A Sino-German $\lambda 6$ cm polarisation survey of the Galactic plane

VIII. Small-diameter sources

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ABSTRACT

Aims. Information of small-diameter sources is extracted from the Sino-German $\lambda 6$ cm polarisation survey of the Galactic plane carried out with the Unumqi 25-m telescope.

Methods. We performed two-dimensional elliptical Gaussian fits to the $\lambda 6$ cm maps to obtain a list of sources with total-intensity and polarised flux densities.

Results. The source list contains 3832 sources with a fitted diameter smaller than 16′ and a peak flux density exceeding 30 mJy, so about 5× the rms noise, of the total-intensity data. The cumulative source count indicates completeness for flux densities exceeding about 60 mJy. We identify 125 linearly polarised sources at $\lambda 6$ cm with a peak polarisation flux density greater than 10 mJy, so about 3× the rms noise of the polarised-intensity data.

Conclusions. Despite lacking compact steep spectrum sources, the $\lambda 6$ cm catalogue lists about 20% more sources than the Effelsberg $\lambda 21$ cm source catalogue at the same angular resolution and for the same area. Most of the faint $\lambda 6$ cm sources must have a flat spectrum and are either H II regions or extragalactic. When compared with the Green Bank $\lambda 6$ cm (GB6) catalogue, we obtain higher flux densities for a number of extended sources with complex structures. Polarised $\lambda 6$ cm sources density are uniformly distributed in Galactic latitude. Their number density decreases towards the inner Galaxy. More than 80% of the polarised sources are most likely extragalactic. With a few exceptions, the sources have a higher percentage polarisation at $\lambda 6$ cm than at $\lambda 21$ cm. Depolarisation seems to occur mostly within the sources with a minor contribution from the Galactic foreground emission.

Key words. radio continuum: general – polarization – catalogs

1. Introduction

Diffuse continuum emission is highly concentrated in a narrow band along the Galactic plane, where the number density of discrete Galactic sources, such as supernova remnants (SNRs) and H II regions, is the highest. Recently, the maps from the Sino-German $\lambda 6$ cm polarisation survey of the Galactic plane have been published in a series of papers (Sun et al. 2007, 2011a; Gao et al. 2010; Xiao et al. 2011). The survey also served as one basis for a systematic study of known SNRs (Sun et al. 2011b; Gao et al. 2011b) and for a search for new ones (Gao et al. 2011a). Han et al. (2013) summarise the $\lambda 6$ cm survey project and the results obtained so far. This paper adds a catalogue of discrete small-diameter sources in the surveyed area, including polarised sources.

At $\lambda 6$ cm, optically thin diffuse thermal emission dominates in the Galactic plane, while diffuse steep-spectrum synchrotron emission dominates at longer wavelengths. Thus, faint H II regions are expected to be better separated and therefore from the diffuse emission at $\lambda 6$ cm than in the single-dish surveys carried out with the Effelsberg 100-m telescope at $\lambda 21$ cm (Reich et al. 1999b, 1997) and $\lambda 11$ cm (Reich et al. 1984, 1990a; Fürst et al. 1990a). On the other hand, the extraction of faint steep-spectrum extragalactic sources from the diffuse Galactic emission becomes more difficult at $\lambda 6$ cm. In any case, $\lambda 6$ cm flux densities are a valuable addition to existing longer wavelength data, and a more precise spectral index determination is provided when the wavelength difference increases.

Synthesis telescope source surveys, such as the most sensitive NRAO VLA Sky Survey (NVSS; Condon et al. 1998) at $\lambda 21$ cm, list many more compact sources along the Galactic plane compared to published single-dish surveys. These observations have much higher angular resolution and sensitivity. They filter out extended Galactic emission and also may underestimate the integrated flux density of extended sources.

Previously, an important $\lambda 6$ cm source survey of the northern sky, the GB6, had been carried out with the former Green Bank 300-ft telescope with an angular resolution of 3′/6 × 3′/4 by Condon et al. (1994). The corresponding source catalogue (Gregory et al. 1996) includes compact sources up to 10′/5. The peak flux density increases with declination with a lower limit of 18 mJy (Gregory et al. 1996). In the reduction process of the GB6 survey, spline functions were used to subtract all kind of extended emission from the raw data, which includes Galactic emission. Therefore the maps in the Galactic plane can not be compared with those from the present $\lambda 6$ cm survey. The GB6 survey processing should not affect the flux...
density determination of compact sources, what can be proved by comparison with the present catalogue.

