Probing the geography, history and chemistry of nearby Galaxies with Future Telescopes

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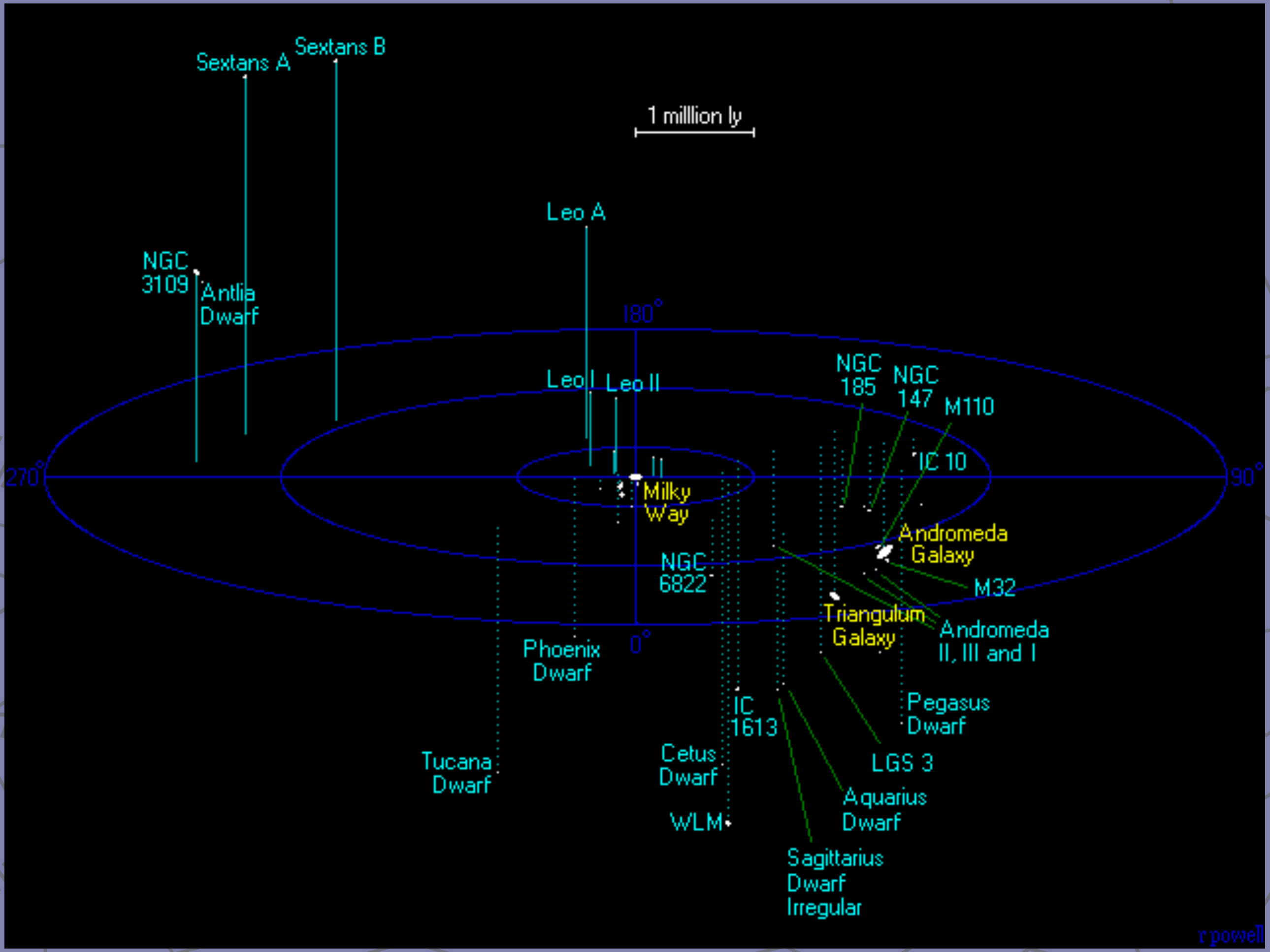
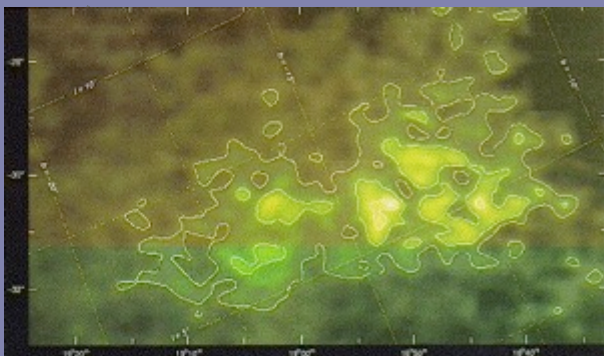
JSPS-DST ASIA ACADEMIC SEMINAR –
CPS 8th International school of Planetary Sciences

Local Group of galaxies



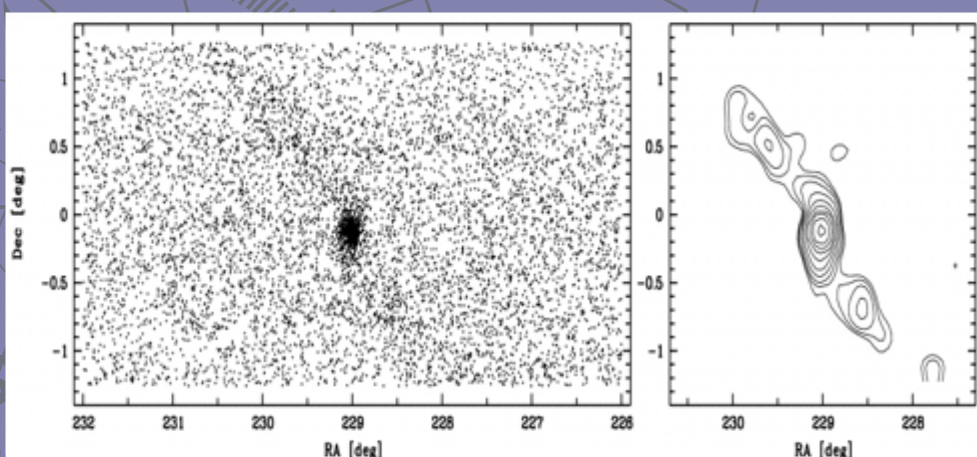
There be fragments yet...

The Milky Way has fragments breaking up even now



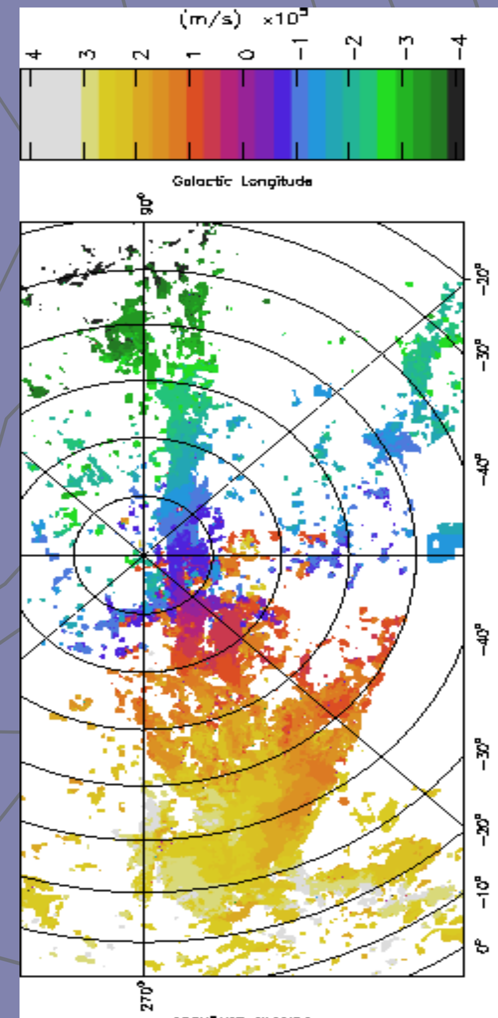
Sagittarius Dwarf

Canis Major Dwarf



Globular cluster tidal tails

Odenkirchen, M. et al., 2001:ApJ, 548,L, 165O

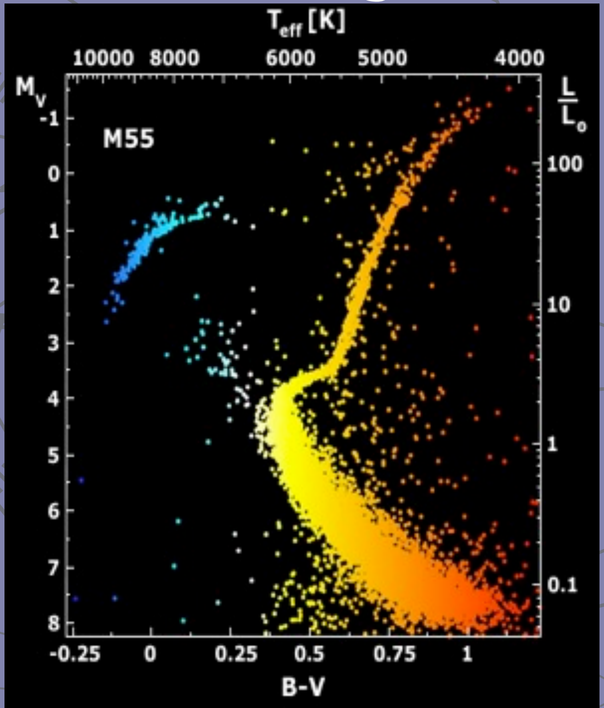


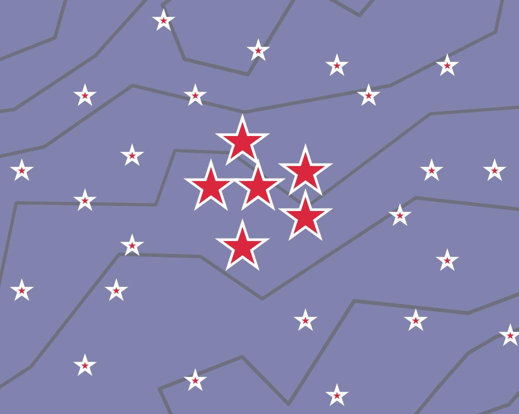
The Magellanic stream

Putman, M. E. et al., 2003: ApJ, 586, 170P: http://iopscience.iop.org/0004-637X/586/1/170/55828.text.h

Equipartition

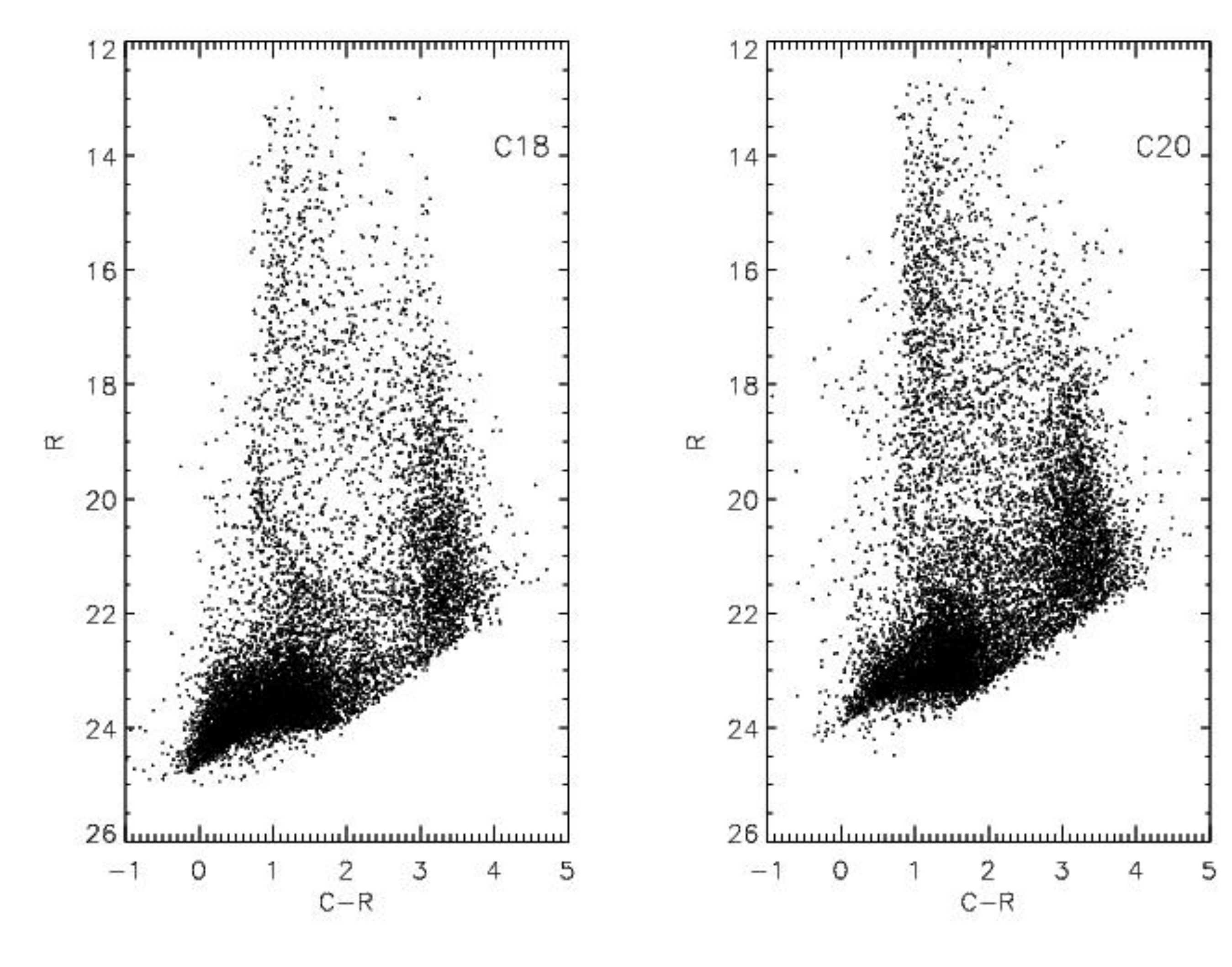
- Globular Clusters
  - Equipartition drives mass segregation
  - High mass stars sink to centre
  - Low mass stars on evaporate from cluster
  - Or to outer regions of cluster



