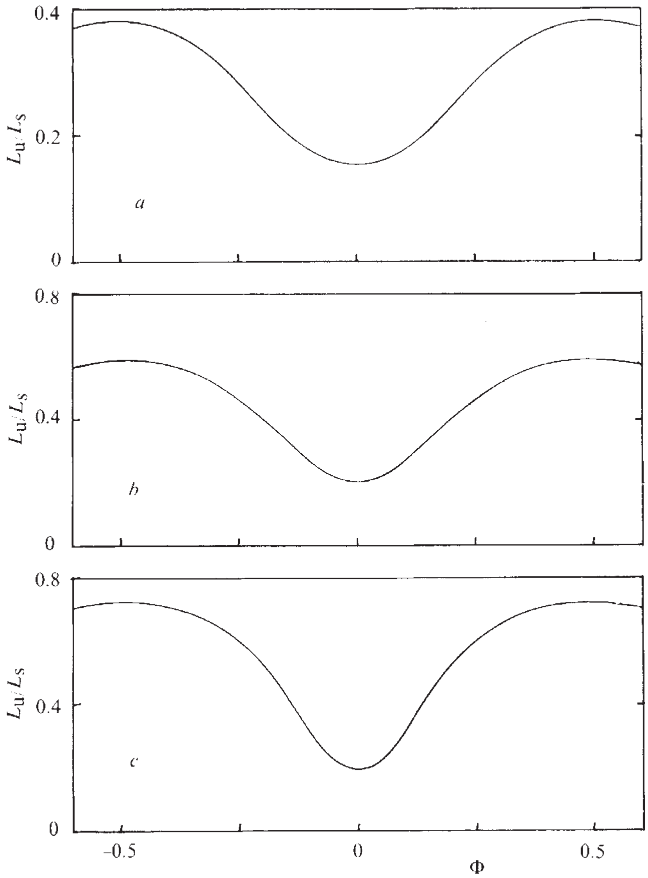


**Fig. 1** The fraction of X-ray flux that reaches the observer unscattered, $L_U/L_S$, is plotted against binary phase Φ for various values of the inclination $i$ and the optical depth to electron scattering $\tau_{es}(\pi/2)$. *a*, $i=30°$, $\tau_{es}(\pi/2)=1.25$; *b*, $i=45°$, $\tau_{es}(\pi/2)=0.75$; *c*, $i=60°$, $\tau_{es}(\pi/2)=0.5$. For each $i$, the value of $\tau_{es}(\pi/2)$ has been chosen to give an overall variation of about a factor of three.

I argued earlier that absorption in the wind must be important but not dominant. That is, we must have

$$\lambda = F/(4\pi D^3 N^2 a) \simeq 1 \qquad (10)$$

where $F$ is the ionising photon flux and $a$ the effective recombination coefficient (see ref. 7 for a fuller discussion). Using $a \sim 3\times 10^{-10}\ T^{-\frac{3}{4}}$, we obtain

$$N \approx 10^{13}(M/M_\odot)^{-\frac{1}{2}} L_{38}{}^{\frac{1}{2}} T_6{}^{\frac{3}{8}}\ \mathrm{cm}^{-3} \qquad (11)$$

where $L_{38}$ is the X-ray luminosity in units of $10^{38}$ erg $s^{-1}$, $T_6$ is the temperature of the wind in units of $10^6$ K and I have assumed the typical ionising photon to have an energy of 5 keV. This density implies

$$\tau_{es}(\pi/2) \approx 0.5(M/M_\odot)^{-\frac{1}{6}} L_{38}{}^{\frac{1}{2}} T_6{}^{\frac{3}{8}} \qquad (12)$$

in rough agreement with previous estimates. This density also indicates that the overall mass loss rate from the large star must be

$$M_1 \approx 10^{-6}(M/M_\odot)^{\frac{1}{2}}(M_1/M) L_{38}{}^{\frac{1}{2}} T_6{}^{\frac{3}{8}}\ M_\odot\ \mathrm{yr}^{-1} \qquad (13)$$

where $M_1$ is the mass of the large star. So for this model we expect the 4.8 h period to change on a time scale of $\sim 10^6$ yr.

