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Galactic coordinate system based on multi-wavelength catalogues

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Outline

- Introduction: why we need to establish a new Galactic Coordinate System (GalCS)
- Data and methods used to find a proper GalCS
- Results and conclusion
- Discussion

Introduction: why we need to establish a new GalCS

- The Galactic coordinate system (GalCS) is a practical coordinate system for studies of the Galactic structure, kinematics, and dynamics.

- The currently used GalCS is based on the FK5 system at J2000.0 (Murry 1989), which was transformed from FK4 system at B1950.0 (Blaauw et al. 1960). It has some limitations and can lead to misunderstandings. (Liu et al. 2011a)

- We need to establish a new GalCS connecting directly to the ICRS with modern observations at various wavelengths. A positive GalCS should be consistent with the feature of the Milky Way.

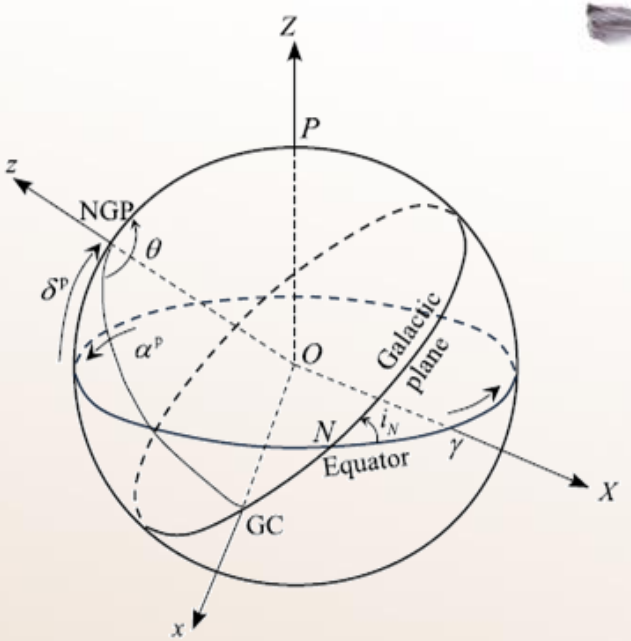
- The GalCS is defined by three parameters α^p, δ^p and θ. The transformation matrix N from the equatorial to the Galactic coordinate system can be written as

$$\mathcal{N} = \mathcal{R}_3(90^\circ - \theta)\,\mathcal{R}_1(90^\circ - \delta^{\rm p})\,\mathcal{R}_3(90^\circ + \alpha^{\rm p})$$

- The parameters referred to the FK5-based J2000.0 reference system were derived as

$$\begin{aligned}
\alpha^{\rm p}_{\rm J2000.0} &= 12^{\rm h}51^{\rm m}26\overset{\rm s}{.}2755,\\
\delta^{\rm p}_{\rm J2000.0} &= +27^\circ 07' 41\overset{''}{.}704,\\
\theta_{\rm J2000.0} &= 122\overset{\circ}{.}93191857,
\end{aligned}$$

- Liu et al. (2012b) has revised the matrix N with 2MASS and SPECFIND v2.0 catalogues in NIR and Radio bands, respectively. And we can make an improvement with other all-sky survey data.