Lists of polarised sources in the Galactic plane are rare and do not exist at all at J$6$ cm. For J$21$ cm, however, several data sets exist: The NVSS (Condon et al. 1998) includes polarisation information. Brown et al. (2003) provides polarisation data from the Canadian Galactic Plane Survey (CGPS) and Van Eck et al. (2011) presents a list of polarised sources along the Galactic plane measured with the VLA, which could be compared with the J$6$ cm polarisation data. The Effelsberg J$21$ cm and J$11$ cm survey source lists (available from the CDS/Strasbourg1) have guided us in the layout of the J$6$ cm source list, where all relevant parameters of individual sources are provided. In Sect. 2, we summarise the J$6$ cm survey project and describe the source fitting procedure in Sect. 3. In Sect. 4, we present the list of sources and describe their individual parameters. In Sect. 5, we briefly discuss the J$6$ cm source catalogue with respect to source statistics and other available catalogues and make concluding remarks in Sect. 6.

2. The J$6$ cm survey

The Sino-German J$6$ cm polarisation survey of the Galactic plane was conducted with the Urumqi 25-m telescope of Xinjiang (formerly Urumqi) Astronomical Observatory, Chinese Academy of Sciences, between 2004 and 2009. The surveyed area covers $10^\circ \leq l \leq 230^\circ$ and $-5^\circ \leq b \leq +5^\circ$. The survey has an angular resolution of 9.5. The system temperature towards the zenith was about 22 K. The central frequency was set to either 4.8 GHz or 4.963 GHz with corresponding bandwidths of 600 MHz and 295 MHz. The system gain is $S_{\lambda} = 0.164$. Detailed information about the receiving system, the survey set-up, and its reduction scheme has already been presented by Sun et al. (2007). The survey maps were published in three sections by Gao et al. (2010); Sun et al. (2011a); Xiao et al. (2011) and are also available on the web2.

The Galactic plane was fully sampled at 3 and mapped by raster scans in the longitude and latitude directions. The primary calibrator was 3C 286 with an assumed flux density of 7.5 Jy and a polarisation percentage of 11.3%. The polarisation angles measured for 3C 286 were found as $32^\circ \pm 1^\circ$ and were not corrected to the nominal value of $33^\circ$. Then 3C 48 and 3C 138 were used as secondary calibrators, and 3C 295 and 3C 147 as unpolarised calibrators. Sun et al. (2007) found a scaling accuracy of better than 4% for total intensities and 5% for polarised intensities.

The raw data from the receiving system contain maps of $I$, $U$, and $Q$ stored in NOD2-format (Haslam 1974). Data processing follows the standard procedures developed for continuum observations with the Effelsberg 100-m telescope as detailed by Sun et al. (2007) and Gao et al. (2010). The positional accuracy of compact sources in the survey maps was found to be in general better than 1 when compared with the high-resolution interferometric NVSS survey (Condon et al. 1998). Maps with larger position offsets were corrected with respect to the NVSS source positions. The final survey maps have a typical measured rms noise including confusion of about 1 mK $T_B$ or 6.1 mJy/beam area for total intensity $I$, 0.5 mK $T_B$ or 3.05 mJy/beam for Stokes $U$ and $Q$, and polarised intensity $P_I$.

3. Source fitting procedure

3.1. Total intensity fit

We used the same Gaussian fitting routine applied to extract compact sources from the Effelsberg J$21$ cm (Reich et al. 1990b, 1997) and J$11$ cm survey maps (Reich et al. 1984; Fürst et al. 1990b) to produce a list of compact sources from the J$6$ cm survey maps. This is the standard NOD2-based fitting routine for continuum and polarisation observations with the Effelsberg 100-m telescope, which has a Gaussian beam shape up to mm-wavelengths.

The fitting routine can be steered in various ways. The standard procedure is to run an automatic fit on a map, where a small area around each source is extracted and corrected for baseline gradients before a fit is applied, which is either a circular or an elliptical Gaussian. The highest peaks in a map are fitted in a first run, and subsequently the peak amplitude limit is decreased. It turns out, that for most J$6$ cm sources, the automatic procedure does not give the best result as seen by the residual emission after source subtraction, so that most sources were fitted individually from the maps by defining the area for the fit where confusing surrounding emission is excluded as well as possible.

