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Erratum: Optical polarization map of the Polaris Flare with RoboPol

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We report an error in the article 'Optical polarization map of the Polaris Flare with RoboPol', published in 2015, MNRAS, 452, 715 (hereafter Panopoulou et al. 2015). The error only affects the conversion of the Electric Vector Position Angle (EVPA) from the celestial system (in which the values are correct) to the Galactic system. The formula used to convert the polarization angles from the celestial to the Galactic system, taken from Stephens et al. (2011) was found to be incomplete. In the following, we explain the formula used by these authors and its limitations, and describe the correction.

We shall consider two objects at Galactic coordinates (l, b) and (l, b'). Their coordinates in the celestial system are (α, δ) and (α', δ), so that they are equidistant from the North Celestial Pole (NCP). The EVPA measured at the position of each object from the line that connects it to the NCP and towards the East (θ) can be converted to an angle with respect to the North Galactic Pole (NGP) (measured towards increasing longitudes) by:

$$\hat{\theta}_G = \hat{O} + \hat{\theta} \tag{1}$$

where $\hat{O}$ is the angle between lines that connect the object to the NCP and NGP (angles $\hat{o}$ and $\hat{o}'$, shown in Fig. 1), as explained by Stephens et al. (2011). $\hat{\theta}_G$ is held in the range $[0^\circ, 180^\circ]$ by adding or subtracting 180°. For the triangles created by each object and the two poles in our Fig. 1, the law of sines gives:

$$\sin\hat{o} = \frac{\sin\hat{a}}{\sin A}\sin B = \sin\hat{o}' \tag{2}$$

Stephens et al. (2011) find the angle $\hat{O}$ by:

$$\hat{O} = \sin^{-1}\left(\frac{\sin\hat{a}\sin B}{\sin A}\right). \tag{3}$$

Since the arcs A and B and the angle $\hat{a}$ are common for both triangles, the angles $\hat{o}$ and $\hat{o}'$ are incorrectly found to be equal.

This ambiguity can be alleviated if we use both the sine and cosine of the angle $\hat{O}$. We shall proceed to derive a formula for angle $\hat{o}$, which can be applied for any angle $\hat{O}$. The law of cosines for the triangle with sides A, B, C is:

$$\cos B = \cos A\cos C + \sin A\sin C\cos\hat{o} \tag{4}$$

We can find the tangent of $\hat{o}$ by solving equation (4) for $\cos\hat{o}$ and dividing equation (2) by the result:

$$\tan\hat{o} = \frac{\sin\hat{a}\sin B}{\frac{\cos B}{\sin C} - \frac{\cos A\cos C}{\sin C}} \tag{5}$$

We may obtain a formula which only takes into account coordinates in the galactic reference frame by substituting $\cos A$ from the law of cosines:

$$\cos A = \cos B\cos C + \sin B\sin C\cos\hat{a} \tag{6}$$

into equation (5). Next we use the identity $\sin^2 C = 1 - \cos^2 C$ to simplify the denominator and finally we divide both the numerator and denominator by $\sin B$ to arrive at:

$$\tan\hat{o} = \frac{\sin\hat{a}}{\cot B\sin C - \cos C\cos\hat{a}} \tag{7}$$

Before arriving at the final formula for $\hat{o}$, we make the following substitutions in equation (7):

$$\hat{a} = l_{\rm NCP} - l, \quad B = 90^\circ - b_{\rm NCP}, \quad C = 90^\circ - b.$$

Finally, the angle $\hat{o}$ is:

$$\hat{o} = \tan^{-1}\left(\frac{\sin(l_{\rm NCP} - l)}{\tan b_{\rm NCP}\cos b - \sin b\cos(l_{\rm NCP} - l)}\right) \tag{8}$$

where we use the arctangent function with two arguments to obtain the angle in the appropriate quadrant. This formula is equivalent to the one used by Appenzeller (1968). The results returned by

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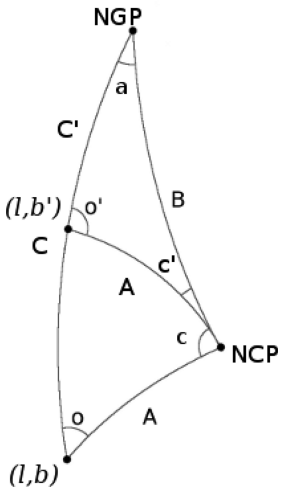

Figure 1. Triangles on the Celestial sphere connecting objects at (l, b) and (l, b') to the NGP and NCP. The angles $\hat{o}$ and $\hat{o}'$ are needed to convert polarization angles in the celestial system to angles in the galactic system. Angle $\hat{o}'$ is incorrectly calculated in Panopoulou et al. (2015).

equation (8) have been compared to those calculated by the function BEAR of the FORTRAN library SLALIB (http://ascl.net/1403.025), which uses a different, but equivalent formula and agree within less than an arcsecond.

Angles computed using equation (3) are incorrect for objects with:

$$90^\circ - b \leq 63^\circ, \quad 45^\circ \leq l \leq 205^\circ \text{ (for } b > 0^\circ)$$

$$90^\circ - |b| \leq 63^\circ, \quad l \leq 20^\circ \quad \text{or} \quad l \geq 205^\circ \text{ (for } b \leq 0^\circ)$$

i.e. for objects within two half-disc regions centred around the two galactic poles. This happens because for these parts of the sky, the angle returned by the arcsine function is the supplementary angle of the desired one. This affects none of the measurements in Stephens et al. (2011) as they are mainly near the Galactic plane. However, the data in Panopoulou et al. (2015) are near the NCP, which has $b_{\rm NCP} = 27^\circ$. Since in Panopoulou et al. (2015) we used equation (3) to find the conversion to $\hat{\theta}_G$, and make the map in Fig. 16, the orientations of segments on the top of the map (in total 77) differ by more than 5° from the correct value. Fig. 16 shows all polarization segments with the correct orientation. In the data accompanying the paper, the Galactic angles of these measurements should be corrected, and we have updated the catalogue in http://cds.u-strasbg.fr/ to contain the correct values. We also show a corrected version of Fig. 19, in which four segments are significantly altered.

