The Astronomical Journal, 130:569–575, 2005 August

THE SPIRAL ARMS AND INTERARM SEPARATION OF THE MILKY WAY: AN UPDATED STATISTICAL STUDY

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Received 2005 February 14; accepted 2005 April 21

ABSTRACT

Measurements of the spiral arms (their pitch angle, number, shape, and the interarm separation) in the Milky Way have been published in the period from 1980 to early 2005, using different methods that yielded slightly or widely differing values, depending on hidden or unknown biases. A meta-analysis would be useful for searching for trends among these individual studies. First, we find a convergence for three parameters: the pitch angle, the number of arms, and the shape of the arms. Second, we find a change for the interarm separation near the Sun, a decrease of about 25%; it is our determination of these parameters that evolves, not the actual physical arms. Third, we recalibrate a recent arm model to take account of that gradual change and compare it with the spread in each arm parameter.

Key words: Galaxy: disk — Galaxy: structure — ISM: general — standards

Online material: color figure

1. INTRODUCTION

Living in the disk plane of the Milky Way makes it difficult to ascertain the distances to the various spiral arms along a line of sight in the disk plane. Measurements of spiral arms in our Galaxy have led to conflicting results in the past. While the basic parameters of the nearby spiral arms will not change over a Galactic rotation period (about 200–250 million years), the methods of measuring the basic arm parameters have become more refined with time, thanks to better calibration and scientific understanding. Numerous studies have been published in the last few years dealing with some spiral arm parameters. A search of NASA's Astrophysics Data System was made to cover the publications since late 2001. The results may be slightly incomplete for some journals yet complete for the main journals, and they are taken nonetheless as representative of the whole. Published results in recent years include fits to data from H II regions, CO clouds, H I gas, young stars, pulsars, far-infrared and near-infrared dust, etc. To keep roughly the same number of entries as in the previous statistical studies, we split the newer studies into tables with 15 entries.

In § 2 the relevant details of the spiral arms from recent studies are compiled and statistically studied. The convergence or gradual change of the statistical results is determined. The distance scale is discussed in § 3. In § 4 model locations for the arms are discussed after recalibration due to a change in the distance scale, followed by comparisons with the data.

2. DATA SELECTION

2.1. *Collection and Classification*

Previous data in the period 1980–1994 have been statistically analyzed (15 papers in Vallée 1995), as well as those in the period 1995 to mid-2001 (17 papers in Vallée 2002). Here we tabulate the results for mid-2001 to mid-2003 in Table 1 (15 papers) and for mid-2003 to early 2005 in Table 2 (15 papers). This group of four tables,[1] with roughly the same number of papers each (~15), is employed to study the convergence or gradual change of our determination of the spiral arm parameters. In the following we show the mean values of the parameter data as a function of time since 1980. The data points are the means from Table 1 in Vallée (1995), Table 1 in Vallée (2002), and Tables 1 and 2 here.

2.2. *Evaluation and Weighting*

When looking from Earth at the spiral arms of an external galaxy, one can easily see the entire galaxy within the field of view, or most of it. This task is impossible to do for the Milky Way, as one can only do it piecewise. Each study of the Milky Way is limited to a particular view (Galactic longitude, observing wavelength, physical process), often seeking one or more arm parameters, but seldom all parameters, depending on the method employed and on other desired goals. One needs a meta-analysis to collect the published pieces, classify them (e.g., in longitude), evaluate (and/or weight) their methods, get some statistics (or trends), and reconstruct a full view (or model, for instance).

Each Galactic arm study comes with its own strengths and weaknesses. We employ here the same relative weighting system as used before in two previous analyses (Table 1 in Vallée 1995; Table 1 in Vallée 2002), assigning the weight of 1 to a few studies with strong limitations (fewer arm tracers, local area, dust complications, more assumptions, small contribution) and assigning the best weight of 3 to a few studies with less limitations (more arm tracers, larger distances, multiple models studied, fewer assumptions, greater contribution). Most studies thus get a relative weight of 2. Relative weights are given in Tables 1 and 2; some details of the studies are discussed below.

Walawender et al. (2001) probed the local Galactic structure through optically polarized starlight. They found the local direction of the Galactic magnetic field, assumed to be along the local spiral arm. They found its radius of curvature to be 7.8 pc.

Drimmel & Spergel (2001) employed several tracers to delineate the spiral structures, using three dust components (arm, disk, and flare) with around 20 parameters.

Frick et al. (2001) obtained a good fit to the rotation measure (RM) of galaxies as a function of longitude but did not indicate the error in the pitch angle. Other arm parameters were assumed.

[1] The four tables summarizing the arm parameters from these 62 studies are also available in ASCII, at the Canadian International Union of Radio Science Web site at http://www.ursi.ca/vallee/MWarms.html.