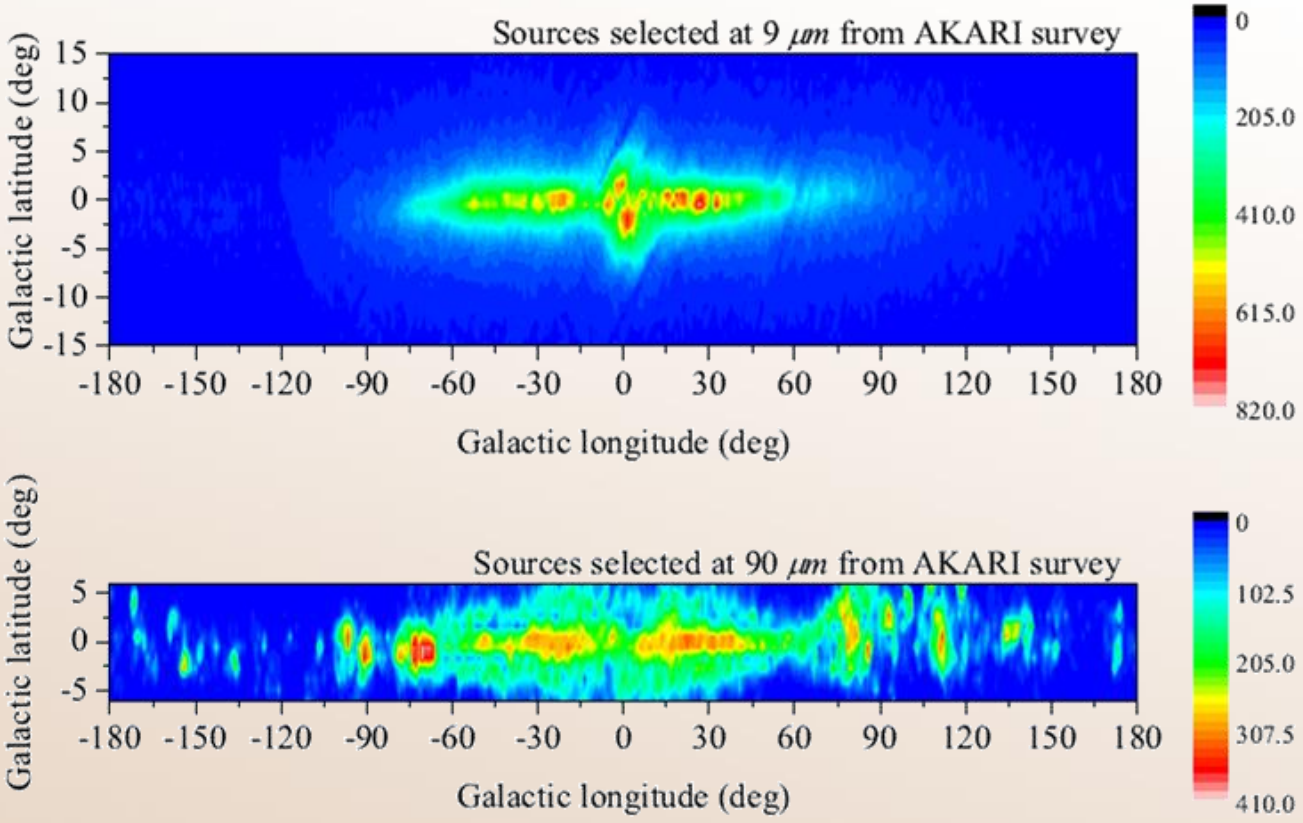
The definition of the GalCS [*x*, *y*, *z*] in the ICRS [*X*, *Y*. *Z*].

