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"Sites of Fine-Scale Electron Density Turbulence
in the Insterstellar Medium"
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Observations of radio-wave scattering effects probe interstellar electron-density turbulence. But with limited use of complementary data sets only broad conclusions have been obtained. The locations of this turbulence are unknown (phases, objects, etc.), as is the mechanism for its production, although it could play a role in various galactic processes. We have used the IRAS data set to search for correlations between scattering and structures traced by infrared emitting dust. We also used the existent HI (21-cm line emission), and 408-MHz radio-continuum all-sky surveys to search for correlations between scattering and structures traced by these emissions. Only lines of sight outside the galactic plane were considered (to better delimit the structures which might be causing scattering). No correlation is apparent between 21-cm line emission, or infrared continuum emission and interstellar scattering. However, a correlation exists between the scattering toward extragalactic radio sources and 408-MHz continuum emission.

As part of this research project:

- We configured and installed the operating system for two Sun 3/60 workstations. These workstations were used to display the IRAS, HI, and 408-MHz images and to investigate lines of sight with known strengths of radio-wave scattering, and extreme scattering.
- We concentrated considerable effort on installing the Astronomical Image Processing System (AIPS) on the Sun workstation dedicated to astrophysics research. This system is supplied by the National Radio Astronomy Observatory. The IRAS, HI, and 408-MHz images are transported in a form written specifically for use on this system. This task was finally completed after an update of the operating system (SunOS 4.0.3) in the Sun workstations (we discovered the older operating system (4.0.0) did not support the AIPS software package).
- We collected the published scattering measurements (specifically, values of ${C_n}^2$ which specify the strength of the turbulence along the line of sight) for pulsars and compact extragalactic sources.

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- We loaded the IRAS FITS images from nine-track tape (received from the National Space Science Data Center at Goddard) into a local VAX and transferred them to the Sun workstation and subsequently to 8mm cartridge tape.

Having configured our computers, brought up the AIPS software, and obtained the relevant data sets, we then proceeded to first examine interesting lines of sight for IR, HI, and 408-MHz structures coincident with known scintillating sources. In particular we looked in some detail at the lines of sight toward the "rapid variables" discovered by Heeschen and collaborators (Heeschen *et al.* 1987). They all lie toward the north celestial pole, some 30 or so degrees off the galactic plane. Some coincidences of rapid variables and IR structures (in this case loops) are seen, whereas nonvariables do not lie on the loops). However, based on this evidence alone the interpretation that these structures are responsible is not solid. Furthermore, subsequent work of ours casts doubt on this interpretation (see below).

Subsequently, we carried out a systematic comparison of scattering with IR emission, 21-cm emission from neutral hydrogen, and low-frequency radio emission (408-MHz emission). These comparisons were made using the all-sky maps available at these frequencies. Initially, the object was to search for correlations between scattering measure (SM; line-of-sight integral of ${C_n}^2$) and sky-brightness in the various emission maps. The scattering measures come from pulsar and extragalactic source observations, thus the comparisons were done for a limited set of lines of sight. The actual comparisons were between $SM - \angle SM(b)\rangle$, and $B - \langle B(b)\rangle$, where SM and B are the scattering measure and sky-brightness toward, for example, a specific pulsar, and $\langle SM(b)\rangle$ and $\langle B(b)\rangle$ are the average values at the galactic latitude of the pulsar (average over galactic longitude). In this way, the uninteresting correlation of everything with galactic latitude is removed from our data.

While, for the limited number of lines of sight investigated (mainly toward pulsars), there is a nice correlation between HI and IR emission there appears to be no correlations between SM and HI emission, or SM and IR emission, or SM and 408-MHz emission. This result may show the use of HI, IRAS, and 408-MHz maps in discussions of the sites of scattering structures (as have recently appeared in the literature) may be misleading at best. However, we suspected that since the pulsars lie at various distances within the interstellar medium, true correlations between scattering material and HI, IR emitting regions, or 408-MHz emitting regions, may be washed out by situations where, for instance, a weakly scattered pulsar lies between us and a strongly infrared-emitting cloud.