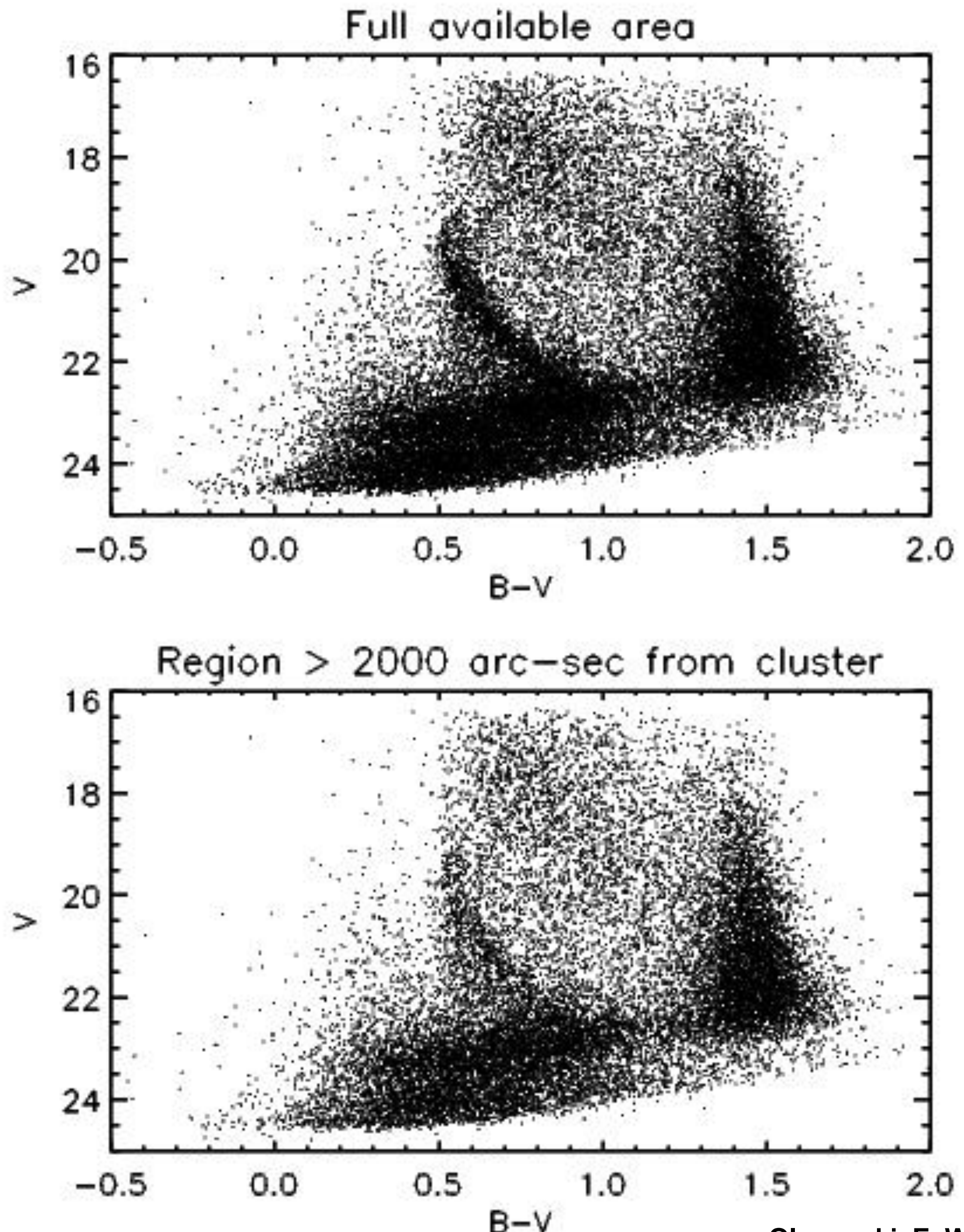


NGC 1851 (One of the five most massive clusters)

Control fields for the Outer Limits Survey –
C18 is located at 3.5 Trad from NGC 1851



Olszewski, E. W.; Saha, A; Knezek, P; Subramaniam, A; de Boer, T; Seitzer, P; (2009), AJ, 138, 1570



Olszewski, E. W.; Saha, A; Knezek, P; Subramaniam, A; de Boer, T; Seitzer, P; (2009), AJ, 138, 1570

FIG. 2.— V versus B-V cmds for two regions surrounding NGC 1851. Top diagram is of all acquired data. Bottom figure is of a region more than 2.85 tidal radii from NGC 1851. In both cases the main sequence is identical to that of the globular, and the double subgiant branches are visible.

Tidal radius = 700 arcsec (41pc)

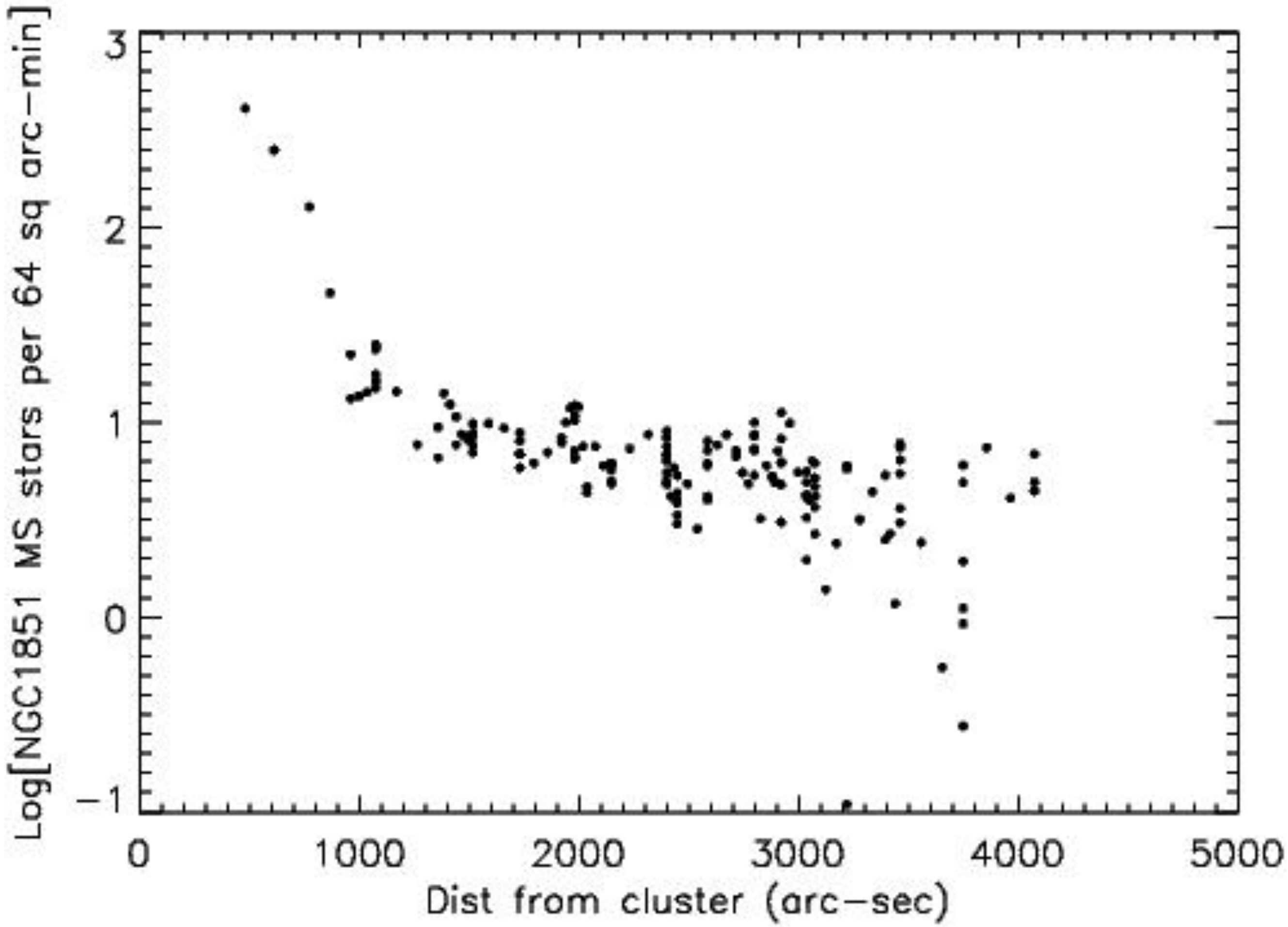
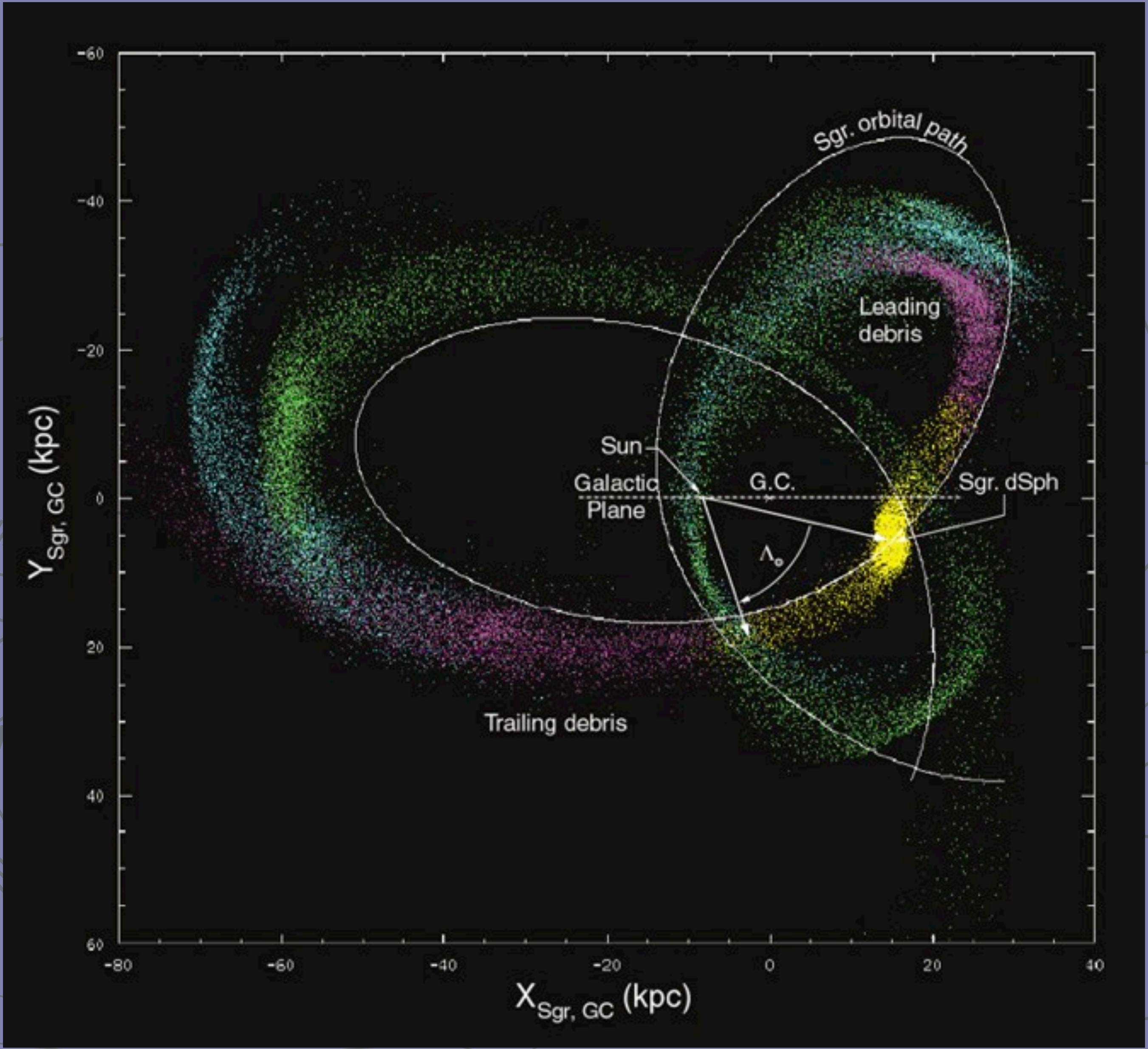


FIG. 8.— Density plot of stars surrounding NGC 1851. The x axis is now linear in radius.

