Investigating the population of Galactic star formation regions and star clusters within a Wide-Fast-Deep Coverage of the Galactic Plane

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Abstract

One of the aims of LSST is to perform a systematic survey of star clusters and star forming regions (SFRs) in our Galaxy. In particular, the observations obtained with LSST will make a big difference in Galactic regions that have been poorly studied in the past, such as the anticenter and the disk beyond the Galactic center, and they will have a strong impact in discovering new distant SFRs. These results can be achieved by exploiting the exquisite depth that will be attained if the wide-fast-deep (WFD) observing strategy of the main survey is also adopted for the Galactic plane, in the g, r, and i filters.

1 White Paper Information

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1. **Science Category:** Mapping the Milky Way
2. **Survey Type Category:** Wide-fast-deep
3. **Observing Strategy Category:** a specific pointing or set of pointings that is (relatively) agnostic of the detailed observing strategy or cadence, (e.g., a science case enabled by very deep precise multi-color photometry)

2 Scientific Motivation

Interest in star clusters is driven by several scientific topics, e.g.: star clusters are laboratories for understanding the physical mechanisms active in stars and are tracers of Galactic chemical evolution thanks to their wide range in ages and distances, both in the disk (open clusters) and in the halo (globular clusters). Moreover, the SFRs are the place where we can see star formation in action. Our knowledge of young clusters and SFRs is currently limited to nearby regions, while LSST observations will allow us to discover SFRs at distances 7 times farther than those achievable even with the deepest wide-area surveys, e.g. PanSTARRS1. This will allow us, for example, to discover the low-mass star population (down to or even below 0.5 $M_{\odot}$) of even quite extincted SFRs ($A_V \sim 5$) in the volume shell from ∼1 kpc up to ∼10 kpc, which would remain unexplored by other surveys. Regarding the oldest clusters, LSST will allow us to detect them in the outer Galactic disk, not only located at high latitudes, like the old clusters already known, but also in the Galactic Plane.

2.1 Star forming regions

We propose a new approach to select low mass young stars and to discover SFRs based on the $g - r$ vs. $r - i$ colour-colour diagram (CCD) that will be obtained with the LSST co-added depth. This method is alternative and complementary to that based on the variability properties of young stars, mentioned in the *Science-Driven Optimization of the LSST Observing Strategy* (LSST Science Collaboration et al., 2017). The approach is based on the co-exploitation of several properties of M-type stars during the pre-main sequence (PMS) phase (Damiani, 2018; Prisinzano et al., 2018, Venuti et al. 2018, in press), as will be described in the following section. The numeric fraction of M-type stars in the Galactic disk is ∼84% (Lada, 2006) and they represent the largest component of the stellar populations. They are crucial to investigate fundamental aspects of star formation (SF), such as the Initial Mass Function (IMF), the modes and timescales of SF and PMS evolution, or the mechanisms of cluster dispersal (Briceño et al., 2007). A quantitatively measure the size/mass of young clusters as a function of galactocentric distance and/or Fe/H might help provide new insights into how cluster formation happens and what fraction of newly formed stars are in big clusters vs. more isolated birth sites. The most common solar-metallicity M-dwarfs (dM) can be unambiguously selected in CCD involving the r magnitude, such as for example the g-r vs. r-i diagram. In fact, due to the strong TiO opacity, the r-band flux of dM stars is depressed (West et al., 2011) and the CCDs shows the well known "elbow" where the dM locus deviates from the earlier-type (hotter/earlier than M) stars (Fukugita et al., 1996), nearly parallel to the reddening vector. PMS M-type stars share the same spectral properties as dM stars but are characterized by a significantly different gravity, which increases as function of age during the evolution from the PMS to the Zero Age MS. In fact, during the PMS phase, Hayashi evolutionary tracks are almost vertical with an excursion in luminosity of ∼1.5 dex. **This implies that PMS M stars can be detected at a distance up to a factor 5 larger than dM stars**. In this context, the selection of young M-type stars in distant SFRs is favoured by a significantly higher stellar density with respect to the more dispersed and uniformly distributed dM stars in the field, that, can only be detected up to a much lower distance. Due to their larger intrinsic luminosity, PMS M-type stars will sample a far larger volume than MS stars at similar apparent magnitudes. Our ability to detect PMS M-type stars strongly depends on extinction along the line of sight. The Galactic plane has a patchy structure including many crowded regions, where the final LSST co-added depth is strongly affected by confusion limits, but also many obscured regions, where the optical source detection has been hampered by the extinction. The LSST final co-added depth that would be achieved by adopting the WFD observing strategy also in the most unexplored regions of the Galactic plane, will enable us to discover the very low mass population of the SFRs at distances that are inaccessible even with deep IR photometric surveys. In fact, the latter only allow us to discover samples biased in favour of young stars with circumstellar disks, while the proposed approach enables us to select larger samples of PMS M-type stars, irrespective of the presence of a disk. The discovery of new SFRs with LSST data by adopting this method is supported by the observational findings showing that SFRs mostly host 1-2 Myr old members (Hillenbrand, 1997; Palla & Stahler, 1999; Venuti et al., 2018), which is the age range for which the proposed method is the most effective. In fact at 1-2 Myr, theoretical isochrones of M-type stars predict luminosities larger than those predicted for older ages.

