THE THIN DISC AND THE BULGE WITH GAIA

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ABSTRACT

The Gaia mission is designed to explore the Galaxy, measuring the phase space parameters of 1 billion stars and providing a description of their astrophysical parameters by combining the astrometric instrument with a photometric system and a radial velocity spectrometer. In spite of the fact that due to the crowding of the stars on the focal plane, the densest regions of the inner Galaxy will be poorly sampled, still a significant numbers of regions will be observed allowing the study of the thin disc and of the bulge. This paper details the tremendous impact that Gaia will have on our understanding of the thin disc and bulge formation and evolution. Finally, simulations of the inner Galaxy in the photometric system of Gaia are presented and discussed.

Key words: Gaia; Galaxy: thin disc; Galaxy: bulge.

1. INTRODUCTION

One of the challenges of modern astrophysics is to cast light on the complexity of galaxy formation and evolution. The diagnostic is hidden in the properties of stellar populations: position, kinematics, age, and chemical composition. Positions and kinematics are the fossil records of the dynamical processes; ages and chemical composition are the tracers of the star formation history.

Gaia is going to provide the phase space coordinates for more than 1 billion stars of our own Galaxy. In addition, multi-band photometry will be available down to V = 20, while spectroscopy will be possible down to V = 17–18. This will provide complete chemical measurements. However, Gaia performances will suffer from the crowding of the stars on the focal plane. While astrometric measurements will be only marginally affected by crowding, the Radial Velocity Spectrometer (RVS) on board will be more severely limited by the crowding of the spectra (Katz et al. 2004). When the star density is of the order of 10 000–20 000 stars per square degree down to V = 18 only the brightest objects can be recovered. All the information about high density regions are then provided by the Broad Band Photometry (BBP) having a crowding limit of 3 million stars per square degree, and the Medium Band Photometry (MBP) with a limit of 100–200 000 stars per square degree. In spite of these limitations, the recent work by Reylé & Robin (2005) has pointed out that a significant number of regions in the inner disc and bulge will still be observable by MBP, BBP, and the RVS. In this paper first we stress the importance of studying the thin disc and the bulge to understand the Galaxy formation. Having precise astrometric measurements, radial velocities if possible, precise distances, magnitudes and reddening for a large sample of stars will allow a tremendous progress on our knowledge of the history of the inner Galaxy. Finally, using the Padova isochrone data base and the Padova Galaxy Model, we simulate some fields in the inner Galaxy to show the performances of the Gaia photometric system.

2. THE THIN DISC

In this section we discuss our present knowledge of the thin disc. In the classical view, the thin disc is believed to be formed by collapse of the gas left over by halo formation. No merger events are foreseen, and the thin disc is supposed to evolve quietly. Nowadays we are aware that many aspects of the thin disc formation and structure are still poorly understood, namely the formation process, the influence of possible merger events (if any), the kinematics, and the initial mass function.

2.1. The Formation Process: the Angular Momentum Problem

The most credited scenario for the formation of the Milky Way is based on both the initial collapse of Baryonic Matter into the potential well of Dark Matter (Eggen et al. 1962) and the aggregation of smaller objects made of either stars or gas (Searle & Zinn 1978; Peebles 2000). In this context, the Milky Way grows around a central body and accreting matter in later epochs forms the external halo and the disc (Gilmore & Wyse 2001). Recent cold dark matter (CMD) models including a cosmological constant appear to fit large scale structure observations (Primack 2004). However, on small scales the formation of the disc is still one of the most serious problems. To understand how discs form needs clarification of how they acquire their specific angular momentum. There are two different angular momentum problems in CMD models. First, the transfer of the angular momentum to the dark matter is too large to allow the formation of big discs (Navarro & Steinmetz 1997) The main reason of this is that an unphysically rapid cooling of the gas in merging satellites is produced when the feedback from star formation (stellar winds, supernova explosions) is not included. More realistic discs form when the stellar feedback is taken into account (Maller & Dekel 2002) The photometric properties of discs are indeed well reproduced by the most recent models (Abadi et al. 2003a). Second, the resulting distribution of specific angular momentum is at odds with observations when the baryons and dark matter have the same initial angular momentum distribution (Abadi et al. 2003a; Navarro & Steinmetz 2000). This hypothesis is based on the idea that the angular momentum arising from large scale tidal torques is similar across the whole halo. This might not be true if the angular momentum of halos grows mainly from the orbital momentum of accreted satellites (Vitvitska et al. 2002). Alternative hypotheses have been advanced by Katz et al. (2003) and Barnes (2002). However, at present no convincing solution has been presented. Reconciling the properties of disc galaxies with the early collapse and high merging rates typical of the hierarchical scenarios remains a challenging affair.

