(1) Signal peptide sequence: Rat growth hormone may indeed have been translated in yeast and been extruded into the rough endoplastic reticulum[22], but it might then have been degraded because of an inability to proceed normally through the yeast secretory pathway. The LeIF-D plasmids used in the present study contain no signal peptide coding sequences, so any interferon made in yeast should have remained in the cystosol.

(2) The sequence context preceding the initiator ATG: For highly expressed yeast genes, nucleotides −1 to −10 in the untranslated leader region of mRNA are typically rich in A with a few Cs and Ts, but no Gs. An A residue is found at position −3 or −4 in all yeast mRNAs to far analysed. The construction used in the expression of interferon from the *ADH*1 promoter followed this rule (leader sequence: AATTCATG); that for rat growth hormone gave a leader sequence (GTGCGATG) very unlike those of yeast mRNAs. This unusual leader sequence may not have supported efficient translation initiation by yeast ribosomes.

(3) Codon usage differences: In addition to major differences in arginine codons, which are mainly AGA in LeIF-D and CGPy in RGH, the rat growth hormone leader region is very rich in CUC and CUG leucine codons. These are very rarely used in yeast proteins[8,23].

Conclusions and prospects

A mammalian protein, human leukocyte interferon, can be made efficiently in yeast by the fusion of its coding sequence to a yeast promoter and transcription terminator within a yeast plasmid vector. In such fusions, the yeast signals specifying the 5′ and 3′ ends of mature mRNA still function predictably after they are grafted onto protein-encoding sequences from another organism. The LeIF-D made in yeast seems to be stable there because it can accumulate to as many as 10^6 molecules per cell. Although the expression levels obtained are high for a preliminary study, improvements may be expected by the use of plasmids with decreased rates of mitotic loss. Alternatively, transformants may be stabilized by chromosomal integration of the hybrid transcription units.

The techniques described here may enable the genetic engineering of yeast to produce many types of protein which normally occur only in other organisms; this may be important for production of pharmaceutical substances and for altered fermentation behaviour of the yeast cells. The yeast system should be particularly advantageous for the synthesis of glycoproteins from higher organisms because the addition of the inner core of carbohydrate occurs by the same mechanism as in animal cells[24] and the secretory pathway follows the general pathway used by animal cells[22].

The authors at Genentech thank Guiseppe Miozzari for encouragement and Laurie May for performing the interferon assays. The authors at University of Washington thank Valerie Williamson and Jeffrey Bennetzen for supplying the cloned *ADH*1 gene, J. Bennetzen for communicating the *ADH*1 sequence before publication and Andrea Barta for communication of RGH experiments. B.H. and G.A. were supported by a NIH grant.

Received 2 June; accepted 27 August 1981.