To remove this possible effect, the best sources to use are extragalactic. However, the original SM data set we were using had a limited number of extragalactic SM measurements. Subsequently, we have made use of the recently published maps of the strength of interplanetary scintillations (IPS; caused by the plasma in the solar system) toward a very large number of extragalactic sources (Hajivassiliou 1992). Groups on the sky of extragalactic sources showing weak IPS can be assumed to have systematically larger angular diameters, compared to sources in other directions (since "stars twinkle, planets don't"). The most plausible explanation for this systematic difference in groups of sources is that interstellar scattering is stronger in some directions than in others, broadening the sizes of sources seen along those stronger scattering directions, prior to the passage of the radiation through the interplanetary medium. Thus a map of the IPS strength for groups of sources in various directions can be directly related to the interstellar scattering in those directions.

We used the published all-sky map of the fraction f of extragalactic sources in small sky-patches showing strong IPS in a way similar to the IRAS, HI, and 408-MHz maps. If one simply compares $f - \langle f(b) \rangle$ for any line of sight with the corresponding $B - \langle B(b) \rangle$ (for 100μm, HI, or 408-MHz), no correlation is found. However, if one first removes from f a model in which some of the interstellar scattering occurs on the surface of an elongated bubble of radius $\sim$ 45pc in the galactic plane and $\sim$ 150pc out of the plane (Hajivassiliou 1992), and *then* compares $f - \langle f(b) \rangle$ to $B - \langle B(b) \rangle$, while no correlation is found between the f and HI, or 100μm emissions, a correlation is found between f and 408-MHz emission.

Figure 1 displays $B - B\langle b \rangle$ for high latitude ($b > 15°$) 21-cm emission with that for high-latitude 100μm emission (a model of the zodiacal light was first removed, and the ecliptic plane was avoided). The (already known; e.g., Boulanger and Pérault 1988) correlation between IR emission from interstellar dust and 21-cm emission from interstellar neutral hydrogen is readily apparent. Figures 2 and 3 show $B - B\langle b \rangle$ for 408-MHz continuum emission versus 21-cm emission and 100μm emission, respectively. Apparently synchrotron emitting regions and neutral gas (or dusty regions) do not gather near each other on the sky, or are only weakly correlated. However, it does seem that while, for instance, synchrotron emission and HI emission are not (or are only very weakly) correlated, they are not independent of each other: stronger than usual 408-MHz emission at a given galactic latitude typically appears only where one sees *average* 21-cm emission, not weaker than average HI, and not stronger than average HI. Stronger than usual 21-cm emission appears only where one sees average 408-MHz emission. Similar statements can be made about the relationship between 408-MHz emission and IR emission. We are continuing to investigate these relationships.

Figure 4 shows the IPS $f - \langle f \rangle$ versus $B - B\langle b \rangle$ for HI emission (where the f bubble-model was subtracted from the all-sky f map as discussed above). The distribution of f is not continuous because of the way the data were binned. There is no apparent correlation between the two measures. Figure 5 shows the IPS $f - \langle f \rangle$ versus $B - B\langle b \rangle$ for 408-MHz emission (where the f bubble-model was subtracted from the all-sky f map as discussed above). Note the increasing occurrence of stronger than usual 408-MHz emission where $f - f\langle b \rangle$ is negative (smaller f, or negative $f - f\langle b \rangle$ imply stronger interstellar scattering). This figure presents the main evidence in favor of a correlation between synchrotron emitting regions and interstellar scattering. Presumably, locations of shocks (e.g., the galactic continuum loops) are locations were turbulence plasmas responsible for scattering are preferentially located. Further work on this apparent relationship is currently underway.

