Intergalactic thermonuclear γ -ray line

SIR—The X-ray emission from clusters of galaxies demonstrates^{1,2} that perhaps as much as $10^{14} M_{\odot}$ of hot $T \approx 10^8$ K gas may often surround galaxies in clusters with a density of perhaps $n = 4 \times 10^{-3} \text{ cm}^{-3}$. If the ion temperature is 10^8 K, the thermonuclear reaction $p + d \rightarrow {}^3\text{He} + \gamma$ should emit γ rays at a rate of roughly $4 \times 10^{41} \text{ s}^{-1}$ with energy $E_{\gamma} = 5.516 \pm 0.016 \text{ MeV}$. Such a source in the Virgo cluster at 15.7 Mpc distance would present a line flux $F_{\gamma} = 1 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1}$ at Earth. Although this flux is 10^{-6} of the line fluxes that can be detected by the satellite Gamma Ray Observatory the concept of thermonuclear reactions in dilute space is sufficiently fascinating to warrant a brief discussion.

The total amount of hot gas around a galaxy cluster is still not precisely known; nor is its temperature distribution. Imagine for simplicity an isothermal gas having $T = 10^8$ K amounting to $10^{14} M_{\odot}$ of hydrogen of density $n = 4 \times 10^{-3} \text{ cm}^{-3}$. Coulomb collisions should easily maintain equality between electron and ion temperatures. Prior to astration³, the cosmic deuterium appears to have existed with an abundance ratio $D/H \approx 1 \times 10^{-4}$. The reaction $p + d \rightarrow {}^3\text{He} + \gamma$ will be the most active thermonuclear reaction in such a plasma. The lifetime $\tau_p(D)$ of a deuteron against interactions with protons can be shown⁴ to be

$$\tau_p(D) = [n_p(\sigma v)]^{-1} = 2.8 \times 10^{21} \tau^{-2} e^{-\tau} / n_p (\text{cm}^{-3}) \text{ s} \quad (1)$$

where the conventional thermonuclear parameter τ is $\tau = 8.018 T_8^{-1/3}$ with the ion temperature $T_8 = 10^{-8} T$. If, for example, $T_8 = 1$ and $n_p = 4 \times 10^{-3}$ this lifetime is $\tau_p(D) = 3.3 \times 10^{25} \text{ s}$. Because this time greatly exceeds the age of the Universe there is no question of significant destruction of D by this situation.

On the other hand, the rate of γ -ray emission is $Q_{\gamma} = N_D/\tau_p(D)$, which can be rather large if the number of deuterons N_D is $10^{-4} N_p$ and if the hot plasma is as massive as $10^{14} M_{\odot}$ of protons. For then $N_D = 1.2 \times 10^{67}$ and $Q_{\gamma} = 3.6 \times 10^{41} \text{ s}^{-1}$. This emission rate Q_{γ} is proportional to $n_p/4 \times 10^{-3}$, to $M_H/10^{14} M_{\odot}$, and has a temperature dependence inversely proportional to that of equation (1). It is the dependence of the emission on the properties of the hot intergalactic gas that makes it interesting. Also of interest is the energy of the line feature, which occurs near the sum of the mass release $\Delta mc^2 = 5.493 \text{ MeV}$ and the most effective thermal⁵ energy $E_0 = 23 \text{ keV}$ in the ion plasma; that is $E_{\gamma} = 5.516 \text{ MeV}$. The width of the line feature is somewhat greater than thermal, being⁴ $\Delta E_0 = 32 \text{ keV FWHM}$ at $T_8 = 1$.

The flux is likely to be too small to measure, however. Imagining that hypothetical cloud at the distance 15.7 Mpc to the Virgo cluster leads to a flux F_{γ}

(Virgo) $= Q_{\gamma}/4\pi R^2 = 1.2 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1}$. This is 10^{-6} of the line fluxes anticipated measurable by the Gamma Ray Observatory, for example, and it does not seem likely that a permanent low-level observatory in space can ever achieve such a low background level. Nonetheless it is interesting that the order of magnitude $Q_{\gamma} \approx 10^{42} \text{ s}^{-1}$ is of the same order as the Q_{γ} (${}^{26}\text{Al}$) from radioactive ${}^{26}\text{Al}$ in the disk of our Galaxy⁵ that was recently detected⁶ by HEAO 3. The Virgo cluster is unfortunately too distant for us to detect, as are therefore other clusters. The contribution to the omnidirectional universal background can be seen to be well beneath the observed continuum following the line of argument developed by Clayton and Silk⁷. Although this calculation therefore seems at first glance academic, it may be unwise to prejudge the scientific future of the unique ideas involved.