The inner Galactic plane has steep intensity gradients in Galactic latitude, which makes it difficult to extract faint sources. In analogy to the treatment of the Effelsberg survey maps, we applied the “unsharp-masking” filtering method by Sofue & Reich (1979) by using a 1 wide filtering beam to remove most of the diffuse emission before applying the source fitting routine, which improves the number of separable sources from unrelated emission and also improves the fit result. The peak flux amplitude limit was taken as 5× the rms noise, e.g. 5 mK $T_B$ or 30 mJy/beam area. In addition we rejected all source fits with the minor axis below 6, which indicates either an RFI-spike, another small-scale distortion, or surrounding emissions that are too complex. Also, fit results of the major axis exceeding 16 were rejected, which is the same limit as used earlier for the Effelsberg J$21$ cm source list with about the same beam size. For sources that are significantly larger than the angular resolution, the application of a single Gaussian fit becomes questionable, because source shapes are complex in general. This is visible by residual emission structures after source subtraction.

We checked the reliability of the listed sources by comparing with the corresponding Effelsberg J$21$ cm (Reich et al. 1990b, 1997) and J$11$ cm source lists (Fürst et al. 1990b). We also compared 1×1 J$6$ cm maps centred on each source with the corresponding Effelsberg maps at J$21$ cm and J$11$ cm to check their reliability further and to identify misidentifications by low-level distortions. A number of sources with poor fits shown by large formal errors could be identified as artificial. There are well-fitted J$6$ cm sources, which are barely or not at all visible in the longer wavelengths surveys.

3.2. Fit of linearly polarised sources

Separating the small-scale emission of polarised sources is not trivial in the presence of significant extended polarised emission. We started from the observed Urumqi J$6$ cm Stokes $U$ and $Q$ maps, which included extended polarised emission structures of up to a few degrees in size. We removed the large-scale components by applying the filtering method by Kothes & Kerton (2002), which is a modification of the Sofue & Reich (1979) filter and separates positive and negative small-scale structures from large-scale emission. The Sofue & Reich (1979) filter only
separates positive small-scale and large-scale emission and is only applicable to total intensity or polarised intensity maps. We filtered the Stokes $U$ and $Q$ survey maps with a filtering beam of $30'\times 30'$ and calculated PI-maps via $P^{I} = (U^{2} + Q^{2})^{1/2}$. For all sources identified in total intensity, we extracted $1'\times 1'$ large fields centred on the source position in PI and applied a Gaussian fit, which takes the positive PI noise bias into account. Polarised peak flux densities of $10\, mJy$ or higher were accepted. The source list was checked using the positions of NVSS sources as reference for each survey map (Sun et al. 2007). If necessary, we fitted the Gaussian fit listed in Col. 9 of the source table. The integrated flux densities from Gaussian fitting and the ring integration gives $6\, cm$ polarisation survey of the Galactic plane. VIII.

Table 1. Flux densities of 3832 compact sources at $6\, cm$.

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<td>605</td>
<td>540</td>
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Notes. The full table is available in electronic form at the CDS.

We estimated its amplitude from a scan across the peak of the S-component, which is accessible from the CDS in Strasbourg. We list the parameters of the 3832 catalogued sources in Table 1.

4. The source list

4.1. Total-intensity data

We list the parameters of the 3832 catalogued sources in Table 1, which is accessible from the CDS in Strasbourg.

From the Gaussian fit of each source, we calculated its integrated flux density, assuming a Gaussian shape using the fitted peak flux density $S_{p}$ and the major $\theta_{max}$ and the minor $\theta_{min}$ axis of the ellipsoid by $S_{i} = S_{p} \times (\theta_{max} \times \theta_{min} \times HPBW^{-2})$, with $HPBW = 9.5'$. We quote the fitted sizes in Table 1. For Gaussian-shaped sources, the intrinsic size calculates as source-size = (fitting size $^2 - HPBW^2)^{1/2}$. The positional accuracy of the $6\, cm$ survey was checked using the positions of NVSS sources as reference for each survey map (Sun et al. 2007). If necessary, they were corrected for a position accuracy of better than $1'$. This error is not included in the positional uncertainty from the Gaussian fit listed in Col. 9 of the source table. The integrated flux density error does not include the survey scaling error of less than $4\%$. As for the Effelsberg $21\, cm$ and $41\, cm$ source lists, we use error classes to quantify the errors from the Gaussian fit.