Data and methods used to find a proper GalCS

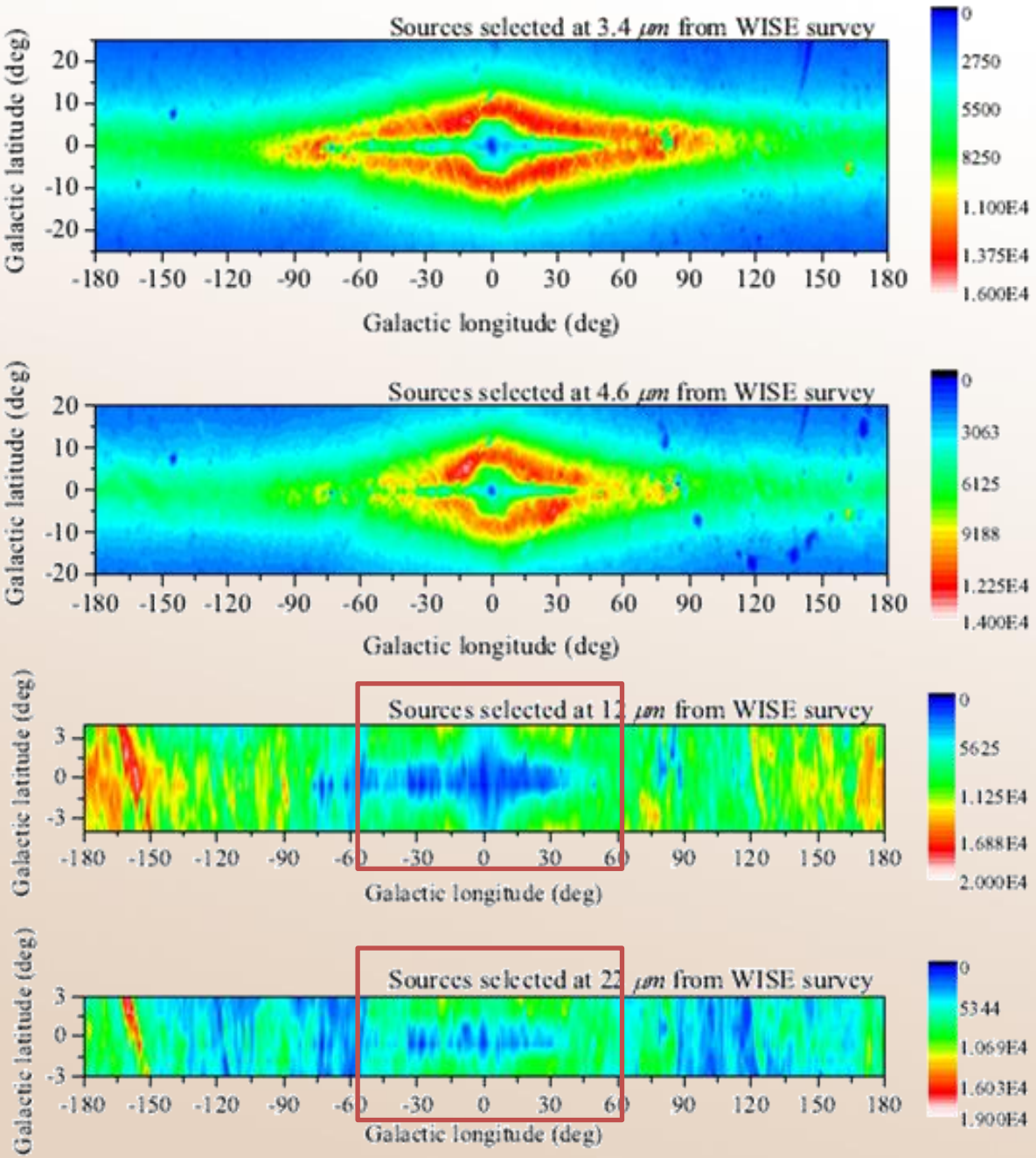
- The fundamentals of our methods:
  - Finding the Galactic plane with the distribution of Galactic sources on the celestial sphere.

- The principles for choosing catalogues and selecting data:
  - From recent all-sky surveys;
  - As large and homogeneous as possible;
  - With relatively weak interstellar extinction.

- The selected catalogues that we used to find the Galactic plane:
  - AKARI: $9\mu m$ (0.101Jy < fluxes < 45 Jy)
    $90\mu m$ (0.46 Jy < fluxes <120 Jy)
  - WISE: $3.4\mu m$ (10 < magnitude < 14.8)
    $4.6\mu m$ (9 < magnitude < 14.5)
    $12\mu m$ (8.5 < magnitude <12.4)
    $22\mu m$ (5.5 < magnitude < 8.8)



The distribution of point sources selected from 9 μm and 90 μm observations of AKARI, respectively.