2.2 Star clusters

Open clusters represent an important fraction of the stellar population of our Galaxy and they are mainly located in the Galactic thin disc. Thus, they can be used to trace the spatial metallicity distribution inside the Galactic disk (see, e.g. Janes, 1979; Twarog et al., 1997; Friel et al., 2002; Magrini et al., 2017, 2018). Complementary to the study of the overall metallicity distribution, the abundance ratios of several elements can provide insightful information both on the SF history in the disk and on the nucleosynthesis processes, production sites and timescales of enrichment of each element. For a complete review of the role of open clusters see Friel (2013).

In this white paper, we focus our analysis on the possibility to **detect star clusters in the outer disc at any height above the Galactic Plane, including those at low latitudes**. On one hand, in the anticenter most of the known open clusters at distances >12 kpc are located at high altitudes above the Galactic plane. Many hypotheses have been proposed to explain this apparent lack of star clusters in the Galactic outskirts at low Galactic heights: i) this might be due to observational biases caused by the higher reddening towards the plane; ii) the Galaxy might be flared and thus the clusters might trace the flare; iii) their location might be due to the effects of stellar migration, particularly effective at the corotation radius. On the other hand, almost nothing is known about clusters located on the other side of the Galaxy, and our knowledge is limited to clusters located in a small region. The aim of LSST is **the detection of star clusters together with their full characterization**: from the upper main sequence to its faint end, from the evolved red giant stars to the white dwarf population. To this purpose, a range of magnitudes, together with accurate proper motions, are needed. The availability of a consistent set of data from the dwarfs to the giants in a cluster allows to calibrate stellar models on samples of coeval objects, in particular for free parameters still not fully constrained (e.g., helium-to-metal enrichment ratio, the efficiency of super-adiabatic convection, the convective core overshooting parameter Gennaro et al., 2010; Tognelli et al., 2012; Prada Moroni et al., 2012). Examples of the kind of work we can do with LSST are shown in Richer et al. (2008) and in Gaia Collaboration et al. (2018), where cluster HR diagrams are cleaned with proper motion. To understand the limits of the detection of stellar clusters with the different cadences, we considered a cluster with a typical age (0.3 Gyr) and metallicity (solar), and we have located it at several distances and with several extinction (see Fig.1, Bottom, right panel). The number of open clusters observed by LSST will be huge. Consider, for instance, the recent works by Castro-Ginard et al. (2018) and Cantat-Gaudin et al. (2018), which, with Gaia DR2 data, discover 30 new OCs in the Solar neighborhood and 28 in the direction of Perseus, respectively, i.e., in regions in which the census of clusters was considered complete, increasing by 20% their number (see Fig.1, Bottom, left panel). The number of known open clusters in the Dias catalogue is about ∼2200 (Dias et al., 2002, in the new version of 2016). The completeness is a decreasing function of the distance, reaching few percent in the outer regions, LSST will allow us to discover from ∼400 to more than 2000 new clusters in the Galactic plane. In addition, the **population of globular clusters** (GCs), which represent the oldest populations of our Galaxy, remains unexplored in regions such as the Galactic plane and bulge. The catalog of Galactic GCs originally contained 156 members (Harris, 1996), but new GCs have been recently discovered in the Galactic plane and bulge (e.g Minniti et al., 2011; Moni Bidin et al., 2012; Minniti et al., 2017a,b, 2018). The difficulties related to the discovery of clusters in the Galactic plane, as the stellar density combined with (differential) interstellar reddening, are reduced with the deep photometry of LSST. These new GCs, detected as high density regions in LSST maps, would be confirmed as globular cluster candidates by their CMDs. The new globular cluster candidates would exhibit a variety of extinctions, and distances, that can also be measured using the LSST multicolor-photometry, and variable stars like RRLyrae. The discovery and characterization of these new GCs is very important for studies on the formation and evolution of the MW, on the age and chemical composition of the oldest stars, on the dynamics of stellar systems, on the interstellar medium, and on Galactic structure and stellar evolution.