The source table includes the following data:

- Col. 1: sequential number;
-Cols. 2 and 3: Galactic longitude and latitude;
-Cols. 4 and 5: right ascension and declination (J2000);
-Col. 6: integrated flux density in $mJy$;
-Col. 7: peak flux density in $mJy$;
-Col. 8: PL – point-like source: fitted size smaller than $10' \times 10'$; SE – slightly extended source: fitted size smaller than $11' \times 11'$; for extended sources:
1. number: fitted FWHM along the major axis in arcmin;
2. number: fitted FWHM along the minor axis in arcmin;
3. number: Galactic position angle of the source ellipsoid;
-Col. 9: error class of the fitting procedure:
1. digit: positional error in units of $5''$;
2. digit: integrated flux density error in units of $5\%$;
3. digit: size error in units of $10''$;
4. digit: error of the Galactic position angle in units of $1'$.

From the small-diameter SNRs in the $6\, cm$ survey, which were discussed by Sun et al. (2011b), a number of sources have apparent sizes below the limit of $16'$ and were thus included in Table 1. The integrated flux densities from Gaussian fitting and the ring integrations performed by Sun et al. (2011b) in general agree within the quoted errors. For a few cases, the different methods lead to flux density differences, which slightly exceed the quoted errors. The complex surrounding of G11.1$-$1.0 (source 15), for example, leads to a lower integrated flux density by ring integration ($3.40 \pm 0.25 \, Jy$) than by the Gaussian fit ($4.234 \pm 0.212 \, Jy$). The same is found for G74.9+1.2 (source 1085), where ring integration gives $6.35 \pm 0.35 \, Jy$ and the Gaussian fit $7.217 \pm 0.361 \, Jy$. SNR G59.8+1.2 (source 819) has a slightly lower Gaussian
The distribution of \( \lambda 6 \) cm sources as a function of Galactic latitude and absolute latitude is shown in Fig. 1. For Galactic longitudes less than 100°, a concentration of extended sources within 1° latitude is visible, which is similar to the Effelsberg \( \lambda 11 \) cm extended source distribution (see Fürst et al. 1990b, Fig. 4), which is slightly wider in latitude. This is a clear indication that extended sources are mostly of Galactic origin. The “PL” and “SE” source distribution is almost latitude independent, indicating that extended sources are extragalactic.

5.1. Total-intensity data

5.1.1. Source statistics

The aim of this paper is to present the \( \lambda 6 \) cm source catalogue in total and polarised intensity. The following brief discussion demonstrates the impact of the new catalogue in view of existing data sets. Using catalogues at various frequencies from different telescopes with large differences in angular resolution to calculate source properties, such as their spectra, may be a difficult exercise in practice. Vollmer et al. (2010) present SPECTFIND V2.0 (accessible via the CDS/Strasbourg), which is a systematic approach to deriving about 65 \( \times 10^3 \) spectra of radio sources. They show examples for the general large scatter in published flux densities, but also discuss methods for deriving reliable spectra.
within absolute latitudes of 1° towards the inner Galaxy, where the diffuse Galactic emission also peaks.

Fürst et al. (1990b) presented cumulative source counts at 21 cm for longitudes from 100° to 240° by counting “PL” and “SE” sources, where the majority are extragalactic. The slope of the source count distribution was fitted by $S^{-1.4}$, which is close to $S^{-1.5}$ as expected for an isotropic source distribution. The same is found for the Effelsberg 21 cm “PL” and “SE” sources for the area from 100° to 230° as shown in Fig. 2. The source counts for the Urumqi “PL” and “SE” sources and the GB6 compact 6 cm sources, excluding border sources (B flag), extended (E flag) and weak sources with large zero-level (W flag), and also sources near a strong source (C flag) (Gregory et al. 1996), are included in Fig. 2. They show a slightly flatter slope, possibly indicating an increase in the fraction of Galactic sources at shorter wavelengths or selection effects by confusion. The high-latitude compact GB6 source count for latitudes over 10° is fitted by $S^{-1.5}$ (Fig. 2). The Galactic plane source numbers drop below the fit for flux densities lower than about 40 mJy for GB6 and 60 mJy for Urumqi 6 cm sources. Below these flux density levels, the catalogues become incomplete.

5.1.2. Comparison with the Effelsberg 21 cm source list

The angular resolution of the Sino-German 6 cm polarisation survey of 9′5 matches that of the 21 cm survey of 9′4 carried out with the Effelsberg 100-m telescope (Reich et al. 1990b, 1997). The source lists from both surveys are limited to source sizes of 16″.