2.2. The Formation Process: Merging History of the Thin Disc?

In the classical view, thin discs are too fragile to fluctuations in the gravitational potential to have suffered accretion events. Since the pioneering work by Eggen et al. (1962) the small scale height of the disc as well as the correlation between metallicity and kinematics of the disc stars has been interpreted in favor of a smooth formation by dissipative collapse (see the recent review by Freeman & Bland-Hawthorn 2002). It is now widely accepted that the presence of two disc components, the thin and the thick disc is due to dynamical heating of an early thin disc by a satellite falling in about 10 Gyr ago (Quinn & Goodman 1986; Wyse 2004). The presence of old stars in the thin disc is used to argue that the Galaxy has not been disturbed by mergers after that time (Wyse 2004). The precise age of the old component is still controversial, going from 8 Gyr to 11 Gyr. However all the dating methods, namely white dwarf luminosity function, open clusters (Carraro et al. 1999), field stars (Bertelli & Nasi 2001) agree on the fact that old stars exist in the thin disc. This would set a limit to the age of the last major merging event (Wyse 2004). Such a quite and smooth thin disc formation would indicate an unusual assembly history in a universe where structures grow hierarchically. It is difficult to accommodate this idea in the popular CMD scenario (see Section 2.1). Recently the hypothesis has been advanced that the thin disc has suffered mergers during its evolution. Simulations have shown that a satellite disrupting after its orbit has been circularized by dynamical friction may contribute to the thin disc without heating it (Helmi et al. 2003; Abadi et al. 2003b; Meza et al. 2004). In this scenario only a small fraction of the old thin disc stars are actually older than the epoch of the last major merger, while essentially all old stars are coming from minor events due to the disruption of satellites on circular orbits at later times (Abadi et al. 2003b). If this model is correct, then relics of accretion events should be identified as coherent groups in the phase space. Up to now, only a few examples have been recognized, the Monoceros ring in the outer disc (Yanny et al. 2003) and the Arcturus stream, a group of stars explained as debris of a satellite in the plane of the disc (Navarro 2004). This scenario need to be confirmed.

As a consequence of the complex formation and evolution process of the disc, all the global properties we derive for its stars, i.e., the age-metallicity relation, if any, metallicity/age–kinematics relation, star formation rate, metallicity gradient should be interpreted at the light of a complex interplay between different processes: 1) local processes; 2) merger history; 3) radial/vertical mixing: as a response to spiral waves perturbations, old stars born at the Sun location can be spread at galactocentric radii going from 4 to 12 Kpc (Sellwood & Binney 2002). Here it is worth recalling that with Gaia the solar neighbourhood, defined as a sample of stars complete down to $M_V = 4.5$ with parallaxes measured with an accuracy better than 10% is going to extend up to 2–3 Kpc (Bertelli 2002). The presence of radial velocity measurements for all the stars brighter than V = 17–18 will produce an unbiased catalogue. This will improve in a dramatic way the possibility of detecting debris of stellar satellites, clarifying the disc formation process.

2.3. Disc Structure

The structure of the disc, the profile of its mass distribution, its scale height and scale length, the presence of a central hole, the existence of an external edge are still under discussion.

2.3.1. The mass distribution and scale parameters

In addition to the classical double exponential mass profile, several mass distributions are proposed in the literature. In particular, using DIRBE data, Freudenreich (1996) finds that the sech^2 distribution is greatly superior to the exponential at low latitudes ($|b| < 5°$). Einasto (1979) law has been recently suggested by Robin et al. (2003) to better reproduce the star counts.

Current observational data do not provide a clear hint for the scale length and scale height. Adopting as reference an exponential profile, the scale height of the thin disc varies from 330 pc (Gilmore & Reid 1983; Reid & Majewski 1993; Chen et al. 2001, among others) to 250–200 pc (Haywood et al. 1997; Vallenari et al. 2000). Kinematics determinations are obtained only in the solar neighbourhood: 350 pc (Siebert et al. 2003).