TABLE 1
15 Studies of the Spiral Arms in the Milky Way (Mid-2001 to Mid-2003)

Reference	Pitch Angle (deg)	Number of Spiral Arms	Arm Shape[a]	Interarm Separation[b] (kpc)	Relative Weight[c]	Data Used
Fish et al. (2003), Fig. 3	10	4	Log	3.3	2	UC H II regions
Russeil (2003), Fig. 5	11	4	Log	3.2	3	H II regions
Nakanishi & Sofue (2003), Fig. 9	12	3	Log	6.0	2	H I gas
Shaviv (2003), Fig. 10	...	4	...	...	1	Glaciations
Kolpak et al. (2003), Fig. 8	12	4	Ring	...	2	Radio H II regions
Yang et al. (2002), Fig. 6	10	4	Log	5.0	2	CO clouds
Grimm et al. (2002), Fig. 7	12	4	Log	3.0	2	X-ray binaries
Han et al. (2002), Fig. 1	12	4	Log	2.4	1	Pulsar RM
Yano et al. (2002), Fig. 2	12	4	Log	...	1	Optical Cepheids
Fosalba et al. (2002), Fig. 1	2	...	...	<4.0	1	Stars in local spur
Araya et al. (2002), Fig. 2	20	4	Ellipse	3.2	2	UC H II regions
Garcia-Sánchez et al. (2001), Fig. 4	7	2	...	3.0	1	Nearby stars
Frick et al. (2001), Fig. 8*c*	15	>3	Log	...	1	RM of galaxies
Drimmel & Spergel (2001), Fig. 19	12	4	Log	3.6	2	Far-IR dust, H II continuum
Walawender et al. (2001)	9	...	Log	...	1	Polarized starlight
Median value	12	4	Log	3.2	...	
Unweighted mean (all data)	11.1	3.8	...	3.63	...	
Selected mean (only weight 2 and weight 3 data)	12.4	3.9	...	3.90	...	
Standard deviation of the mean	±1.1	±0.2	...	0.4	...	

[a] For the arm shape, the azimuthal angle φ follows a function of the radius r, $f(r)$.
[b] Distance between the Perseus arm and Sagittarius arm, going through the Sun's location.
[c] Relative weight 3 is best.

Garcia-Sánchez et al. (2001) studied the local stars, using several Galactic potential models and density wave theory. Their study was limited by the relative lack of nearby stars in the *Hipparcos* catalog. They did not show an error analysis for the pitch angle, and their model could not accommodate a four-arm structure.

Araya et al. (2002) studied ultracompact H II regions, linking them together to show the arms over a wide distance range. One arm can be drawn from only two H II regions.

Fosalba et al. (2002) studied Galactic starlight polarization, with the vast majority of such measured stars being within 2 kpc of the Sun. Low-latitude stars have a mean polarization direction of 88°, which is assumed to be parallel to the local arm direction.

Yano et al. (2002) studied six dozen Galactic Cepheids near the Sun to detect some spiral structure. Some of the arm parameters are assumed.

Han et al. (2002) fitted the RMs of pulsars to a mean value of three previously published arm models, and they showed some

TABLE 2
15 Studies of the Spiral Arms in the Milky Way (Mid-2003 to Early 2005)

Reference	Pitch Angle (deg)	Number of Spiral Arms	Arm Shape[a]	Interarm Separation[b] (kpc)	Relative Weight[c]	Data Used
Russeil et al. (2005), Table 2	...	4	Log	...	2	Hα gas
Vallée (2005), Fig. 1	12	4	Log	2.5	1	Pulsar RM
Sewilo et al. (2004), Fig. 2	12	4	Log	3.3	2	Radio H II regions
Könyves et al. (2004), Fig. 3	15	>2	...	4.0	2	Far-IR dust loops
Luna et al. (2004), Fig. 1*a*	12	4	Log	2.4	2	CO gas
Gómez & Cox (2004), Fig. 7	13	4	Log	2.9	1	Thermal gas
De Simone et al. (2004), Table 2	15	2	...	...	1	Optical stellar velocity
McClure-Griffiths et al. (2004), Fig. 3	12	4	Log	3.1	1	H I gas density
Paladini et al. (2004), Fig. 12	14	4	Log	2.8	3	Radio H II regions
Drimmel et al. (2003), Fig. 1	12	4	Log	3.7	1	Near-IR dust extinction
Cordes & Lazio (2003b), Fig. 9	15	4	Log	2.7	3	Thermal electrons
Melnik (2003), Fig. 3	5	2	Ring	1.8	1	OB associations
Negueruela & Marco (2003), Fig. 7	12	4	Log	...	2	O and B stars
Bissantz et al. (2003), Fig. 5	16	4	Log	...	2	Near-IR flux and gas
Watson et al. (2003), Fig. 3	12	4	Log	3.3	3	UC H II regions
Median value	12	4	Log	2.9	...	
Unweighted mean (all data)	12.6	3.7	...	2.95	...	
Selected mean (only weight 2 and weight 3 data)	13.5	4.0	...	3.08	...	
Standard deviation of the mean	±0.7	±0.2	...	0.2	...	