The minimum peak flux density limit of the 21 cm source list for the anti-centre area for longitudes over 95°5 (Reich et al. 1997) was 79 mJy, while it was 98 mJy for longitudes below 95°5 (Reich et al. 1990b). For a 21 cm peak flux density limit of 98 (79) mJy, non-thermal sources with spectral indices larger than $\alpha = -1.0 \pm 0.8$ ($S \sim \nu^\alpha$) should be detected and included in the 6 cm source list. Fainter sources or sources with a steeper spectrum will be missed. The spectral index distribution for Westerbork Northern Sky Survey (WENSS; Rengelink et al. 1997) sources at 327 MHz and NVSS sources at 1.4 GHz derived from about 186 000 sources by Zhang et al. (2003) shows that about 40% of compact sources have spectra steeper than $\alpha = -1.0$. Thus, a significant fraction of compact 21 cm sources will be missed at 6 cm. On the other hand, flat-spectrum sources with a 6 cm peak flux density below 90 (70) mJy will be missed at 21 cm. Some extended sources might be missed, when they slightly exceed the size limit in one catalogue, but were just below in the other.

In the latitude limits of ±4° of the Effelsberg 21 cm inner Galactic plane survey and longitudes between 10° and 95.5°, we find 1127 sources at 6 cm, while the 21 cm source list has 827 entries. Among them 673 sources are listed in both catalogues. In the anti-centre area, for longitudes higher than 95.5°, we find 1950 sources at 6 cm compared to 1643 sources at 21 cm, where 1414 6 cm sources have a counterpart in the 21 cm catalogue.

All together, the 6 cm source list contains about 20% more sources than the 21 cm source list. From the mentioned selection effects, we conclude that most of the faint 6 cm sources must be flat-spectrum synchrotron sources or optically thin thermal sources. This is a significant fraction of sources in the Galactic plane at 6 cm.

The 21 cm and 6 cm surveys have about the same angular resolution, which allows us to calculate spectral indices with peak flux densities rather than integrated flux densities, where differences in the fitted sizes at the two wavelengths decrease the accuracy. We show the result for sources listed in both catalogues in Fig. 3. The two lines indicate spectral indices of $\alpha = -0.80$ and $\alpha = -0.07$, which were derived from a double Gaussian fit. Some clustering of sources along these lines is seen. Extragalactic sources have a median spectral index of $\alpha \approx -0.9$ (Zhang et al. 2003). Figure 3 shows that most of the strong sources have a flat spectrum with $\alpha \approx -0.1$.

5.1.3. Comparison with the GB6 source list

The 6 cm multi-beam source survey carried out with the former 300-ft Green Bank Telescope (Condon et al. 1994) has an angular resolution of 5′6×3′4. We compared the GB6 integrated flux densities from the catalogue compiled by Gregory et al. (1996) with the present source list. The Gregory et al. (1996)
catalogue includes sources up to 10.5 in size. The present \( \lambda 6 \) cm source list includes sources with sizes up to 13'. We took into account that for a small number of objects the GB6 catalogue lists two sources because of its higher angular resolution. Their flux densities were added for the comparison. In cases where the two GB6 sources have a positional difference of a few arcminutes, the Gaussian fit of a single extended source has a large error and the residuals are large. We have not sorted these few cases out and show the result of the comparison in Fig. 4. For many sources, the flux density ratio is close to one, as expected, with an increasing scatter towards lower flux densities. There are a number of outliers. Figure 4 shows more sources with significantly higher flux densities in the Urumqi catalogue compared to the GB6 list, than for the opposite case. For sources with low flux densities, this effect is masked by the general scatter in the flux density ratio.

