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33 GHz structure on the Galactic plane

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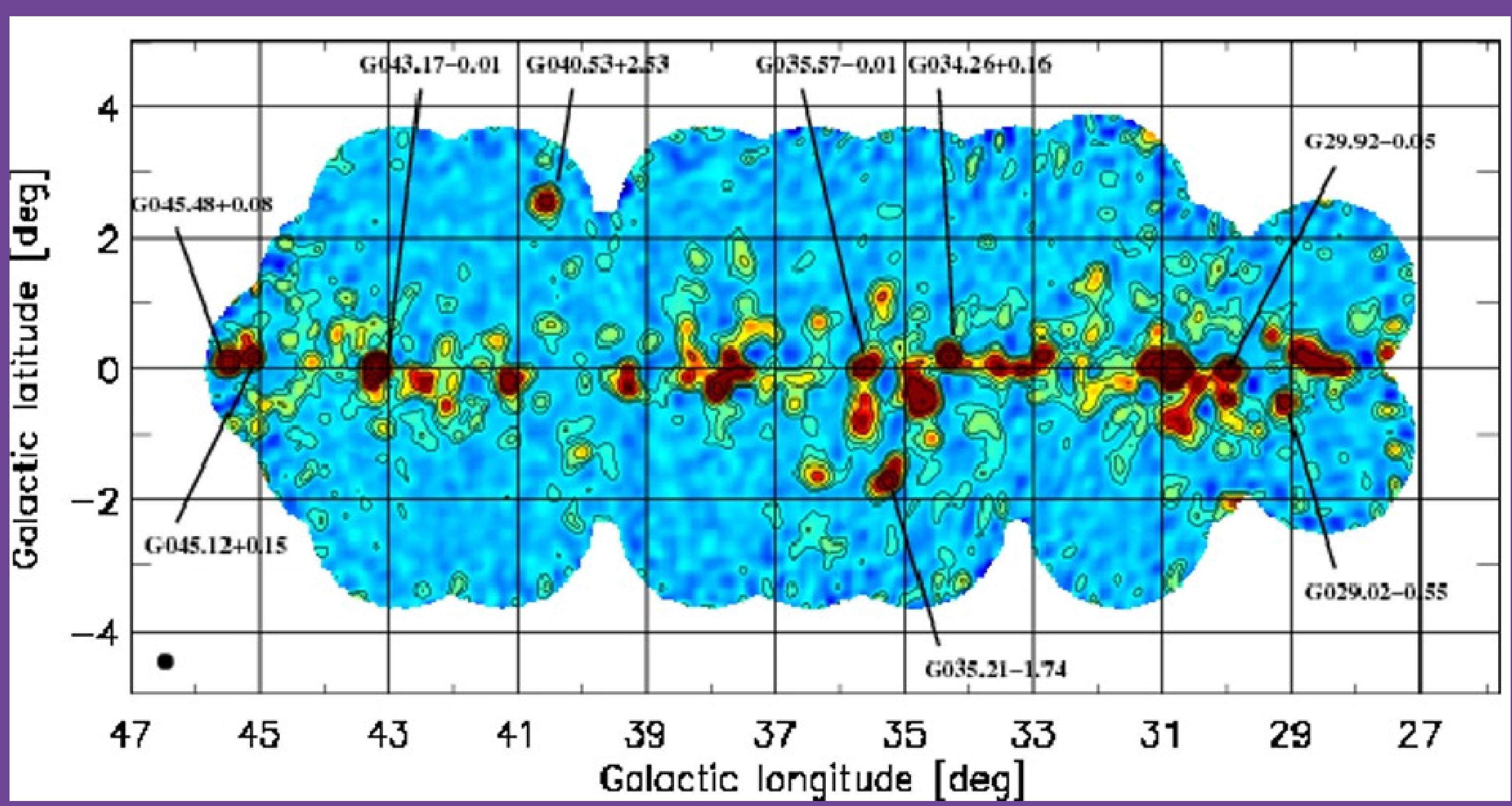
ABSTRACT: We report an investigation of free-free, synchrotron and dust emission using 33 GHz Very Small Array (VSA) data in the ℓ ~ 27° to ~ 46°, |b| < 4° region of the Galactic plane. The angular resolution is 13 arcmin. We derive spectral energy distributions for 9 well-defined, unconfused sources, using ancillary radio and FIR data. We investigate the distribution of diffuse emission and the clumpiness along the Galactic plane.