Olszewski, E. W.; Saha, A; Knezek, P; Subramaniam, A; de Boer, T; Seitzer, P; (2009), AJ, 138, 1570

Sagittarius Stream



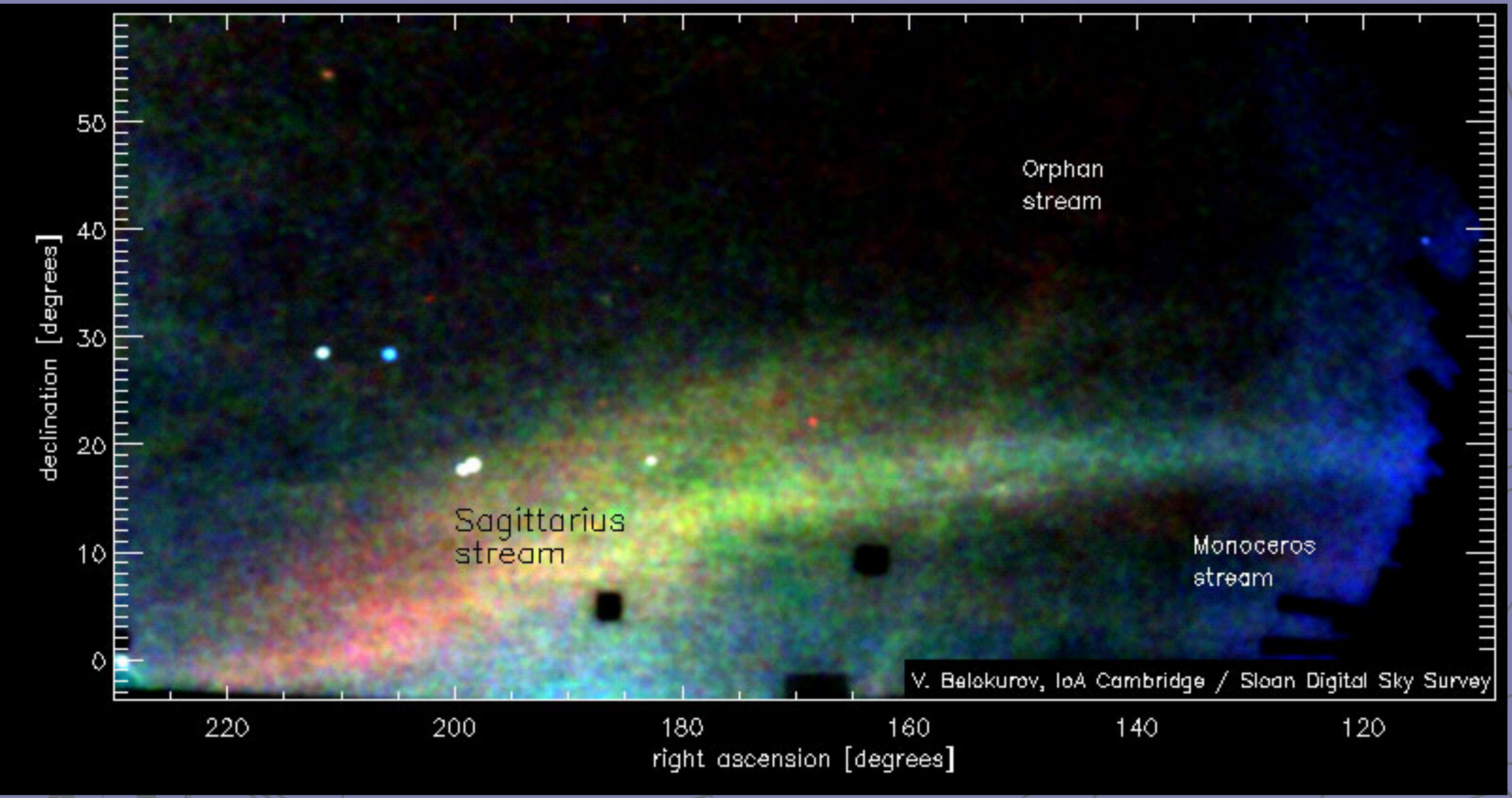
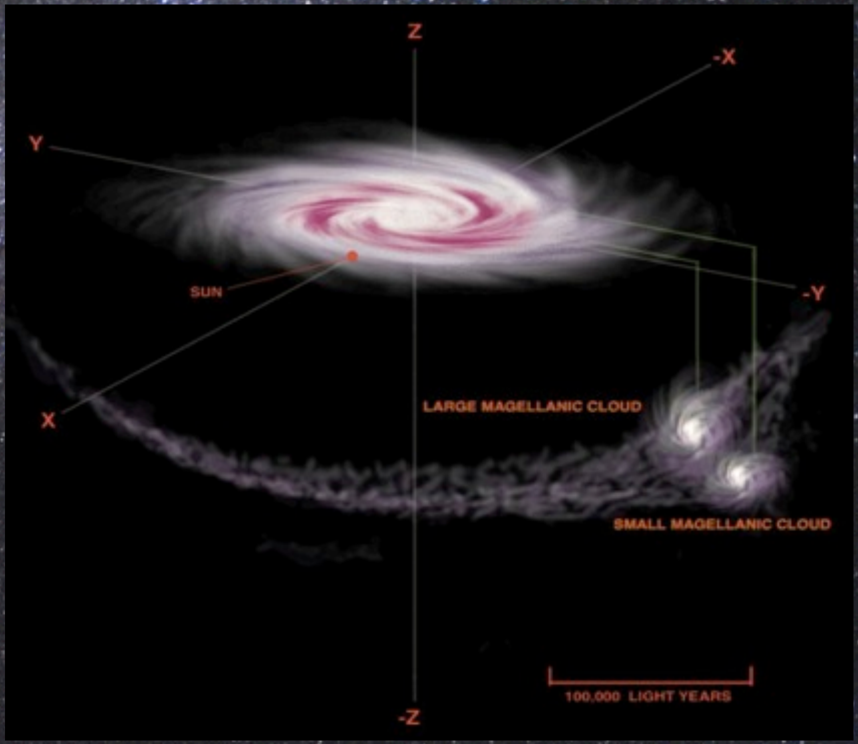


Image by Vasily Belokurov, SDSS-II Collaboration

- Magellanic Clouds (Large Magellanic Cloud & Small Magellanic Cloud) are two irregular and nearly face on galaxies which are located at a distance of 50 kpc & 60 kpc respectively from our Galaxy.
- They are known to have interactions with each other as well as with our Galaxy.
- These interactions have altered the structure of the LMC & SMC.
- Magellanic bridge, Magellanic stream and leading arms are signatures of these interactions.



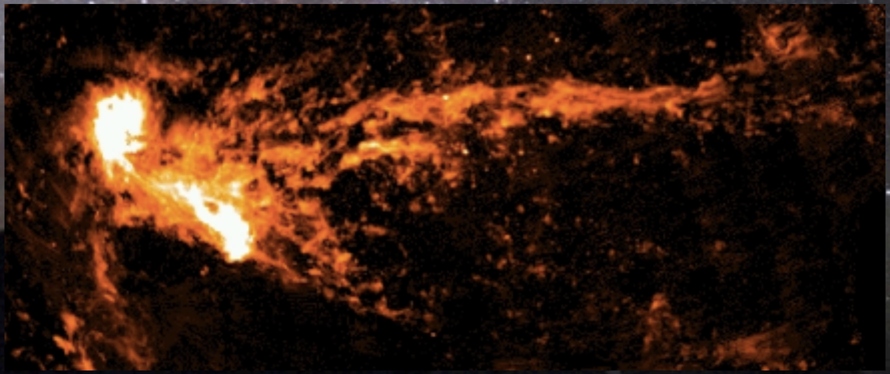
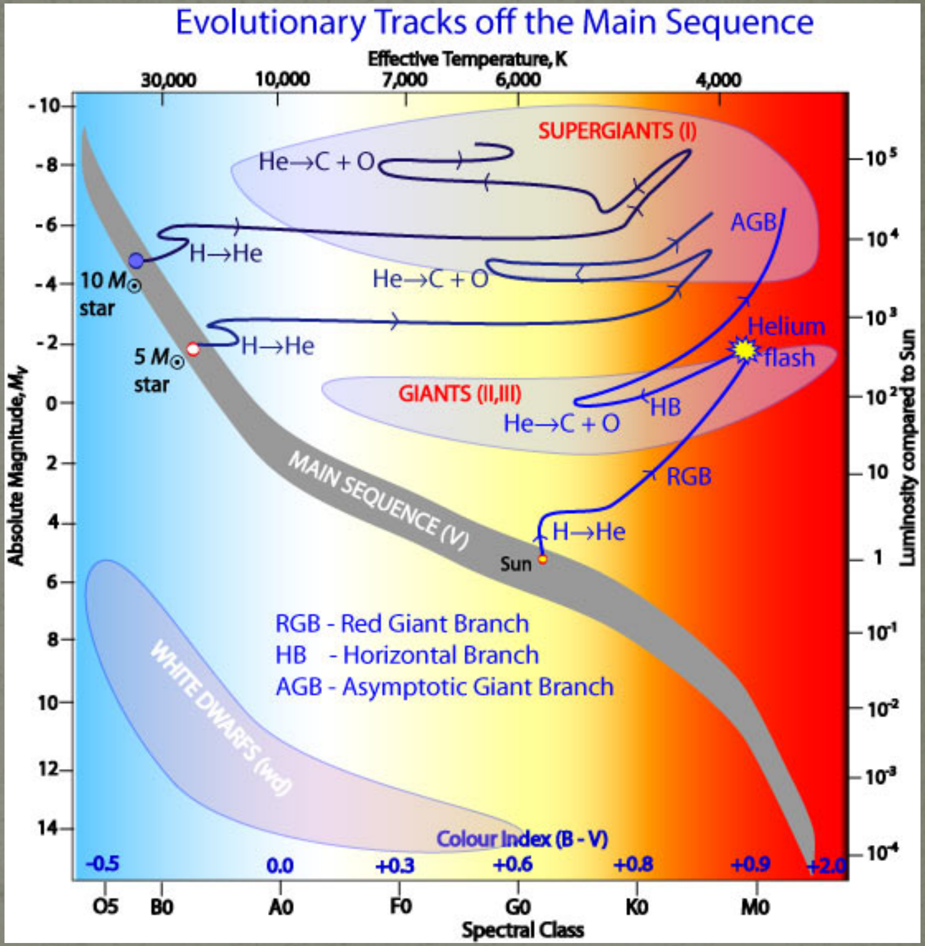


Image by M.E. Putman (University of Colorado),
L. Staveley-Smith (CSIRO),

Effect of Metallicity on Stellar evolution

The mass-loss rate of stars hotter than 25000 K is predicted to scale with metallicity
(Z) as ˙M~Z^(0.69±0.10)
(Vink et al. 2001).
Mokiem et al. (2007) showed that this prediction holds for early-type stars in
the Galaxy (Z = Z☉), Large Magellanic Cloud
(LMC; Z = 0.5 Z☉), and Small Magellanic Cloud
(SMC; Z = 0.2 Z☉), yielding the empirical relation
˙M ~ Z^(0.78±0.17).
Tramper et al. (2011) 1109.5502 - IC 1613, WLM and NGC 3109



The Large cloud

- An elongated kinematically cold face-on disk
- A pronounced off centered bar
- Strong star formation and patchy dust absorption
- Suspected spiral arms
- Well studied structure poorly understood kinematics

Mass	$2x10^{10}$ Mo
Radius	9 Kpc (tidal)
Metallicity	0.008
Distance	50 Kpc
Center Coordinates	5^h23^m, -69^o 45’

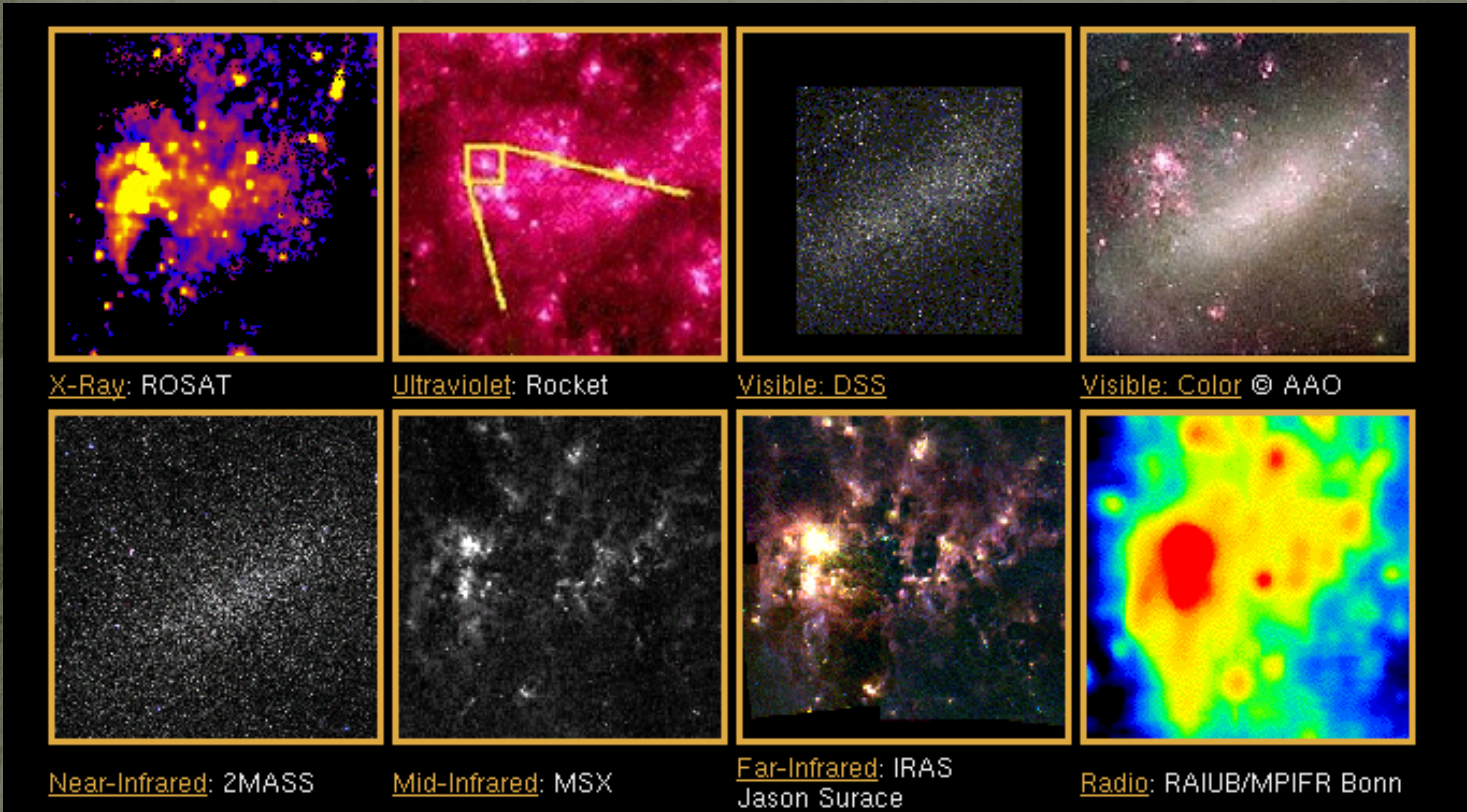
The Small cloud

- Patchy irregular morphology
- Less pronounced bar
- Eastern wing
- Poorly understood structure and kinematics