The scale length derived from star counts and integrated light distribution is found to vary from 3.0 kpc (Eaton et al. 1984; Freudenreich 1998) to 2.0 kpc (Robin et al. 2003; Vallenari et al. 2000). Kinematic determinations are found to lie in the range 2–4.3 kpc (Mayor 1974; Fux & Martinet 1994; Bienayme & Sechaud 1997; Lewis & Freeman 1989).

2.3.2. The central hole and the external disc

Concerning the structure of the inner disc, one of the major concerns is whether the extrapolation of the exponential profile is appropriate toward the centre or a decrease in the central distribution should be preferred. Such a central hole has been detected in the distribution of stars, molecular and atomic gas in a large number of external barred galaxies (50% according to Anderson et al. 2002). This hole might represent instead of an abrupt truncation, a gradual density decrease or a constant density profile toward the centre. In our own Galaxy, there is no general agreement on the presence of a central density decrease. The integrated light distribution of COBE/DIRBE data can be reproduced either including a central hole (Freudenreich 1998; Lépine & Leroy 2000) or ignoring it (Bissantz & Gerhard 2002). Microlensing experiments are in favor of it, but the data are hampered by the presence of highly variable and poorly determined interstellar extinction (Kiraga & Paczynski 1994). Star counts in the inner disc strongly suggest that a deficit of stars is necessary to fit the data (Bertelli et al. 1995; Robin et al. 2003; López-Corredoira et al. 2004). However the presently available data cannot distinguish between a real density decrease and a flared stellar distribution. A flare cannot be excluded: it would place the stars at higher distances from the plane than predicted by an exponential distribution, giving the impression of a hole.

The presence of a truncation in the optical disc at large radii is observed in external galaxies at about four scale length (Pohlen et al. 2000). In our Galaxy, several studies have detected a possible edge of the disc at a distance of about 14 kpc (Robin et al. 1992; Ruphy et al. 1996; Freudenreich 1998) while others do not need it to reproduce the data (Vallenari et al. 2000; Robin et al. 2003). The significance of this is not clear. In addition, the presence of a warp and a possible flare of the external disc seen in the COBE data (Freudenreich 1998; Drimmel & Spergel 2001), in OB stars (Reed 1996; Paladini et al. 2004) and in HI and molecular gas distribution (Diplas & Savage 1991; Nakanishi & Sofue 2003; May et al. 1997) adds further uncertainties on the detection of the external edge of the disc. The truncation of the disc, if any, might be related to the properties of the angular momentum of the early protocloud, but it might be as well related to the dynamical evolution of the disc (see Freeman & Bland-Hawthorn 2002, for a broader discussion).

2.4. Thin Disc Kinematics

To investigate the formation of the thin disc it is fundamental to obtain precise information about the global kinematic properties (i.e., the velocity ellipsoids), so that deviation from the expected behavior can reliably be recognized. At present the kinematics of the thin disc are poorly known: the structure of the velocity ellipsoid, its vertex deviation and vertical tilt rest on a small sample of stars. The vertex deviation gives a measure of the extent at which the local ellipsoid is radially aligned. Up to now measurements are available for a large sample of stars only in the solar vicinity, where it is found to vary from 25° for the old population to about 0° for the young stars (Dehnen & Binney 1998; Bienaymé 1999; Soubiran et al. 2003). Its determination is strongly affected by the presence of moving groups. The nature of the vertex deviation has been widely discussed in literature (we quote among others Kuijken & Tremaine 1994; Dehnen & Binney 1998; Binney & Merrifield 1998), but it is still far from being completely understood. It might be due either to a non-axisymmetric component or to local spiral perturbation, or finally to partially mixed populations. The vertical tilt of the velocity ellipsoid is still ill-determined. Its value indicate whether the ellipsoids are aligned with the coordinate axes of a spherical or cylindrical system, giving information about the Galactic potential and dark matter distribution. As it is strongly related to the coupling of the U (the velocity in the direction of the Galactic centre) and W^2 (the velocity perpendicularly to the plane), it can properly be derived only from 3-dimensional velocities. A few determinations are available up to now (Bienaymé 1999). Finally, the radial variation of the velocity ellipsoid is poorly constrained by the data. We are aware of only two studies in which the velocity dispersion of the thin disc has been observed at different radii (Neese & Yoss 1988; Lewis & Freeman 1989). From the observations of 300 stars Neese & Yoss (1988) derive a linear trend of the velocity dispersion with the radius. Lewis & Freeman (1989) observed 600 old K giants with broad-band photometry and medium resolution spectroscopy at radii going from 1 kpc to 17 kpc in low absorption windows. They found that the radial and tangential velocity dispersions in the disc fall exponentially with R.