We have marked four “outlier” sources in Fig. 4 that show large differences in flux densities. We briefly discuss these cases to demonstrate the strengths and limitations of the different catalogues. All four sources are extended H\( \text{II} \) regions (Paladini et al. 2003) with small-scale structures measured with interferometers. Source 372 \((l, b = 35.075, -1.494)\) has an integrated (peak) flux density of 5075 (3923) mJy in the present list and 8692 (1480) mJy in the GB6 source list. These flux density differences are clearly outside the errors of about 10%. The flux density ratio is 0.58 and thus exceptionally low, see Fig. 4. The Effelsberg \( \lambda 21 \) cm and \( \lambda 11 \) cm catalogues list 6.27 ± 0.63 Jy and 6.47 ± 0.65 Jy integrated flux densities, respectively, consistent with the spectrum of an optically-thin H\( \text{II} \)-region. The present \( \lambda 6 \) cm flux density seems to be slightly lower than expected, while the GB6 flux density is clearly too high. The much larger GB6 factor to convert peak flux into integrated flux density resulting from its smaller beam size seems to cause this inconsistency, which is connected to the uncertainties in the size determination. The other three sources 421 \((l, b = 37.852, -0.331)\), 1144 \((l, b = 79.284, 0.291)\), and 2429 \((l, b = 150.378, -1.604)\) are “outliers” in the other direction, with a flux density ratio clearly exceeding 1 as seen from Fig. 4. The single-dish spectrum of source 421 is inverted up to 8.35 GHz (Langston et al. 2000), which indicates the presence of an optically-thick sub-component within the H\( \text{II} \)-region. The two other H\( \text{II} \) regions, sources 1144 and 2429, are optically thin. Numerous small components were detected by interferometers, which do not give the correct integrated flux density when summed up. The factor to convert peak into integrated flux density is near 2 for both sources and catalogues. The maps of these extended sources show a core-halo structure with a compact not always centred core. The obtained integrated flux density depends on the beam size to include the entire source. The almost identical Effelsberg \( \lambda 21 \) cm and Urumqi \( \lambda 6 \) cm beams imply that from these flux densities the most reliable spectra are obtained for extended sources.

5.2. The polarised sources

5.2.1. Distribution along the Galactic plane

The latitude distribution of polarised \( \lambda 6 \) cm sources in the Galactic plane is nearly uniform. From the 125 sources, 61 have absolute latitudes below 2.5° and 64 between 2.5° and 5°. The longitude distribution, however, shows an increase in the number density with longitude: 51 sources are between 10° and 120° and 74 sources between 120° and 230°, which means that depolarisation and confusion is higher towards the inner Galaxy than for its outer region. For the survey section from 10° to 60°, Sun et al. (2011a) showed that the “polarisation horizon” is about 4 kpc at \( \lambda 6 \) cm, otherwise the Galaxy is Faraday-thin. Among the polarised sources, there are both Galactic and extragalactic sources. Although the absolute number of polarised sources is small, the uniform distribution and missing concentration of polarised sources towards the Galactic plane indicates that the fraction of Galactic sources in the sample is quite small.
We compared the number of polarised $^6\lambda$21 cm sources from the NVSS with an angular resolution of 45'' for the area of the $^6\lambda$6 cm survey observed with a 9.5' beam. Since the majority of polarised sources is extragalactic with a mean non-thermal spectral index around $\alpha = -0.9$, a polarised $^6\lambda$21 cm flux density of 30 mJy corresponds to the 10 mJy polarised source limit at $^6\lambda$6 cm in case of no depolarisation. The number of polarised NVSS sources is 88, where 9 of them are double sources, which were not resolved with the large Urumqi beam. Thirty-two of the NVSS sources are between 10° and 120° and 56 sources between 120° and 230° longitude. The NVSS numbers are close to those from the Urumqi survey, which indicates that the angular resolution and the wavelength are not an important selection effect for sources with strong polarised emission. The NVSS lists about 20% more strong polarised sources ($>30$ mJy) for the entire longitude range, but for higher latitudes: 95 sources for $+5^\circ$ to $+15^\circ$ and 113 sources for $-15^\circ$ to $-5^\circ$. The NVSS polarised source deficit in the Galactic plane refers entirely to the inner Galaxy, where the Galactic plane gets Faraday-thick (Sun et al. 2011a). This indicates that a line-of-sight of several kpc through the Galactic disk is needed to cause depolarisation of strong polarised signals on small scales. This changes for fainter polarised NVSS sources, where a latitude dependence exists. Selection effects of confusion with the fluctuating diffuse Galactic emission are more severe and have some influence on the detection of polarised sources.