I note also that inhomogeneities in the wind and variations of the wind strength can lead to irregular variations in the low energy cut-off. Absorption is more important near X-ray minimum, and so the X-ray curves calculated on the basis of electron scattering alone will be distorted downwards near minimum. Thus the variation will be less pronounced at high energies than at low energies where absorption is more important. I note in passing that a mass loss rate of $\sim 10^{-3}\ M_\odot\ \mathrm{yr}^{-1}$ of the kind suggested by van den Heuvel and De Loore for the source Cen X-3 (ref. 8) would entirely extinguish any X-ray flux from the compact object. Unless the velocity of the wind exceeds the escape velocity from the system by several orders of magnitude, the wind density required would imply $\tau_{es}(\pi/2) \gg 1$ and $\lambda \ll 1$.

This model predicts that a large fraction of the total X-ray luminosity is absorbed in the stellar wind. Basko and Sunyaev[9] show that for stars with a high mass loss rate most of the energy is absorbed by gas with $T \sim 10^6$ K (comparable to $T_B$). Most of this energy is re-radiated as ultraviolet and as soft X rays from a region whose size is comparable to that of the system. This confirms that the spectrum from the gas will be flat out to wavelengths as long as 2.2 μm, before turning over to Rayleigh-Jeans at longer wavelengths. If this soft X-ray flux were visible we expect it to vary in a similar way to the infrared flux. The hard X-ray flux varies by a much greater amount and so cannot come from the same region. Also, the optical flux predicted here is much less than that expected from a straightforward extrapolation of the infrared flux along the Rayleigh-Jeans curve, as would be the case if the bulk of the infrared flux came from the stellar surface. Finally, I stress again the uniqueness of the system Cyg X-3 and, in a sense, the uniqueness of this model. For the parameters of Cyg X-3 we can have $\tau_{es} \sim 1$ and $\lambda \sim 1$. If the system were larger or smaller we could not satisfy both of these for any wind density, since $\lambda \tau_{es}{}^2 \propto D^{-1}$, independent of $N$.

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# Close Pairs of QSOs

IT has recently been argued[1,2] that the observation of close pairs of QSOs with very different redshifts provides support for non-cosmological explanations of the redshifts. We show in this note that the pairs observed so far may be comfortably explained as random coincidences and that the small probabilities that are often quoted depend on the use of *a posteriori* statistics.

The expected number of close pairs of QSOs is given by

$$\mathcal{N} = N_Q\ (\pi R^2)\ \rho(\leq m) \qquad (1)$$

where $N_Q$ is the total number of QSOs whose redshifts have been determined, $R$ (in arc s) is the 'region of interest' around any given QSO (or the maximum allowable separation for 'close' pairs), and $\rho(\leq m)$ is the total number of QSOs per square arc s down to a limiting magnitude $m$. Equation (1) may be rewritten inserting typical numbers[3], as

$$\mathcal{N}(R,m)\approx 7\times 10^{-2}\ (N_Q/1{,}000)\ (R/10'')^2\ 10^{0.6(m_v-19)} \qquad (1')$$

It should be noted that the typical *a posteriori* probabilities, calculated with the aid of equation (1), for the chance occurrence of a pair of close QSOs are not terribly small; they roughly correspond to 3 $\sigma$ events.

We recall the basic observational facts. There are now two known 'close' pairs of QSOs: Ton155, 156 (ref. 1) with a separation of 35″, redshifts $z=1.7$ and 0.55, and $m_v\approx 16.0$ and 16.6 mag; and 1548+115 a, b (ref. 2) with a separation of 5″, redshifts of $z=0.44$ and 1.9, and $m_v\simeq 17$ and 19 mag.

We note that the initial observation[1] of a close pair of QSOs, Ton155 and Ton156, could not be regarded by itself as statistically significant because the typical correlation-separation previously discussed[4] was several degrees (yielding for typical values of $R$ and $m$ in equation (1) values of $\mathcal{N}\gg 1$). But we might legitimately have used the initial observation to define an hypothesis to be tested, for example: QSOs brighter than $m_v=17$ mag have a much higher chance of appearing close together, $R\leq 35''$, than would be expected from a random distribution. On the basis of this hypothesis, the subsequent observation of the close pair 4C11.50 a, b (=1548 and 115 a, b) is not remarkable. First, $m_v$ (1548 and 115 b) is $\sim 19$ mag, much fainter than either of the Ton objects, so that the above defined hypothesis does not even cover this case. If we extend the limiting magnitude down to 19.4 mag (so it comfortably covers the observed pair 4C11.50 a, b), then $P\,(35'', 19.4)\sim 0.5$ compared with the observed value of 2. Actually even this calculation underestimates the expected number of pairs on the cosmological hypothesis. There is no *a priori* reason to suppose that $m=19$ mag or even $m=19.4$ mag is especially significant and one will always get unrealistically small probabilities for events if one calculates after the fact the chance expectation using the already observed parameters to define the experiment. In fact, experience shows that *a posteriori* probabilities at the 1% level are not particularly uncommon for random events; but of course *a posteriori* probabilities at the $10^{-6}$ or $10^{-10}$ level still are.