2.5. Age-Velocity Relation

The random motion of the stars near the Sun is well known to increase with stellar age. This effect is known as the disc age-velocity relation (AVR). It is interpreted as due to a heating of the thin disc as a function of time. In spite of the efforts done in the recent past, this effect is still poorly constrained by the data. Broadly speaking, the total velocity dispersion of the stars rises from ~ 20 km s^{-1} for young ages to about 40–60 km s^{-1} for old objects. The AVR can be parametrized as $\sigma(t) = \sigma_0(1 + t/\tau)^\alpha$ where σ_0 is the initial value of the velocity dispersion, τ is a constant, and α is the heating index (Wielen 1977). Pre-Hipparcos determinations of α are in the range 0.47–0.61 (Edvardsson et al. 1993; Wielen 1977; Fuchs et al. 2001). These determinations are based on small samples of data. Hipparcos high quality measurements represent a great improvement toward the determination of the age–velocity relation giving the availability of a larger sample. However, even from post-Hipparcos measurements, the heating index α is poorly constrained (Hänninen & Flynn 2002; Binney et al. 2000). In addition, it is still a matter of discussion whether the effect saturates after 3–4 Gyr (Gomez et al. 1997) or not, as suggested by the recent study by Nordström et al. (2004). The determination of the AVR is probably still dominated by systematic errors, mainly on the age. An uncertainty of 50% on the age of young stars is enough to reduce the heating index from 0.5 to 0.3 while a 20% error produces only a neglegible variation on α (Hänninen & Flynn 2002). On the theoretical ground, a number of mechanisms have been proposed at present to explain the existence of the AVR, but none can reproduce the observations. In particular, the scatter against giant molecular clouds in the gas layer of the Galaxy (Spitzer & Schwarzschild 1951) produces too much heating in the vertical direction, while the perturbative effect on stellar orbits by spiral arms gives an amount of vertical heating too low in comparison with observations (Carlberg 1987). The heating of the disc by massive objects (black holes) in the dark halo (Lacey & Ostriker 1985) in combination with giant molecular clouds might reproduce the observations (Hänninen & Flynn 2002). However these are ad-hoc solutions and no dynamical evidence has been found up to now of the presence of such massive objects in the Galaxy. Dark clumps on orbits passing through or near to the galactic disc have recently been proposed as candidates to perturb the disc, gradually increasing the scale height (Benson et al. 2004). Substructures in dark matter halos are predicted by the standard Λ-dominated cold dark matter model of galaxy formation. This semi-analytical model by Benson et al is quite promising but needs to be explored in more details. The Gaia satellite will provide a wealth of new data on distances and kinematics within several kpc, the multi-band photometric system of Gaia will allow a better precision on age determinations, so that much improvement is expected on the age-velocity relation.

2.6. The Initial Mass Function: Is It Constant Everywhere?

The determination of the initial mass function (IMF) is a cornerstone in astrophysics, since the stellar mass distribution determines the evolution, the surface brightness, the chemical enrichment, and the baryonic content of the galaxies. It provides also a diagnostic on the fragmentation of molecular clouds and star formation. The shape of the IMF is believed to be remarkably uniform in different spatial environments and in time (Chabrier 2003; Kroupa 2002) The uniformity of the IMF would suggest that the star formation is proceeding by a scale free process. However, suggestions that the IMF might not be constant are advanced:

1. as a response at the conditions of density and temperature at high redshift, where hints are arising that the characteristic mass of the IMF is decreasing with time, from a few solar masses for early star formation conditions to 0.2–0.3 $M_\odot$ for the metal poor spheroid and to 0.1 for the disc population (Chiosi et al. 1998; Chabrier 2003);
2. to explain the properties of the low surface brightness where the formation process is taking place in extremely poor metal content environment (Lee et al. 2004; Schombert et al. 1990);
3. to reproduce the relation between Fe abundance and gas content in the intra-cluster medium (Portinari et al. 2004).

