Revealing Old Supernova Remnants Through H I 21cm Line Emission

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Forbidden-Velocity Wings

Large-scale (l,v) diagrams of HI 21-cm line emission in the Galactic plane usually show faint, small, high-velocity bumps protruding from their surroundings. These faint "wing"- like features are ***extended to the velocities well beyond the maximum or minimum velocities permitted by the Galactic rotation***. Some of those "forbidden-velocity wings (FVWs)" are shown in Figure 1. FVWs are probably ***due to some energetic phenomena*** in the Galaxy, because they are significantly beyond the smooth boundary, confined in small area, and smoothly extended from the Galactic emission. The FVWs are distinguished from high-velocity clouds (HVCs) that have discrete peaks isolated from the Galactic HI .

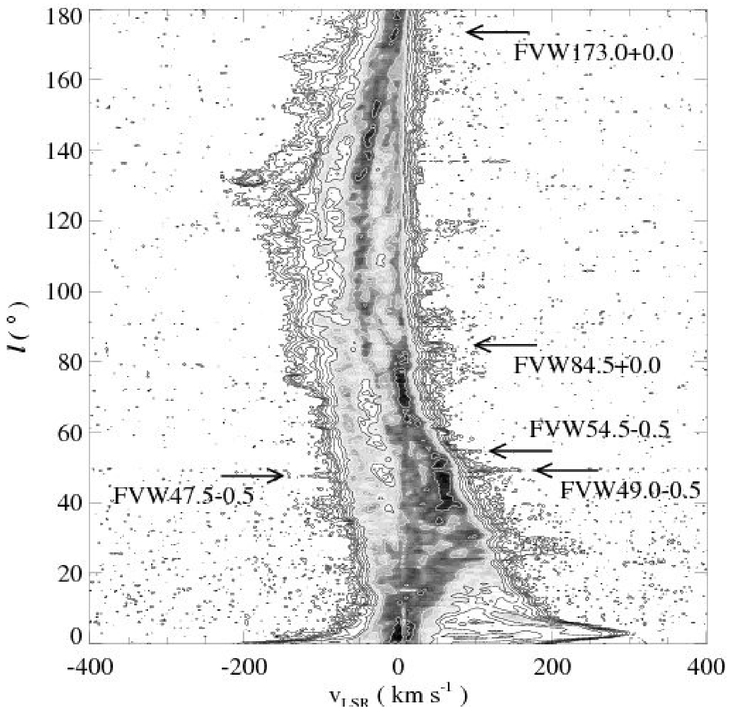

Figure 1. Large-scale (l,v) diagram of the 1st and 2nd quadrants at b = −0.◦ 5 in use of the LDS data. Contours are 0.1, 0.2, 0.4, 0.7, 1, 2, 5, 10, 30, 50, 100 K in brightness temperature.

Most of the old supernova remnant population in the Milky Way has not been identified because of intrinsic faintness and background contamination in both the radio continuum and X-ray emission. We have suggested these FVWs could be the HI gas accelerated by the supernova explosion. (Koo & Kang, 2004)

We identified about 90 FVWs in the Galactic plane in use of the Leiden/Dwingeloo Survey and the Southern Galactic Plane Survey data. (Kang & Koo, 2007) We compared our catalog with those of known SNR, galaxies, and HVCs, and found that 85% of FVWs are not coincident with these known objects. To investigate their nature, high-resolution observations are required.

High-Resolution HI Observation

We have carried out high-resolution observations of some of these FVWs in use of Arecibo 305-m and Green Bank 100-m radio telescope, and found that many of them (50-60%) are part of expanding HI shell. Most of them do not have any early type stars inside, and do not have corresponding emission in radio continuum and X-ray data. These FVWs could be ***old SNRs that are too faint to be visible in the radio continuum or by X-rays, but which are nevertheless revealed via their HI emission***.