1. Beggs, J. D. *Nature* **275**, 104–109 (1978).
2. Hinnen, A., Hicks, J. B. & Fink, G. R. *Proc. natn. Acad. Sci. U.S.A.* **75**, 1929–1933 (1978).
3. Williamson, V. M., Bennetzen, J., Young, E. T., Nasmyth, K. & Hall, B. D. *Nature* **283**, 214–216 (1980).
4. Petes, T. D. *A. Rev. Biochem.* **49**, 845–876 (1980).
5. Henikoff, S., Tatchell, K., Hall, B. D. & Nasmyth, K. A. *Nature* **289**, 33–37 (1981).
6. Beggs, J. D., van den Berg, J., van Ooyen, A. & Weissmann, C. Nature **283**, 835–840 (1980).
7. Goeddel, D. V. *et al. Nature* **290**, 20–26 (1981).
8. Bennetzen, J. L. & Hall, B. D. *J. biol. Chem.* (submitted).
9. Smith, M. *et al. Cell* **16**, 753–761 (1979).
10. Faye, G., Leung, D. W., Tachell, K., Hall, B. D. & Smith, M. *Proc. natn. Acad. Sci. U.S.A.* (in the press).
11. Nagata, S., Mantei, N. & Weissmann, C. *Nature* **287**, 401–408 (1980).
12. Lawn, R. M. *et al. Science* **212**, 1159–1162 (1981).
13. Goeddel, D. V. *et al. Nature* **287**, 411–416 (1980).
14. Stinchcomb, D. T., Struhl, K. & Davis, R. W. *Nature* **282**, 39–43 (1979).
15. Stewart, W. E. II *The Interferon System* (Springer, New York, 1979).
16. Miozzari, G., Neideiberger, P. & Hutter, R. *J. Bact.* **134**, 48–59 (1978).
17. Kingsman, A. J., Clarke, L., Mortimer, R. & Carbon, J. *Gene* **7**, 141–153 (1979).
18. Staehlin, T., Hobbs, D. S., Kung, H. & Pestka, S. *Proc. natn. Acad. Sci. U.S.A.* (in the press).
19. Kozak, M. *Cell* **15**, 1109–1123 (1978).
20. Sherman, F., Stewart, J. W. & Schweingruber, A. M. *Cell* **20**, 215–222 (1980).
21. Seeburg, P. H., Shine, J., Martial, J. A., Baxter, J. D. & Goodman, H. M. *Nature* **270**, 486–494 (1977).
22. Novick, P., Field, C. & Schekman, R. *Cell* **21**, 205–215 (1980).
23. Holland, J. P. & Holland, M. J. *J. biol. Chem.* **255**, 2596–2605 (1980).
24. Ballou, L., Cohen, R. E. & Ballou, C. E., *J. biol. Chem.* **255**, 5986–5991 (1980).
25. Kuo, S.-C. & Yamamoto, S. *Meth. Cell Biol.* **11**, 169–183 (1975).
26. Birnboim, H. C. & Doly, J. *Nucleic Acids Res.* **7**, 1513–1523 (1979).
27. Maxam, A. M. & Gilbert, W. *Meth. Enzym.* **65**, 490–565 (1980).
28. Tschumper, G. & Carbon, J. *Gene* **10**, 157–166 (1980).
29. Backman, K., Ptashne, M. & Gilbert, W. *Proc. natn. Acad. Sci. U.S.A.* **73**, 4174–4178 (1976).
30. O'Farrell, P. H. *J. biol. Chem.* **250**, 4007–4021 (1975).

LETTERS TO NATURE

Supermassive binaries in active galactic nuclei

Daniel P. Whitmire & John J. Matese

Department of Physics, University of Southwestern Louisiana, Lafayette, Louisiana 70504, USA

Recent observational evidence[1–6] indicating the apparent precession of jets in compact and extended radio sources suggests the presence of a second massive body in the nuclei of the associated active galaxies[7] (we include quasars as active nuclei). On the basis of their similarities with close binaries in the Galaxy, two of which (SS433 and Her X-1) are known to contain precessing beams and disks, we consider here the possibility that the secondary object is a Roche overflowing supermassive star (SMS) of mass $M_2 \sim 10^6$–$10^8 M_\odot$ in orbit around a primary massive black hole (MBH) of mass $M_1 \sim 10^7$–$10^9 M_\odot$.

Jet precession and evolutionary considerations led Begelman, Blandford and Rees[7] to propose a binary model containing two MBHs in which the observed jet motion is identified with the geodetic precession of the more massive component ($M_1 \sim 10^8 M_\odot$). Although this model can account for the inversion-symmetric morphology[5] and apparent precession seen in extended radio jets (such as 3C315, NGC326, 3C196 and 3C305), which indicate precession periods $P_p \sim 10^5$–10^8 yr (refs 3, 4, 7), it does not easily explain the $\sim 10^3$-yr precession periods suggested for the fast-moving compact VLBI features seen in 3C273 and 3C345 (refs 1, 2, 7). The basic problem is that precession periods $\leq 10^3$ yr require orbital separation distances that are short lived due to gravitational radiation, unless implausibly low masses are assumed[1].

