earlier Pleistocene devoid of these major ice ages in spite of similar orbital forcing. Although not mentioned as a possibility by Mix, this state of affairs suggests that the control of these ice fluctuations may reside in the internal instability of the slow-response parts of the climatic system that allows the possibility for a bifurcation to a free, long-period, oscillatory mode. We have suggested models illustrating this possibility (see, for example, ref. 6).

The most recent version of such an 'oscillator' model[7] emphasizes the potential role of atmospheric CO_2 as the critical free variable in the climatic system that, along with the global ice mass and some measure of the deep ocean state, can form the basis for a 'natural' nonlinear oscillator. It was shown that, by virtue of the many possibilities for positive feedback inherent in recently proposed biological, chemical and physical scenarios[8–12], the carbon cycle can provide the instability necessary to drive major climatic variability without external forcing. Moreover, with the addition of orbital forcing, a model containing relatively few adjustable parameters (rate constants) can be constructed that can give a 'first order' account of the evolution of some of the main Pleistocene variables — $\delta^{18}O$ and surface temperature[4], global ice mass, and the atmospheric CO_2 variations suggested by Shackleton and Pisias[13] and now supported to a large extent by the Vostok findings[1–3]. Although there are discrepancies, this model (which at present is the only closed, self-consistent, time-dependent model purporting to treat all these phenomena simultaneously) predicts a good deal of the variability discussed in these Vostok reports, including the phase lags.

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The GB790325b γ-ray error box revisited

SIR—In the light of the recently discovered optical flashes[1] about 5 arc min from the published 1 arc min error box of the γ-burst (GRB) GB790325b (ref. 2), scrutiny of the γ-ray localization is called for[3]. We have therefore examined our previous work to see whether the flashes were produced by GB790325b. We find that the GRB error box cannot be enlarged significantly, and that an extremely improbable combination of circumstances would be required to move it a distance equivalent to several times its characteristic dimension. Thus, the optical flasher is probably either a new phenomenon or a serendipitous nearby GRB or soft γ-repeater (SGR).

GB790325b was observed by seven instruments on five spacecraft[2,4]. The published error-box boundaries use the three 'best' data sets, with the remainder of the data providing confirmation in the form of larger, overlapping error boxes. The three crucial instruments are the Lockheed ARPA-301 experiment on the US Air Force P78-1 satellite (ARPA), the Pioneer Venus Orbiter γ-burst detector (PVO) and the Signe experiment on Venera 12 (S12). The uncertainty in the GRB position is caused by uncertainties in the relative arrival times of the γ-ray wavefront at the nominal spacecraft locations. For this event, a 100-ms timing error at any given spacecraft corresponds approximately to a 1 arc min error in the GRB location. It follows that GRB/flasher compatibility requires arrival time uncertainties several times larger than we used previously; or unknown errors in the spacecraft ephemerides or clock calibrations; or mistakes in the calculations.

The lag uncertainty in cross-correlating data from the various experiments usually accounts for most of the timing uncertainty. Fortunately, GB790325b contained a district fiducial — an intense, isolated, narrow (300-ms-wide full-width-half-maximum) peak about halfway through the GRB. Thus, lag uncertainties well below 100 ms should be expected *a priori*. In fact, analyses using the entire available time histories gave 1σ uncertainties (determined using a modified χ^2 method) comparable to our time-bin widths of 12–32 ms. Also, we are confident that the lag calculations have not been biased by spectral variability. Our spectral data do not show strong evolution in this event, and our cross-correlation analysis gave no evidence for nonstatistical differences between the various time histories.

Additional arrival time uncertainties arise from imprecise knowledge of spacecraft clock calibrations and ephemerides. Based on design goals and experience with overdetermined error boxes (the 5 March event being the best example[5,6]), these additional uncertainties are known to range from a few milliseconds for PVO and most near-Earth spacecraft, to at most a few tens of milliseconds for some interplanetary probes. For the US spacecraft these accuracies are 'guaranteed' and should not be considered in the same light as statistical fluctuations. In any case, we are hard pressed to produce total 3σ arrival-time uncertainties greater than ~100 ms. (Hence the original 1 arc min error box.) Because a 5 arc min discrepancy corresponds to at least 15σ, our attention must turn from uncertainties to mistakes.

We have checked virtually every step in the process that generated this GRB error box. For example, we tracked spacecraft ephemerides and clock calibrations over long periods of time to look for irregularities. For S12 and ARPA, independent experiments on the same spacecraft gave internally consistent results. We checked the PVO ephemeris against the position of Venus using the *Astronomical Almanac*. All the actual calculations were done independently, and with identical results, at Goddard, Los Alamos and Toulouse laboratories. Finally, with one unlikely exception, even if the data from any one spacecraft were discarded, the flasher location would still be excluded by the other two. The exception involves 'throwing out' PVO (despite its accurate ephemeris and numerous clock calibrations) and invoking a source proper motion of 2 arc s yr^{-1} to the south-west. This motion is within about a factor of two of the maximum allowed by the flasher observations (D. Hartmann, in preparation).

In summary, it is extremely difficult to reconcile the optical and γ-ray error boxes. There seem to be four possibilities remaining. First, the optical flashes are spurious. This is probably excluded by the spatial coincidence of the three flashes. Second, a new kind of optical 'superflaring' has been discovered. The possibility cannot be excluded and may have implications concerning Schaefer's flashes[7,8]. Third, the flashes are from a serendipitous GRB. This requires a total GRB population of at least several thousand, but the inferred flasher repetition rate of about one per month seems high for a GRB. Finally, the flashes are from a serendipitous SGR. The repetition rate and temporal proximity of two of the flashes (and possibly the 20° galactic latitude?) support this conclusion, but the apparent rarity of SGRs[9] is a problem for a serendipitous discovery in a small region of space.

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