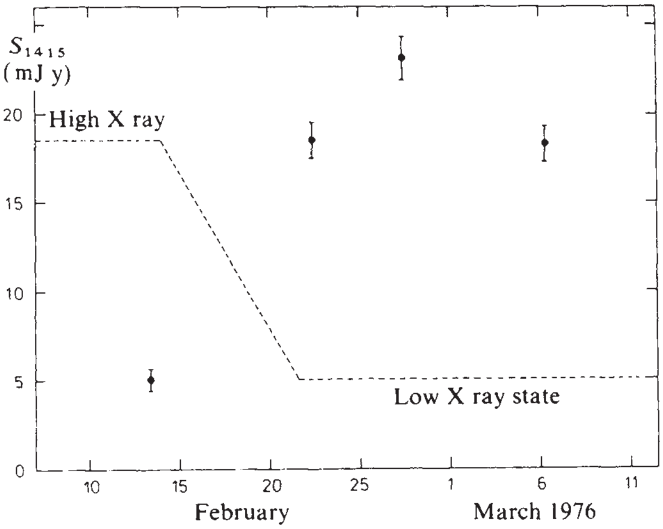

Fig. 1 The radio and X-ray behaviour of Cyg X-1 during February–March 1976. The radio data are from Table 1. The dashed line gives a schematic representation of the Ariel V X-ray data taken from Holt *et al.*[8].

At that time, the X-ray and radio emission both increased, distinguishing that short lived "transient event" from the "transition" reported here.

There are several possible explanations for the anti-correlation observed in the X-ray and radio behaviour of Cyg X-1 during transitions. First, heightened X-ray emission could be produced by a hot gas which eventually envelops the radio emitting region, blanketing it out by free–free absorption. When the gas expands sufficiently, the cut-off frequency would become lower and the radio source would reappear in its normal state. Second, the event responsible for the enhanced X radiation might either interrupt the supply of relativistic electrons to a non-thermal radio source or result in such an increased radiation density that inverse Compton losses would extinguish the source. A cut-off of the additional X-ray supply would then again result in a return of the radio source to its normal state. To decide between these and other alternatives, it is crucially important to monitor the radio spectrum of Cyg X-1 throughout future transitions.

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L. L. E. Braes
G. K. Miley

Leiden Observatory,
Huygens Laboratory,
Wassenaarseweg 78,
Leiden 2405, The Netherlands

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New test of the cosmological nature of QSO redshifts

In spite of extensive observations the nature of the redshift of a quasistellar object (QSO) remains a controversial issue[1]. The redshift–magnitude relation, QSO–galaxy associations, time variability faster than light motion and several other criteria are being used to argue in favour of or against the cosmological nature of the QSO redshift. It is therefore desirable not only to improve the statistics of the existing data but also to think of new tests to clarify this important issue. Recent improvements[2,3] in the spectrophotometry of QSOs enable us to propose a potential test of the cosmological hypothesis in the following manner.

Consider a plot of the emission line width (for example, the full width at half maximum intensity, FWHM) of a specified spectral line against the redshift of a QSO. Assuming that all QSOs are intrinsically identical, and are at cosmological distances corresponding to their redshifts, the FWHM of a typical line of rest wavelength λ_0 in a QSO of redshift z is given by

$$w = w_0 (1+z) \quad (1)$$

where w_0 is the FWHM in the rest frame of the QSO. A plot of w against $1+z$ should therefore be a straight line through the origin. The test involves plotting w against $1+z$ for a large number of QSOs, using the same spectral line for all of them.

In a hypothesis where the redshift is largely of gravitational origin there is no simple model-independent relation like equation (1). For example, in the model of the type considered by Greenstein and Schmidt[4], the line width arises from the gravitational broadening at the surface and the relation between w and z is given by

$$w = \frac{R_g}{2R} \lambda_0 (1+z)^3 \frac{\Delta R}{R} \quad (2)$$

where R_g is the gravitational radius of the object, $4\pi R^2$ is the surface area of the object and ΔR the thickness of the emitting region in the Schwarzschild coordinates. Both R and ΔR depend upon the model. For the Hoyle–Fowler type models with central emission line redshifts[5] even more complicated forms than equation (2) arise.

For the local Doppler shift explanation of the type advanced by Terrell[6] the relation (1) will hold. Thus a tight straight-line plot will be a positive test of the cosmological or Doppler hypothesis. In practice, however, the test is not so easy to apply and we discuss briefly some of the difficulties and how they could be resolved.

First, the measurements of FWHM have to be made very accurately. With the image tube scanner technique[2] it is possible to have resolutions better than 7 Å in FWHM. Since the line widths are at least 20 Å in most cases it now seems possible for at least a start to be made. It is of course necessary to choose the same spectral line for all QSOs in any given sample. Thus Ly α may be chosen for high redshift QSOs ($z \gtrsim 1$) and the MgII line for low redshift QSOs ($z \lesssim 1$). The CIV line can also serve a good line for a large number of QSOs of moderately high redshifts.