References

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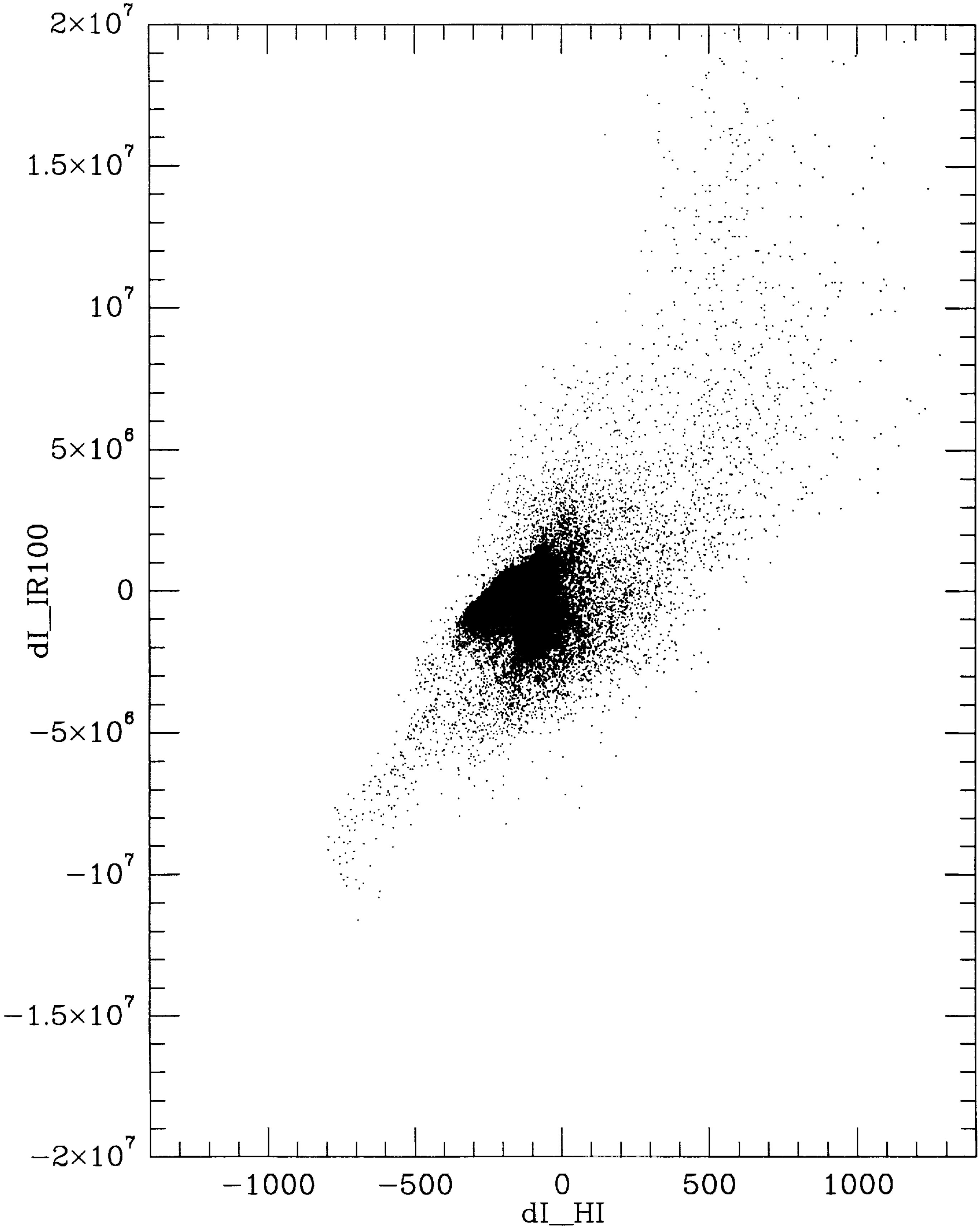
2×10^7
1.5×10^7
10^7
5×10^6
0
−5×10^6
−10^7
−1.5×10^7
−2×10^7
dI_IR100
−1000
−500
0
500
1000
dI_HI