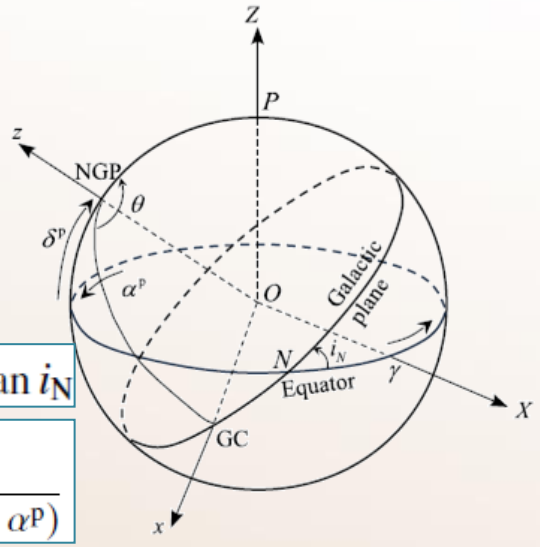
The distribution of point sources selected at 3.4 μm, 4.6 μm, 12 μm, and 22 μm, respectively, from the WISE all-sky catalogue.

- We can calculate $(\alpha^p, \delta^p, \theta)$ for the GalCS orientation with methods in Liu et al. (2011b) , and several improvements are applied. Here we have two methods.

  - i . *z-fixed method*

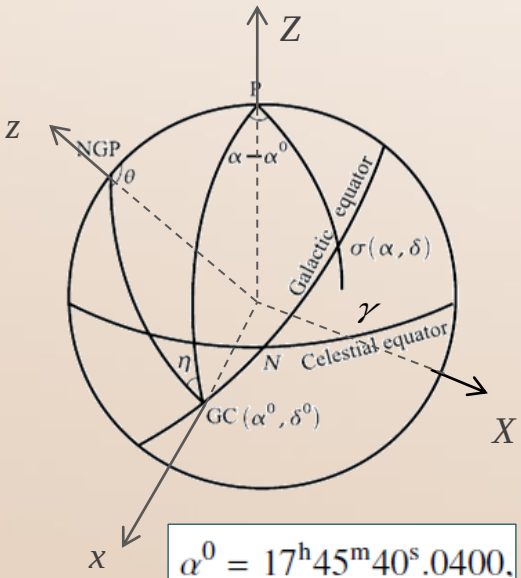
    a) Obtain the position of the z–axis (α^p, δ^p) by fitting the equation of the fundamental plane.

    b) Find the position of the *x*–axis (the position angle θ) close to the direction of GC (Sgr A*).



$$\tan\delta = \sin(\alpha - \alpha_{\mathrm{N}}) \cdot \tan i_{\mathrm{N}}$$

$$\tan\theta = \frac{\sin\left(\alpha^0 - \alpha^{\mathrm{P}}\right)}{\cos\delta^{\mathrm{P}} \tan\delta^0 - \sin\delta^{\mathrm{P}} \cos\left(\alpha^0 - \alpha^{\mathrm{P}}\right)}$$



$$\alpha^0 = 17^{\mathrm{h}}45^{\mathrm{m}}40^{\mathrm{s}}.0400,$$
$$\delta^0 = -29^\circ 00' 28''.138.$$

Reid & Brunthaler (2004)

