PHYSICAL INTERPRETATIONS FROM QUASAR LIGHT CURVES -- 3C273

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Light curves of quasars give information on time scales (hence limits on size of principal luminous source), and on phase of variation (hence evidence bearing on the distance of surrounding regions or shells).

Insights derived from photometry as to the physical mechanisms involved have been slower to come. Some information lies in the amplitude of variation. The fractional amplitudes of most quasars are so big as to rule out the hypothesis that the luminosity comes from a very large number of separate accreting or exploding sources. There is evidence for inverse correlation of amplitude with redshift or with quasar luminosity (some of this can be accounted for by time dilation associated with large z). The correlation is consistent with models in which a modest number of variable sources contribute to the output of a quasar, but single-source models can also produce such data. Unambiguous detections of stable periodicities would be extremely important but have been elusive. Finally, at least in principle, some clues as to the character of the source may be present in the form of the variations.

3C273 has the longest relatively well-sampled run of historical photometric data. Our previously published light curves for this object included visual estimates from photographic plates, and comprised only mean points over lunations for 100-day intervals. Figure 1 presents for the first time the definitive light curve covering nearly a century and including objectively determined individual points. Prior to 1963 these come entirely from iris photometry of the Harvard historical plate collection; most of the remainder are photoelectric. Two cautions are in order: The four highest points are from plates taken with the smallest cameras having apertures of only several cm and very short focal lengths. Quasar images are very small and usually near the plate limit for these cameras, hence are unusually sensitive to occasional grain-clumpings or other accidents enlarging the image. These bright points could well be spurious, in which case there is no excess of positive over negative "flaring". Also, within a given year may be individual points having standard deviations as high as 0.2 mag; this exaggerates somewhat the appearance of sharp annual drops and rises.

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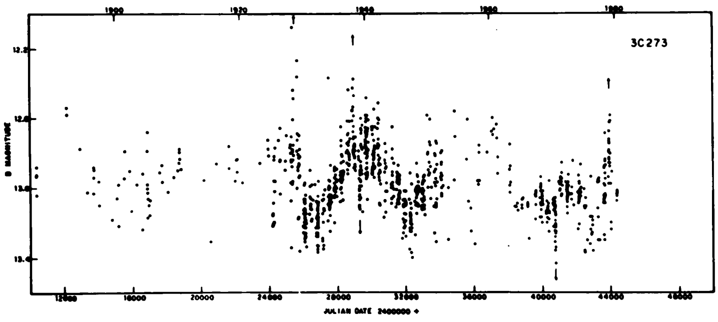

Period analysis. Angione and Smith (AJ) have treated this light curve using Deeming's method of power spectrum analysis applicable to unequally spaced data. The Harvard data alone give only a single and highly significant period of about 16 years, but this is heavily weighted by the fact that 90% of the Harvard points lie in the interval 1928-1955 where the nearly sinusoidal variation is strongly marked. If a true period, it should be present in the preceding and subsequent data. However, a separate analysis excluding the 1928-1955 interval shows only a weak 20-year period (largely due to alias) and a possibly significant 6-year period. This means either that we are being fooled by random variations or that real quasi-periodicity may be involved. The latter interpretation is consistent with current models of an accretion disk around a massive black hole, in which e.g. different transient disk pulsation periods ranging from days to decades may be present, and/or variable obscuring clouds may be orbiting at different distances from a small bright nuclear region.

Character of the Variations. Most quasar optical light curves appear essentially the same whether displayed inverted or even with time-reversal. Angione and Smith (1972) showed that, for 22 quasars with relatively rich historical data, any selected rate of change of brightness was effectively equally represented among increases and decreases. If true flaring were an important phenomenon, we might expect excess of rapid rises and of peaks standing out from the general run of brightness. But even a casual inspection of the 3C273 light curve shows one can make as good a case for anti-flares (or "dropouts"). This stupendously powerful central source of 3C273 must somehow be able equally to appear to increase or decrease by up to nearly a factor of two on times scales ranging from weeks to decades, yet normally remaining within rather tight limits. Irregular feeding of the monster may well play a role. Here again, obscuration of the central source by electron-scattering clouds orbiting in or above an accretion disk at radii in the range of 10^{15} to 10^{17} cm offers a mechanism intrinsically able to reproduce the character of the observed light curve, including the wide range of time scales, the symmetrical rise and fall of brightness, and the presence of transient quasi-periodicities. On this picture, quasars observed relatively pole-on should in general suffer less obscuration, hence have larger absolute magnitudes, be seen on the average at greater red-shifts, and have smaller amplitudes of variation than would the majority of quasars seen relatively edge-on.