Fig. 1

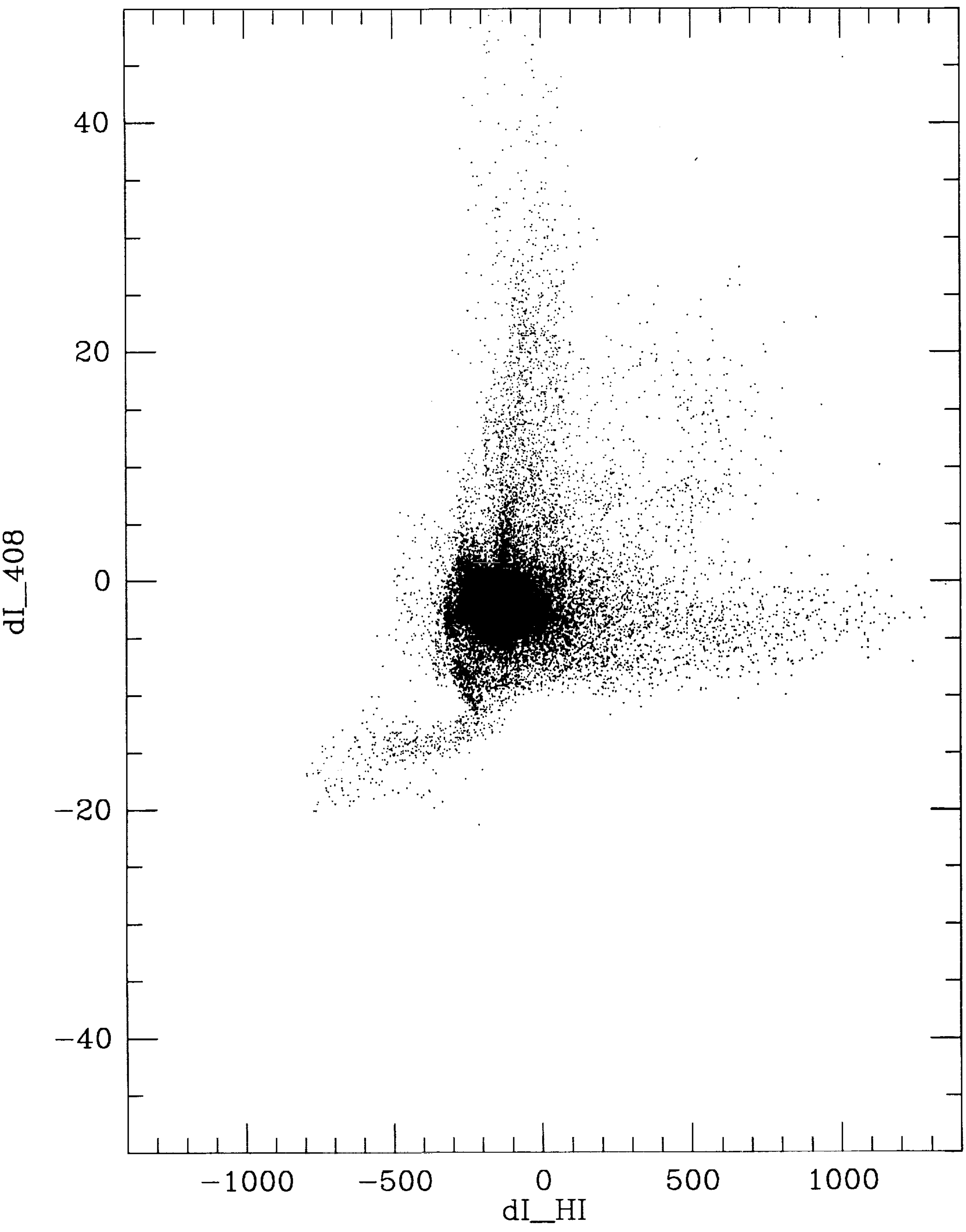