Searches for radio sources on the Galactic plane are faced with challenges which are different from those at higher lattitudes, where high resolution optical imaging and spectroscopy are available. The diffuse emission on the Galactic plane is interpreted as a mixture of synchrotron emission with a flux density spectral index (defined as $S \sim \nu^{\alpha}$) of α ~ -0.7 at ν < 1 GHz, and free-free emission. On the plane, where optical extinction is severe, radio recombination lines (RRLs) can take the place of Hα lines in identifying HII regions ([1],[2],[3]). At the lower frequencies (0.4 to 5 GHz), where fully sampled surveys are traditionally made, the strong diffuse background on the Galactic ridge complicates the identification of individual sources. HII regions and SNR have a spectral index α of -0.11 to -0.13 ([4]) and -0.3 to -0.8 (average of -0.5 at GHz frequencies, e.g. [5]), respectively. Hence, in principle, SNRs can be distinguished from HII regions by comparing the radio with the FIR emission from the associated dust. Furthermore, recent observations have cemented the existence of a third component; anomalous microwave emission (AME) due to spinning dust, both at intermediate lattitudes and near the Galactic plane ([5],[6],[7]).

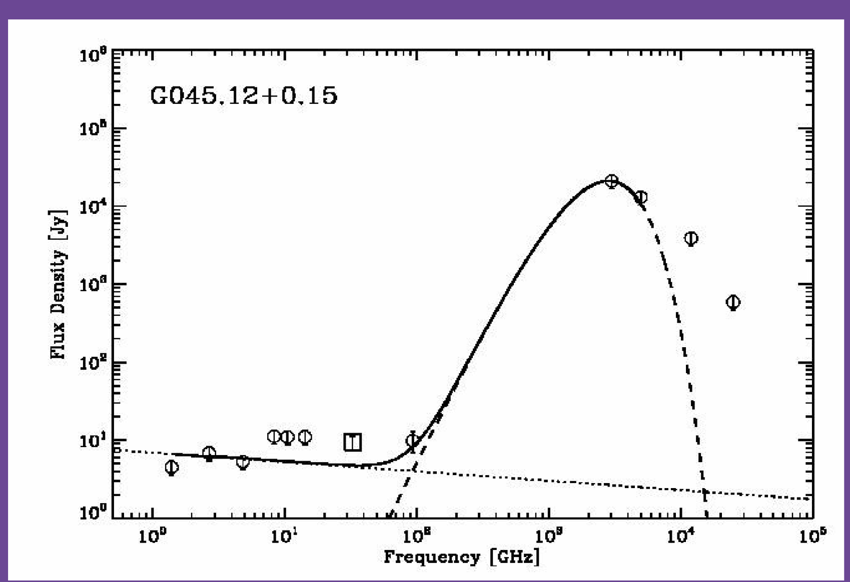
We present a high sensitivity 33 GHz map made with the VSA of a 19° section of the Galactic plane. The VSA detects structure up to a scale of ~50 arcmin, with a resolution of 13 arcmin. The major part of this structure detected at 33 GHz is free-free emission from HII regions. We use the VSA 33 GHz data in conjunction with ancillary data in the radio (1.4 to 94 GHz) to FIR (IRAS 100, 60, 25, 12 μm) to investigate the physical properties of the warm dust and ionised gas in 9 well-defined HII regions detected in the survey. We construct SED plots for these HII regions on the Galactic plane.