The stellar populations of the Milky Way are the ideal workbench to derive the IMF and improve our knowledge of the star formation process even for low mass stars. The determination of the IMF of the Galactic stellar populations has been the subject of many studies in the recent past. While all the authors agree on a power law Salpeter IMF for masses higher than ~ 1 $M_\odot$, no general consensus is reached in the low mass region. When the stellar mass is in the range 0.1–0.6 $M_\odot$ the IMF slope is found to vary from 0.5 for the thick disc (Reylé & Robin 2002) to 1 in the solar vicinity (Chabrier 2003), and to 1.45 ± 0.1 in the Galactic Bulge (Zoccali et al. 2000). In the mass range 0.5–0.8, the IMF slope is 2 ± 0.2 for the Bulge (Zoccali et al. 2000; Holtzman et al. 1998) and the solar neighbourhood (Chabrier 2003) and becomes 0.5 for the thick disc(Reylé & Robin 2002). It is unclear whether these variations are real or not, and whether they are suggesting a dependence of the stellar formation process on the metal content. It should be stressed that no direct determination of the IMF is possible: the observable quantity, the present day luminosity function is then converted into the IMF through the knowledge of the mass–luminosity relation which in turns, rely on stellar models.

To derive the IMF from the photometry of field stars is a cumbersome affair, since several effects are conspiring:

1. the degeneracy between IMF and star formation rate (Binney et al. 2000);
2. the dependence from the Galactic structure, especially when a small volume is sampled. In fact the velocity dispersion of different Galactic populations should be taken into account: old, low-mass stars having larger scale height (300 pc) than young stars (50 pc) are under-represented close to the Galactic plane;
3. the dependence of the stellar luminosity and colour from the (usually unknown) metal content;
4. the binary star correction (Kroupa 2001).

The knowledge of the parallaxes is of fundamental importance in order to get precise absolute luminosities. Up to now, parallaxes are known for stars as faint as $M_v = 9.5$, corresponding to a minimum mass of about 0.4 $M_\odot$, up to 20 pc, while for faint M dwarfs up to 5 pc (Leinert et al. 1997). Gaia is going to observe a complete sample of stars more massive than 1 $M_\odot$ up to 2000 pc with parallax precision better than 10%, while a complete sample of stars as low as 0.16 $M_\odot$ will be observed inside 50 pc.

3. WHAT DO WE KNOW ABOUT THE BULGE?

In spite of the many efforts dedicated to understanding the bulge properties in the recent past, still many unanswered questions remain about its formation process, age, metal content, mass distribution and kinematics.

3.1. The Formation of the Bulge

How and when bulges form and evolve are crucial clues to the formation of galaxies. Several plausible bulge formation scenarios are proposed in the literature. The bulge can form at the centre of a dissipative collapse (Eggen et al. 1962), or through merger induced low intensity star bursts and stellar accretion (Aguerri et al. 2001; Scannapieco & Tissera 2003; Wyse et al. 1997). A class of models predict that the bar forms by an instability of the stellar disc. The bulge is then formed from this bar, at later times (Pfenniger & Norman 1990; Raha et al. 1991). In other models, the bulge is formed from the disc at earlier stages, when the gas disc fragments in massive clumps. Then the merging of these clumps can give rise to a bulge structure (Noguchi 1999; Immeli et al. 2004). The diagnostic to distinguish between these models is hidden in the ages, age distribution, enrichment law, presence or absence of metal gradient of the stellar populations.