Fig. 2

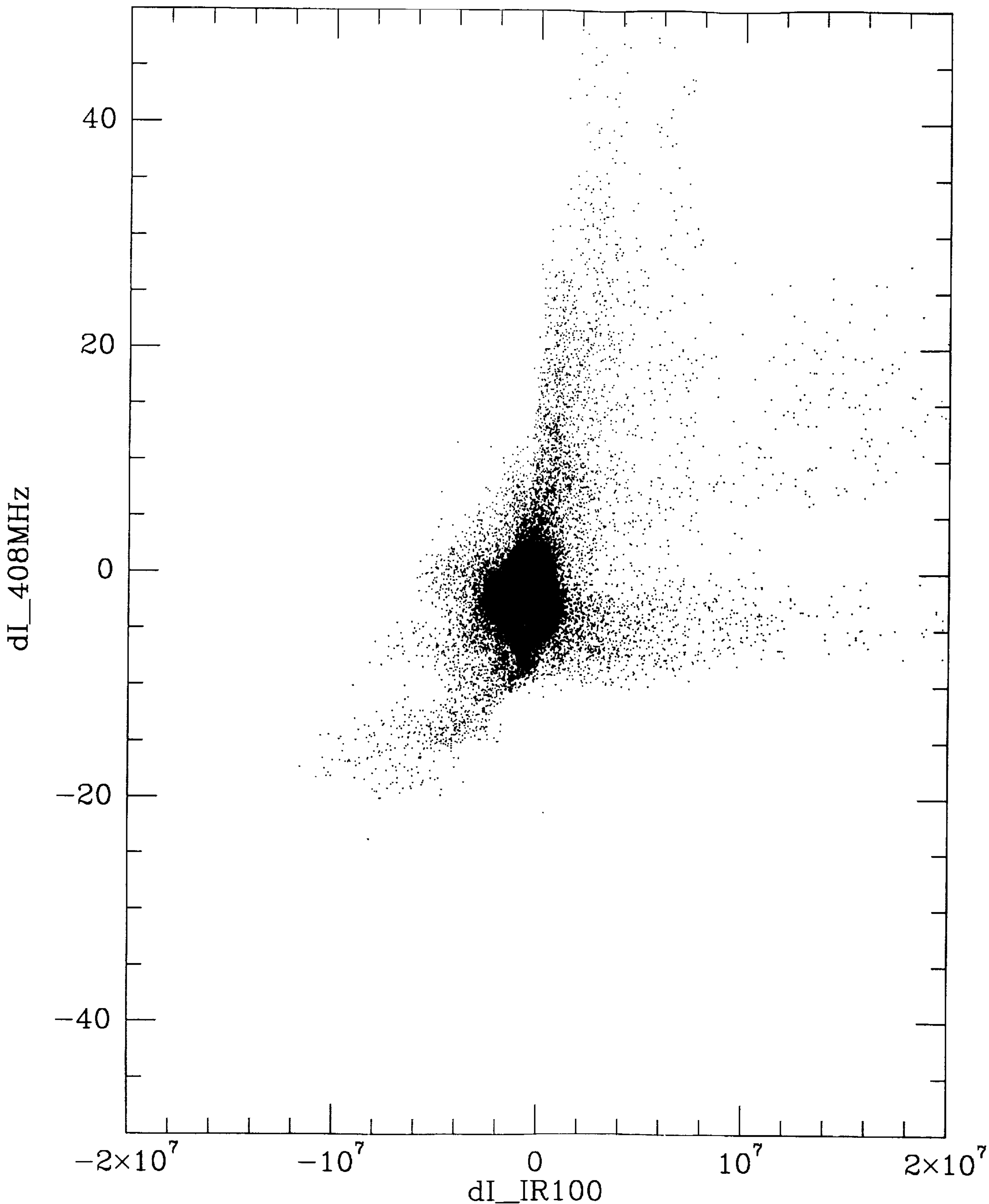