Two similar scaled-down relativistic precession models[8,9] were originally proposed for SS433, but the subsequent discovery[10] of a 13-day orbital period (rather than an expected period of 4–8 min) suggests[11] that these relativistic models are probably not applicable to SS433. There are, however, other binary models for SS433 which are simultaneously compatible with a 13-day orbital period and a 164-day beam precession period; two, the slaved disk (SD)[12–14] and the disk-driven (DD) precession[15] models, will be considered below in the context of a SMS/MBH binary model for active nuclei.

Drawing our analogy from SS433 and Her X-1, we assume that active galactic nuclei which exhibit jet precession are powered by accretion onto a MBH when a companion SMS fills its critical Roche surface. Most of the compact core continuum radiation (optical and flat spectrum radio) is assumed to originate in the accretion disk around M_1 and only a negligible contribution originates with the SMS (compare with SS433 and cataclysmic variables). Well known luminosity and lifetime arguments suggest that $M_1 \sim 10^7$–$10^9 M_\odot$ and $M_2 \sim 10^6$–$10^8 M_\odot$. We thus adopt as representative masses $M_1 \sim 10^8 M_\odot$ and $M_2 \sim 10^7 M_\odot$, values also used by Begelman *et al.* We do not speculate here on the evolutionary details for such a binary system, except to note that some aspects of the Begelman *et al.* evolution involving galactic mergers might be relevant and that misalignment between extended jets and the minor axis of elliptical galaxies is sometimes observed. The SMS must form relatively near the critical separation radius where Roche overflow is possible (in which case mass transfer might be initiated by pulsational or rotational instabilities), or have a lifetime sufficiently long that it remains in a quasi-equilibrium while viscous drag or mass loss reduces the orbital separation. After Roche overflow has begun, further mass transfer could be driven by continued orbit decay due to viscous drag or angular momentum loss from the system[16,17]. Investigations of the stability of SMSs indicate that stars of mass $\sim 10^6$–$10^8 M_\odot$ may be stabilized against hydrodynamic collapse for $\sim 10^6$–10^7 yr by the presence of a modest amount of differential rotation[18–21], and by possible contributions from macroscopic turbulence and internal magnetic fields (spinars)[20,21]. The relatively short lifetime of SMSs may require that their formation be triggered by a merger event.

If the SMS fills its critical Roche surface, then its mean radius is given by[22,23]

$$\frac{R_2}{r} \approx \frac{0.462}{(1+q)^{1/3}} \qquad q \geqslant 3 \tag{1}$$

where r is the semimajor axis (assumed to be approximately circular) and $q \equiv M_1/M_2$ is the mass ratio. For $q \sim 10$, $R_2/r \sim 0.21$. Thus, in sources with compact cores there is a small but potentially significant probability of eclipsing. Assuming random orientations and disk radii $\leqslant R_2$, the probability of eclipsing in a given source is ~ 0.07 for $R_2/r \sim 0.21$. Note that this probability is fairly insensitive to q. An estimate of the expected orbital period and possible selection effects are discussed below.

Although the evidence for massive binaries is more direct in the precessing jet sources, in the context of binary models many and perhaps all active nuclei probably contain SMS/MBH binaries. Precessing jets would then be seen only in those sources in which there is misalignment between the orbit normal and the spin axis of M_1 or M_2. As the beam precession angle θ is not expected to be too large (for example, SS433, $\theta \approx 20°$ and Her X-1, $\theta \sim 5°$), eclipsing should be more probable in compact cores in which the associated jets lie nearly in the plane of the sky.