3 Technical Description

3.1 High-level description

Add the currently excluded Galactic Plane region to the uniform (wide-fast-deep) cadence.

3.2 Footprint – pointings, regions and/or constraints

Including the regions of the Plane, above and below the Galactic Plane (10^o).

3.3 Image quality

No constraints.

3.4 Individual image depth and/or sky brightness

No extra constraints beyond the standard lunar avoidance for WFD.

3.5 Co-added image depth and/or total number of visits

Uniform WFD cadence.

3.6 Number of visits within a night

No constraints.

3.7 Distribution of visits over time

Uniform cadence over 10 years to allow good proper motion and parallaxes measurement.

3.8 Filter choice

Standard WFD set of filters, with priority to g, r, and i filters.

3.9 Exposure constraints

Standard WFD exposure.

3.10 Other constraints

3.11 Estimated time requirement

The estimate of the time requirement of a WDF survey of the Plane will amount to 2% of the duration of the whole survey.

Properties	Importance
Image quality	1
Sky brightness	1
Individual image depth	3
Co-added image depth	1
Number of exposures in a visit	3
Number of visits (in a night)	3
Total number of visits	1
Time between visits (in a night)	3
Time between visits (between nights)	1
Long-term gaps between visits	2
Other (please add other constraints as needed)	

Table 1: **Constraint Rankings:** Summary of the relative importance of various survey strategy constraints. Please rank the importance of each of these considerations, from 1=very important, 2=somewhat important, 3=not important. If a given constraint depends on other parameters in the table, but these other parameters are not important in themselves, please only mark the final constraint as important. For example, individual image depth depends on image quality, sky brightness, and number of exposures in a visit; if your science depends on the individual image depth but not directly on the other parameters, individual image depth would be '1' and the other parameters could be marked as '3', giving us the most flexibility when determining the composition of a visit, for example.

3.12 Technical trades

In our proposal the primary science goals are reached with the increased depth of the co-added images and also with the repeated observations with a long time baseline in order to measure proper motions and parallaxes. Considering the distribution of visits: for our science cases a uniform coverage over the whole survey is desirable to have a long baseline for measuring parallaxes and proper motions.

4 Performance Evaluation

Star forming regions: For PMS M-type stars, the key interest regarding the observing strategy of the survey is mainly the photometric co-added depth. Since the method is based on the g, r, and i CCD, the metrics is dependent on the limiting magnitudes in these three bands. In fact, the maximum distance to which PMS stars can be detected is basically set by the filter with the lowest sensitivity. This distance depends on stellar mass, age and extinction. Fig. 1 shows the maximum distance as a function of the stellar masses including the range of M-type stars ($M \leq 0.5\ M_{\odot}$). The results were obtained by assuming the $5\,\sigma$ stacked point-source depths of the simulated ten-year survey, roughly estimated from Figure 3.2 of LSST Science Collaborations and LSST Project (2009, LSST Science Book, Version 2.0, arXiv:0912.0201), that are g=26.3, r=26.5, i=26.3, for the 30 visits for each filter planned in the Galactic plane and g=27.5, r=27.7, i=27.0, for the 80, 180 and 180 visits, respectively, in the g, r, and i filters, as planned in the main survey in the regions outside the Galactic plane. For comparison, we also estimated the maximum distances by considering the 3π stack 5σ depths of PanSTARRS1 magnitudes g=23.3, r=23.2, i=23.1. We will refer to the first set of limiting magnitudes as the "30-visits-maglim" and to the second one as the "WFD-survey-maglim"