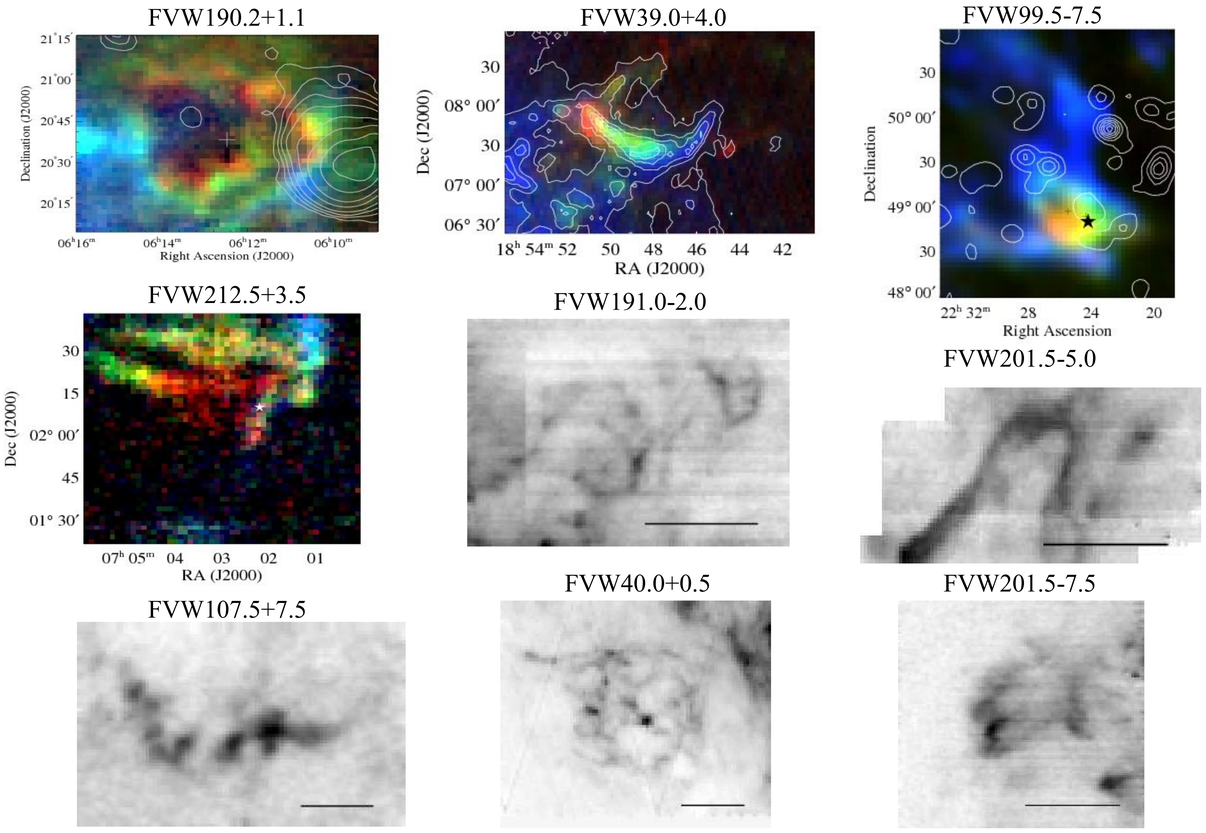

Figure 2. HI images of shell-type FVWs. In RGB images, blue color represents lower velocity and red color does higher velocity. In these images, expanding shells are clearly visible. Grey maps are integrated images.

FVW173.0+1.5 : New SNR!

In Arecibo image, FVW173.0+1.5 appears as a expanding shell. Interestingly there are very faint filamentary shell-like continuum emission on the periphery of HI shell. Their positional correlation strongly suggests their association. The spectral index ($F \sim \nu^{-\alpha}$) of faint continuum filament in north turned out to be ***nonthermal*** (α =0.42-0.52), similar to typical shell type SNRs (α~0.5) (Effelsberg 2695 MHz, WENSS 327 MHz)

If this shell is located in the Perseus Arm (~2 kpc), the observed parameters are :
HI mass : 960 Mo (uncertainty ~40%) at 15-45 km/s, Vsys ~ -10 km/s, Vexp ~ 55km/s, kinematic energy ~ 5e+49 ergs, size ~ 90x120pc.