5.2.2. Percentage polarisation

So far, no systematic survey for polarised sources at $^6\lambda$6 cm along the Galactic plane has been available. Thus, we compared the $^6\lambda$6 cm polarisation data with $^6\lambda$21 cm data from the catalogues listed in Sect. 4.2 and indicated in Table 2 as PC21. The polarised $^6\lambda$6 cm sources have 88 counterparts at $^6\lambda$21 cm. In most cases, the percentage polarisation, PC, increases towards the shorter wavelength as can be seen from Fig. 5, where $^6\lambda$6 cm PC is plotted versus $^6\lambda$21 cm PC. Faraday rotation depends on $^6\lambda^2$, and thus intrinsically highly polarised sources are seen to be more depolarised at $^6\lambda$21 cm than at $^6\lambda$6 cm. With few exceptions, the $^6\lambda$21 cm polarisation data are from high-resolution interferometric data, which resolve some single sources in the $^6\lambda$6 cm catalogue into two polarised components, but differential Faraday rotation within the sources is not resolved. The weak effect of Galactic differential Faraday rotation towards the inner Galaxy as taken from the source distribution discussed above indicates that the increase in the percentage polarisation at $^6\lambda$6 results mainly from decreasing internal source depolarisation.

5.2.3. Identification

Compared to the number of fitted total-intensity sources, the fraction of 125 Gaussian-fitted linearly polarised sources is just 3.3%. One may ask what is special to this small subgroup of sources that they are polarised, while the majority is not. We have used the VizieR service of the CDS for source identifications and found 32 extragalactic objects. Nine are Galactic and four sources might be SNR substructures or extragalactic sources projected against SNR shells. From the remaining 80 sources, 68 have spectra steeper than $\alpha = -0.6$, 3 have spectra flatter than $\alpha = -0.1$. This indicates that more than 80% of the polarised sources are extragalactic. Among the nine identified Galactic sources, six are SNRs, one is a planetary nebula, and two polarised objects were catalogued as H II regions. In principle, a H II region may depolarise and/or act as a Faraday screen when hosting a regular magnetic field component to rotate polarised background emission. This will cause a difference to the polarised emission in its surroundings. Such objects were discussed by Sun et al. (2007), including modelling, and also in other $^6\lambda$6 cm survey papers.

Source 627 ($l, b = 50.192, 3.307$) is identified with the flat-spectrum planetary nebula PK050+31 with an apparent diameter of 2' at 688 pc distance (Stanghellini et al. 2008). The object might be similar to the planetary nebula Sh 2–216 discussed by Ransom et al. (2008) and might act as a Faraday screen in the same way as described for H II regions above. Because its distance is small, a large fraction of the polarised Galactic emission is located behind PK050+31 and gets rotated.

6. Concluding remarks

We present a list of 3832 compact sources extracted from the Sino-German $^6\lambda$6 cm polarisation survey of the Galactic plane, where 125 or about 3.3% of the sample are polarised. The $^6\lambda$6 cm survey complements earlier $^6\lambda$21 cm and $^6\lambda$11 cm surveys from the Effelsberg 100-m telescope with similar angular resolution and sensitivity. Most of the listed sources have counterparts at $^6\lambda$21 cm and $^6\lambda$11 cm, where the extension of the wavelength range up to $^6\lambda$6 cm allows a more precise spectrum determination. It is of interest to determine the spectrum of H II regions at high frequencies, in particular, when they include compact optically-thick components. The identification of objects with spinning dust emission, which peaks between $^6\lambda$3 cm and $^6\lambda$1 cm, critically depends on reliable thermal emission spectra. The $^6\lambda$6 cm source catalogue lists about 20% more sources than the Effelsberg $^6\lambda$21 cm catalogue, which must be faint flat-spectrum sources. Their location in the Galactic plane suggests that most of them are faint H II regions, although confirmation is needed.

We compared the integrated flux densities from the Urumqi $^6\lambda$6 cm survey with those measured with the former Green Bank 300-ft telescope (GB6) with higher angular resolution. The integrated flux densities of extended sources seem to be more precise in the present catalogue.
We found a similar number and distribution of strong polarised NVSS sources at $\lambda 21$ cm compared to polarised $\lambda 6$ cm sources in the Galactic plane, despite their large angular resolution difference. The percentage polarisation increases from $\lambda 21$ cm to $\lambda 6$ cm. We conclude that the depolarisation properties of compact sources are mainly caused by internal effects, while small-scale Galactic Faraday effects do not contribute to the depolarisation except for the inner Galaxy with lines-of-sight of several kpc.

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Xiao, L., Fürst, E., Reich, W., & Han, J. L. 2008, A&A, 482, 783
Table 2. List of compact polarised \( \lambda 6\) cm sources.

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A55, page 9 of 10
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