Fig. 3

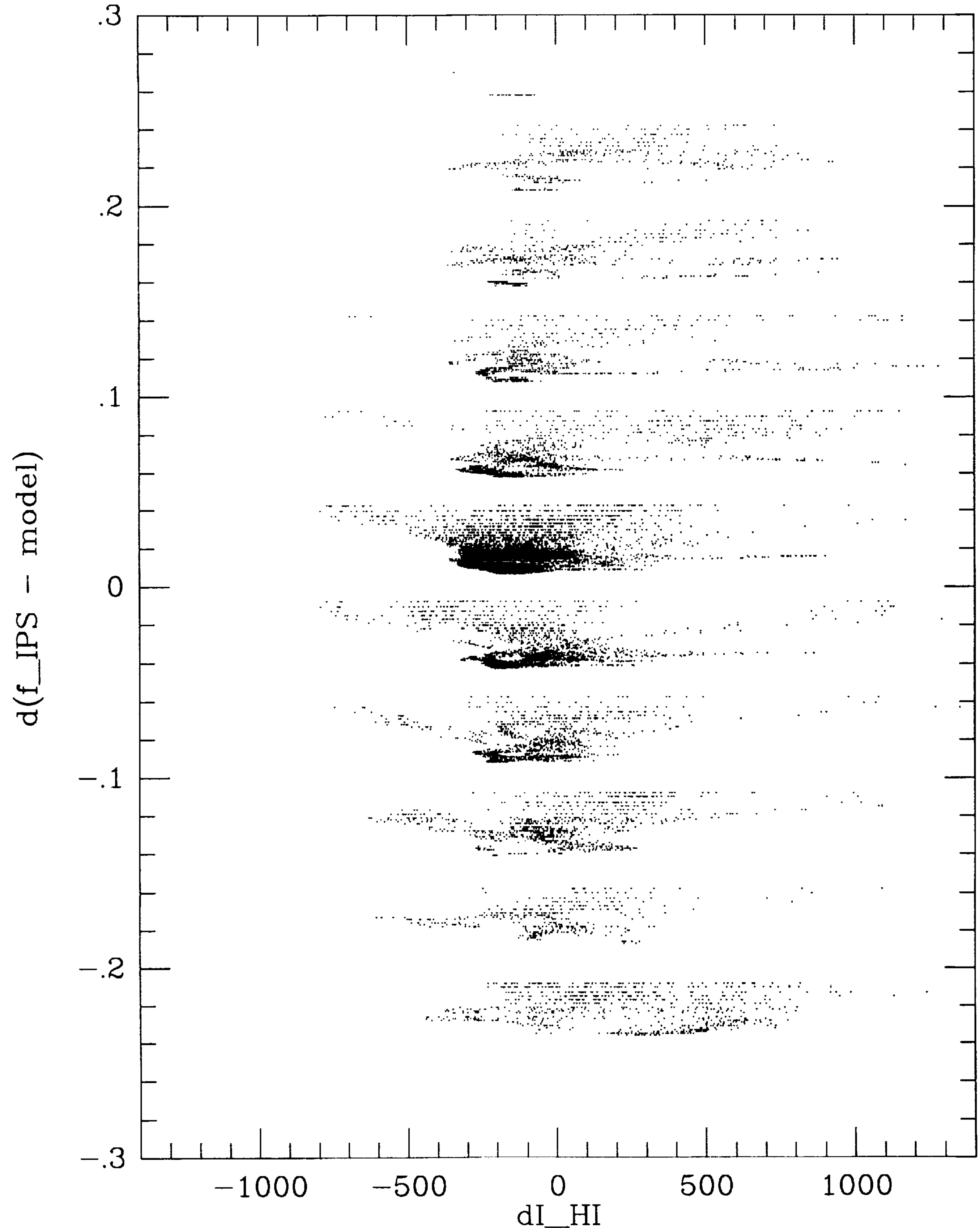

Fig. 4