The distances have been obtained by considering the absolute magnitudes in the same filters in the 1, 10 and 100 Myr isochrones computed by Tognelli et al. (2018), assuming A_V=1, 5 and 10 mag, i.e. covering the cases of low , high, and very high reddened regions (Green et al., 2018). Then a figure of merit can be deduced from the volume that can be mapped with PMS M-type and dM stars at a given extinction, as a function of stellar masses. The values of the maximum distances obtained assuming the "30-visits-maglim" and the "WFD-survey-maglim" depths are shown in Table 2. For comparison, the analogous values that will be achievable with PanSTARRS1 are also given.

The exquisite LSST WFD co-added depth will have a strong impact in the context of the SFR studies. In fact, it will make possible to detect the very low mass population (down to $0.1 M_{\odot}$) of highly embedded (A_V ∼5) SFRs, up to ∼1 kpc, well beyond what could be achieved with the "30-visits-maglim" (up to 0.67 kpc); or the PanSTARRS1 limit (0.17 kpc). Instead, in case of low reddening (A_V ∼1), it will be possible to discover the entire cluster population of very young stars down to $0.1\,M_{\odot}$ up to 10 kpc, involving a very large unexplored volume (e.g. in the direction of Vela-Puppis) that would be inaccessible with "30-visits-maglim" depth. The difference in depth between the LSST WFD and the 30-visits strategy (about 1.2 magnitude) corresponds to about a factor 1.7 in distance. Since the number of star clusters roughly increases with d^2, we define the figure of merit (FoM) as the relative fraction of detected clusters (FoM=N/$N_{\rm WDF}$). Therefore, **for the WFD co-added depth FoM=1, while for the 30-visits co-added depth FoM=0.34**. For comparison, the difference in depth between the LSST WFD strategy and PanSTARRS1 (about 4.2 magnitude) corresponds to about a factor 7 in distance and therefore for the PanSTARRS1 observations FoM=0.02. **This means that by adopting the WFD observing strategy in the Galactic plane, we will be able to discover a number of clusters at least a factor 3 larger than the one that would be discovered by adopting the 30-visits observing strategy.**

Star clusters: For the star clusters located in the regions with the high reddening, we would benefit to be included in the main WFD survey because with the 30 visits (planned for the Galactic plane) we will arrive to observe only the turnoff and red giant clump, with a consequently lower accuracy in deriving the cluster parameters (age, metallicity, reddening via isochrone fitting). We are also performing a more detailed analysis of the extinction through the disk using the new dust map of Green et al. (2018) to derive the limits in magnitudes for clusters in the disk at different galactic coordinates and distances. A FoM to evaluate the advantages of the WDF survey with respect to the 30 visits of the Galactic disk can be estimated on the basis of the limiting magnitude that can be reached and which part of a cluster CMD can be observed given this limiting magnitude. We have considered that the WDF survey should arrive ∼1.2 mag deeper than the 30 visits, and for instance, it would allow a better characterization and isochrone fitting of the most extinct ones. Similarly to the star formation regions, since the number of clusters scales with d^2, the WFD observing strategy in the plane will allow us to enlarge the number of old star clusters that we can discover and characterize of at least a factor 3 with respect to the 30-visits observing strategy. If we consider a FoM=1 for the WDF Survey of the Galactic Plane, the lower magnitude limit due to only 30 visits, would imply, as for the star forming regions, a FoM=0.34.

