modeled by means of a binary black hole (Sillanpää et al. 1988; Lehto & Valtonen 1996; Katz 1997). For OJ 287, the estimated mass ratio of the black holes is 200:1.

In our case, the Balmer line profile variation could be ascribed to a "stationary" profile plus a superimposed component of variable radial velocity. Variations in intensity in the binary black hole scenario are a probable consequence of: a) changes in the accretion rate(s), b) tidal perturbations, and/or c) orientation and occultation effects. Variations in shape are a natural consequence of the differences in the radial velocities observed as the two bodies evolve in their orbits. Additional circumstantial evidence to support this scenario comes from the conclusion reached by Hutchings and Neff (1992) that the observed morphology of Kaz 102, "may be a galaxy in the very late stages of absobing a smaller companion".

Finally, given the fact that the continuum varies along with Hα, we could also consider the possibility that the features in the line profiles could be the product of "light echoes"(for example, the response to continuum variation by predominantly radially moving gas). It has been argued, however, that line profile variations, in contrast to flux variations, are *not* reverberation effects (e.g., Perry, van Groningen & Wanders 1994; Wanders & Peterson 1996). Continuum changes occur on time-scales of weeks, whereas shape changes are detectable in time-scales of several years. This last fact seems to be confirmed by our study. Wanders (1997) has proposed that variations of line profiles could be explained as projection effects due to an anisotropically illuminated BLR. Flux variability *within* the profile structures would be explainable as stochastic variations in the cloud distribution with a small number of clouds.

We feel that this is, by far, not a solved problem, and that monitoring of the continuum and Balmer lines at sufficient S/N and temporal sampling, with the aim of discriminating among the possibilities described above, is clearly worthed and needed.

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