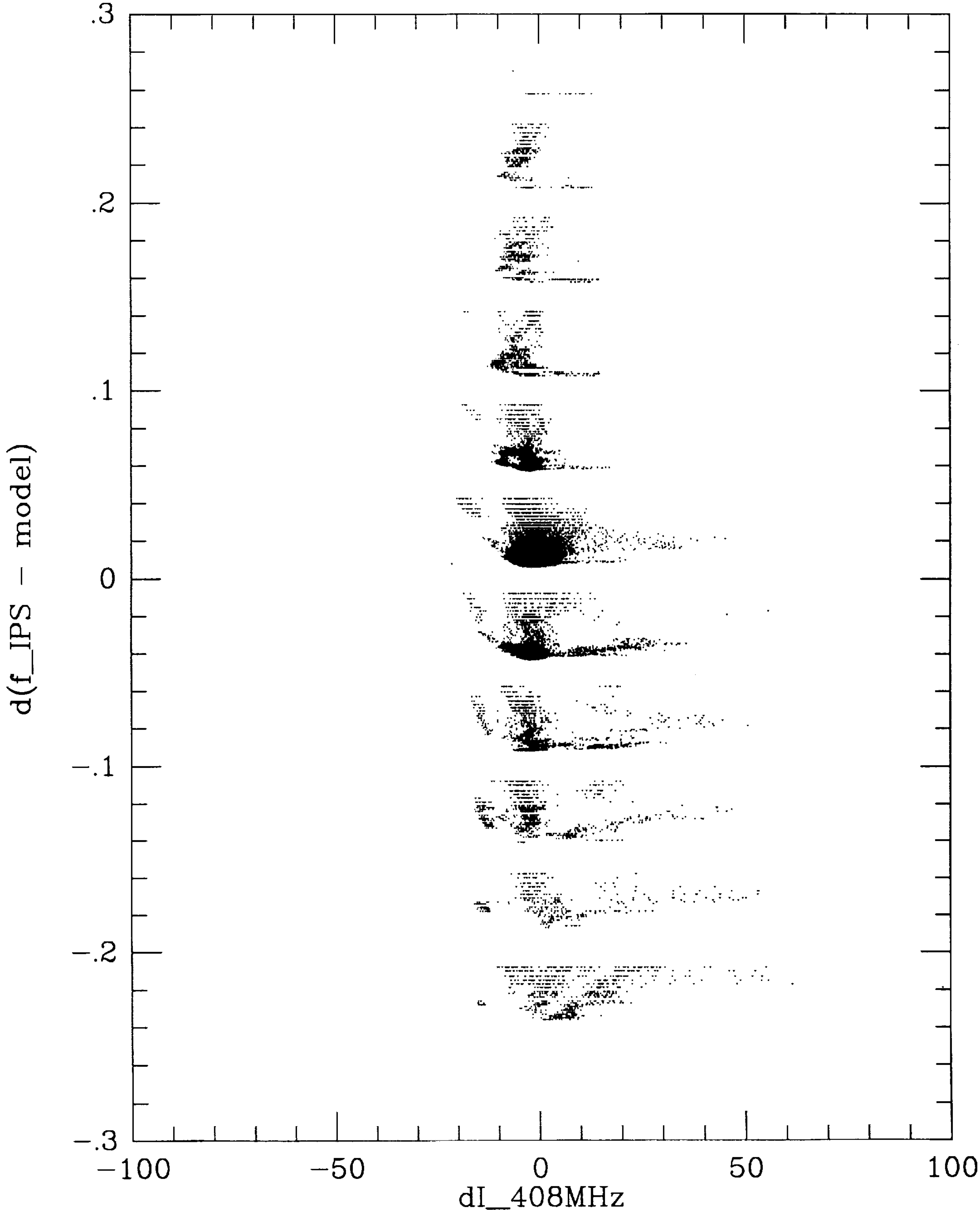

Fig. 5