In addition, another important aspect to be considered is the measurements of proper motions, fundamental to identify cluster members. Proper motions can be measured by LSST with an accuracy of 0.1 mas yr^{-1} in the magnitude range $16<r<20$, and the accuracy linearly decreases until 1 mas yr^{-1} for $20<r<24$.

Table 2: Maximum distances at 0.5 and 0.1 $M_\odot$ at 1, 10 and 100 Myr and for A_V=1, 5 and 10 mag assuming PanSTARRS, 30-visits and WFD-survey depths. The max distances at 1 Myr for a given Av and M* are highlighted in boldface.

A_V mag	Age [Myr]	Mass [$M_\odot$]	max distance [kpc] PanSTARRS1	max distance [kpc] 30-visits	max distance [kpc] WFD-survey
1	1	0.5	**10.33**	**41.12**	**71.46**
1	10	0.5	3.88	15.43	26.81
1	100	0.5	2.61	10.40	18.07
5	1	0.5	**1.12**	**4.46**	**7.75**
5	10	0.5	0.42	1.67	2.91
5	100	0.5	0.28	1.13	1.96
10	1	0.5	**0.07**	**0.28**	**0.48**
10	10	0.5	0.03	0.10	0.18
10	100	0.5	0.02	0.07	0.12
1	1	0.1	**1.54**	**6.14**	**10.68**
1	10	0.1	0.72	2.88	5.01
1	100	0.1	0.27	1.09	1.89
5	1	0.1	**0.17**	**0.67**	**1.16**
5	10	0.1	0.08	0.31	0.54
5	100	0.1	0.03	0.12	0.21
10	1	0.1	**0.01**	**0.04**	**0.07**
10	10	0.1	0.00	0.02	0.03
10	100	0.1	0.00	0.01	0.01

Typical values of the proper motion for clusters within few kpc are 1-5 mas yr^{-1}. These numbers translate into 0.5-2 mas yr^{-1} for clusters at 10 kpc. For r=22 (corresponding to the upper main sequence for an extinct cluster or to the intermediate MS for a less extinct one) we will achieve the sufficient precision required to distinguish a cluster member from field stars. A more frequent cadence will help to separate proper motions from parallaxes and to improve the final accuracy. A FoM to evaluate the advantages of the deep-wide-fast survey with respect to the 30-visits survey of the Galactic plane is given by the final accuracy on the proper motions and ability to separate them from parallaxes, an operation that requires a long temporal baseline. Following Ivezić et al. (2008), the expected proper motion and parallax errors for a 10-year long baseline survey, as a function of apparent magnitude, are 0.6 mas and 0.2 mas yr^{-1} for r=21, respectively, 0.8 mas and 0.3 mas yr^{-1} for r=22, 1.3 mas and 0.5 mas yr^{-1} for r=23 and finally 2.9 mas and 1.0 mas yr^{-1} for r=24. However, the accuracy on these quantities are lower with a shorter temporal baseline, and with a lower number of visits. For instance, the proper motion errors increase of a factor 5 and the parallax errors of a factor 2 with a shorter baseline of three years. Considering a FoM=1 for the WDF survey of the Plane, and increasing errors of a factor 5 on proper motions due to shorter temporal baseline and/or lower number of visits would imply a FoM=0.2.

Considering both the requirements on the magnitude limit to fully characterize a star clusters (FoM=0.34) and on the proper motion to identify its member stars (FoM=0.2), we will have an overall FoM=0.068 accepting a strategy of only 30 visits with respect to the WDF strategy (FoM=1).

