matters arising

Distance to Cygnus X-1

CHENG *et al.*[1] have recently re-examined our estimates[2,3] of the distance to Cygnus X-1. They have noted that the Cepheid V547 Cyg is at $d = 6.6$ kpc, yet has colour excess 1.1, far less than predicted by a uniform reddening extrapolation. On this basis they conclude 'the only independent distance check (on Cyg X-1) is so widely in error.' It is well known (see refs 4, 5) that the dust responsible for interstellar reddening is stratified in layers, and thus for every non-zero galactic latitude there exists a distance beyond which stars show no further colour excess regardless of modulus. In such fields one therefore expects the most distant observable stars to have colour excess no greater than that of intermediate distance objects; V547 Cyg is entirely consistent with this concept. It is also wrong to state that there exist no other independent estimates of distance, as we pointed out previously. Evidence based on spectroscopic modulus[6], linear polarisation[7], cluster membership[8] and interstellar lines[9] all indicate $d > 2$ kpc. Each of these methods has its own assumptions which may be individually questioned and evaluated; none of the methods, however, uses the same assumptions as the colour excess method we used. We find it quite convincing that five independent methods, although none individually of extreme accuracy, are all in agreement.

Cheng *et al.*[1] speculate that the "possibility" of X-ray heating of the primary makes distance estimates uncertain. The amount of heating is a directly measured quantity and has been shown to be entirely trivial[10]. They also state that an extrapolation of the reddening diagram to beyond 1 pkc is unwarranted. But if one adopts $d \leqslant 1$ kpc as they claim as a possibility, then no extrapolation is necessary, and one must then postulate that this star is situated behind interstellar matter which creates reddening per unit distance far exceeding all other of the ≈ 125 objects we measured within 50′ of Cyg X-1. The alternative of circumstellar rather than interstellar reddening is excluded by the lack of infrared excess in HDE226868. Furthermore, the polarisation agreement[7] means that this excess material, implied by the authors to be in a small globule, manages in a fraction of a pc to exactly compensate for the linear polarisation otherwise provided by 2 kpc of interstellar matter.

Although we agree that Cyg X-1 is not proven to be a black hole, and other models for the system are still viable, we think that the overwhelming weight of observational evidence places this object at $d > 2$ kpc regardless of its nature.

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Indirect methods for detecting γ-ray bursts from supernovae

PORTER[1] suggests the possibility of detecting γ quanta from supernova bursts with a detector located at sea level. He bases his calculations on the results of a Monte Carlo computation procedure for electromagnetic showers[2]. It follows from the tables of cascade functions[2] that the mean particle number behind the cascade curve peak decreases with depth t as $e^{-\lambda t}$, where λ is much smaller than $\lambda_{\min}$ the minimum cross section of photon absorption in the matter. This result is at variance with the assertion that the shower development at low levels is determined by absorption of photons with the greatest permeability[3]. The experimental data used by Messel and Crawford[2] produced a discrepancy for photon absorption in air compared with the calculations of Ivanenko[4], which they explained by the fact that the Compton scattering had been inaccurately included in his work. Since all essential processes are accurately included in the Monte Carlo procedure, the disagreement with the cascade curves obtained by the momentum method[5,6] was ascribed[2] to the low accuracy of the reconstruction of the function based on a limited number of momenta

Numerical integration of the cascade theory one-dimensional equations[7,8] makes it possible to include accurately all processes and to calculate the longitudinal shower development down to sufficiently low depths to produce a good estimate of the absorption coefficient λ. Inclusion of annihilation of positrons would result in an appreciable increase of the calculation volume because the two-equation system must be replaced by a three-equation system The contribution from annihilation was, therefore, estimated The terms, including particle redistribution resulting from annihilation, were inserted into the system of two transport equations, and the positron number was taken as 0.4 and 0.5 times the total charged-particle number in two separate runs. The calculations were carried out for an electromagnetic shower in lead where the annihilation effect is greatest. Annihilation γ quanta from stopped positrons were also included. The estimate shows that the contribution from annihilation may be neglected to an accuracy of 3–5%. This result is in line with other calculations[9,10].

Table 1 1 MeV photon absorption coefficient

Element	$\lambda_{\min}$	λ_{calc}	λ_{MC}
Air	0.61	—	0.04 (ref. 2)
C	0.60	0.53 ± 0.01	—
Fe	0.41	0.33 ± 0.01	—
Cu	0.40	—	0.38 ± 0.02 (ref. 11) 0.11 (ref. 2) 0.24 ± 0.02 (ref. 4)
Pb	0.27	0.21 ± 0.01	0.25 ± 0.02 (ref. 12) 0.27 ± 0.03 (ref. 13)

A lower boundary for λ can be obtained when numerically integrating the one-dimensional equations, since the inclusion of scattering will only increase the cascade particle absorption with depth. For $E > 10$ MeV in heavy elements $E > 1$ MeV in light elements, the scattering effect on the cascade curve shape may be neglected[5,6]. We have calculated the cascade curves in lead, iron, and carbon from a primary (electron or photon) with energy E_0 in the 1–10^3 GeV range for several values of E from 316 MeV to 10 KeV. The calculated and