[a] For the arm shape, the azimuthal angle φ follows a function of the radius r, $f(r)$.
[b] Distance between the Perseus arm and Sagittarius arm, going through the Sun's location.
[c] Relative weight 3 is best.

reasonable agreement with this mean arm model. While they did not fit the arm parameters themselves, their choice of models excluded more extreme arm models.

Grimm et al. (2002) found a clear signature of the spiral arms in the spatial distribution of high-mass X-ray-emitting binary stars. They provided maps of the distribution in various projections. While they did not fit the arm parameters themselves, their data exclude two-arm models.

Yang et al. (2002) showed that cold molecular clouds in the northern Galactic plane showed a high concentration toward the spiral arms. They noted that large pitch angles cannot match the CO clouds.

Kolpak et al. (2003) found clear evidence for the Sagittarius and Perseus arms in their study of the distribution of radio H ii regions. However, the pitch angle is assumed to be inward and is not well defined.

Shaviv (2003) found a correlation between the ice age epochs and the change in Galactic cosmic-ray flux as a function of the Sun's orbit around the Milky Way, as a result of its passage in and out of successive spiral arms. Galactic cosmic rays are produced in supernovae and mostly reside in the spiral arms. The peaks of the ice ages, and thus of the cosmic rays, indicate four spiral arms. The Galactic cosmic-ray flux, as recorded in Fe/Ni meteorites, also indicates the same periodicities as seen in the ice age epochs (near 145 Myr).

Nakanishi & Sofue (2003) used H i data to trace three prominent spiral arms and found them to be roughly logarithmic, with a range in pitch angles, assuming pure circular motions.

Russeil (2003) compiled a catalog of star-forming complexes, obtained mostly through optical and radio observations. All stellar distances have been recalculated with the same calibration procedure.

Fish et al. (2003) used OH Zeeman masers and found some weak evidence of magnetic field correlations with the Galactic spiral arms. Although they assumed a spiral model, the correlations disappear for more extreme spiral models.

Watson et al. (2003) used H_2CO and H110α radio lines from ultracompact H ii regions to resolve distance ambiguities and determine the spiral arms. Although they assumed a spiral model, the correlations quickly disappear for more extreme spiral models.

Bissantz et al. (2003) employed many smoothed particle hydrodynamics simulations to fit the molecular CO gas and near-infrared luminosity. The use of such models entails making several assumptions about unobserved conditions.

Negueruela & Marco (2003) studied distant O- and B-type stars in the second Galactic quadrant, calculated their distances from their colors and spectral types, and found many to be tracers of the distant Cygnus arm.

Melnik (2003) studied the local spiral structure of the Milky Way using the velocity field of nearby OB associations. He found fragments of the Carina and Perseus arms, which he linked together with a low pitch angle. Overall, he assumed a two-arm structure.

Cordes & Lazio (2003b) proposed a new four-arm model, suitably modified to account for the Galactic distribution of free electrons. As a result, pulsar distances were recalibrated and found on average to be closer by a factor of 2/3 (Fig. 13 in Cordes & Lazio 2003a).

Drimmel et al. (2003) produced a Galactic extinction model at optical and near-infrared wavelengths, providing improved components to the spiral arms. They made use of direction-dependent rescaling factors, based on far-infrared luminosity. Proper dust correction is a difficult endeavor.

Paladini et al. (2004) studied the large-scale spatial distribution of radio H ii regions. They found a good correlation with a recent spiral model, but it disappears with more extreme models.

McClure-Griffiths et al. (2004) studied the H i 21 cm line in the fourth Galactic quadrant and found evidence for a continuation and some distortion of the outer (Cygnus) arm. It could be the last major structure before the end of the H i disk.

De Simone et al. (2004) studied the stellar velocity distribution in the solar neighborhood, using stochastic spiral waves. Heating by spiral structures results in an age-velocity dispersion relation. However, the range of allowed pitch angle is large (their Table 1).

Gómez & Cox (2004) used magnetohydrodynamics to simulate the observations of thermal gas (using the older fit of Taylor & Cordes [1993]). Their good correlation disappears with more extreme spiral models. The magnetic field in the arms is parallel to the arms, but between the arms the field pitch angle is somewhat radially outward as it approaches the next arm and somewhat radially inward as it leaves the spiral arm.

Luna et al. (2004) studied CO gas and high mass star formation in the longitude range from 270° to 350°, using tangent points to spiral arms with relative maxima in the integrated intensity of CO gas.

