THE OPTICAL VARIABILITY OF QUASARS: TESTING THE STARBURST, ACCRETION DISK AND MICROLENSING PARADIGMS

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The long-term variability of a large, statistically well defined sample of optically selected QSOs has been studied. The variability-luminosity and variability-redshift correlations, as well as the wavelength dependence of the variability have been investigated by means of statistical estimators that are "robust" and permit at the same time to eliminate the influence of the measurement errors. The results obtained by analysing both the ensemble structure function and the individual variability indices in the QSOs rest frame show that:

1. A negative correlation between variability and luminosity is clearly present, in the sense that more luminous QSOs show less variability
2. A significant positive correlation exists between variability and redshift
3. Such correlations may be parameterized either with a model in which the timescale of the variability is fixed for all the QSOs and the amplitude linearly increases with the absolute magnitude and redshift, or with a model in which the timescale of the variability linearly depends on the absolute magnitude and the amplitude is only a function of the redshift.
4. The amplitude of the R-band variability turns out to be smaller (of a factor 1.13 ± 0.05) than the B-band variability

The dependence of the variability time scale on the wavelength is a standard prediction of the accretion disk model. The temperature of the disk decreases with the radius, and the dynamical, thermal and viscous time scales all increase as $r^{3/2}$. In particular, in the standard model, involving instabilities in a thin accretion disk around a supermassive black hole, the intrinsic characteristic time scale should vary as $\tau \propto \lambda^2$. More in general, if the source is thermal and if the flux variability is due to temperature changes, the observed wavelength dependence can be naturally produced. The only requirement concerns the turnover in the spectral energy distribution that should not be located at such a high frequency that the spectral slope in the observed band becomes independent of the temperature. If brighter objects are on average hotter and the variability is due to temperature changes, one would expect a negative correlation between variability and luminosity, as observed. Assuming for example a spectrum of black body or thermal bremsstrahlung, the spectral turnover of brighter objects is progressively shifted at higher frequencies producing progressively smaller flux changes, from $\delta I/I \propto \delta T/T(h\nu/kT)$ for $kT < h\nu$, to $\delta I/I \propto \delta T/T$ for $kT > h\nu$.

The broad-band variability in the starburst model is defined by the superposition of a variable component, supernova explosions (SNe) generating rapidly evolving compact supernova remnants (cSNR), and a non-variable component, a young stellar cluster and the other stars of the galaxy. The spectrum of the non-variable component has been predicted to show a $F_\nu \propto \nu^\alpha$ with $\alpha \sim -1.0 \div 0$. The variable/non-variable relative luminosities can be estimated on the basis of stellar evolution and of the variability pattern. The optical/UV spectrum of the variable component is expected to be harder than the non-variable component with $\alpha \sim 0.5$. In this simple form, the starburst scenario predicts a decrease of the $\Delta M_{\rm B}/\Delta M_{\rm R}$ with increasing redshift, compatible with the data, and with increasing absolute luminosity, contrary to the observational trend. This suggests that more general situations have to be envisaged in which the fraction on the non-variable component and/or the pulse properties (e.g. the spectral distribution) depend on the global luminosity of the object.

A non-achromatic behaviour can be accommodated in the microlensing scenario. For a source comparable in size to the Einstein ring of the lens, with a quasar disk redder at larger radii, the bluer compact core would produce a larger amplitude of the variations in the blue passband whereas the larger extent of the red image would cause a small amplitude variation, albeit with a longer duration, in the red. However, it cannot be denied that achromatic light variations would have been one of the most significant characteristics of the microlensing model and the present observation of the wavelength dependence make it less appealing/compelling.

Further details are given in Cristiani, Trentini, La Franca, Aretxaga, Andreani, Vio, Gemmo, 1996, A&A **306**, 395 and Cristiani,Trentini, La Franca, Andreani, 1996, A&A submitted.

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