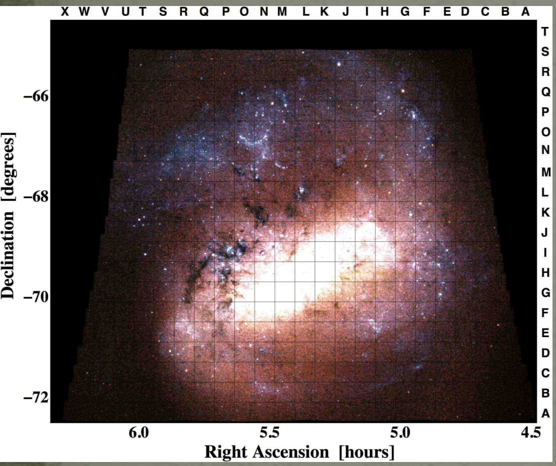
Mass	$2x10^9$ Mo
Radius	5-6 Kpc (approx.)
Metallicity	0.004
Distance	60 Kpc
Center Coordinates	$0^h\ 52^m$, -72^o 49’

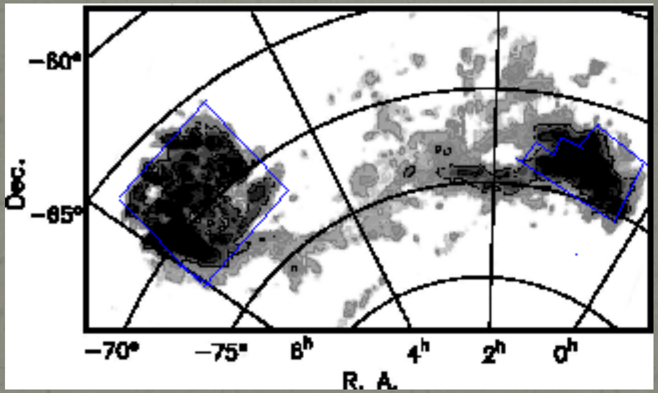
What's different in MCs?

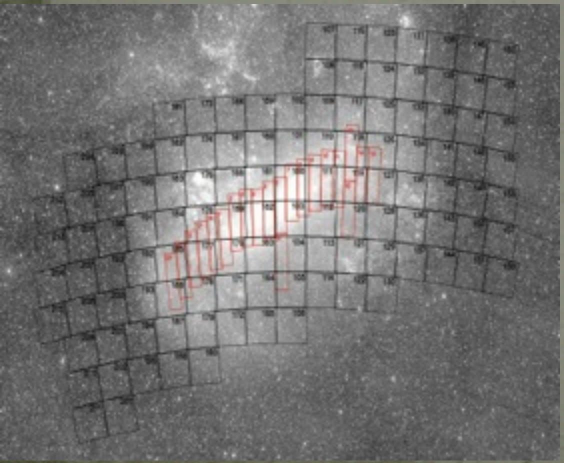
1. Poor chemical enrichment: LMC – 40%, SMC – 10%
2. Rich in Gas, vigorous star formation – nearest starburst region (30 Dor - LMC)
3. Rich star clusters in L&SMC
4. Gas kinematics does not show a bar
5. No direct evidence of a halo
6. Structure of the SMC is not clear
7. Nearest interacting pair
8. Individual stars can be resolved

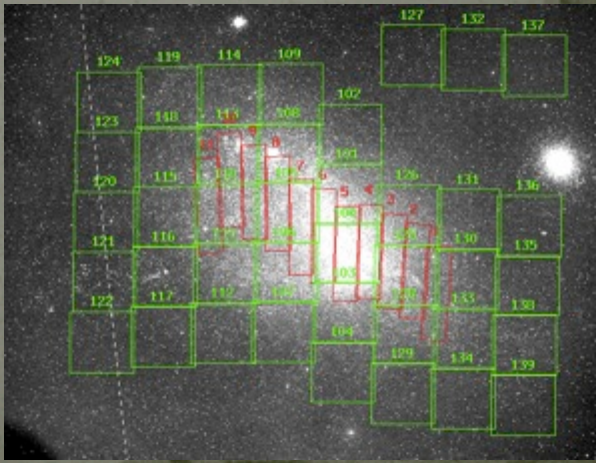

X-Ray: ROSAT
Ultraviolet: Rocket
Visible: DSS
Visible: Color © AAO
Near-Infrared: 2MASS
Mid-Infrared: MSX
Far-Infrared: IRAS
Jason Surace
Radio: RAIUB/MPIFR Bonn

Sky coverage of data sets (OGLEII, OGLE III, MCPS)



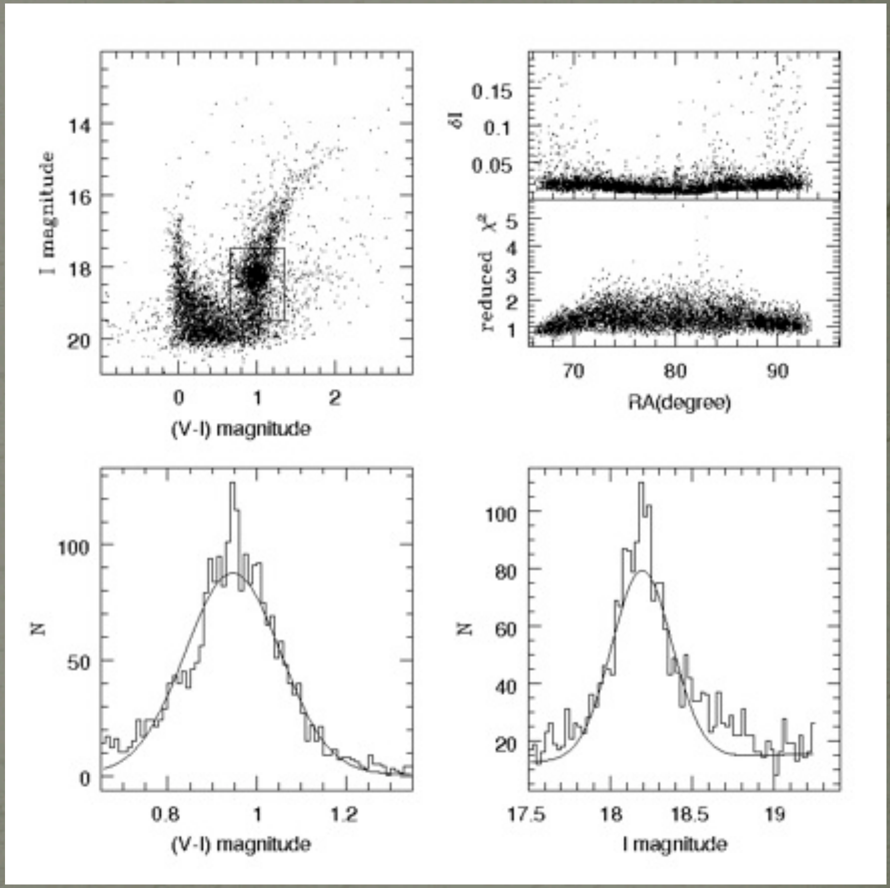






Red clump stars as tracers

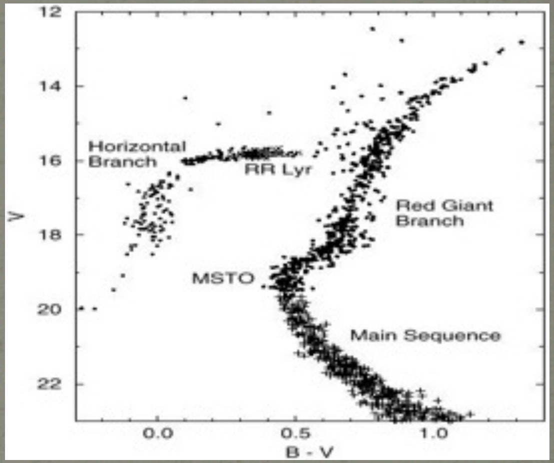
- Red clump stars are core helium burning stars which are metal rich and more massive counterpart of horizontal branch stars.
- Empirically, it is found that they have a constant absolute I band magnitude and a characteristic (V-I) colour.
- They occupy a compact region in the CMD.
- The peak and width values of the magnitude and colour distributions of red clump stars are used to estimate the relative distances within and line of sight depth of the LMC.

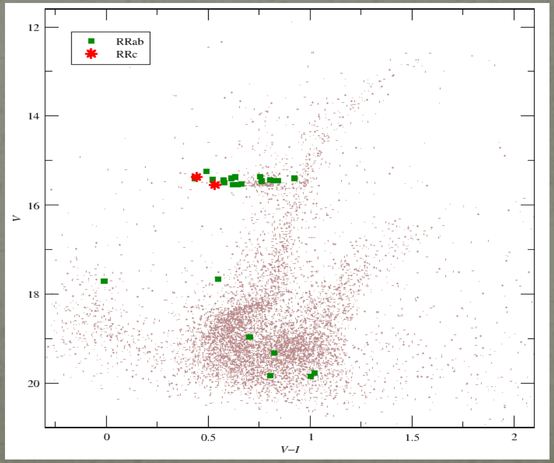


Subramanian, S & Subramaniam. A., 2010: A&A, 520, 24

RRLyrae Stars

- RRLyrae stars are pulsating horizontal branch stars. They are population II stars.
- The ab type stars could be considered to belong to a similar sub class and hence assumed to have similar properties.
- The mean magnitude of these stars in the I pass band, after correcting for the metallicity and extinction effects, can be used for the estimation of distance.
- The observed dispersion, after correcting for metallicity and evolutionary effects, in their mean magnitude is a measure of the depth in their distribution.
- The observed region is divided into sub-regions. For each su-region mean magnitude of these stars and the dispersion from the mean are estimated.





Cepheids

- Cepheids are pulsating yellow super giants.

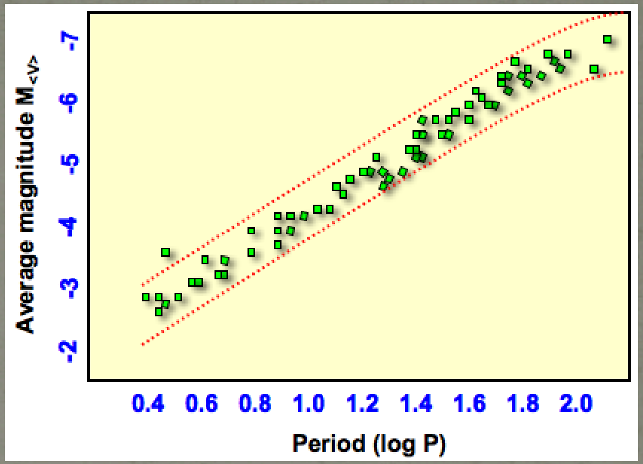
- $M_\lambda = \alpha * \log p + \beta$
- $m_\lambda - M_\lambda = 5\log d - 5 + A_\lambda$

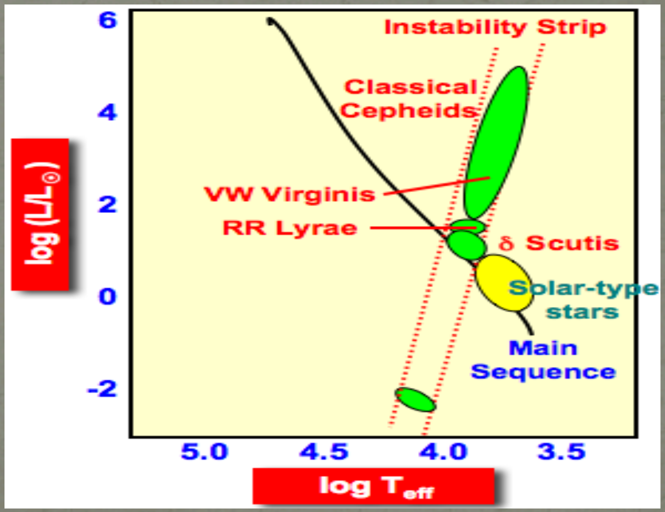
- $m_\lambda = \alpha_\lambda * \log p + \beta_\lambda + \mu_{avg} + \Delta\mu +$
- $R_\lambda * [E(B-V)_{avg} + \Delta E(B-V)$

- $m_\lambda = \alpha_\lambda * \log p + \beta'_\lambda + \Delta\mu + R_\lambda * \Delta E(B-V)$

- Using the above formula we can find the relative position of each Cepheid with respect to the center of the galaxy.

- The scatter in the PL relation can be used to estimate the line of sight depth of the galaxy.