Könyves et al. (2004) used far-infrared dust loops and arcs and traced out the spiral structures in the neighborhood of the Sun. The distances to the loops were obtained through their associated objects.

Sewilo et al. (2004) also used H_2CO and H110α lines to resolve the distance ambiguities to several radio H ii regions and obtain their locations, then compared them with a recent spiral arm model. They found a good correlation with that model, but it disappears with more extreme models.

Vallée (2005) used pulsars with a known RM and rescaled the pulsar distance according to the latest electron density calibration of Cordes & Lazio (2003a); the nearby pulsar distribution in the Milky Way plane is still only weakly correlated with a recent spiral arm model, contrary to expectations. Still, several distant pulsars can be found along the Perseus arm (longitude near 90°) and the Sagittarius arm (longitude near 50°).

Russeil et al. (2005) obtained a deep Hα study of the Milky Way near longitude 332° and found proper distance estimates for several optical H ii regions. They fitted many layers, each one at a different radial velocity and kinematic distance, and identified each with a spiral arm or another large object (association, supernova, cloud complex); they found the Sagittarius-Carina arm at -24 km s^{-1} and 1.9 kpc, etc.

2.3. *Statistics and Trends*

Tables 1 and 2 assemble chronologically the results found in the literature for the basic spiral arm parameters. In addition, the last rows present the median and mean statistical values and the standard deviations of the mean. We also recalculate the mean values *after* excluding the studies with the lowest relative weight of 1.

Figure 1 (*top left*) shows the convergence in our determination of the pitch angle since 1980. Clearly, the error bars decrease with time, while the mean values are quite close to each other at around 12°.

Figure 1 (*top right*) shows the convergence in our determination of the number of arms since 1980. One can grasp a gradual increase in the percentage of studies finding four arms, perhaps reaching 100% within 10 years.

Figure 1 (*bottom left*) shows the convergence of our determination of the arm shape since 1980. The percentage of studies