In the slaved disk model[12–14,24], it is assumed that the spin axis $\vec{S}_2$ of the secondary is misaligned with the orbit normal. The observed precession period, $P_{\rm SD}$, is then associated with the forced precession of the secondary (which has a quadrupole moment by virtue of its rotational distortion) by the primary. The secondary is assumed to fill its critical Roche surface and is losing mass through the inner Lagrange point. As the angular momentum of the transferred matter will depend on the orientation of $\vec{S}_2$, the accretion disk around M_1 will orient itself accordingly. If the transferred material is processed through the disk in a time that is short compared with the precession period of $\vec{S}_2$, then the disk orientation will follow $\vec{S}_2$. The disk is thus coupled to or 'slaved' to the precessing axis of the secondary star[24]. As in the case of SS433, we assume that the beams are ejected normal to the surfaces of the precessing disk[12–14]. Note that Linfield[1] has independently suggested an accretion disk as the source of the $\sim 10^3$-yr precession period in the compact jets in 3C273 and 3C345.

The problem of long-lived forced precession in a fluid star was noted by Roberts[24] who indicated that different shells may precess at different rates, leading to complex internal motions. Superficially, such differential precession might seem to lead to alignment on a relatively short time scale. However, forced precession may be maintained if the precessing modes involve radial motion and circulation in the star[25]. Other authors have concluded that long-term forced precession is possible[26] and that the alignment time scale can be comparable with or longer than the synchronization time scale[27].

The forced precession rate of the SMS is given by[23,14]

$$\frac{\Omega_{\rm SD}}{\omega_0} \approx \left(\frac{k'}{k}\right)\left(\frac{\omega_2}{\omega_0}\right)\left(\frac{R_2}{r}\right)^3\left(\frac{M_1}{M_2}\right)(1-e^2)^{-3/2} \tag{2}$$

where k' is the apsidal motion constant, k the gyration parameter, e the eccentricity, r the semimajor axis, ω_0 the orbital angular velocity and ω_2 the angular velocity of the secondary. Assuming an approximately circular orbit and synchronous rotation, we may substitute R_2/r from equation (1) into equation (2), yielding $\Omega_{\rm SD}/\omega_0 \sim 0.1(k'/k)$, which is independent of M_1, M_2 and q provided $q \geqslant 3$. For a SMS model with polytropic index $n = 3$ (refs 18, 19), we may use the table given by Motz[28] to obtain $k'/k \approx 0.19$, which is consistent with the estimate[14] of $k'/k \leqslant 1/3$ for $n \geqslant 2.5$. Inserting this into equation (2) and setting $\Omega_{\rm SD} \sim 2\pi$ per 10^3 yr gives an orbital period of $P_0 \sim 20$ yr. For $M_1 = 10^8 M_\odot$, $q \geqslant 3$ and $e \approx 0$, the corresponding binary separation distance is $r \sim 5 \times 10^{16}$ cm. The relativistic parameter, $2GM_2/c^2R_2$, is $\sim 3 \times 10^{-4}$. Thus the SMS could easily be supported by an expected modest amount of differential rotation and magnetic field.

An orbital period of ~ 20 yr is potentially observable in sources such as 3C273 and 3C345 which exhibit $\sim 10^3$-yr precession periods. Unfortunately, selection effects may enhance the probability of observing non-eclipsing compact sources. Relativistic jets that are oriented nearly towards the observer will be Doppler enhanced and more easily detected[1,7], such as the asymmetric compact superluminal jets in 3C273 (ref. 29). But compact cores with transverse jets are more likely to exhibit eclipsing because the beam precession angle is expected to be relatively small. On the other hand, the basic SMS/MBH binary model may be applicable to sources in which there is no misalignment. Consequently, our eclipsing probability estimate of ~ 0.07 may be relevant to most active nuclei.

