A new non-thermal galactic radio source with a possible binary system

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Helfand and Becker[1] recently discussed the unusual filamentary appearance of the galactic radio sources G357.7–0.1 and G5.3–1.0, both of which had originally been classified as supernova remnants (SNR$_s$)[2,3], and proposed that these sources belong to a new class of non-thermal radio sources that originate in accreting binary systems containing a neutron star or a black hole. Becker and Helfand[4] have pointed out that other galactic sources may be identified as members of this class; we report here our claim that a new non-thermal galactic object (G18.95 – 1.1), detected in the recently published 2.695-GHz galactic plane survey[5], is a possible candidate. That the integrated flux density spectral index $\alpha = -0.4$ ($S_\nu \sim \nu^\alpha$) and the polarization is ≈2.5% at 4.75 GHz, proves the non-thermal nature of the new source; morphologically, a classification of this object as a SNR seems impossible. G18.95 – 1.1 consists of various arcs all pointing towards a central radio peak; we suggest that the object is a binary system containing a compact component, located at or close to this radio peak, accelerating electrons to relativistic energies—observed in the arcs by the synchrotron emission of the accelerating electrons.

The source G18.95 – 1.1 has subsequently been observed at 1.42 GHz and 4.75 GHz with the Effelsberg 100-m telescope and at 10 GHz with the Nobeyama 45-m dish. The 4.75-GHz map is shown in Fig. 1 and the spectrum is plotted in Fig. 2. Both the spectral index and the polarization reveal the non-thermal nature of G18.95 – 1.1.

How do we classify this object? The peak radio intensity is close to the centre of the object and shows a bar-like structure with peaks near each end of the bar (Fig. 1). Even the highest available angular resolution does not allow separation of any compact source from the diffuse emission. The grey-scale radiograph in Fig. 3 allows the determination of the source structure in much greater detail. From this presentation it is apparent that G18.95 – 1.1 consists of various arcs pointing towards the radio peak slightly off-centre to the north-east. Clearly, the morphology of G18.95 – 1.1 defies any classification as a SNR and also contradicts the general appearance of radio galaxies. Its arcs may be of similar origin to the filaments in G357.7 – 0.1 discussed by Helfand and Becker[1]. We therefore suggest a binary system containing a compact component as the source of G18.95 – 1.1. This possible centre of activity should be expected to be located in the central bar, perhaps at or close to the peak emission north-east of the centre. If the central location of this source is not the result of projectional effects, the velocity of the binary system relative to the filamentary structure is low, or the source is much younger than G357.7 – 0.1 and G5.3 – 1.0.

The estimation of source parameters (for example, age, distance) is hindered by the insufficient data available. We suggest that deep optical observations (no corresponding emission could be found in the Palomar plates) and a search for X-ray emission be made. At radio wavelengths, more sensitive polarization

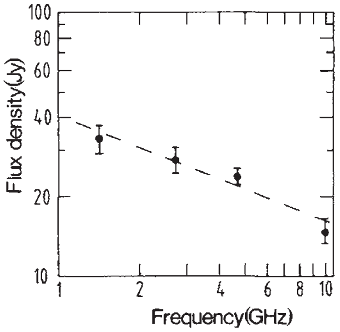

Fig. 2 The radio spectrum of G18.95 – 1.1. The integrated flux densities are: S(1.42 GHz) = 32.9 Jy, S(2.695 GHz) = 27.4 Jy, S(4.75 GHz) = 23.8 Jy and S(10 GHz) = 14.6 Jy; the typical error is 10%. The mean flux density spectral index $\alpha = -0.4$. There may be a steepening of the spectrum from $\alpha = -0.4$, in the inner part near the radio peak, to $\alpha = -0.5$ at the outer arcs, but the accuracy of the spectral index is 0.2. The errors are mainly attributable to the uncertainty in the estimation of the base levels.

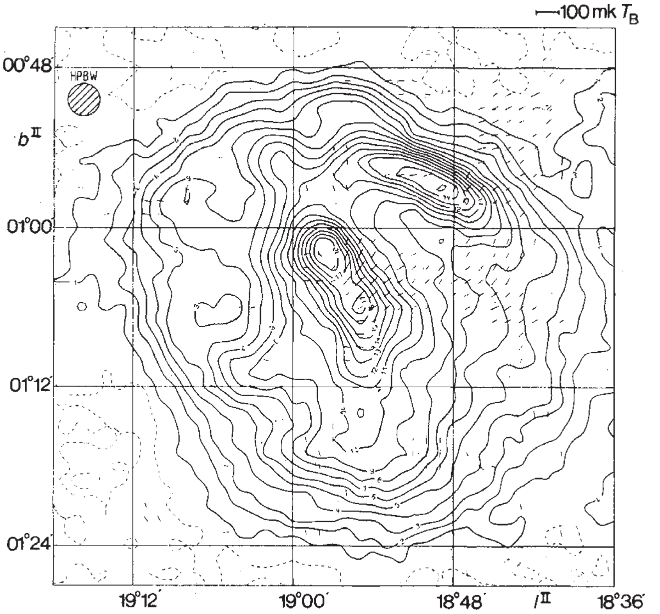

Fig. 1 4.75-GHz map of G18.95 – 1.1. Contour steps are 50 mK brightness temperature T_B. The angular resolution is 2.4 arc min. Superposed are the linear polarization intensity E-vectors. The integrated polarization percentage is 2.5%.

Fig. 3 The grey-scale map of G18.95 – 1.1.

measurements together with improved angular resolution (possibly using the Very Large Array) and a search for a pulsar will certainly help to understand the nature of G18.95 − 1.1. If our assumption of a binary system as the source of G18.95 − 1.1 is confirmed, this object will provide important information on the interaction of binary systems with the surrounding interstellar medium.