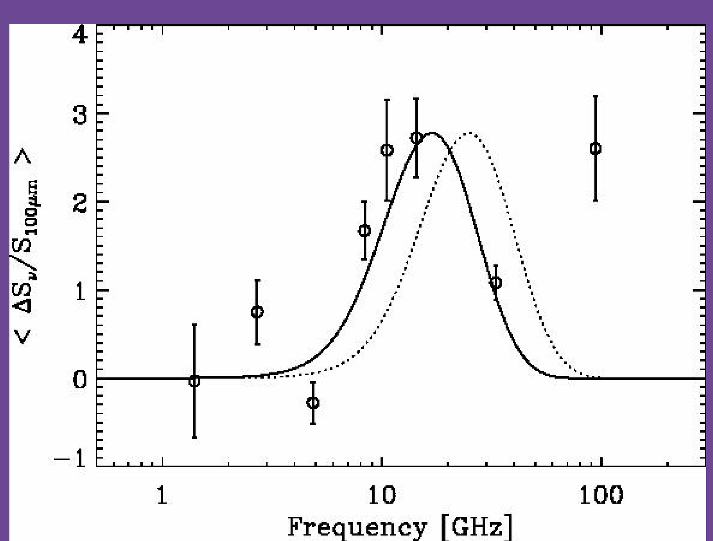
The 33 GHz VSA map of the Galactic plane covering the region between l = 27° and 46° and b ± 3°.5. Units are Jy/beam. Contour levels are at 0.5, 1, 2, 4, 8, 16, 32 and 64 per cent of the peak brightness (66.8 Jy/beam). The nine HII regions studied are also shown.

The 33 GHz data from the VSA survey was used, in conjunction with the Ka-band WMAP survey, to derive the fraction of the free-free emission and the clumpy component on the Galactic plane, relative to the total continuum. Objects can be readily identified using data from relevant surveys, mainly 2.7 GHz at 1/12 of the frequency and the 100 μm FIR data convolved to the resolution of the 33 GHz VSA survey. We found that the HII regions and SNR can be separated by virtue of the ratio of radio to FIR integrated flux densities. The majority of 33 GHz sources are HII regions.

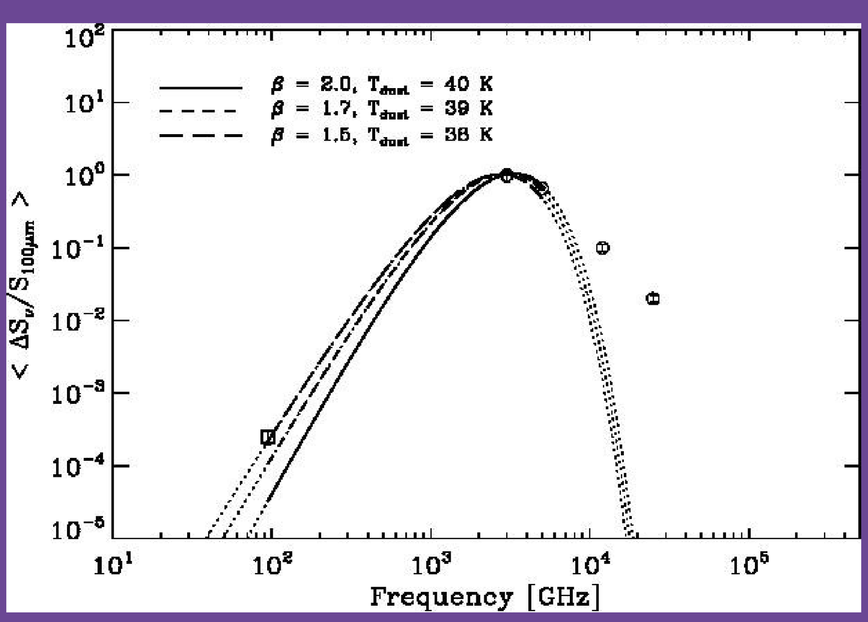
There is a clear detection of AME from warm dust in the HII regions studied. When combined with published data on individual HII regions, the 33 GHz emissivity relative to 100 μm is 4.65 ± 0.40 μK $(\mathrm{MJy/sr})^{-1}$ at a 11.5σ level. This value is 3-5 times less than that of cool (20 K) dust in the field. We find that the AME is on average 41±10% of the radio continuum in these sources.