If the slaved disk model is applicable to the extended jets with precession periods $\sim 10^5$–10^8 yr (refs 1, 3, 4, 7), then the implied orbital periods are $\sim 2 \times 10^3$–2×10^6 yr, which are obviously not directly observable. However, if these extended jets are subrelativistic, then their curvature may not be due to precession[1] and the SD model is not applicable. In this case, active nuclei associated with the extended curved jets, as well as the extended linear jets, may still potentially exhibit eclipsing (but of less certain period) if the basic SMS/MBH binary model is relevant. Consequently, sources with extended jets lying near the plane of the sky might constitute a preferred sample in which relativistic beaming effects would be much less important.

Comparing the ratio of orbital period to precession period in the SD and geodetic models (Begelman *et al.*) gives $(P_{\rm SD}/P_{\rm geo}) \sim 2.5 \times 10^{-3}$ for $M_2 \sim 10^7 M_\odot$ and $r \sim 5 \times 10^{16}$ cm. The gravitational radiation time scale (Begelman *et al.*) for the SD model parameters ($M_1 \sim 10^8 M_\odot$, $M_2 \sim 10^7 M_\odot$ and $r \sim 5 \times 10^{16}$ cm) is $t_{\rm GR} \sim 2 \times 10^9$ yr. Thus in the SD model, the system is not seriously unstable to gravitational radiation. Begelman *et al.* estimate a precession period of ~ 500 yr for the fast-moving jets in 3C273 and 3C345. However, their suggested parameters of $M_1 \sim M_2 \sim 10^8 M_\odot$, $r \sim 1.7 \times 10^{16}$ cm and $t_{\rm GR} \sim 10^6$ yr are inconsistent with a precession period of 500 yr (compare with their equation (8) which gives a precession period of $\sim 2.3 \times 10^3$ yr). Although these parameters are intended only as order-of-magnitude estimates and might be adjusted to ensure consistency, this illustrates the difficulty in obtaining the required precession periods with geodetic precession, as noted elsewhere[1]. (Lens Thirring and Kerr-quadrupole-moment precession of M_1 by M_2 is even less effective.) The geodetic model can, however, easily account for the extended jet precession periods.

The disk-driven precession model (DD) has also been proposed[15] to account for SS443 and might be relevant to precession in extragalactic jets. In this model, a stationary massive outer disk around the compact object causes the compact object's spin axis $\vec{S}_1$ (plus the inner portion of the disk) to precess due to the Lens Thirring effect. From angular momentum considerations, a critical radius, r_p, is identified such that disk material at radii $\geqslant r_p$ is not precessed by the compact object plus inner disk while material interior to r_p is aligned with the precessing equatorial plane of the compact object. It is assumed that accreting matter is collimated and ejected out along $\vec{S}_1$, which is also the direction normal to the inner disk[8,30,31].

Applied to SS433, the DD model requires a radial inflow rate of $v_r/v_\theta \sim 10^{-10}$–$10^{-9}$, corresponding to a disk viscosity parameter of $\alpha \sim 10^{-9}$–10^{-7} at r_p[15]. This very small inflow rate is the opposite extreme of the more conventional rate required for the SD model[14] and the two models are therefore mutually exclusive. However, the required inflow rate is less extreme for disks around MBHs. The formulae given by Sarazin *et al.*[15] refer to a $1\,M_\odot$ compact object. Inserting the M_1 dependence into their equation (5) and using the appropriate angular momentum for an extreme Kerr black hole leads to an inflow rate of $v_r/v_\theta \sim 10^{-5}$ at r_p, assuming $M_1 \sim 10^8 M_\odot$, $P_{LT} \sim 10^3$ yr and $\dot{M}/\dot{M}$(Eddington) ~ 500. The latter assumption is appropriate for SS433 but may be an overestimate here. If $P_{LT} \sim 10^7$ yr, $v_r/v_\theta \sim 10^{-2}$ for the same parameters.

The required disk mass could most easily be obtained by Roche overflow from a companion SMS by analogy with SS433, Her X-1 and numerous other galactic binaries with compact objects and accretion disks. In this case, eclipsing may occur as previously discussed, but it is not possible to obtain a simple relationship between the orbit and precession periods. If the necessary supercritical accretion and inflow rates are realizable, there might be a weak statistical relationship between the precession period and luminosity (as reflected by $\dot{M}$) because $\Omega_{LT} \propto \dot{M}^{3/2}$.