  - ii . *x-fixed method*

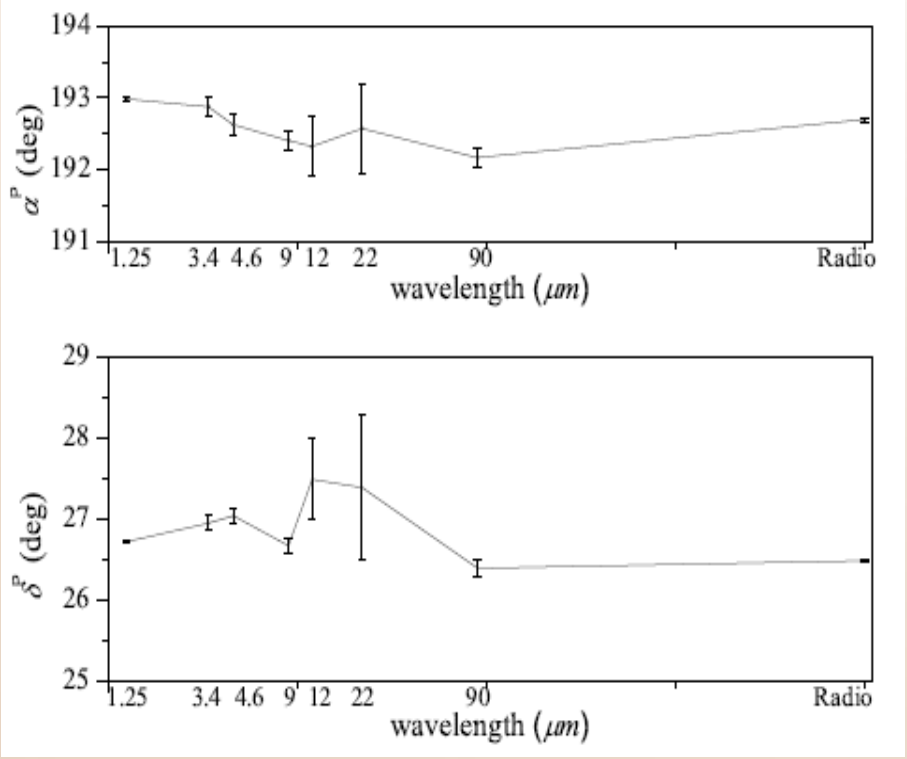
    a) Adopt the direction of GC (α^0, δ^0) to be the position of the *x*-axis.

    b) Calculate the position of the z-axis (the position angle η).

$$\cos\delta^0 \tan\delta = \sin\delta^0 \cos\left(\alpha - \alpha^0\right) + \sin\left(\alpha - \alpha^0\right) \tan\eta,$$

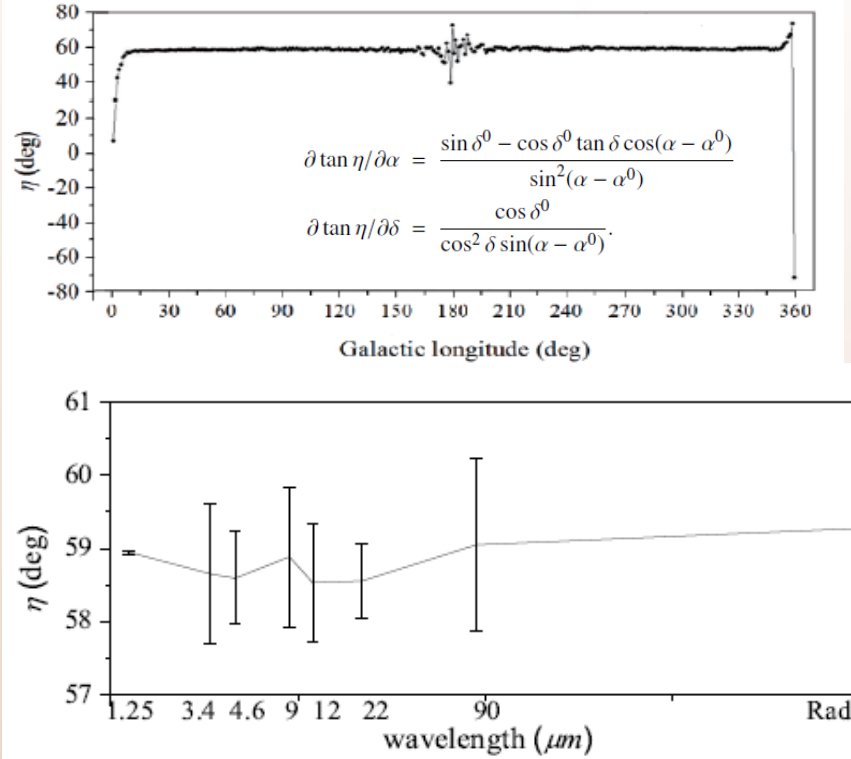
Results and conclusion

- *z*-fixed method



$$\tan\theta = \frac{\sin\left(\alpha^0 - \alpha^P\right)}{\cos\delta^P \tan\delta^0 - \sin\delta^P \cos\left(\alpha^0 - \alpha^P\right)}$$

