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The Galactic Center at 327 MHz

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Figure 1 presents a wide-field, high dynamic-range, 327 MHz VLA[2] image of the Galactic center (GC). This image was constructed from archival VLA data using new 3-D image restoration techniques which resolve the problem of non-coplanar baselines encountered at long wavelengths. In a recent paper (LaRosa et al. 2000) we presented a catalog of over a hundred sources from this image, 23 extended sources and 78 small-diameter sources. The catalog contains flux densities, positions, sizes, and, where possible, a 20/90 cm spectral index. We also present subimages of all the extended sources. We refer the reader to LaRosa et al. (2000) for the details. In this note we will concentrate on observations of the nonthermal filaments and briefly describe a new model for their formation.

The origin and evolution of the nonthermal filaments (NTFs) observed in the GC is an outstanding problem. All of the 7 classified NTFs are visible on Figure 1: Four of these are labeled threads, the other three are the "Snake," the "Pelican," and the Sgr C filament. The wide-field imaging at 327 MHz lead to the discovery of the "Pelican" (Lang et al. 1999). This filament has the distinction of being the farthest NTF in projection from Sgr A and the only NTF that is parallel to the Galactic plane. One critical issue for understanding the activity and overall structure of the GC is whether these filamentary sources trace a pervasive, large-scale magnetic field or are local independent structures (e.g., Yusef-Zadeh 1989; Morris 1994, 1996; Uchida & Gusten 1995; Yusef-Zadeh, Wardle & Parastaran 1997; Shore & LaRosa 1999; Lang et al. 1999; Lang, Morris & Echevarria 1999; LaRosa et al. 2000).

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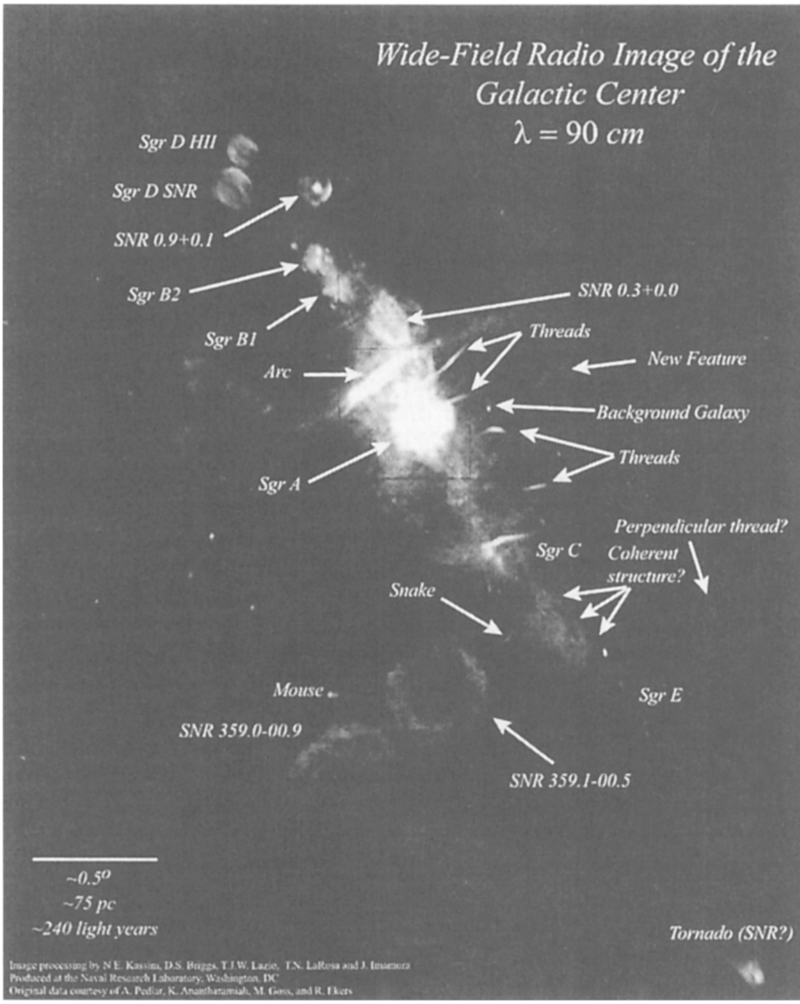

Figure 1. The Galactic Center at 327 MHz. This is a $4° \times 2.5°$ image with an angular resolution of $43'' \times 23''$ and an rms sensitivity of ≈ 5 mJy beam^{-1}(away from the strong emission along the Galactic plane).