LMC – field CMD

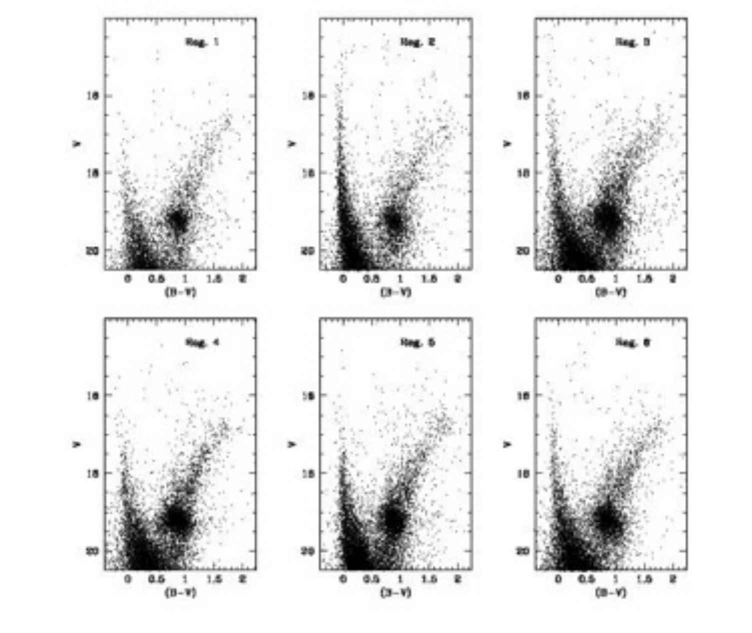
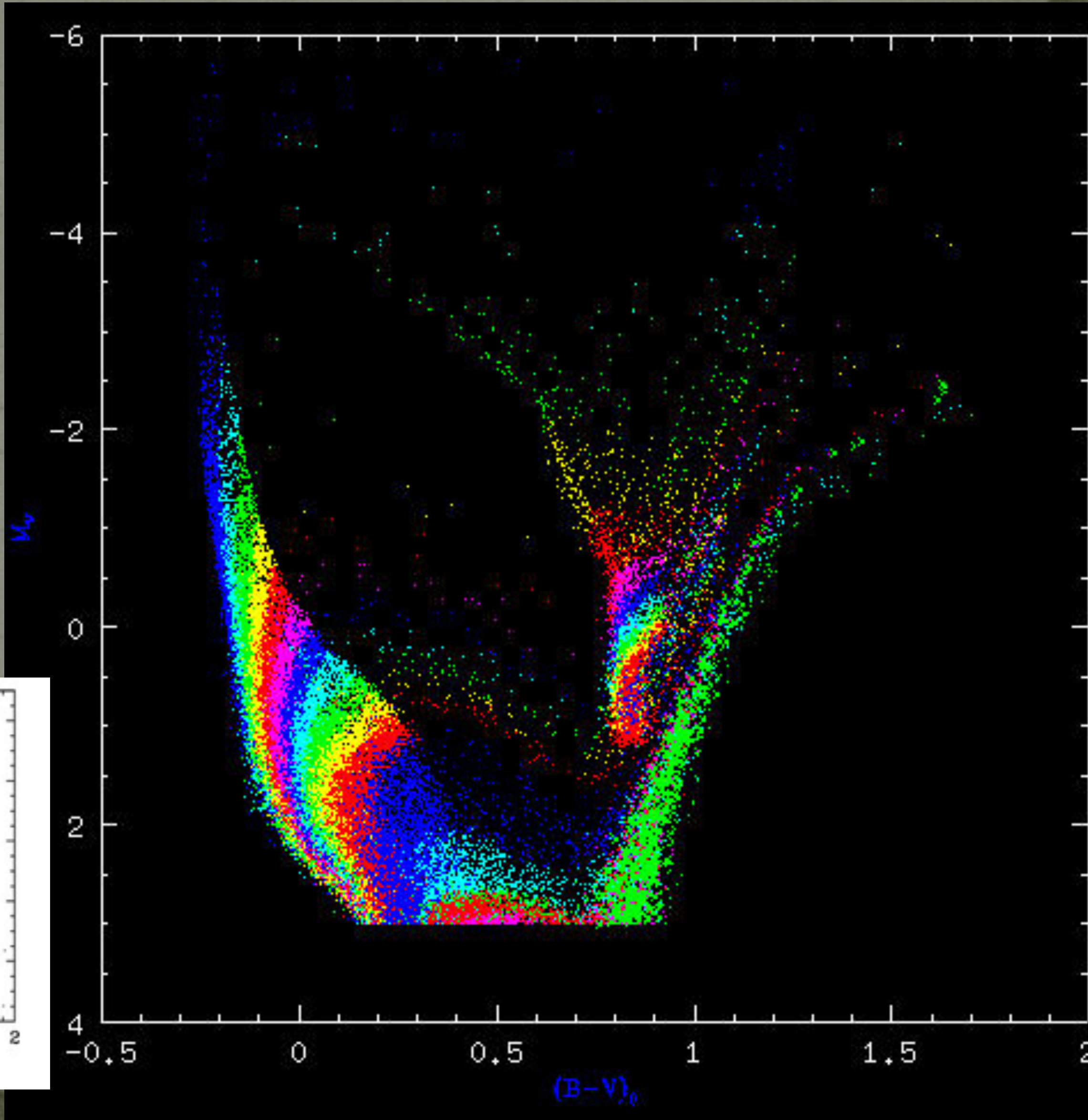


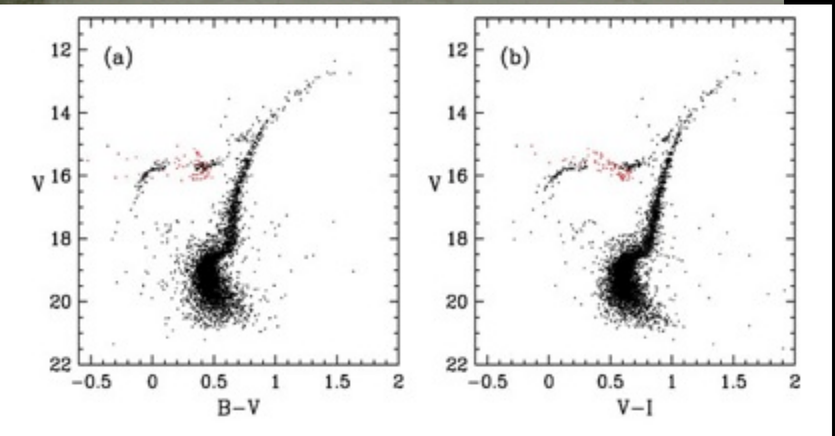
Fig. 2. The V vs (B−V) CMDs of all the six regions studied here are shown. These CMDs are used to estimate the stellar density after correcting for data incompleteness.

Synthetic CMDs

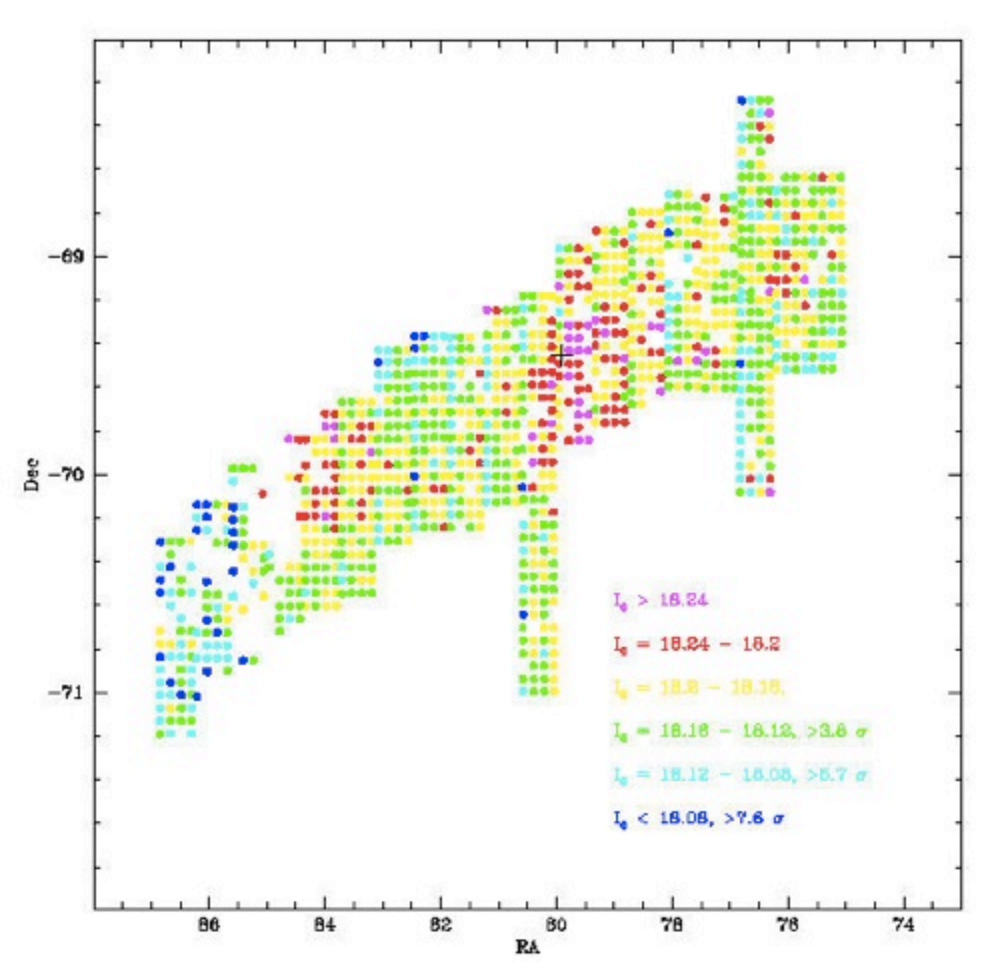
Subramaniam, A., 2004: A&A, 425, 837



Globular cluster CMD



Structure of the bar – A warp



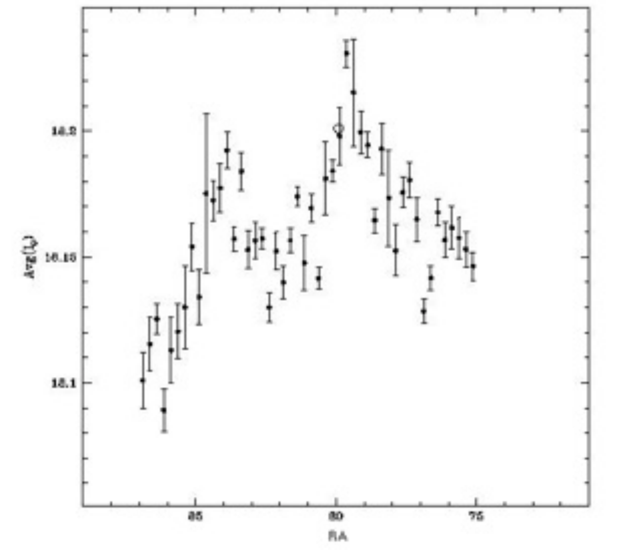


Fig. 4— The average of the I_0 along the declination is estimated for various RA and the value avg(I_0) is shown against RA. The error indicates the scatter in I_0 along the declination. The open circle shows the location of the center of LMC.

Subramaniam, A, 2003, ApJ Letters , 598, L19-L23

Counter-rotating component near the LMC central region

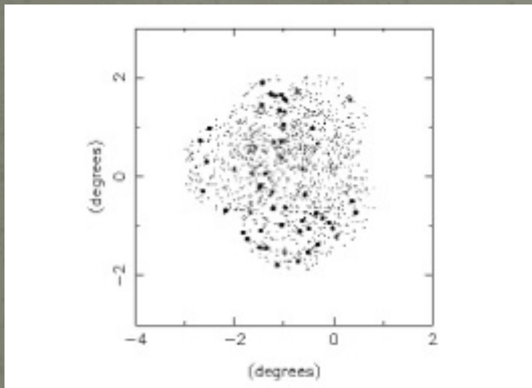
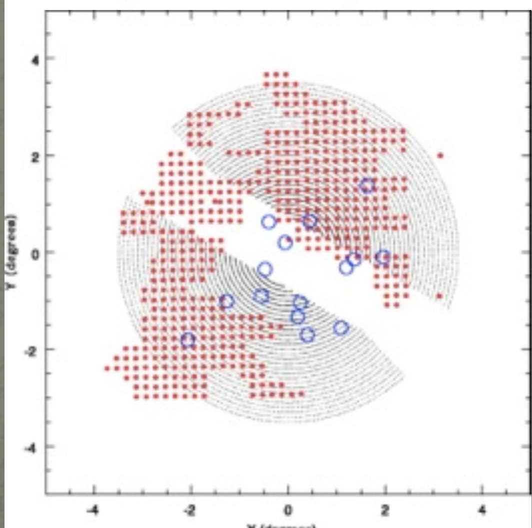
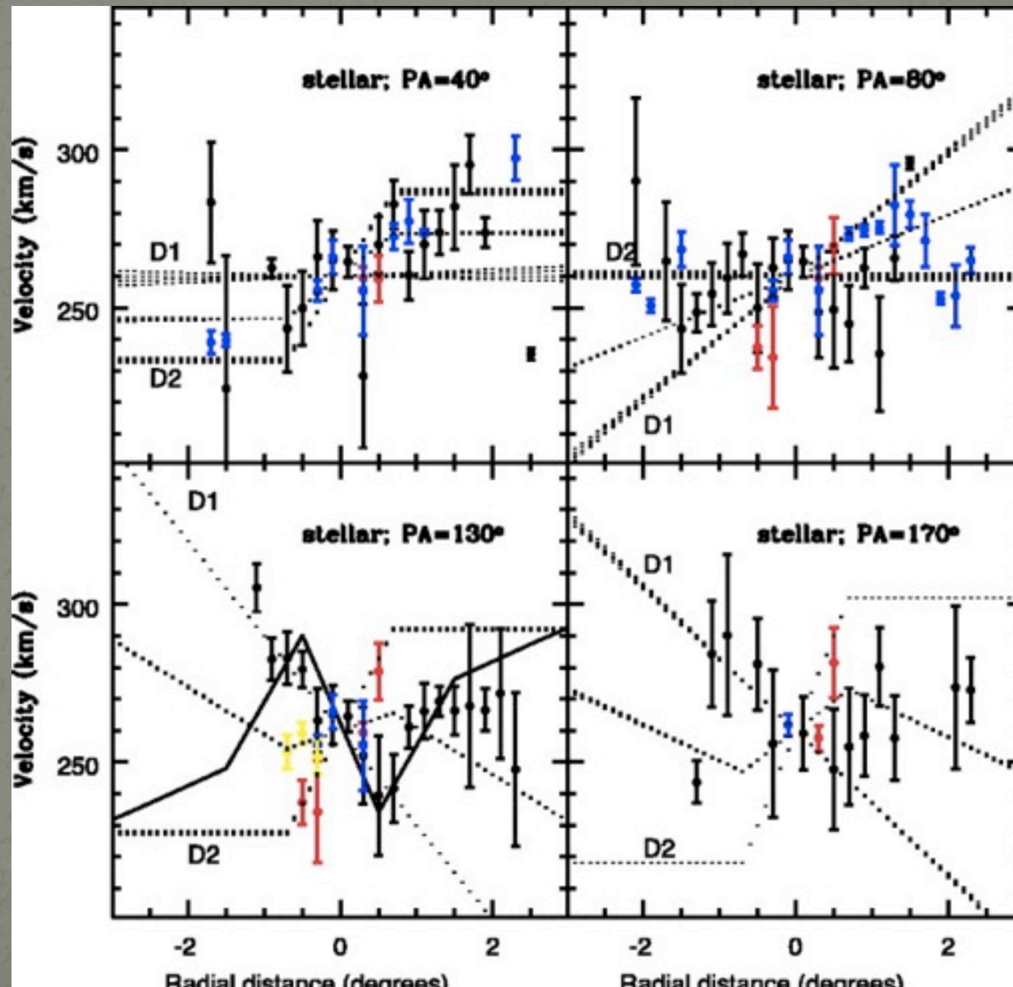