- *x*-fixed method



$$\begin{aligned}\tan\theta &= \sin\eta/\tan\delta^0\\ \cos\delta^P &= \sin\eta\cos\delta^0/\sin\theta\\ \sin(\alpha^0-\alpha^P) &= \sin\theta/\cos\delta^0.\end{aligned}$$

$$\alpha^{p}_{z-fixed} = 192^{\circ}.582$$
$$\delta^{p}_{z-fixed} = 26^{\circ}.8935$$
$$\theta_{z-fixed} = 122^{\circ}.86216.$$

$$\alpha^{p}_{x-fixed} = 192^{\circ}.777$$
$$\delta^{p}_{x-fixed} = 26^{\circ}.9298$$
$$\theta_{x-fixed} = 122^{\circ}.95017.$$

$$\alpha^{p}_{J2000.0} = 192\,^{o}.859$$
$$\delta^{p}_{J2000.0} = 27\,^{o}.1283$$
$$\theta_{J2000.0} = 122\,^{o}.93192$$

(transformed from $(\alpha^0, \delta^0, \eta)$)

- We recommend results derived from the x-fixed method to define the new GalCS, taking consideration of the validity of observation and the reliability of the parameters.

$$\mathcal{N} = \begin{pmatrix} -0.0546612380 & -0.8728436979 & -0.4849288897 \\ +0.4910591503 & -0.4463642883 & +0.7480774245 \\ -0.8694096043 & -0.1972379304 & +0.4530167092 \end{pmatrix}.$$

$$d\mathcal{N} = \begin{pmatrix} +0.9999992027 & -0.0009752458 & -0.0008021612 \\ +0.0009780078 & +0.9999935703 & +0.0034500541 \\ +0.0007987914 & -0.0034508359 & +0.9999937268 \end{pmatrix}.$$

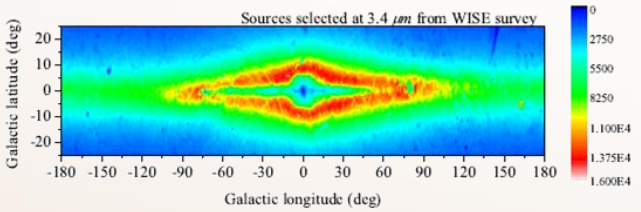
Discussion

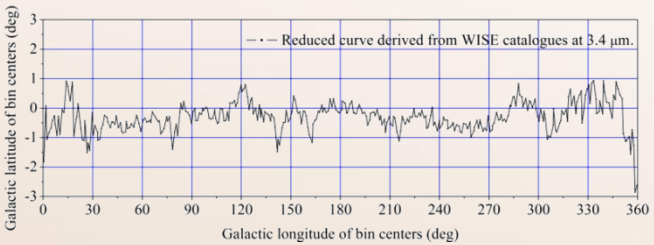
- ⅰ. The impact of the character of data on calculating the GalCS parameters.

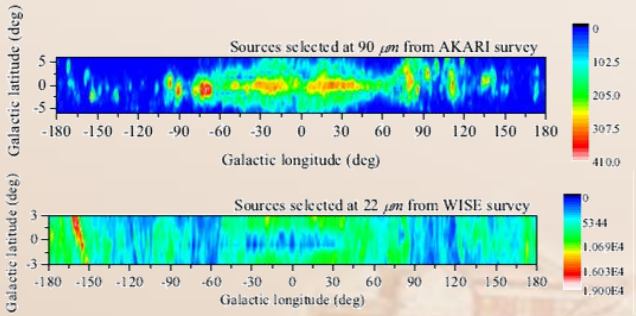
  a. The notable extinction near the Galactic plane.

  b. The projection effect caused by the Sun , which is about 15 pc above the Galactic plane (Zhu 2009).