This research was supported by NASA DPR S-10987C for the OSSE spectrometer for Gamma Ray Observatory as funded by subcontract N00014-83-C-2162 from Naval Research Laboratory.

DONALD D. CLAYTON

Department of Space Physics
and Astronomy,
Rice University,
Houston, Texas 77251, USA

1. Fabian, A. C., Nielsen, P. E. J. & Canizares, C. R. *Nature* **310**, 733–740 (1984).
2. Jones, C. & Forman, W. *Astrophys. J.* **276**, 38–55 (1984).
3. Clayton, D. D. *Astrophys. J.* (in the press).
4. Clayton, D. D. *Principles of Stellar Evolution and Nucleosynthesis*, Ch. 4, 5 (University of Chicago Press, 1983).
5. Clayton, D. D. *Astrophys. J.* **280**, 144–149 (1984).
6. Mahoney, W. A., Ling, J. C., Jacobson, A. S. & Lingenfelter, R. E. *Astrophys. J.* **262**, 742–748 (1982).
7. Clayton, D. D. & Silk, J. *Astrophys. J. Lett.* **158**, L43–L48 (1969).

The transmission of AIDS

SIR — Shearer and Rabson¹ have remarked that anatomical differences between the vagina and the rectum may in part be responsible for the frequency with which acquired immune deficiency syndrome (AIDS) is acquired by anal-receptive sexual intercourse; I wish to draw attention to some additional and possibly relevant differences between these organs.

The mucosa of the healthy vagina is much less densely populated by lymphocytes than that of the gut. Only occasional lymph follicles, and no large aggregates such as Waldeyer's ring or Peyer's patches, are found. In addition, to my knowledge there have not been described in the vagina specialized structures analogous to the intestinal M cells — membranous epithelial cells overlying Peyer's patches which take up from the lumen, and present to underlying lymphoid tissue, a variety of antigenic materials including macromolecules and viruses^{2,3}. These contrasts suggest that direct encounters between lymphocytotropic viral agents, specifically

HTLV-III / LAV, and their potential target cells, and thus infection and viral replication may be facilitated in the gut but may occur only rarely, if at all, following simple deposition of virus in the vagina.

With regard to a possible role of semen or sperm antigens in immune dysregulation, it is well known that the intestinal tract is highly active in an extensive system of mucosal immunity⁴. But little has been published on mucosal immunity in the female genital tract. Direct comparisons of antigen uptake, recognition and processing between the gut and the vagina do not appear to have been made. Limited inferences from the literature lead me to suppose that immune surveillance mechanisms may operate at a much more restricted level in the vagina. The hypothesis of semen-induced immune dysregulation^{5,6} should be evaluated in light of existing information and new data on reproductive/genital and lower-intestinal mucosal immunology.

GERALD A. AHRONHEIM

Ste. Justine's Hospital and the
University of Montreal,
Montreal, Quebec H3T 1C5, Canada

1. Shearer, G.M. & Rabson, A.S. *Nature* **308**, 230 (1984).
2. Owen, R.L. *Gastroenterology* **72**, 440 (1977).
3. Wolf, J.L. *et al. Science* **212**, 471 (1981).
4. Bienenstock, F. & Befus, A.D. *Immunology* **41**, 249 (1980).
5. Mavligit, G.M. *et al. J. Am. Med. Ass.* **251**, 237 (1984).
6. Sonnabend, J., Witkin, A.S., & Partilo, D.T. *J. Am. Med. Ass.* **249**, 2370 (1983).

Bird territory and weight gain

SIR — In challenging much of the work by Carpenter *et al* on weight gain of birds in relation to their territory size, Butlin² invokes the possibility that the rate of weight gain is related to the bird's body weight, that is $M = kM$, where M is the weight of the bird and k is a constant. This translates to $\Delta M/M = k \Delta t$, which integrates simply to $\ln M = kt + C$ where t is time and C is a constant. Rearranging this expression gives $M = e^{kt+C}$.

With the realistic assumption that $M = 0$ at $t = 0$, that is at or before conception, we have $C = -\infty$, the modulus of which is substantially greater than kt except after an infinite time. For all practical timespans this results in $M = 0$.

The consequence of this is that the bird has zero weight until an infinite time has passed whereupon it grows at an exponential rate — although by that time it probably wouldn't notice the difference. Of course, we can juggle the boundary condition to achieve more sensible answers but we still have unstoppable exponential growth predicted by the model.

R. WHITTINGTON

Hunters Way,
Bunkers Lane,
Rookley,
Isle of Wight, UK

1. Carpenter, F.L., Paton, D. & Hixon, M. *Proc. natn. Acad. Sci. U.S.A.* **80**, 7259 (1983).
2. Butlin, R.K. *Nature* **312**, 313 (1984).