It is interesting to estimate the number of close QSO pairs that one would expect *a priori* on the cosmological hypothesis down to the limiting magnitude (~21 mag) of the blue Sky Survey (on which most of the identifications are made). For a total of $10^{-3}$ QSOs with known redshifts (perhaps a reasonable expectation for the next several years) and a maximum separation of 10″, we expect one or possibly a few pairs. If we enlarge the maximum separation to 30″ we expect about ten close pairs. These estimates are of course uncertain by at least a factor of three because we do not yet have an accurate determination of the QSO spatial density at faint magnitudes. Nevertheless, close pairs of QSOs should be rather common when it becomes standard practice to measure redshifts for all faint stars near accurate radio source positions.

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# Response of Dayside Thermosphere to an Intense Geomagnetic Storm

INCREASES in the density of the neutral thermosphere associated with geomagnetic activity were first noted by Jacchia[1]. Although the thermosphere will not be in equilibrium, and acceleration by electrodynamic forces may be involved, on balance the increased density must reflect additional heating. Further studies[2–4] by orbital drag analysis from observations of artificial Earth satellites have led to a complex and somewhat confusing picture. The heating seems to be slightly greater[3,4] at high latitudes and, for larger disturbances, sometimes much greater[2,3]. Also, the heating seems to be slightly greater[3,4] on the nightside, but possibly with the opposite trend[3] for larger disturbances ($K_p>5$). Jacchia *et al.*[3] also found that the time delay between the peak of the storm, as measured by the planetary 3-h indices $K_p$ or $a_p$, and the maximum response was a little shorter at high latitudes; on the other hand Roemer[4] concluded that the time delay was independent of latitude, height or local time.

The low $g$ accelerometer calibration system (LOGACS) experiment[5,6] carried on an attitude-controlled Agena vehicle launched by the United States Air Force on May 22, 1967, provided a unique opportunity to determine the response to an intense storm. As the histogram in Fig. 1 shows, the planetary 3-h geomagnetic index, $a_p$, started to increase on May 25, reached a peak of 236, then fell slightly before increasing to the conventional maximum of 400 for two successive 3-h periods. Figure 1 also gives the hourly equatorial Dst index[7] which is based only on the horizontal $H$ components at low latitude observatories and effectively measures the strength of the ring current during the storm.

The LOGACS accelerometer provided values of atmospheric density with an estimated accuracy better than 10% and a time resolution of 1 s, although at much longer intervals. Using these values, DeVries[5,6] found that the density in the (northern) nightside auroral regions increased with the onset of geomagnetic activity whereas the density in the (northern) dayside auroral regions initially decreased. The density over the rest of the Earth apparently reached a maximum with a time delay ranging from near zero in the nightside auroral regions to about 6 h at the dayside equator. DeVries concluded that most of the energy was injected in the nightside auroral regions probably, he suggested, by Joule heating[8] at or below 150 km, and transported over the rest of the Earth by convective circulation and atmospheric gravity waves.

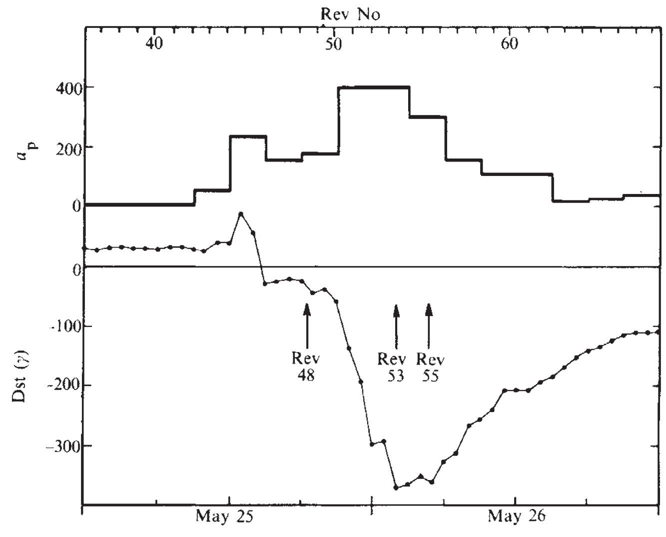


**Fig. 1** Geomagnetic activity during the storm as given by the planetary 3 h index $a_p$ (histogram) and the hourly equatorial Dst index. Rev, revolution.