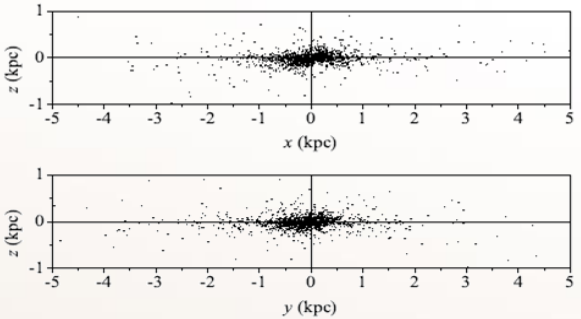
  c. Other factors (e.g. the distribution of objects and the probable contamination, etc.).

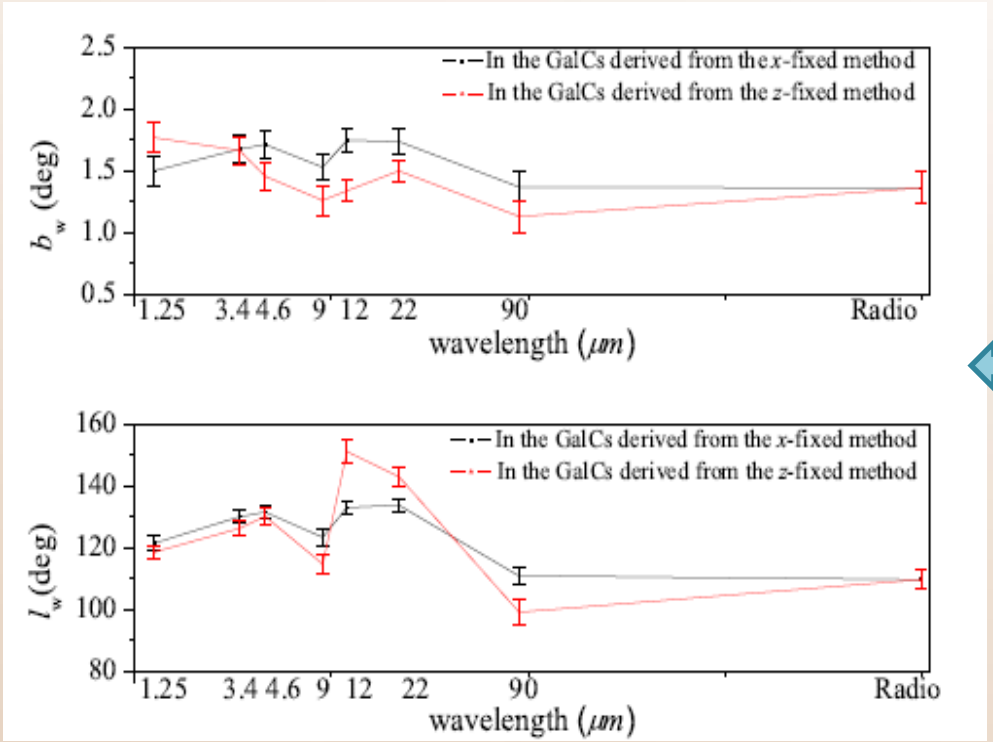






- ii . The effect of the different GalCS on the study of the Galactic structure (e.g. the Galactic warp)





The warp parameters fitted in the GalCS in eight bands. b_w is the inclination angle of the warp plane with respect to the Galactic plane, and l_w is the Galactic longitude of the intersecting line of the two planes.

The data used to fit the warp plane is from Hipparcos O-B5 stars (Miyamoto & Zhu 1998).

This work was funded by the National Natural Science Foundation of China (NSFC) under grant No. 11173014 and Natural Science Foundation of JiangSu Province under grant No. BK20130546. This research is based on observations with AKARI, a JAXA project with the participation of ESA, and has made use of the NASA/ IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Thank you !