A preliminary (w, $1+z$) plot for a sample of southern sources[7,8] reveals a large scatter (see Fig. 1) for the MgII line of low redshift QSOs. A similar plot for the CIV line in a number of high redshift QSOs based on the data given by J. Baldwin (personal communication) also shows no linear relationship. The scatter may of course be due to variation in w_0 from QSO to QSO, and this illustrates another difficulty of arriving at a decisive conclusion. However, intrinsic line widths probably do not vary by more than a factor of 10 and the scatter could be reduced by properly selected criteria, for example the nature of radio spectra[9]. To arrive at a suitable criterion it is necessary to have a better understanding of the causes of emission lines

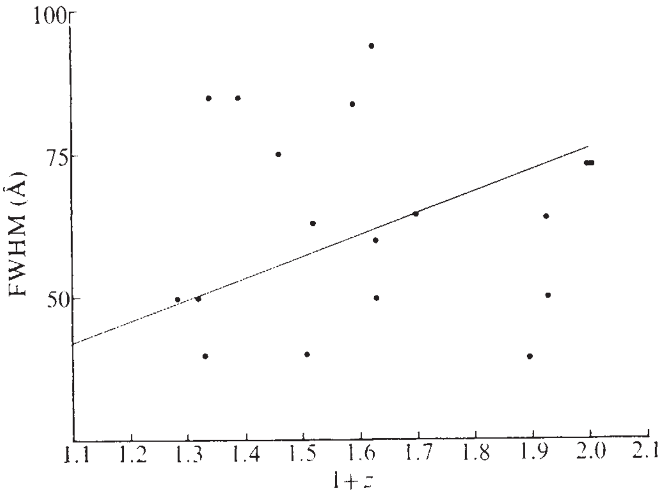

Fig. 1 Plot of FWHM against $1+z$ for MgII line for 18 southern sources. The scatter about the line of least square fit to relation (1) shows how at present no linear trend is apparent from the data.

in QSOs from theoretical as well as from empirical approaches based on observations[10]. The situation is no worse than in the m–z relation for QSOs, where the scatter is supposed to arise (if the cosmological hypothesis is right) from the variation in the intrinsic luminosity by several magnitudes. On the other hand the proposed test is free of the added uncertainty of not knowing the deceleration parameter q_0 in the m–z relation.

It is possible to apply this test to emission line galaxies such as Seyferts, but the smallness of the redshift makes the variation of w with z insensitive according to equation (1). For QSOs, with their large redshifts, this test appears better suited. With the redshifts and extensive optical information on more than 570 QSOs available (Burbidge, Crowne and Smith, preprint) it may be worthwhile attempting this test with better measurements of line widths which should become possible in the future.

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J. V. NARLIKAR
S. RAMADURAI*

Tata Institute of Fundamental Research, Bombay 400 005, India

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*Present address: Department of Theoretical Physics, 12 Parks Road, Oxford.

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Interacting galaxies and QSO absorption lines

THE spectra of quasi-stellar objects are observed to have absorption lines with redshifts mostly below the redshift of the emission lines[1]. The absorbing clouds are thought to be either near the QSO[1–5] or at cosmological distances from it[6–8]. On the first interpretation, the clouds are supposed to be accelerated to high velocities ($\lesssim 0.5c$ away from the QSO) by radiation pressure. However, the small internal velocity dispersions inferred for the clouds from the absorption line widths ($\sim 50\ \mathrm{km\ s^{-1}}$) pose serious problems to this model[9] and we consider here the second interpretation. The interception cross section of intervening galaxies for QSO photons has hitherto been calculated[10] on the assumption that the galaxies do not evolve. The data so far available (Fig. 1), although probably contaminated by selection effects[1], seem to indicate that the number of absorption redshift systems increases more rapidly as a function of the emission line redshift than can be accounted for without such evolution. The possibility has been considered[7,8] that the intervening clouds are collapsing protogalaxies, but we think it likely that most galaxies form[11] before $z = 5$ and, instead, attribute the rapid increase in the number of redshift systems to tidal interaction of galaxies at earlier epochs. Because galaxies were closer together in the past, chance collisions were more frequent and the effects of these interactions were more pronounced.

The effects of an encounter between a galaxy and a neighbour are proportional to the tidal force and to the duration of the encounter. This force is inversely proportional to the cube of the distance r between the galaxies; the duration of the collision is proportional to r/v, where v is the relative velocity of the galaxies (since we intend to calculate the probability of a tidally distorting collision as a function of z only, the vectorial properties of the collision are irrelevant). Thus, the amount of disruption that a galaxy suffers in an encounter is proportional to $r^{-2}v^{-1}$. The expectation value of this quantity can be calculated if we know the probability of finding, near any given galaxy, another one with distance between r and $r+ar$ and with velocity between v and $v+dv$. In other words, we must know how the phase space spanned by r and v is occupied and then convolve $r^{-2}v^{-1}$ with the density distribution in phase space.

The average distribution is found from the cosmological model used to describe the large-scale evolution of the Universe, but in addition the effects of clustering must be considered. The empirical evidence on the pair correlation of galaxies[12] is unfortunately insufficient for our purposes, first because the dependence of the correlation on redshift is unknown, second because the velocity correlation is unknown. We are currently working on the results of an N-body model of the evolution of clustering to determine the density distribution in phase space and here anticipate the results by assuming the Keplerian approximation $v \propto r^{-1/2}$ and by assuming that the clustering at

Fig. 1 Number N of absorption redshift systems against the emission redshift of the background QSO. Dots: observations[1]; drawn lines: predictions for a universe with $q_0 = 0$. Lower curve: no tidal distortion. Upper curve: tidal distortion parameter $\varepsilon = 0.3$, clustering parameter $\gamma = 0$. Because of incompleteness of the sample, N has not been expressed as a fraction of the total number of sources observed. Therefore, the observed points may be fitted to the curves by applying an unknown multiplication factor to N, which in the diagram corresponds to vertical displacement.