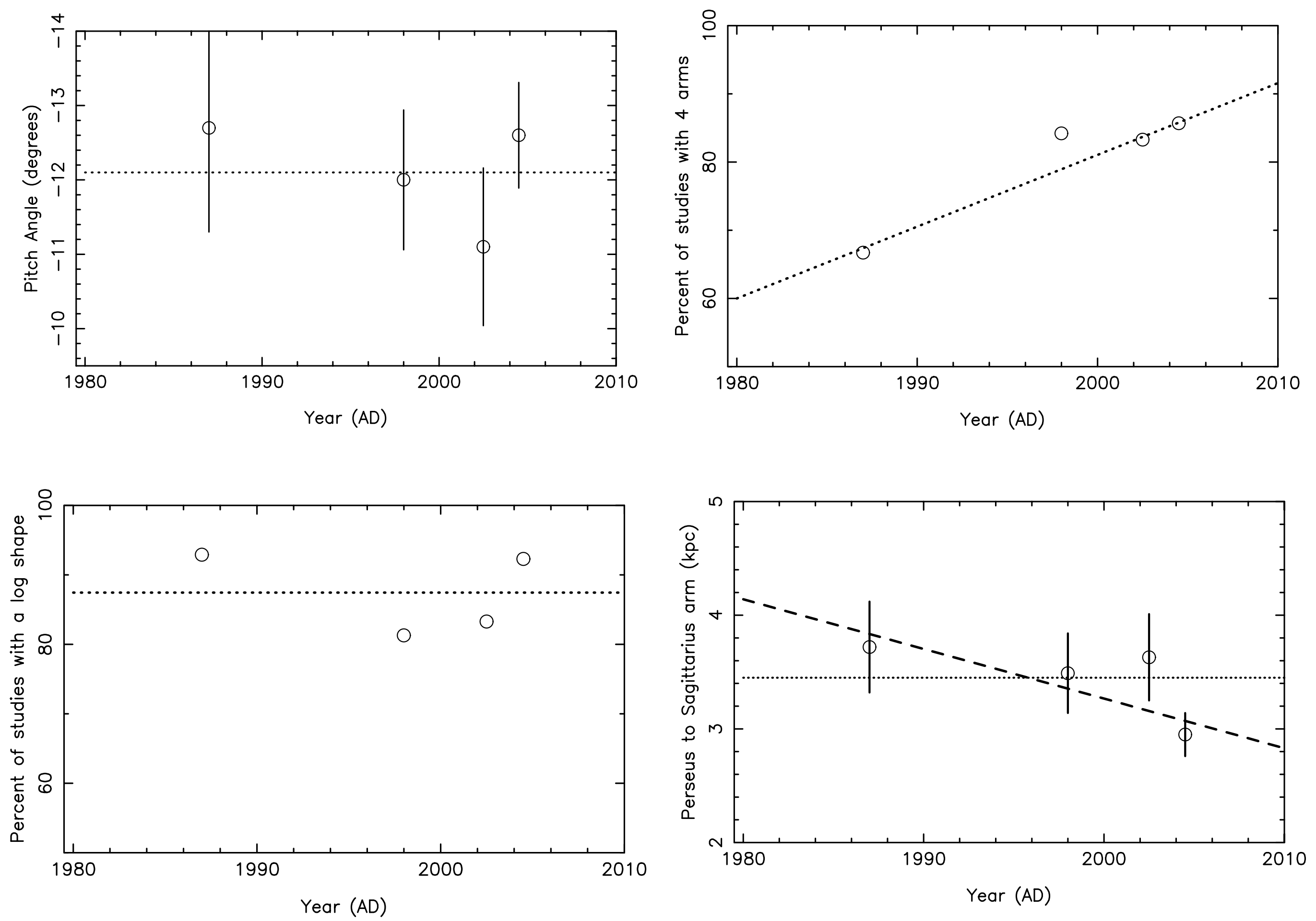

Fig. 1.—Observed convergence or gradual change since 1980 in our determination of the arm parameters. *Top left*: Statistical convergence of the mean value of the observed pitch angle in each time period. An unweighted straight average is shown (*dotted line*). *Top right*: Statistical convergence of the percentage of studies determining four arms. *Bottom left*: Statistical convergence of the percentage of studies determining a logarithmic arm shape. *Bottom right*: Statistical change of the mean value of the observed interarm separation in each time period. A weighted least-squares fit is shown (*dashed line*), as well as an unweighted straight average (*dotted line*).

finding a quasi or nearly logarithmic arm shape is overwhelming, near 90%, but may require finer averaging owing to disturbances such as star nurseries, star clusters, and superbubbles due to multiple supernovae explosions.

3. CALIBRATION OF THE DISTANCE SCALE

There are four types of data that point to a smaller distance scale in the Milky Way than we originally thought a quarter of a century ago: the interarm separation, the Sun's distance to the Galactic center, the pulsar distribution in the plane, and the distance to well-known H II regions in nearby spiral arms. If we do not use the real distance scale, we get incorrect estimates of the true distances to objects such as pulsars. Incorrect distances would affect models of the mass distribution, such as the quantity and location of dust required to dim an object (i.e., a star) or the value of the circular speed of an object around the Galactic center.

1. Figure 1 (*bottom right*) shows the convergence of our determination of the interarm separation since 1980. Clearly, the error bars decrease slightly with time, while the mean values for each time period are comparable but show a downward trend with time. A least-squares fit (*dashed line*) was obtained with the standard routine LINFIT, using a weight inversely proportional to the square of the errors involved (Bevington 1969, p. 92). Also, we show the unweighted straight average of the mean values (*dotted line*). The difference from the 4 kpc value in 1980 amounts to a decrease of about 25% in a quarter century.

If we only select nonkinetic data, we get fewer, nearby data with distances determined through luminosity, absorption, or spectral models (for dust, RM, thermal electrons, and associations). In the first and oldest group (Vallée 1995) the interarm separation was 3.8 kpc with a standard deviation of the mean of 0.5 kpc; in the second group (Vallée 2002) it was 3.7 kpc with a standard deviation of the mean of 0.7 kpc; the third group (Table 1 here) gives an interarm separation of 3.0 kpc with a standard deviation of the mean of 0.3 kpc; and the fourth group (Table 2 here) gives 3.2 kpc with a standard deviation of the mean of 0.4 kpc. Thus, for the nonkinetic data only, the interarm separation was 3.8 kpc early on and is now about 3.10 kpc, indicative of a decrease of about 18%.

2. Since 1995 various determinations of the distance from the Sun to the Galactic center have been made. Kinematic velocity methods often omit important effects, such as tidal perturbations from very nearby small galaxies (the Sagittarius dwarf, etc.), the central Galactic bar (within 3 kpc of the Galactic center), or the dark halo mass interior to the Sun's quasi-circular orbit. Photometric methods also have calibration problems, owing to dust model determinations; recent measurements using RR Lyrae and δ Scuti stars yield 7.8 ± 0.4 kpc (Carney et al. 1995) and 7.9 ± 0.3 kpc (McNamara et al. 2000), respectively.