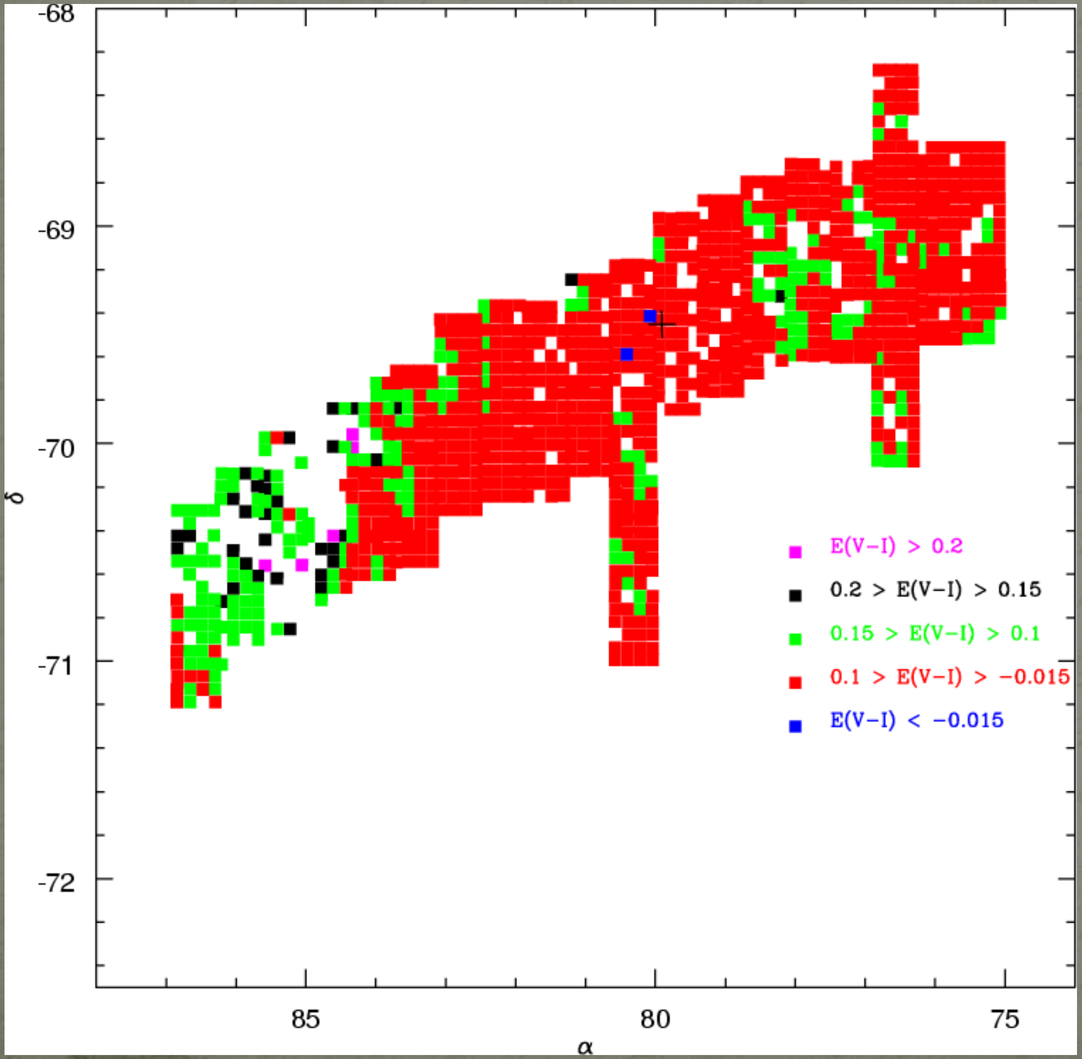
Figure 2. The location of the target objects in the LMC. The stars are marked according to their radial velocities, as in Fig. 1.

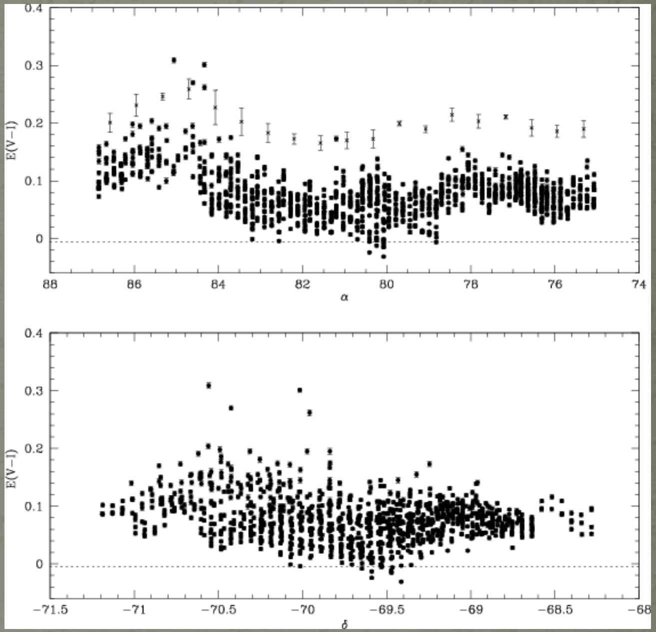




Subramaniam, A & Prabhu, T.P. 2005, ApJ Letters, 625, L47-50

Reddening and Extinction





Subramaniam, A., 2005, A&A, 430, 421

Test case – to study the formation and evolution of a Galaxy:

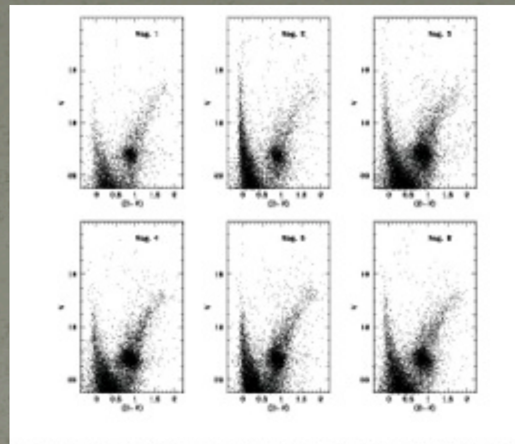
- **To understand the structure of the Magellanic Clouds as well as the evolution of these galaxies due to interactions, by studying different stellar populations in these galaxies.**

- **The stellar populations we study are**
- **Cepheids – young stars (~ 100 Myr Population I)**
- **Red clump stars – intermediate age stars (~ 2-8 Gyr Population I)**
- **RR Lyrae stars – old age stars (~ 10 -12Gyr Population II)**
- **All these stars are standard candles and we use them to find the relative distance between regions within the MC's ,the line of sight depth of the MC's and eventually the structure of the MC's.**

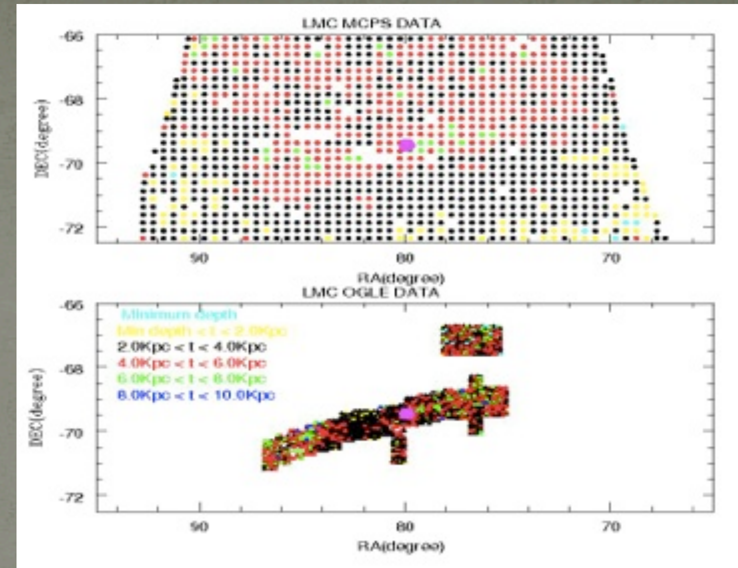
- **Structure of the Large Magellanic Cloud**

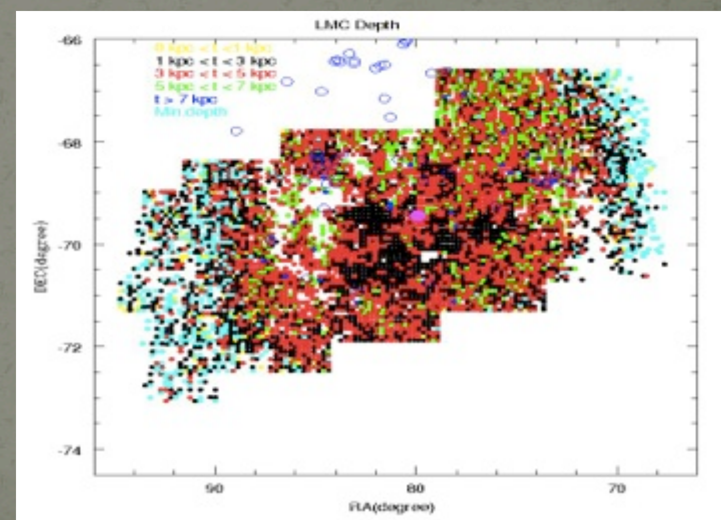
- **Structure of the Small Magellanic Cloud**

LMC Disk - thickness



Region	Range of depth in kpc	Avg. depth in kpc	Std deviation in kpc
LMC eastern bar (RA > 84°)	0.69 – 9.10	4.95	1.49
LMC western bar (RA<80°)	1.26 – 10.44	4.14	1.35
LMC central bar (80°<RA<84°)	0.69 – 8.50	3.21	1.03
LMC bar	0.69 – 10.44	3.95	1.42
LMC eastern disk (RA>88° & -68°>Dec>-71°)	0.65 – 5.89	2.80	0.92
LMC western disk (RA<74° & -68°>Dec>71°)	0.65 – 5.58	3.08	0.99
LMC northern disk (RA>-68°)	1.00 – 7.10	4.17	0.97
LMC southern disk (RA<-71°)	0.65 – 4.58	2.63	0.79
LMC disk	0.65 – 7.10	3.44	1.16

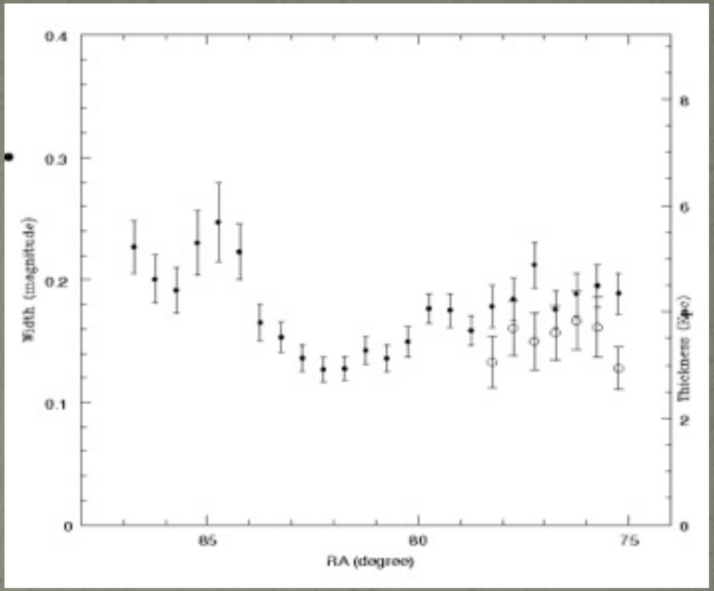


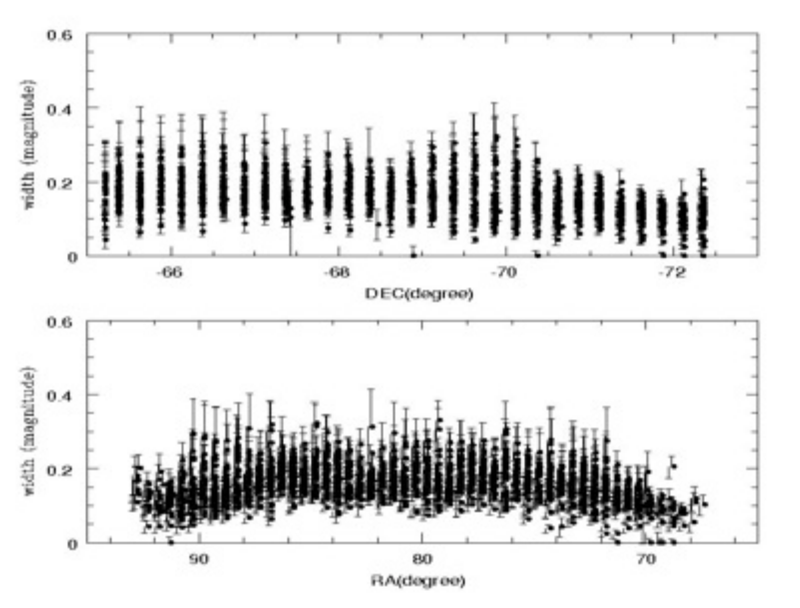


Subramanian.S & Subramaniam.A, 2009: A&A, 496, 399 (OGLE II and MCPS results)

