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博士学位论文摘要选登

中德 6 cm 银道面偏振巡天第 2 天区以及大尺度超新星遗迹的研究

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射电偏振观测是研究星际介质性质的有力工具. 一方面偏振巡天可以直接指示大尺度磁场的取向, 有助于我们理解银河系的大尺度磁场结构和超新星遗迹的演化及其与星际介质的相互作用. 另一方面通过结合其他波段偏振数据可以分析星际介质以及偏振源超新星遗迹里面的法拉第旋转, 从而得到里面热电子密度、填充因子、规则磁场强度和扰动磁场的性质. 之前的偏振巡天主要是在低频波段进行, 受法拉第效应的影响很严重, 探测到偏振辐射的距离 (偏振视界) 很近. 在 6 cm 波段, 偏振观测受法拉第效应影响很小, 我们能够探测到更远的偏振辐射, 更好地研究银河系星际介质整体的性质. 通过对天区内法拉第屏的研究, 可以揭示银河系同步辐射的空间分布以及这些屏本身的物理性质; 另外 6 cm 波段的总强度数据是研究弥漫结构或者大尺度超新星遗迹 (其它的大望远镜很难观测到这样大的超新星遗迹) 在高频波段谱偏折行为的重要数据, 这可以帮助我们理解银河系相对论电子能量分布、盘和晕的相互作用以及大尺度超新星遗迹晚期的演化.

我们利用乌鲁木齐 25 m 望远镜和安装在上面的马普射电天文研究所研制的 6 cm 偏振接收机, 已经于 2009 年 8 月成功地完成了中德 6 cm 银道面偏振巡天. 作者的主要工作是处理并分析第 2 块巡天天区 ($60^\circ \le l \le 129^\circ$, $|b| \le 5^\circ$) 的数据. 我们尝试利用 WMAP K 波段偏振数据, 考虑谱指数模型以及银河系 3D 辐射模型模拟的法拉第旋率分布, 外推到 6 cm 来补偿丢失的大尺度偏振结构. 结合 "校准" 前后的图像, 我们仔细分析了天区内的延展目标. 对天区内发现的电离氢复合区边缘的消偏振现象利用法拉第屏模型进行分析讨论. 并利用结构函数分析整个巡天天区扰动的分布.

此外我们利用这套系统, 观测并研究了两个大尺度超新星遗迹 S147 和 G65.2+5.7 的射电性质. 对超新星遗迹 S147, 我们利用新观测的 6 cm 数据和 Effelsberg 11 cm 数据首次证实这个超新星遗迹谱的偏折发生在 $\sim$1.5 GHz, 发现偏折来自弥漫辐射成分并讨论谱偏折的可能起源. 根据两个波段的偏振数据, 我们给出了这个超新星遗迹东边壳层的法拉第旋率和磁场强度的估计.

对低表面亮度超新星遗迹 G65.2+5.7, 首次得到 6 cm 的辐射流量, 结合 Effelsberg 新的 11 cm 观测数据, 得到这个超新星遗迹的谱指数. 我们讨论了北边壳层在两个波段显示的消偏振机制, 并根据 6 cm 偏折角估算出了这个超新星遗迹南边壳层的法拉第旋率和磁场强度. 我们发现和超新星遗迹成协的中性氢壳层并估算了这个壳层的质量以及反推爆发前的电子密度, 得出低表面亮度是由于在低密度区域爆发所致.

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Research on the Second Region of Sino-German 6 cm Polarization Survey of the Galactic Plane and Large-scale Supernova Remnants

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Polarization observation provides a useful tool to study the properties of interstellar medium (ISM). It could directly show the orientation of large-scale magnetic fields, and help us understand the structure of large-scale magnetic field in our Galaxy and the evolution of supernova remnants (SNRs). Moreover, combing with polarization observations at other wavelengths, the Faraday rotation could be applied to study the properties of the thermal electron density, filling factor, regular and random magnetic fields in ISM and SNRs. The previous polarization measurements mostly conducted at low frequencies were significantly influenced by the Faraday effects of ISM, while at 6 cm, they are much less affected and polarized emission from larger distances could be detected. By studying Faraday screens, we could explore the physical parameters of the sources as well as the synchrotron emissivities of the Galaxy. The 6 cm total intensity measurements are the key data to clarify the spectrum behavior of diffused emission or individual objects at high frequencies, and help us understand the distribution of relativistic electrons, the disk-halo interaction and the evolution of late-stage SNRs.

In August 2009, the project of 6 cm continuum and polarization survey of Galactic plane had been completed successfully using the 25 m radio telescope at Urumqi. The work presented in this thesis is mainly based on data analysis of the second survey region with $60^{\rm o} \leq l \leq 129^{\rm o}$ and $|b| \leq 5^{\rm o}$. We tried to compensate the missing large-scale structures by extrapolating the WMAP K-band polarization data with the spectral index model and simulation of the rotation measures (RMs). By comparing the maps pre- with post- "calibration", we studied the extended objects in this region. We analyzed the depolarization structure at the periphery of HII region complex using Faraday screen model, and studied the distribution of fluctuation in the entire survey region using structure functions.

Besides, we investigated observationally the radio properties of two large-scale SNRs S147 and G65.2+5.7. Using the new 6 cm and Effelsberg 11 cm data, we confirmed the spectral index break of SNR S147. It is found that the spectral break index mainly comes from the diffused emission and the possible mechanism was briefly discussed. In addition, we calculated the RM and the magnetic field in the eastern filamentary shell of the SNR.

For the low surface brightness SNR G65.2+5.7, we obtained the spectral index of this SNR using the new 6 cm and 11 cm flux densities. The depolarization at both wavelengthes in the northern shell has been discussed, and the RM and the magnetic field in the southern shell of the SNR were calculated. We recognized a HI bubble associated with the SNR. Its mass was estimated and the electron density in this region before the explosion was then inferred. We conclude that the SNR might be expanding in a preblown cavity.