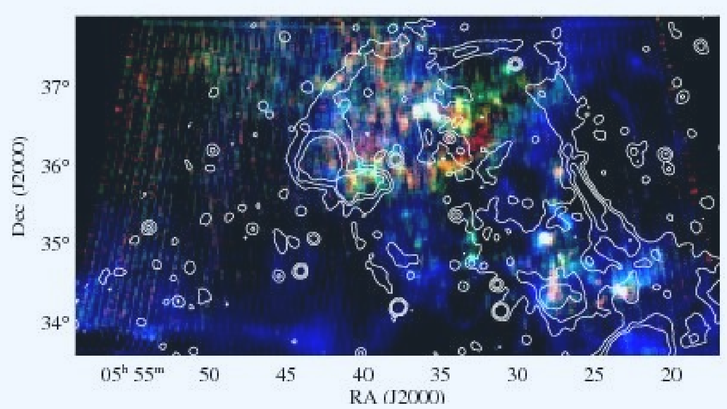

Figure 3. The three color image is Arecibo HI emission image of FVW173.0+1.5. (Red : 45-35, Green : 35-25, Blue : 25-15 km/s) Effelsberg 11-cm radio continuum data are overlaid with white contours, and their contour levels are 30, 100, 200 mK.

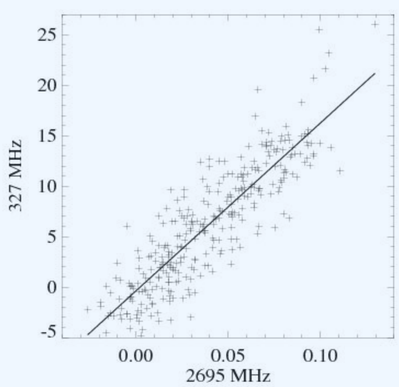

Figure 4. T-T plot of FVW173.0+1.5 using Effelsberg 2695 MHz, WENSS 327 MHz data.

Possible X-ray emission?

In ROSAT hard band (0.5-2.0keV) image, there is faint X-ray emission inside FVW173.0+1.5. They are also visible in ROSAT point source removed background images, especially band 5 and 6. The count rate in band 5, for example, is 8000+-600 counts/s/arcmin^2. Future study is required.

Band	Energy range (keV)
Band 1	0.11 - 0.284
Band 2	0.14 - 0.284
Band 3	0.2 - 0.83
Band 4	0.44 - 1.01
Band 5	0.56 - 1.21
Band 6	0.73 - 1.56
Band 7	1.05 - 2.04

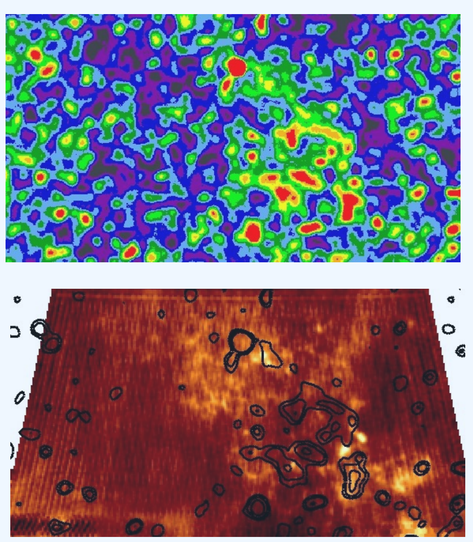

Figure 5. (Top) ROSAT hard band (0.5 – 2.0keV) image. (bottom) HI integrated map image with X-ray contours, 0.07, 0.085, 0.11 counts.

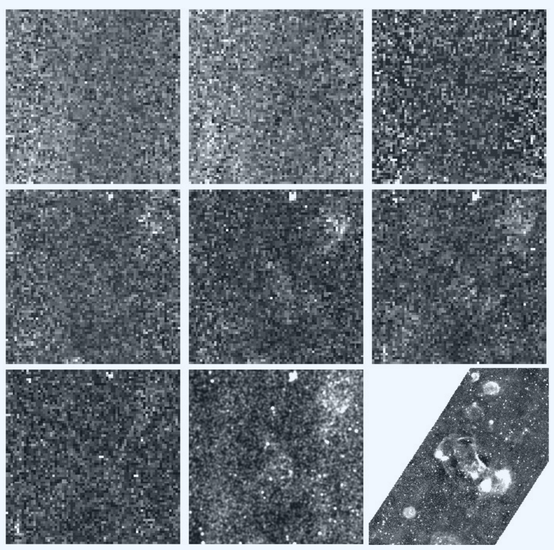

Figure 6. ROSAT image in larger scale. Panel 1-7 : ROSAT point source removed background images. Panel 8 : hard band (0.5-2.0keV) image. Panel 9 : Effelsberg 11-cm radio continuum image