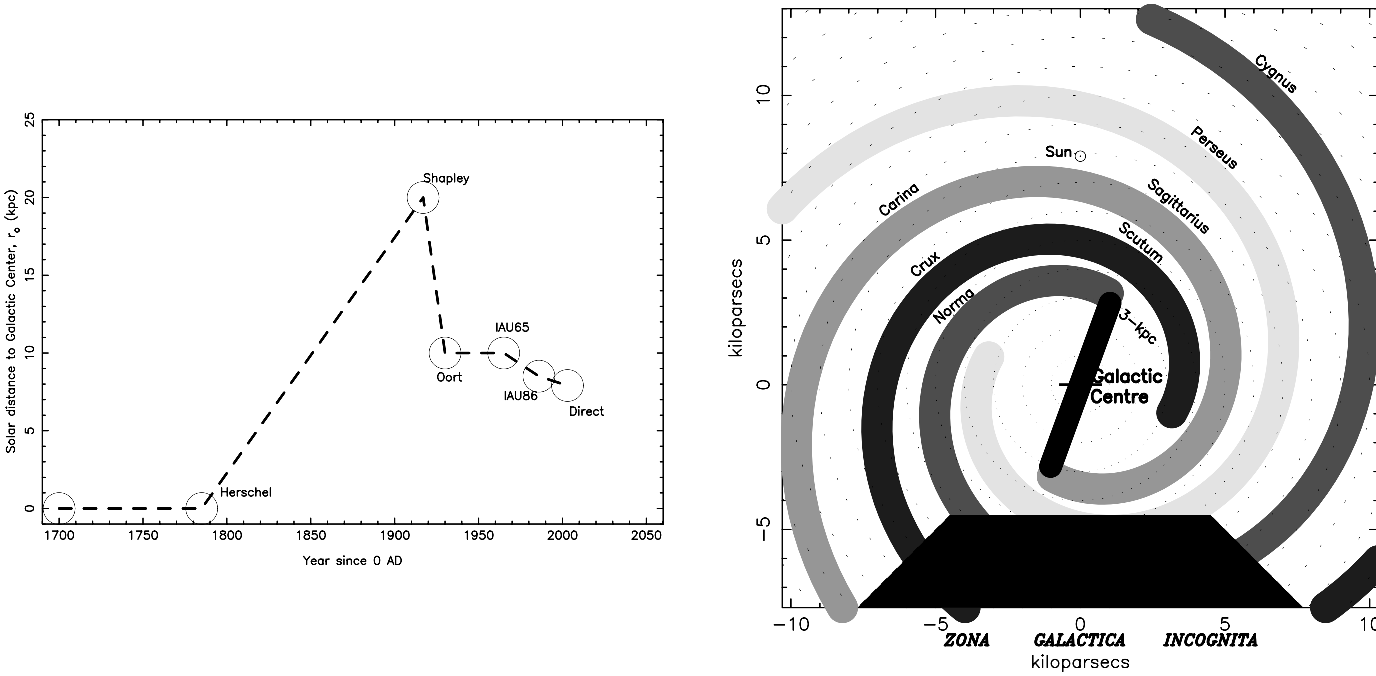

Fig. 2.—Revised distance scale in kiloparsecs (1 kpc is 3.08×10^{19} m). *Left*: Historical determination of the distance from the Sun to the Galactic center since 1700. *Right*: Current determination of the locations of the spiral arms, with a distance from the Sun to the Galactic center of 7.9 kpc. Each arm has been arbitrarily given a different color but a constant width. [*See the electronic edition of the Journal for a color version of the right panel of this figure*.]

Direct measurement methods, via proper motion and line-of-sight velocity or via cluster and statistical parallax, yield 8.0 ± 0.9 kpc (Genzel et al. 2000) and 7.9 ± 0.4 kpc (Eisenhauer et al. 2003), respectively. A straight mean and rms of all four determinations above gives 7.9 ± 0.1 kpc.

Figure 2 (*left*) shows the gradual change of the distance from the Sun to the Galactic center and its successive steps. Before Shapley, the notion of the distance from the Sun to the Galactic center was not clear, because it was not possible to estimate the position of the Galactic center. There is now room for more direct measurements in order to decrease the rms below 0.1 kpc. In the remainder of this paper, we adopt the value of 7.9 kpc. This differs from the canonical value of 10 kpc, a decrease of 21% in a quarter century.

3. Independently, our determination of pulsar distances has changed as well. The recent thermal density model for pulsar distances (Fig. 13 in Cordes & Lazio 2003a) puts pulsars at a distance on average 1/3 closer to the Sun than in the earlier model (Taylor & Cordes 1993). This represents a decrease of 33% in the last eighth of a century.

4. Also, our determination of the distance to a star-forming region in the Perseus arm has been evolving. The star-forming region W3(OH) was often placed at a distance of 3 kpc (e.g., Hughes & Vallée 1978). A recent, precise measurement of the distance to W3(OH), using the Very Long Baseline Array (VLBA) for a trigonometric parallax of methanol masers there, yielded a preliminary value near 1.95 kpc (X.-W. Zheng & M. Reid 2005, private communication). This recent determination represents a decrease of 35% in a quarter century. Very few such distance determinations using VLBA trigonometry have been made so far, and it is normally assumed that the large W3/W4/W5 complex is a well-known part of the Perseus arm (e.g., Hughes & Vallée 1978). It is not known exactly where W3(OH) is located inside the Perseus arm.