3.2. The Shape of the Bulge and its Kinematics

Nowadays a convincing evidence has been found for a bar in the Galaxy: NIR light distribution, various source counts, the atomic and molecular gas morphology and kinematics and microlensing (Ng et al. 1996; Gerhard 1996; Kuijken 1996; Dwek et al. 1995; Binney et al. 1997; Bissantz & Gerhard 2002; Gerhard 2002; Peyaud & et al. 2004). However, the detailed shape, orientation, length of the bar are still under discussion. Several models are proposed in the literature, going from spherical symmetry to oblate or triaxial, mainly derived from IR integrated light (we quote among others: Dwek et al. 1995; Kent et al. 1991; López-Corredoira et al. 1999). However, no clear consensus is reached on a specific model. In particular the position angle of the inner ($l < 10^\circ$) bulge/bar with the direction Sun-Galactic centre is still very uncertain. While kinematics determinations based on OH/IR stars suggest a large angle of about 40° (Sevenster et al. 1999), photometry determinations still give contrasting results, going from 40° (van Loon et al. 2003) to 25° (Dwek et al. 1995), down to about 12° (Hammersley et al. 2000; Robin et al. 2003). The external bar/bulge position angle (at $l > 10^\circ$) has been recently discussed on the basis of NIR observations. Hammersley et al. (2000) and Picaud & Robin (2004) on the basis of NIR star-counts on the Galactic plane detect an excess of stars around $l \sim 27^\circ$ with respect to the expected disc population. If this overdensity corresponds to the Galactic Bar, then the position angle of the bar comes out to be about 43°. The question then arises whether the Galactic bulge and Galactic bar are two distinct structures, having different position angles and being located in the inner and external regions, respectively (López-Corredoira et al. 1999; Alard 2001).

Realistic kinematic bulge models are very difficult to calculate (Fux 2001; Bissantz et al. 2004). What is missing is a self-contained model fully taking into account all observational information going from the luminosity functions to the kinematics of stars and gas. On the observational side, the kinematics along the line of sight in different directions has been considered only in a few cases (Sharples et al. 1990; Minniti et al. 1992; Zoccali et al. 2001; Kuijken & Rich 2002). Recently Sumi et al. (2004) have produced a catalogue of proper motions of 5 million stars in the direction of the bulge over 11 deg^2 from OGLE-II data with an accuracy of 0.8–3.5 mas per year, depending on star brightness.

3.3. The Age and the Metal Content of the Bulge

The age of the bulge is found to range from 10 Gyr (Holtzman et al. 1998; Picaud & Robin 2004; Vallenari et al. 1996) to the age of the halo (Ortolani et al. 1995). On the basis of isochrone fitting no better precision can be obtained. In fact, at the turnoff level an uncertainty of 0.07 mag will result in an error of 1 Gyr on the age determination. The spatial distribution of the bulge stars plays an important role in the determination of the age of the stellar population, its main effect being of modifying the magnitude of the stars in the colour-magnitude diagram around the turnoff of 0.2–0.4 mag (Vallenari et al. 1999; Vallenari & Ortolani 2001). The age metallicity degeneracy, the disc contamination will contribute to making the determination of the age of the bulge extremely difficult. Finally, many hints are now pointing out that the extinction varies on small scales, but also suggest a peculiar interstellar extinction law in the direction of the bulge with $R_V = A_V/E(B–V) = 1.7–2.5$ (Udalski 2003; Popowski 2000; Sumi 2004; Ruffle et al. 2004). OH/IR stars are found in the inner bulge from DENIS–ISOGAL data (Sevenster et al. 1997; van Loon et al. 2003). They are oxygen-rich cool AGB stars in the superwind phase and are suspected to be of intermediate age, possibly in the range 1–8 Gyr. However, no young stars are found in the Baade Window, even when the disc contamination is removed using HST proper motion (Kuijken & Rich 2002).

Concerning the metal content distribution of the bulge, while all authors agree that the distribution is peaked at the solar value, the metallicity spread is still unclear. In addition to the well known high metallicity clusters, recent studies have detected clusters as metal poor as Fe/H ~ -1.5 such as NGC 6558 (Davidge et al. 2004) or Terzan 4 and Terzan 5 (Origlia & Rich 2004). The field population is believed to be in the range Fe/H $= -1.5$ – 0.5 (McWilliam & Rich 2004; Ramírez et al. 2000; Kubiak et al. 2002), but low resolution spectroscopy of giant stars by Sadler et al. (1996) suggest the presence of stars as metal rich as Fe/H ~ 1.2. Finally, the presence of a metal gradient in the bulge population is still not assessed (Minniti et al. 1995; Feltzing & Gilmore 2000; Escudero & Costa 2001).