The error presented above only affects a small part of the region studied. Our finding that the magnetic field exhibits ordered structure and seems to be aligned with cloud filaments is enhanced by the correction. Thus, the conclusions of Panopoulou et al. (2015) are not significantly affected by the error presented here.

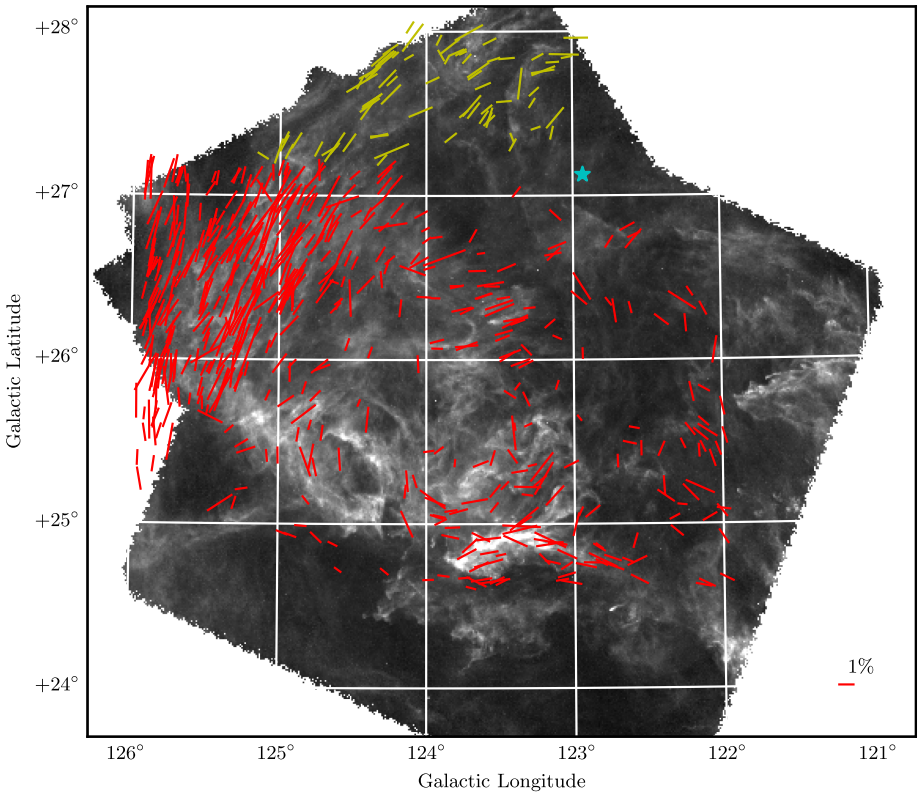

Figure 16. Corrected version of Fig. 16 in Panopoulou et al. (2015): polarization segments over plotted on top of the 250 μm dust emission image of the Polaris Flare from the online archive of the *Herschel* Gould Belt Survey. Yellow segments are measurements with Galactic angles affected by the incomplete conversion by more than 5°.

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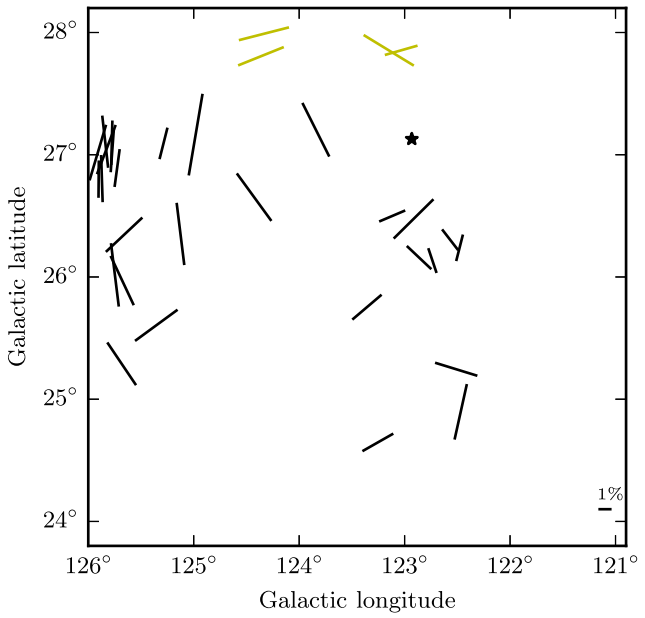

Figure 19. Corrected version of Fig. 19 in Panopoulou et al. (2015): polarization segments of possibly intrinsically polarized sources. Segments affected by the error reported here are shown in yellow.

REFERENCES

Appenzeller I., 1968, ApJ, 151, 907
Panopoulou G. V. et al., 2015, MNRAS, 452, 715
Stephens I. W., Looney L. W., Dowell C. D., Vaillancourt J. E., Tassis K., 2011, ApJ, 728, 99

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table 2.
(http://www.mnras.oxfordjournals.org/lookup/suppl/doi:10.1093/mnras/stw1785/-/DC1).

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