Summarizing, a straight average of these measurements (interarm separation down 25% and 18%, Sun–Galactic center distance down 21%, pulsar distance down 33%, and Perseus distance down 35%) of distances within the Milky Way shows an average shrinkage by about 26% over about a quarter century.

4. MODEL ARM LOCATIONS AND COMPARISONS WITH THE DATA

4.1. *Rescaling*

The spiral arm model in Vallée (2002) must now be rescaled to account for the new Sun–Galactic center distance of 7.9 kpc adopted here. From Table 1 in Vallée (2002) the new model parameters become, after rescaling by 7.9/7.2, $r_0 = 2.52$ kpc and an interarm separation at the Sun of 2.74 kpc. The other model parameters stay the same at $\theta_0 = 0°$, $m = 4$, and $p = 127°$.

Figure 2 (*right*) shows a sketch of our current determination of the locations of the spiral arms, as adapted for a Sun–Galactic center distance of 7.9 kpc. Details of the adopted model are given in Vallée (2002). The arm width is arbitrary (set at 1 kpc) but representative of arms in other galaxies. The Sun is not located in an arm but in a stellar spur (not shown); for a recent review, see Olano (2001) and Vallée (2004).

4.2. *Comparisons*

Figure 3 shows histograms of the arm parameters, as published in the period 1980.0–2005.2. For comparison, the vertical dotted line shows the data from the rescaled model in Figure 2 (*right*). The newer data in Tables 1 and 2 confirm the earlier model parameters.

On the whole, there is a good convergence of our determination of the pitch angle, the number of spiral arms, and the arm shape, none of which appears to show a change with time in their mean values (Fig. 1, *top left*, *top right*, *bottom left*). The new model employed has parameters that are found near the *center* of the spreads of the observational data (Fig. 3, *top left*, *top right*, *bottom left*).

4.3. *Interarm Separation*

We draw attention to the fact that there is a *gradual change* in the determination of the value for the interarm separation near