SED plot for G045.12+0.15. The excess emission at 33 GHz is clearly seen, indicated with the square symbol. The best-fit free-free spectrum through the 2.7 and 5.0 GHz data is shown as a dotted line, along with a 30 K thermal dust spectrum (dashed line) through the 100 μm and 60 μm data points, with β set to 1.5, with errors of 1σ.



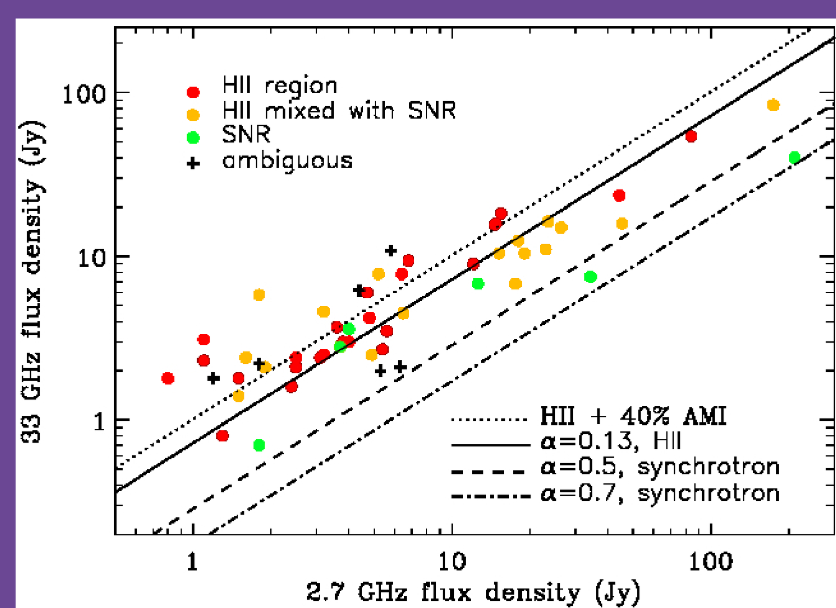
The spectrum of the averaged radio emission relative to 100 μm emission for the 9 HII regions. The values are in units of 10^{-4} and the plotted errors are 1σ. The dotted curve is the Draine & Lazarian ([8]) model for rotational emission from spinning dust grains in warm ionized medium. The solid line is the same model shifted to lower frequencies by a factor of 0.68.



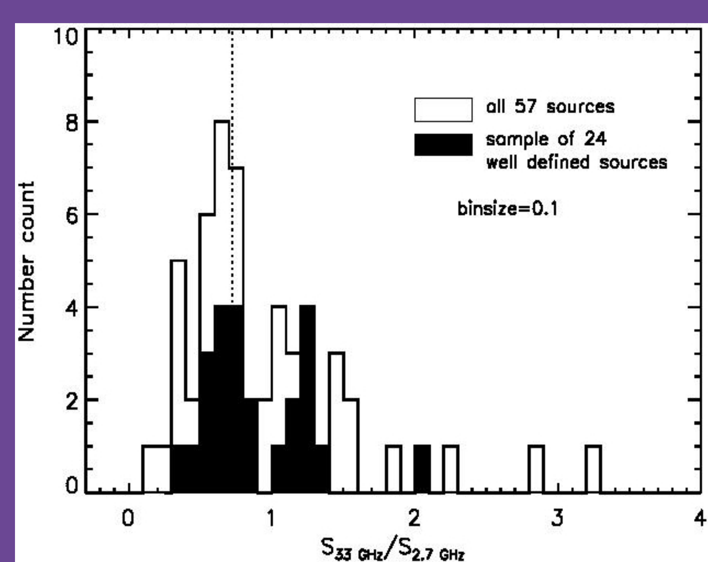
The mean emissivities of the 9 HII regions in the IRAS bands and the 94 GHz excess emission with respect to 100 μm thermal dust. The β = 1.5, 1.7 and 2.0 spectra for thermal dust are shown separately. The best fit is for a dust temperature of 39 K and β = 1.5.