5 Special Data Processing

Standard LSST Data Management pipelines are requested

6 Acknowledgements

7 References

References

Barba, R., et al. 2018, ApJ, submitted

Briceño, C., Preibisch, T., Sherry, W. H., et al. 2007, Protostars and Planets V, 345

Cantat-Gaudin, T., Krone-Martins, A., Sedaghat, N., et al. 2018, arXiv:1810.05494

Castro-Ginard, A., Jordi, C., Luri, X., et al. 2018, A&A, 618, A59

Damiani, F. 2018, A&A, 615, A148

Dias, W. S., Alessi, B. S., Moitinho, A., & Lépine, J. R. D. 2002, A&A, 389, 871

Friel, E. D., Janes, K. A., Tavarez, M., et al. 2002, AJ, 124, 2693

Friel, E. D. 2013, Planets, Stars and Stellar Systems. Volume 5: Galactic Structure and Stellar Populations, 5, 347

Fukugita, M., Ichikawa, T., Gunn, J. E., et al. 1996, AJ, 111, 1748

Gaia Collaboration, Babusiaux, C., van Leeuwen, F., et al. 2018, A&A, 616, A10

Gennaro, M., Prada Moroni, P. G., & Degl'Innocenti, S. 2010, A&A, 518, A13

Green, G. M., Schlafly, E. F., Finkbeiner, D., et al. 2018, MNRAS, 478, 651

Harris W. E., 1996, AJ, 112, 1487

Hillenbrand, L. A. 1997, AJ, 113, 1733

Janes, K. A. 1979, ApJs, 39, 135

Ivezić, Ž., Monet, D. G., Bond, N., et al. 2008, A Giant Step: from Milli- to Micro-arcsecond Astrometry, 248, 537

Lada, C. J. 2006, ApJL, 640, L63

LSST Science Collaboration, Marshall, P., Anguita, T., et al. 2017, arXiv:1708.04058

Magrini, L., Randich, S., Kordopatis, G., et al. 2017, A&A, 603, A2

Magrini, L., Spina, L., Randich, S., et al. 2018, A&A, 617, A106

Minniti, D., Hempel, M., Toledo, I., et al. 2011, A&A, 527, 81

Minniti, D., Palma, T., Dekany, I., et al. 2017a, ApJ, 838, L14

Minniti, D., Geisler, D., Alonso-Garcia, J., et al. 2017b, ApJ, 849, L24

Minniti, D., Schlafly, E., Palma, T., et al. 2018, ApJ, 866, 12M

Moni Bidin, C., Mauro, F., D. Geisler, D. , et al. 2012, A&A, 535, 33

Muench, A. A., Lada, E. A., Lada, C. J., & Alves, J. 2002, ApJ, 573, 366

Palla, F. & Stahler, S. W. 1999, ApJ, 525, 772

Prada Moroni, P. G., Gennaro, M., Bono, G., et al. 2012, ApJ, 749, 108

Prisinzano, L., Damiani, F., Guarcello, M. G., et al. 2018, A&A, 617, A63

Richer, H. B., Dotter, A., Hurley, J., et al. 2008, AJ, 135, 2141

Tognelli, E., Degl'Innocenti, S., & Prada Moroni, P. G. 2012, A&A, 548, A41

Tognelli, E., Prada Moroni, P. G., & Degl'Innocenti, S. 2018, MNRAS, 476, 27

Twarog, B. A., Ashman, K. M., & Anthony-Twarog, B. J. 1997, AJ, 114, 2556

Venuti, L., Prisinzano, L., Sacco, G. G., et al. 2018, A&A, 609, A10

West, A. A., Bochanski, J. J., Bowler, B. P., et al. 2011, in Astronomical Society of the Pacific Conference Series, Vol. 448, 16th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, ed. C. Johns-Krull, M. K. Browning, & A. A. West, 531