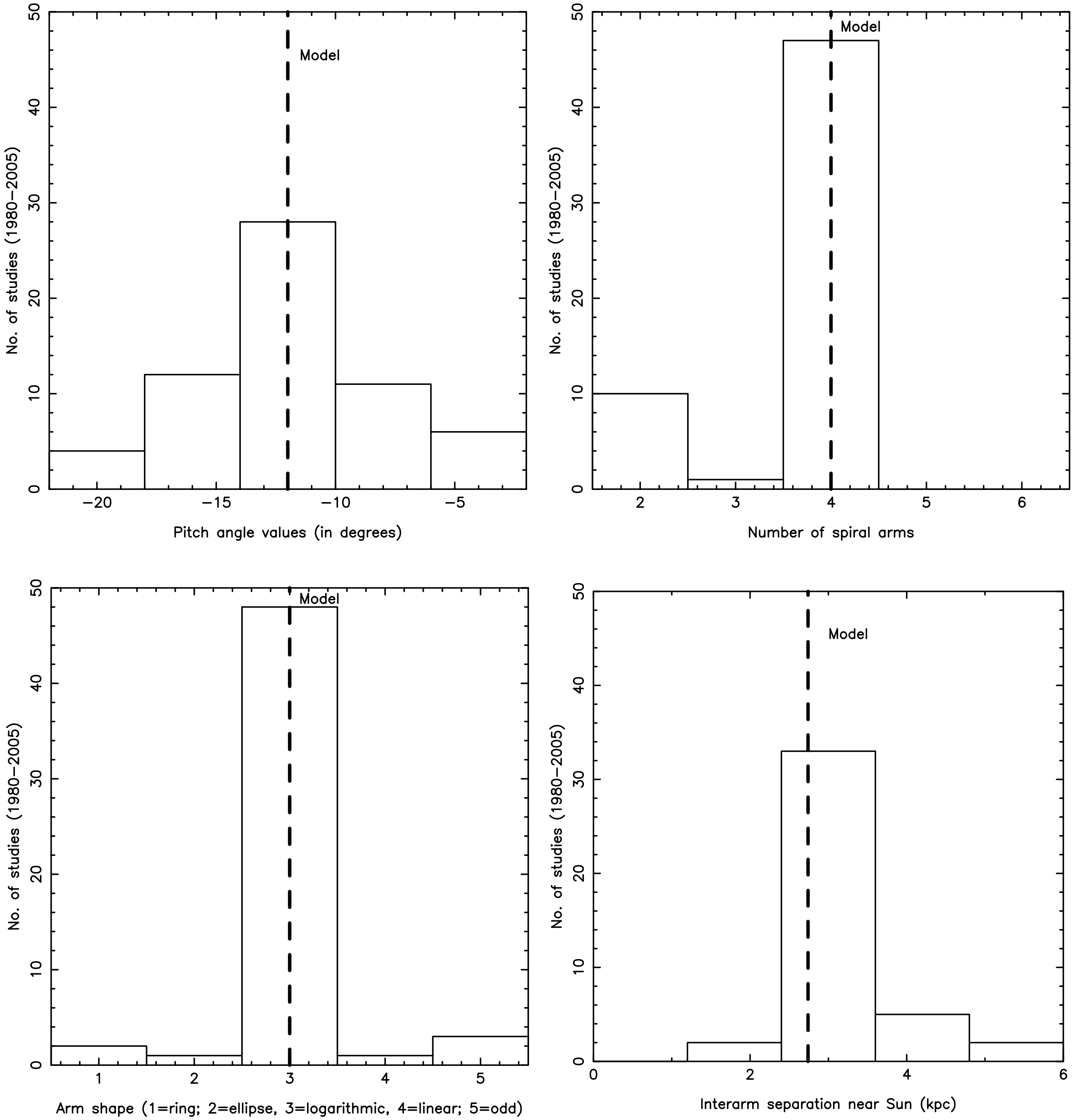

FIG. 3.—Histograms of data for the studies since 1980. The dashed vertical lines indicate the new model used in Fig. 2 (*right*). *Top left*: Observed pitch angle. *Top right*: Observed number of spiral arms. *Bottom left*: Observed arm shape. The arm shapes include (1) a ring or a quasi ring, (2) an ellipse or an ellipsoid, (3) a logarithmic spiral, (4) a short linear arm approximation, or (5) an odd or more complex shape. *Bottom right*: Observed interarm separation.

the Sun, which decreased by about 25% in the period studied (Fig. 1, *bottom right*). The new model has an interarm separation parameter of 2.74 kpc (Fig. 2, *right*), slightly shorter than the current observed mean value near 2.95 kpc (Table 2) and slightly shorter than the *center* of the spread in the observational data (Fig. 3, *bottom right*). Future observations will test this shorter interarm separation.

A recent measurement of the distance from the Sun to W3(OH) in the Perseus spiral arm yielded 1.95 kpc (X.-W. Zheng & M. Reid 2005, private communication). Our recalibrated model (Fig. 2, *right*) predicts a distance from the Sun to the nearest spiral arm in that direction ($l = 134\overset{\circ}{.}0$, $b = +1\overset{\circ}{.}0$) to be near 1.91 kpc. These data are virtually the same, within the combined errors involved (0.04 kpc).

5. CONCLUSION

On a practical side, one may ask what this compilation is giving (i.e., what positive contribution) that is not given by individual articles. Sitting in the midplane of the Milky Way, each study is limited to a particular field of view, so one needs a meta-analysis to collect and classify the pieces and evaluate and reconstruct the full view. Each article studies only a few arm parameters in a small wavelength range, depending on the method employed and other desired goals.

1. In conclusion, we assembled recent data since mid-2001, classified their methods and the parameters of the spiral arms in the Milky Way, and performed an evaluation and a statistical analysis of them (Tables 1 and 2). We looked for convergence or gradual changes in the spiral arm parameters over the 25 year period since 1980, using these data, as well as earlier ones from Vallée (1995, 2002), separated in time into four groups of around 15 entries each. We found convergence for the mean values of the pitch angle (Fig. 1, *top left*), the number of arms (Fig. 1, *top right*), and the arm shape (Fig. 1, *bottom left*). Interestingly, we found a change since 1980 in our determination of the interarm separation between the Sagittarius and the Perseus arms, through the Sun (Fig. 1, *bottom right*).

2. A change in the determination of the distance of the Sun from the Galactic center (Fig. 2, *left*) convinced us to do a recalibration of our earlier spiral arm model. Our recalibrated logarithmic model (Fig. 2, *right*) is close to the center of the spread in the observed data (Fig. 3).

3. We predict a model-recalibrated interarm separation within 1 σ of the mean of the observational determinations (median of observations at 2.95 kpc; new model with 2.74 kpc). The small difference of 0.2 kpc is much smaller than a typical arm width of 1 kpc.

4. A check of the prediction of our recalibrated model with the precise measurement of the Sun's distance to W3(OH) in the Perseus arm shows an agreement within the combined errors (trigonometric data with 1.95 kpc; new model with 1.91 kpc). The small difference is not significant because of the relative location of this object inside its spiral arm.

I thank Xing-Wu Zheng (Center for Astrophysics) for a communication in advance of publication and a thoughtful referee for helpful suggestions.

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