Well-defined SNRs, as listed in the Green ([5]) catalogue, are detected at 33 GHz. The RRL data from the Paladini et al. ([1]) catalogue was used in confirming the SNR/HII region separations and in assigning the HII regions to a particular spiral arm. We find that the clumpy component is ~10-15 % of the total emission on the Galactic plane, in a narrow distribution in latitude of FWHM 2º.

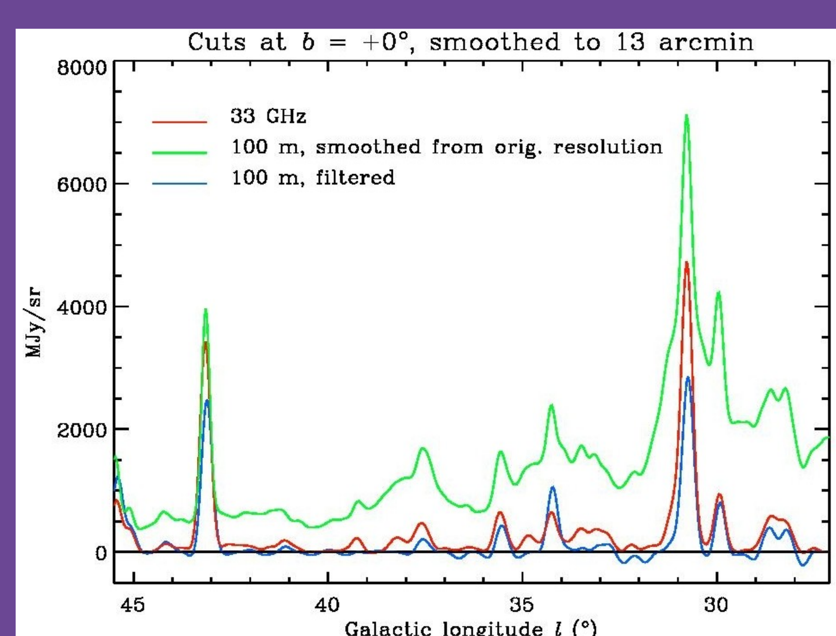
We plot the 33 GHz vs. 2.7 GHz flux density for the 57 sources in the VSA catalogue. Approximately half the sources are identified as HII regions with RRLs and dust association. The remaining fraction were a mixture of a HII region overlying an SNR or were ambiguous. There is a significant excess over the expected spectral index of 0.13 for HII regions, due to AME.



The histograms of all the 57 sources in the catalogue and 24 sources with S > 5 Jy at 33 GHz. The peak in both histograms occurs around $S_{33GHz}/S_{2.7GHz} \approx$ 0.7, as expected (0.722) for a free-free spectrum. Also shown is a significant population at both higher and lower $S_{33GHz}/S_{2.7GHz}$ which correspond to AME and synchrotron contributions, respectively.



The 13 arcmin structure, i.e. the clumpiness of the ISM is 10-15 % of the total emission, as measured by WMAP Ka-band. At 100 μm, the ratio of 13 arcmin scale emission to total is similar. We show that the 33 GHz sources are mainly (~85-90 percent) free-free objects [9].



References:
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[9] Todorovic et al., in preparation