Flared LMC bar

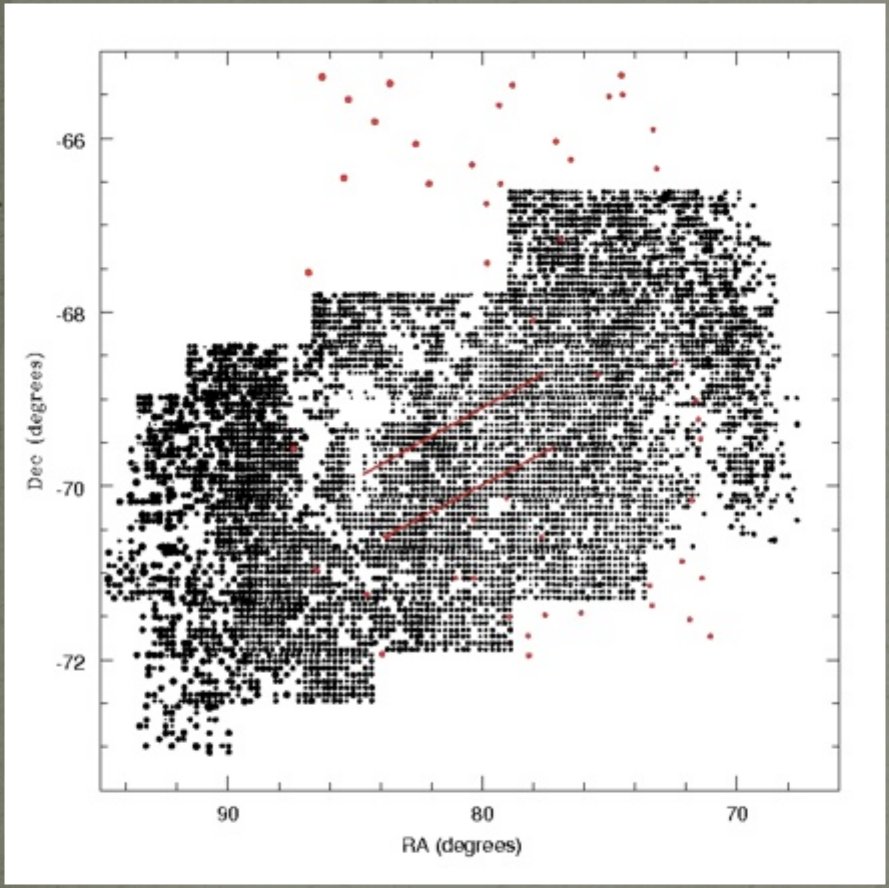
- The depth profile indicates flaring of the LMC bar.
- The northern disk depth is larger than the southern disk depth.
- There is no indication of depth variation between the eastern and the western disk.
- The LMC bar and the northern disk have larger depth compared to the other regions of LMC.





- **Subramanian.S & Subramaniam.A., 2009: A&A, 496, 399**

LMC bar – very much part of the disk

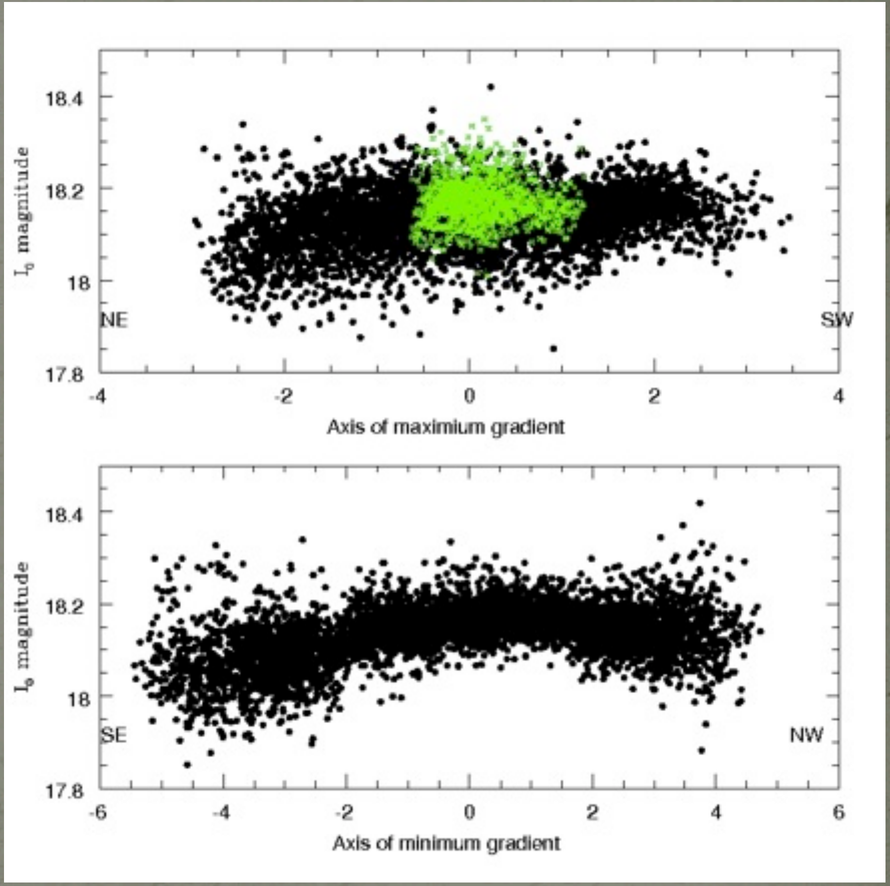


- The absence of any definite feature correlated to the location of the optical bar in the plot is striking.
- This suggests that the bar is not located in front of the disk, at least in the tracer adopted.
- Thus, the bar is likely to be very much part of the LMC disk.
- Another striking feature is the brightening of RC stars in the eastern and western ends of the LMC disk.
- This suggests a warp or different RC population in the ends of the disk.

Subramaniam.A & Subramanian.S., 2009, ApJ Letters, 703, L37

LMC Bar

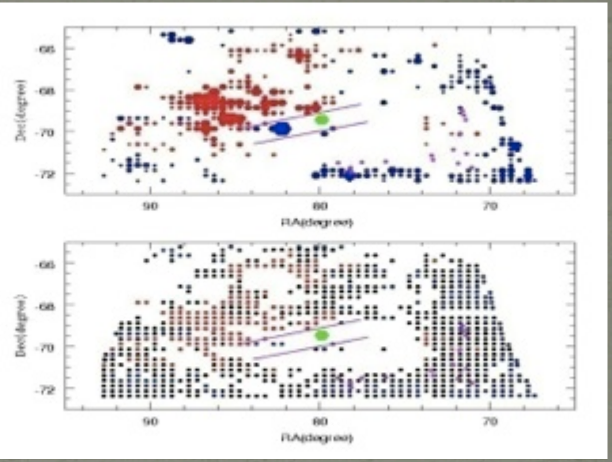
- The edge-on view of the LMC along the axes of minimum and maximum gradient are shown.
- In the lower plot, the bar is located between X = −2◦ and +2◦ , along with the disk in this edge-on view.
- In this central region, we see a single and relatively thin structure, suggestive of the bar located within the disk and in the plane of the disk.
- The upper panel is suggestive of gradient in I_0 ,which is basically the inclination of the disk.

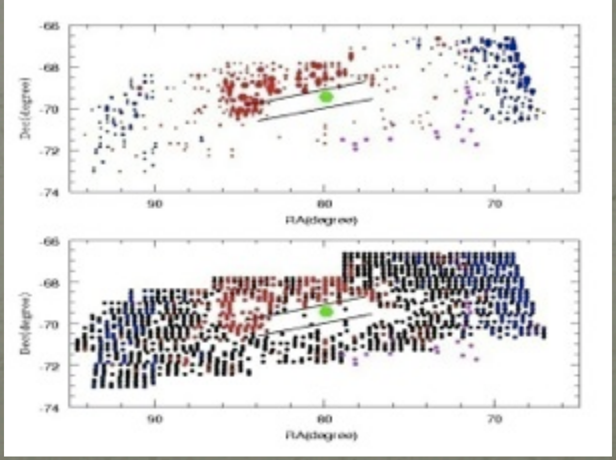


Subramaniam.A & Subramanian.S., 2009, ApJ Letters, 703, L37

Structure of the LMC Disk

- The plane fitting procedure is applied to 780 regions of the MCPS data and 1262 regions of OGLE III data.
- The regions which show deviations above 3 sigma are considered as real deviations.
- The north-western, south-western and south-eastern parts of the LMC disk are infront of the fitted plane and/or RC population are different.
- Similarly, the north-eastern region, north of the LMC bar is behind the fitted plane and/ or the RC population is different.
- $i=37.2^{o}\pm2^{o}.3$, $\varphi = 141^{o}.4\pm3^{o}.7$ (MCPS)
- $i=23.0^{o}\pm 0^{o}.8$, $\varphi = 163^{o}.7\pm1^{o}.5$. (OGLE III)





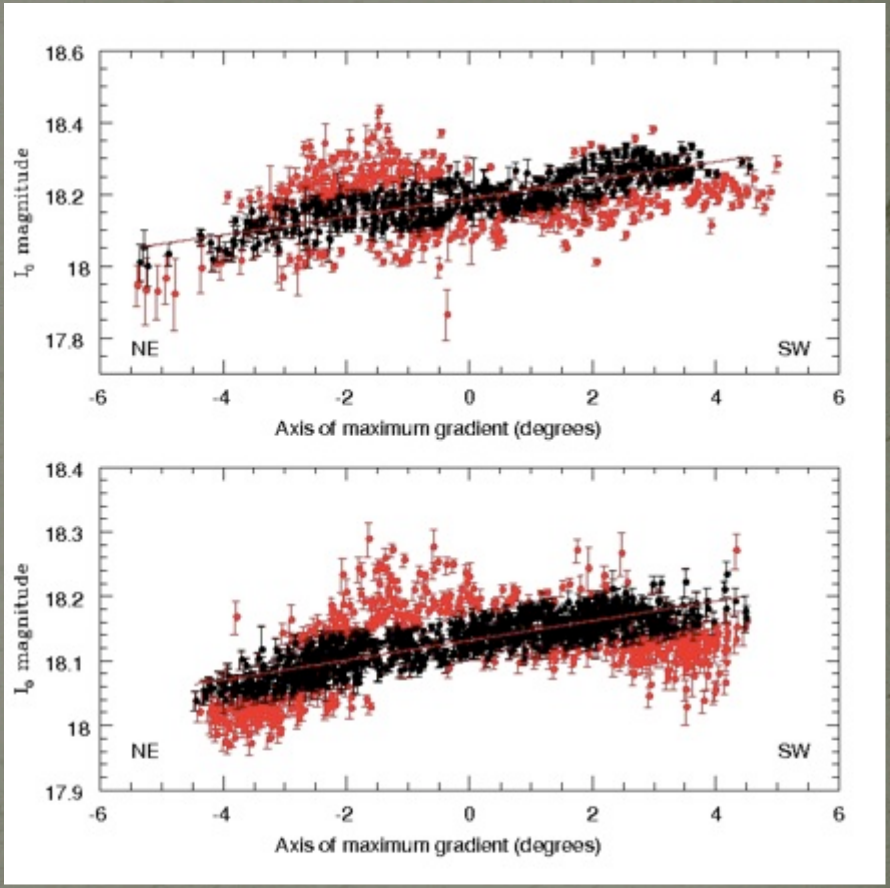
Subramanian, S & Subramaniam, A., 2010, A&A, 520, 24

Deviations and warps

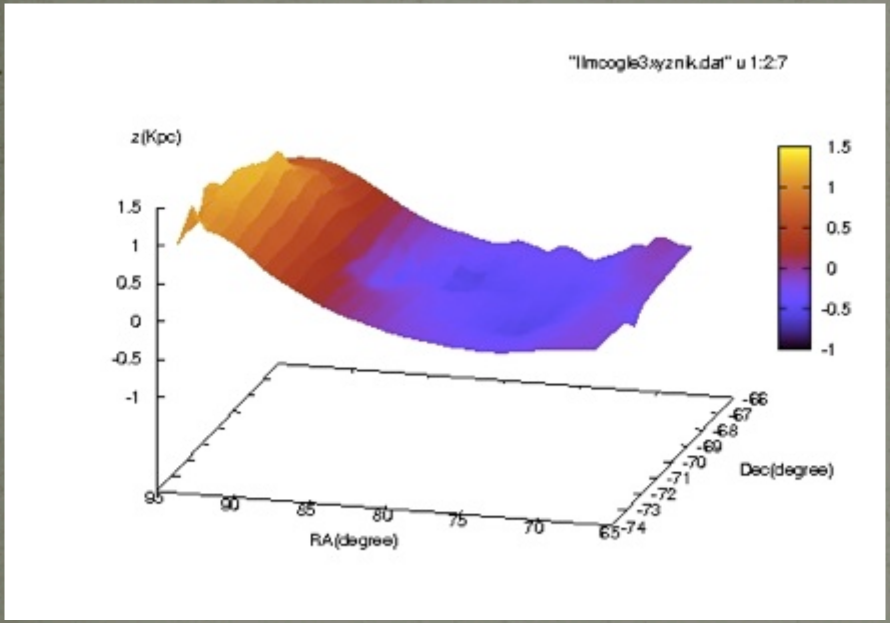
- Regions in the north west, south west and south east of the LMC disk are warped with respect to the fitted plane.