Clearly all three models (geodetic precession, slaved disk and disk-driven) can accommodate precession in extended sources ($P_p \sim 10^5$–10^8 yr), but only the slaved disk model can easily explain the short period ($\sim 10^3$ yr) precession indicated by VLBI observations of fast-moving jets in 3C273 and 3C345 (refs 1, 2). All three models have been proposed to explain the 164-day beam precession period in SS433, a binary system now believed to consist of a relatively normal Roche overflowing star and a compact object[32,33]. The compact binary system Her X-1/HZ Her is known to contain a large precessing disk, and therefore of the three models considered only the slaved disk model is applicable to this system. There are, of course, numerous other examples of (non-misaligned) galactic binary systems which are radiating near their Eddington limit due to Roche overflow from a normal star onto a compact object. Thus active galactic nuclei, especially those suggesting jet precession, may be scaled-up versions of these better understood galactic binaries. Recently, Neill *et al.*[34] have concluded that their VLBI observations of SS433 favour the kinematical precessing jet model of Linfield[1] for the superluminal jets seen in 3C273 and 3C345 over the density gradient model of Readhead *et al.*[35].

In the context of the slaved disk model, orbital periods of $\sim$20 yr are expected in compact sources with $\sim 10^3$-yr precession periods. If the jets and compact core continuum originate in the accretion disk, then the probability of eclipsing should be greatest in compact sources whose associated fast-moving jets lie near the plane of the sky, although selection effects due to relativistic beaming may discriminate against this geometry. The basic SMS/MBH binary model may also be relevant to active nuclei which do not exhibit precession because of a lack of misalignment, in which case $\sim$7% of all active compact cores could potentially be eclipsed. The observational probability might be improved by choosing a sample which includes compact central cores that are associated with the more common extended jets (as well as any compact jets) which lie close to the plane of the sky.

We thank Dr R. Linfield for discussions and a preprint.

Received 11 May; accepted 20 August 1981.