Higher frequency observations show that the NTFs share a number of characteristics (see Morris 1996 for a review). They are typically 30–50 pc long and have widths of order tenths of pc; these remarkable aspect ratios are perhaps the most difficult characteristic of the NTFs to explain. The filaments are strongly linearly polarized with magnetic fields aligned along their length. At high resolution, in both total and polarized intensity, the NTFs show subfilaments that appear to be braided around each other and overlap (e.g., Yusef-Zadeh, Wardle, & Parastaran 1997; Lang, Morris, & Echevarria 1999). At 327 MHz the peak brightness for almost all of the filaments occurs at their geometric center and

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coincides with the location of the intersection of the subfilaments. This suggests that this location may be a site of particle acceleration.

Another commonality among the NTFs is their spectral index. We have determined the 20/90 cm spectral index ($S \propto \nu^{\alpha}$) as a function of position along a number of the NTFs. We find, contrary to earlier work, that the spectral index of the Sgr C filament is constant with length at $\alpha = -0.5$. The uncertainties in the spectral indicies of the northern and southern threads prevent a definitive statement, but they also appear to have constant indices in the range $\alpha = -0.4$ to -0.6. Lang, Morris, & Echevarria (1999) have also found that the 6/20 cm spectral index for the northern thread is constant. The synchrotron lifetime, even for these rather strong magnetic fields, is 5×10^4 yrs, and electrons streaming at the Alfvèn speed can easily traverse 100 pc in this lifetime. Thus, even if electrons are injected into the filaments at one end, as some models suggest, they would not show spectral aging over distances less than 100 pc.

Dynamical arguments suggest that NTF magnetic fields are quite strong, of order 1 mG (Yusef-Zadeh & Morris 1987). Such strong fields constitute a large magnetic pressure and would rapidly expand unless confined. It has therefore been inferred that these are not isolated magnetic structures but are the illuminated flux tubes of a large-scale field that pervades the entire region. All the well studied filaments are associated with molecular gas (e.g., Staghun et al. 1996), and it has been hypothesized that interaction between the cloud magnetic field and the large-scale field results in particle acceleration and injection of high-energy electrons into the filaments (Serabyn & Morris 1994). For example the southeast end of the Sgr C filament connects to an H II region molecular cloud complex. High-energy electrons are presumably injected in the filament at this end and propagate along the filament. However, it is not clear how this interaction can produce such an intrinsically narrow structure.

Recently Shore & LaRosa (1999) have proposed a dynamical model for the NTFs. Their model is based on a analogy to cometary plasma tails. They propose that the NTFs are a result of a cloud-wind interaction. Consider a comet in the solar wind. The solar wind advects a magnetic field, which is impeded when it encounters the comet. The flow therefore stretches and drapes the field around the comet creating a long thin current sheet in the cloud wake. The process of field line draping an amplification was originally proposed by Alfvèn in 1957 and has been confirmed by numerous computer simulations and in situ observations of comets (e.g., Luhmann 1995). Assuming a Galactic wind as inferred from X-ray observations (Koyama et al. 1996), Shore & LaRosa (1999) show that stable structures with aspect ratios of order 50 can be formed in the wake of a molecular cloud. This model has several advantages. It explains the NTF morphology, and particle acceleration is a natural consequence of the wake structure. Furthermore, since it views the NTF magnetic field as an amplification of weak background field, it reduces by several orders of magnitude the magnetic field energy in the GC region. Clearly, detailed numerical simulations of such a cloud-wind interaction are required to substantiate this model.

In summary, the 327 MHz observations presented here demonstrate that low frequencies can yield significant new insights into a complicated region such as the Galactic center. The GRMT will clearly be a very important instrument in future Galactic center studies.

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