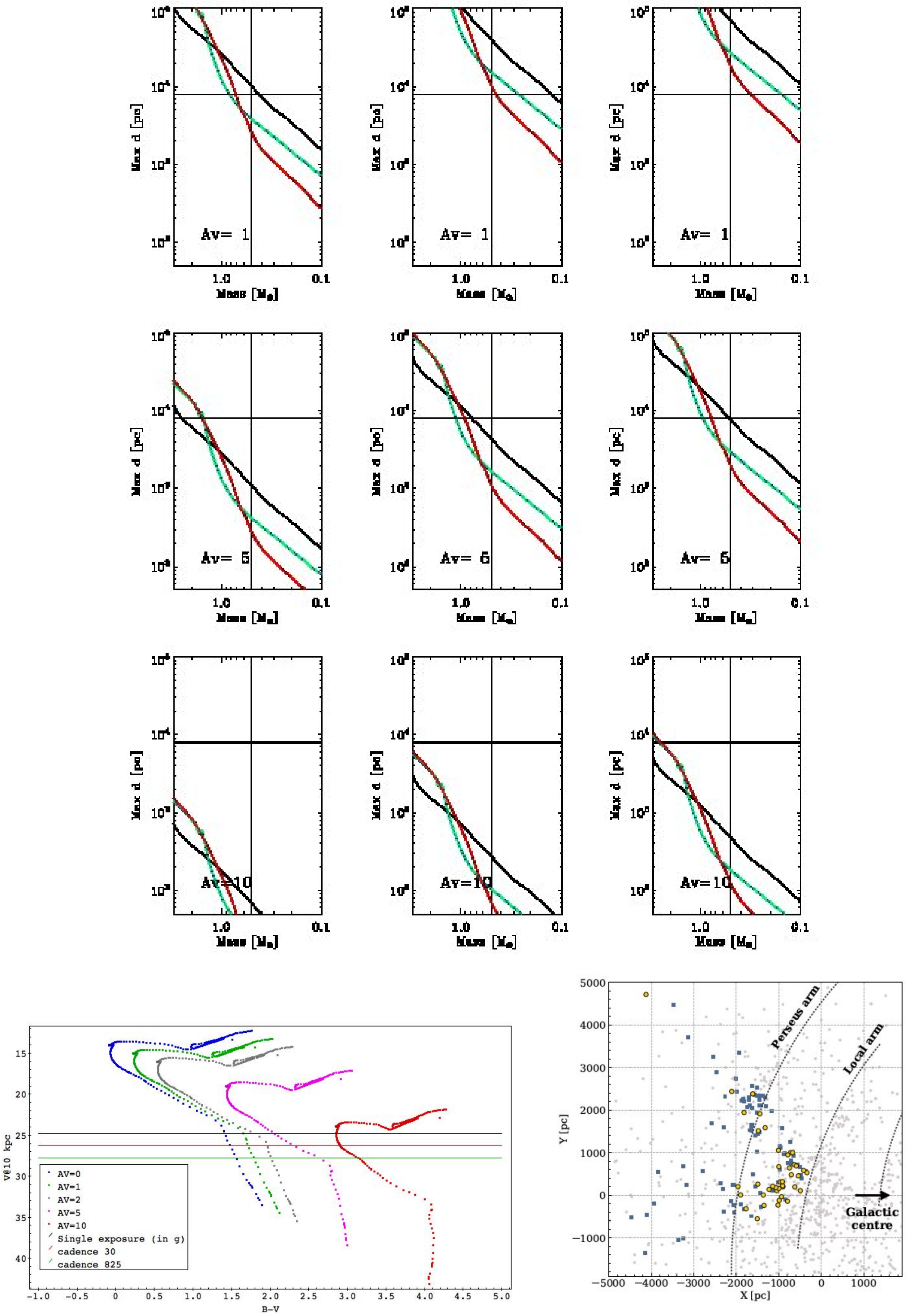

Figure 1: Top: Maximum distances as a function of stellar mass in the PMS phase (1-10 Myr, black and green lines, respectively) and at 100 Myr (red lines), at different extinctions, assuming A_V=1, 5 and 10 mag. Horizontal solid line indicates the distance of the Galactic Center, while the vertical one is drawn at 0.5 $M_{\odot}$. The values are given assuming the PanSTARRS1 (left panels), the "30-visits-maglim" (central panels) and the "WFD-survey-maglim" (right panels) 5 σ stacked depths. Bottom: *Left* : Theoretical CMD of a cluster of 0.3 Gyr in the outer disc/beyond the Galactic center at a distance of 10 kpc with five reddening values. *Right*: Locations of open clusters on the projected Galactic plane, for both previously known (gray dots) and new COIN-Gaia open clusters (yellow dots) from Cantat-Gaudin et al. (2018).