1. Linfield, R. *Astrophys. J.* (in the press).
2. Linfield, R. *Bull. astr. astrophys. Soc.* **12,** 854 (1980).
3. Lonsdale, C. J. & Morison, I. *Nature* **288,** 66 (1980).
4. Ekers, R. D., Fanti, R., Lari, C. & Parma, P. *Nature* **276,** 588 (1978).
5. Miley, G. K. *The Physics of Non-Thermal Radio Sources* (ed. Setti, G.) (Reidel, Dordrecht, 1976); *A. Rev. Astr. Astrophys.* **18,** 165 (1980).
6. Northover, K. J. E. *Mon. Not. R. astr. Soc.* **177,** 307 (1976).
7. Begelman, M. C., Blandford, R. D. & Rees, M. J. *Nature* **287,** 307 (1980).
8. Martin, P. G. & Rees, M. J. *Mon. Not. R. astr. Soc.* **189,** 19 (1979).
9. Begelman, M. C., Sarazin, C. L., Hatchett, S. P., McKee, C. F. & Arons, J. *Astrophys. J.* **238,** 722 (1980).
10. Crampton, D., Cowley, A. P. & Hutchings, J. B. *Astrophys. J. Lett.* **235,** L131 (1980).
11. Margon, B. *Proc. NATO Advanced Study Institute, Galactic X-ray Sources* (in the press).
12. Katz, J. I. *Astrophys. J. Lett.* **236,** L127 (1980).
13. Whitmire, D. P. & Matese, J. J. *Mon. Not. R. astr. Soc.* **193,** 707 (1980).
14. Hut, P. & Van den Heuvel, E. P. J. *Astr. Astrophys.* **94,** 327 (1981).
15. Sarazin, C. L., Begelman, M. C. & Hatchett, S. P. *Astrophys. J. Lett.* **238,** L129 (1980).
16. Whitmire, D. P. & Matese, J. *Mon. Not. astr. Soc.* **194,** 293 (1981).
17. Robinson, E. L., Nather, R. E. & Patterson, J. *Astrophys. J.* **219,** 168 (1978).
18. Fowler, W. A. *Astrophys. J.* **144,** 180 (1966).
19. Fowler, W. A. *IAU Symp.* No. 46 (1971).
20. Ozernoi, L. M. *Soviet Astr.* **10,** 241 (1966).
21. Morrison, P. *Astrophys. J.* **157,** L73 (1969).
22. Paczyński, B. A. *Rev. Astr. Astrophys.* **9,** 183 (1971).
23. Kopal, Z. *Close Binary Stars* (Wiley, New York, 1959).
24. Roberts, W. J. *Astrophys. J.* **187,** 575 (1974).
25. Papaloizou, J. & Pringle, J. E. *Mon. Not. astr. Soc.* (to be published, 1981).
26. Kopal, Z. *Dynamics of Close Binary Systems* (Reidel, Dordrecht, 1978).
27. Hut, P. *Astr. Astrophys.* **99,** 126 (1981).
28. Motz, L. *Astrophys. J.* **115,** 562 (1952).
29. Pearson, T. J. *et al. Nature* **290,** 365 (1981).
30. Bardeen, J. M. & Patterson, J. A. *Astrophys. J. Lett.* **195,** L65 (1975).
31. Rees, M. J. *Nature* **275,** 516 (1978).
32. Margon, B. *Ann. N.Y. Acad. Sci.* (in the press).
33. Margon, B., Grandi, S. A. & Downes, R. A. *Astrophys. J.* **241,** 306 (1980).
34. Neill, A. E., Lockhart, T. G. & Preston, R. A. *Astrophys. J.* (submitted).
35. Readhead, A. C. S., Cohen, M. H., Pearson, J. J. & Wilkinson, P. N. *Nature* **276,** 768 (1978).

Laboratory produced visible spectral emission features correlate with those of the Red Rectangle

Thomas J. Wdowiak

Physics Department, University of Alabama in Birmingham, Birmingham, Alabama 35294, USA

Warren-Smith *et al.*[1] and Schmidt *et al.*[2] have obtained peculiar optical spectra of the Red Rectangle, which is a nebula centred on the star HD44179 that possesses the geometry of a hollow biconical shape with the star at the apex. This is also the source of IR emission features at 3.3, 6.2 and 7.7 μm (refs 3, 4). Warren-Smith *et al.*[1] report the presence of R-type band-like features, characterized by a profile of sharp rise from shorter wavelengths and a gradual degradation to the red, occurring at λ5,779, 5,855, 5,880 and 6,615, with the first two and the last being the most intense. They attribute the origin of these emissions to unsaturated carbon molecules or carbynes. I report here that matrix isolation experiments directed towards understanding the origin of the diffuse interstellar bands also show spectral emission features having characteristics similar to those found in the visible spectrum of the Red Rectangle nebulosity. These experiments suggest that the observed Red Rectangle emissions have their origins in fluorescence phenomena of species that are matrix-isolated in grain mantles.

From a 0.5% methane in argon plasma, I have produced a species having a spectral absorption pattern that correlates with the principal diffuse interstellar bands[5]. The products of the discharge are trapped in an argon matrix at $T < 20$K and spectroscopic measurements made by transmitting through the sample light from an 80-W tungsten lamp (DGB; estimated filament temperature 3,150K) used with a Kodak heat rejection filter having decreasing transmission between λ3,750 and λ3,250.

Besides the absorption features described in ref. 5, the spectra exhibit four fluorescence features excited by the tungsten lamp. One of these features is probably R-line fluorescence of chromium ions as impurities in the sapphire substrate