4. HOW GAIA WILL SEE THE INNER GALAXY

As we discussed in Section 1, the inner Galaxy will be hardly accessible using the radial velocity spectrometer, while broad and medium band photometry will measure a large part of the inner disc and bulge. This stresses the importance of the photometric system of Gaia. In this section we simulate the inner disc and bulge of the Galaxy in the 3F medium band photometric system of Gaia (Jordi & Høg 2005). First synthetic magnitudes and colours are calculated convolving spectral energy distributions of different metallicity, effective temperature and gravity with the passband transmission following Bressan et al. (1999), Chiosi et al. (1997) in order to calculate the bolometric corrections for each passband. Then stellar isochrones by Girardiet al. (2000) are converted to the observational plane. Finally, the Padova Galaxy Model (Bertelli et al. 1995; Vallenari et al. 2000; Bertelli et al. 2003) is used to simulate the sky as it may be seen by Gaia. More details about the above Galactic and stellar models can be found in the quoted papers. Discriminating stars accordingly to their metal content will be possible using different metallicity indexes (see Jordi et al 2005, this meeting). Figure 1 presents the giant star bulge population in the C(41–47) index corrected for the dependence on TiO absorption for effective temperatures $T_{\rm eff} < 4000$ against C(57-75) index which has a strong dependence on the $T_{\rm eff}$. This diagram is populated by stars of different metallicity, reddening, and age (8–12 Gyr). However, the driving parameter is the metallicity. The ITiO index is defined as: ITiO $=$ C(57-78) $-$ C(78-89) $+$ 0.26 $\times$ C(57$-$75) $-$ 0.08. This index measures the TiO absorption band at 780 nm and allows an easy separation for M and G dwarf stars. It is a good metallicity indicator for giant stars for stars redder than C(57–75) $=$ 1.3 as it is evident from Figure2.

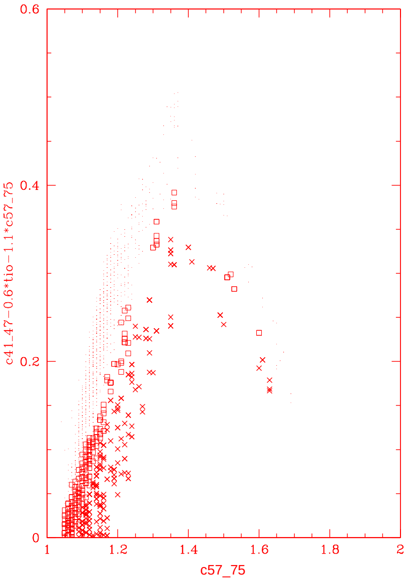

Figure 1. C(41–47) corrected for the dependence on TiO absorption against C(57–75) for the giant population of the bulge at (l,b)=(10,−4). Dots represent stars with metal content $0.008 < Z < 0.03$, squares are for $0.005 < Z < 0.008$, and crosses are for $Z < 0.005$.

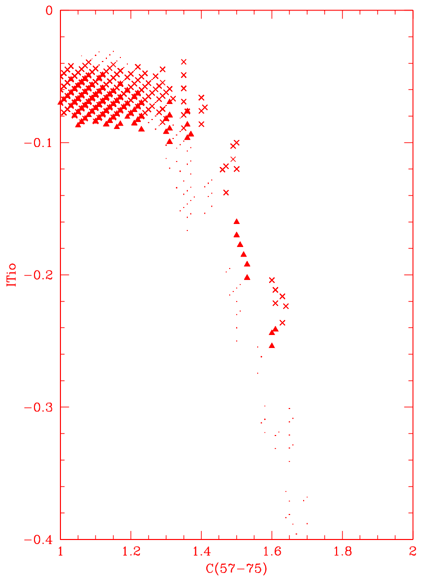

Figure 2. ITiO index against C(57–75) for the giant population of the bulge at (l,b)=(10,−4). Dots represent stars with metal content $0.008 < Z < 0.03$, triangles are for $0.005 < Z < 0.008$, and crosses are for $Z < 0.005$.

5. CONCLUSIONS

The Gaia mission will produce a data set of unprecedented size and precision which will revolutionize our understanding of all aspects of Galactic astronomy. In this paper, we have highlighted the many areas in which the combined measurements of astrometry, photometric system and RVS will improve our present knowledge of the thin disc and bulge formation and evolution. During the coming decade prior to the satellite launch much work needs to be done in order to determine the iterative Galactic modelling schemes which will make optimal use of the Gaia data set and will lead us to a coherent interpretation of the vast quantity of information that it contains.

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