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A higher limit to the mean galaxy mass allowed by gravitational lens image distortion

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Tyson *et al.*[1], in a recent discussion of the gravitational lens distortion, by foreground galaxies, of the images of distant ('background') galaxies, claim that their non-detection of this effect implies a low mean mass for the foreground galaxies. The effect they sought is a change in the coherent ellipticity, that is, the ratio of the angular diameters orthogonal and parallel to the separation vector to the foreground galaxy. Using samples of galaxies in different ranges of magnitude to represent the 'foreground' ($19 < J < 21.5$) and 'background' ($22.5 < J < 23.5$) galaxies, they found no significant effect and therefore deduced a 2σ upper limit to the mean mass of the foreground galaxies of only 2.8×10^{11} $H^{-1}\,M_\odot$ out to a radius of $80\,H^{-1}$ kpc (where H is Hubble's constant in units of $100\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$). The corresponding mass-to-light ratio and the known luminosity density of the Universe then requires that the mass density in the form of galaxies is $\Omega_{\mathrm{gal}} < 0.03$, which is in marked contrast to the values $\Omega_{\mathrm{gal}} \sim 0.2$ obtained by various dynamical arguments, namely, the rotation curves of individual galaxies, the virial equation applied to groups and clusters and the cosmic virial theorem[2–5]. I show here that, by including the effect of galaxy clustering, the limit on Ω_{gal} is indeed raised to $\Omega_{\mathrm{gal}} \lesssim 0.2$, in accordance with the dynamical determinations.

Tyson *et al.*[1] noted that for the two magnitude ranges they used, there should be little overlap in the distances of their two sets of galaxies, and substantiated this by Monte Carlo experiments using a Schechter[6] luminosity function. They claimed therefore that almost all observed pairs should be a genuine background–foreground pair (the lensing effect is insignificant if the two galaxies are close together). However, this step is invalid if galaxy clustering is taken into account, because for any observed pair, what we really require is the conditional probability of finding a 'background' (that is, faint) galaxy at a particular distance given the presence of the foreground galaxy, since this becomes significantly confused by nearby clustered low-luminosity galaxies. It is easy to see that this has a substantial effect by considering the standard form for the galaxy autocorrelation function[7], $\xi(s) = (s/r_0)^{-\gamma}$, with index $\gamma = 1.8$ and scale length $r_0 \approx 5\,H^{-1}$ Mpc. Even at the maximum pair separation used by Tyson *et al.*, corresponding to $220\,H^{-1}$ kpc at the mean distance $D = 720\,H^{-1}$ Mpc of the foreground galaxies, the clustering increases the number of expected neighbours by factors of several hundred relative to that for a random distribution.

More exactly, we can integrate the correlation function to show that the number of galaxies per unit solid angle at separation θ from a given foreground galaxy, distance D from the observer, will be[8]

$$N' = N + D^2\Phi(M)G(\gamma)r_0^{\gamma}(\theta D)^{1-\gamma}$$

where N is the mean surface density, Φ is the integral luminosity function and $G = 3.678$ for $\gamma = 1.8$. Now, from Tyson *et al.*, we find the mean background density to be 5,670 galaxies per deg^2 or $N = 1.86 \times 10^7\ \mathrm{rad}^{-2}$. Also, with the previously specified values of D, G, r_0 and γ and taking[9] $\Phi \simeq 0.05\,H^3\ \mathrm{Mpc}^{-3}$ (in this context Φ is the number density of galaxies in the magnitude range $-16.5 \geqslant M_{\mathrm{B}} - 5\log H \geqslant -17.5$ corresponding to $22.5 < J < 23.5$ at $D = 720\,H^{-1}$ Mpc), the second term on the right-hand side has the value $1.7 \times 10^8\,\theta_{\mathrm{s}}^{-0.8}$, where θ_{s} is the separation in arc seconds.

In other words, the fraction of genuine background–foreground pairs that are able to show a measurable lensing effect is only $1/(1 + 9\,\theta_{\mathrm{s}}^{-0.8})$ so that the mean distortion will be diluted by a factor ranging from 4.0 at $\theta = 4$ arc s to 1.5 at $\theta = 40$ arc s. (Note that the ratio will be the same even if there is a bias against detecting close pairs, because of the presence of the bright foreground galaxy, thus reducing the apparent clustering.) As the effect sought is greatest at small separations, this obviously greatly limits the power of the test. When the dilution factor is included, even the most massive model considered by Tyson *et al.* (outer radius $190\,H^{-1}$ kpc, equivalent circular velocity $300\ \mathrm{km\,s^{-1}}$, that is, mass $\simeq 2.1\,H^{-1} \times 10^{12}\,M_\odot$) is within 2.5σ of the observed points for all except one of the bins in θ. It may therefore be prudent, at present, to take a conservative upper limit of $\sim 2 \times 10^{12}\,H^{-1}\,M_\odot$ for the mass of a mean foreground galaxy, which raises the limit on the density parameter to $\Omega_{\mathrm{gal}} \lesssim 0.2$. We note also that if the clustered galaxies are preferentially aligned[10], then the situation is even worse than we have assumed and almost any density parameter will be allowed, because this effect will work in opposition to the lens effect that causes an orthogonal elongation.

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Synthesis of ethylene and ethane by partial oxidation of methane over lithium-doped magnesium oxide

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The partial oxidation of methane into more useful chemicals such as methanol, ethylene and benzene has been investigated extensively, although yields for these products have been poor[1–4]. Moreover, in several of these processes the required oxidant is N_2O rather than O_2. Recent work[5] in our laboratory has demon-