- The edge-on view of the LMC disk along the minor axis suggests an off-centered symmetric warp.

Subramanian, S & Subramaniam, A., 2010, A&A, 520, 24

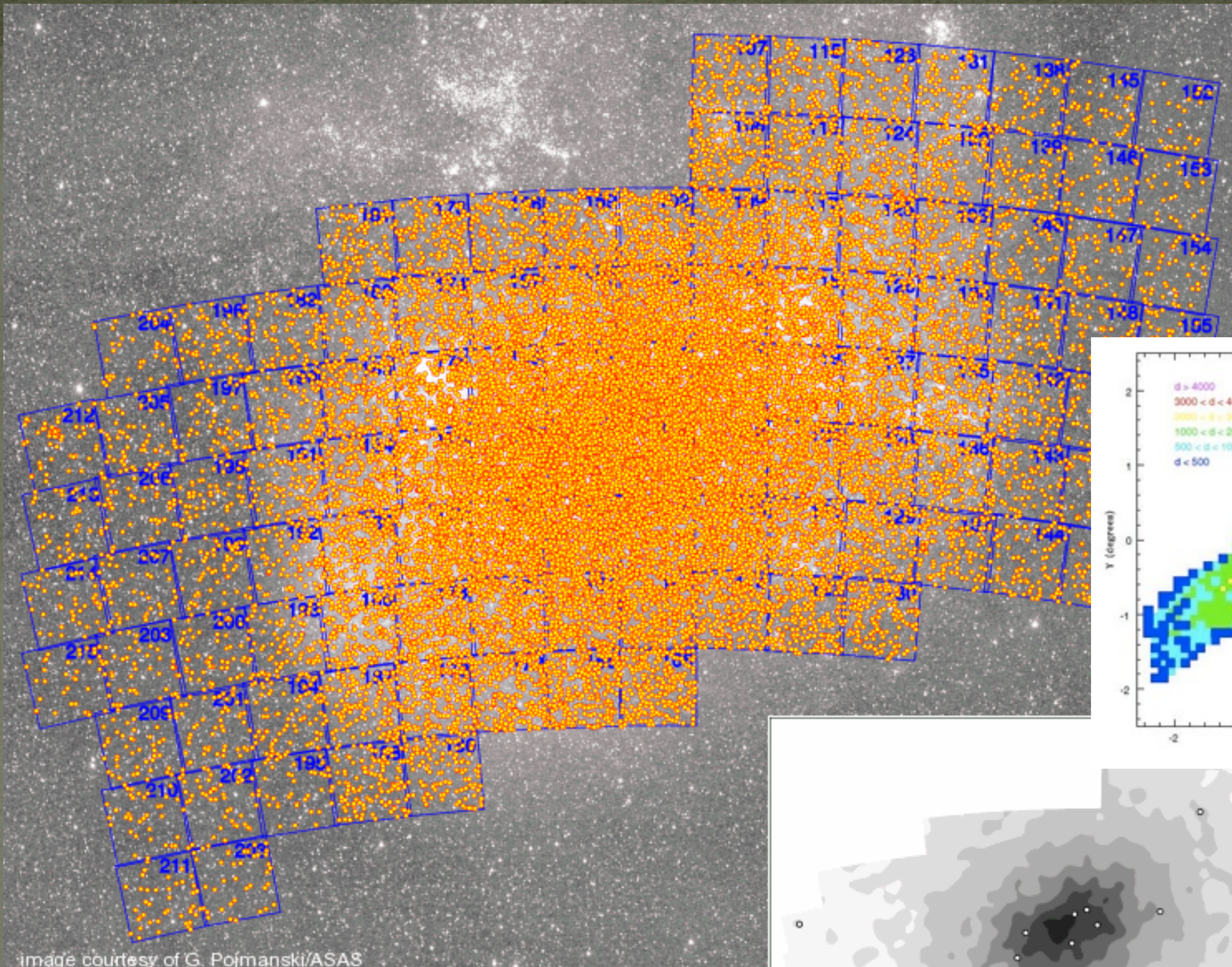


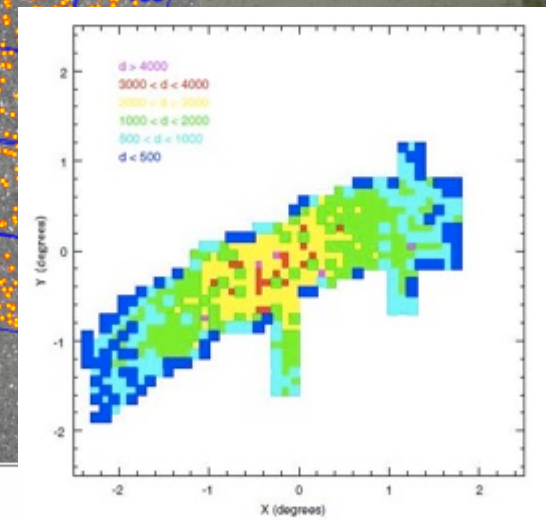
3D picture of the LMC disk

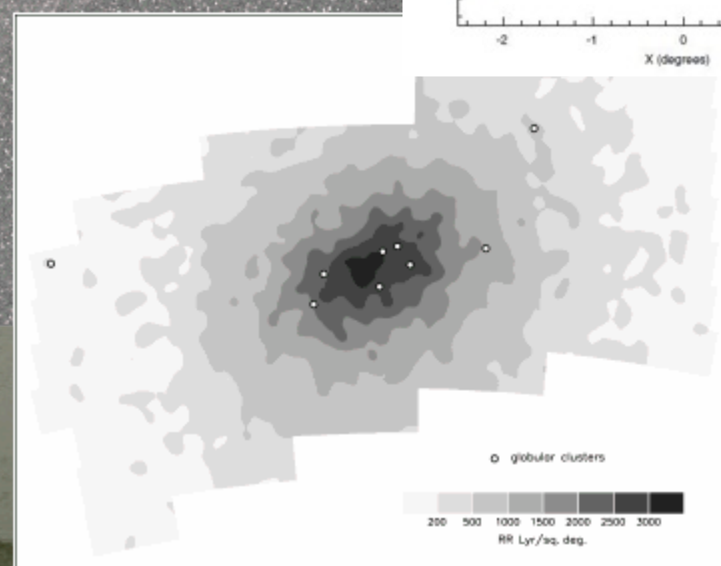


Subramanian, S & Subramaniam, A., 2010, A&A, 520, 24

- The figure clearly shows that the inner regions have smaller inclination and the outer regions have large inclination.
- The increase in the inclination seems to be start at a closer radius in the north-east, when compared to the south-west, which makes it off-centered.
- The change of structure in the outer LMC could be due to tidal effects.





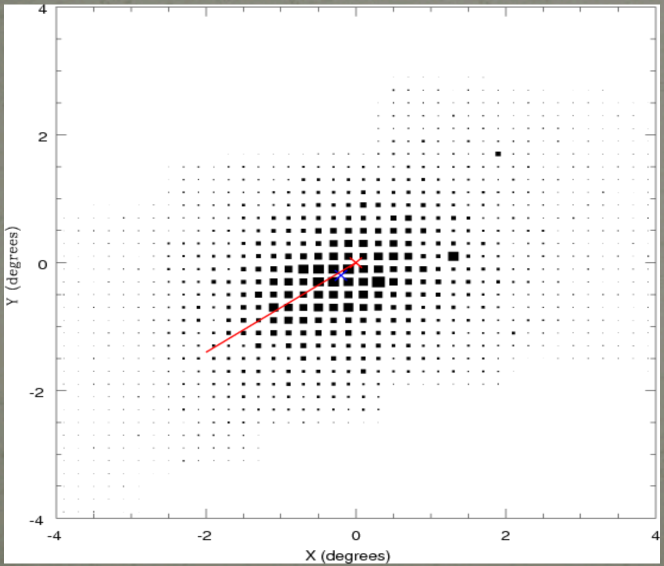


Subramaniam, A., 2005, A&A, 449, 101:
RR Lyrea stars – disk & inner halo
Confirmed by OGLE3 in 2009

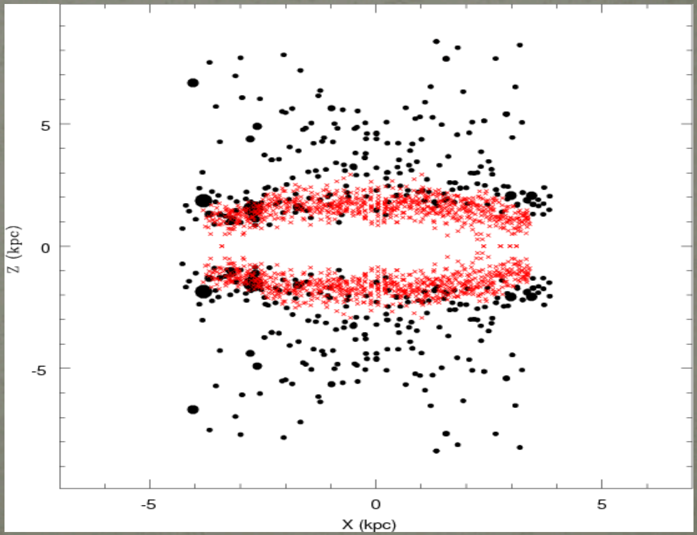
LMC Halo

Subramaniam, A & Subramanian, S., 2009, A&A Letters, 503, 9

- The smooth spatial variation in the density is found to have an elongated distribution.
- The direction of elongation is found to be similar to the elongation of the bar of the LMC.
- The position angle (PA) of the elongation is estimated to be PA = $125^o \pm 17^o$



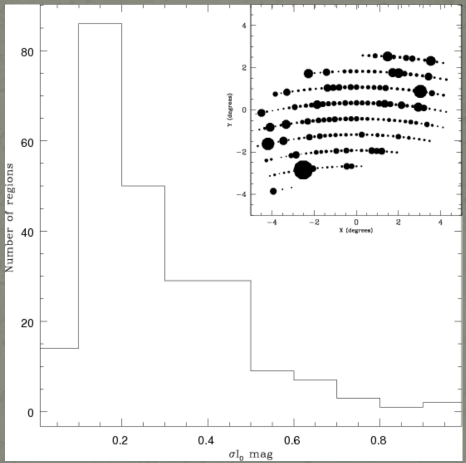
- The observed dispersion in the mean magnitude is an upper limit of the scale height, as intrinsic variation is not reduced.
- The Z distances corresponding to the depth are plotted in an edge on view along the X axis. The red points are the depth of the disk estimated from the red clump stars.

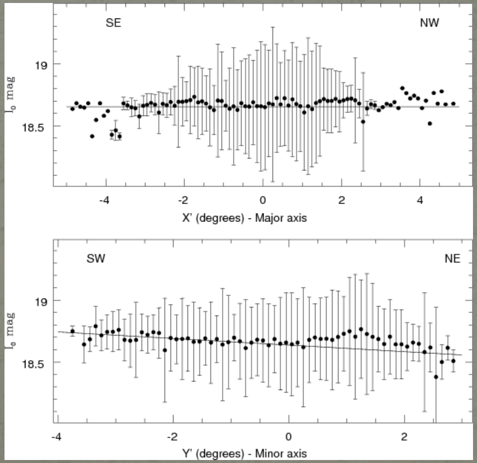


RR Lyrea stars – mostly in the disk!

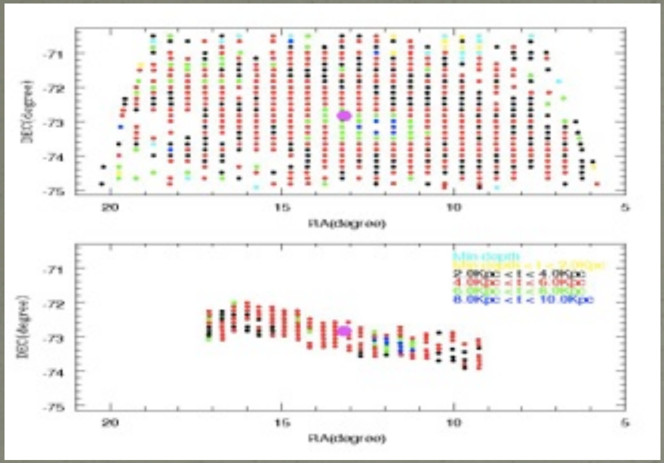
- The distribution shows that there may be two populations, one with smaller scale height and the other much larger.
- The distribution of the dereddened magnitude along the minor axis shows variation suggesting inclination.
- The inclination estimated is 31± 3.5. (very similar to the disk)

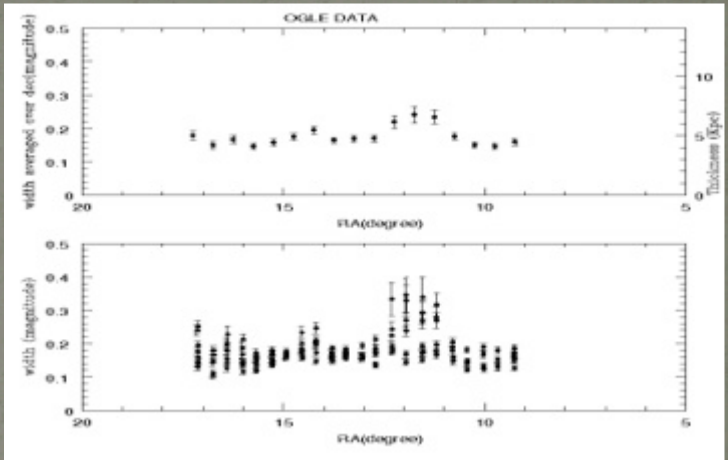
Subramaniam, A & Subramanian, S., 2009, A&A Letters, 503, 9

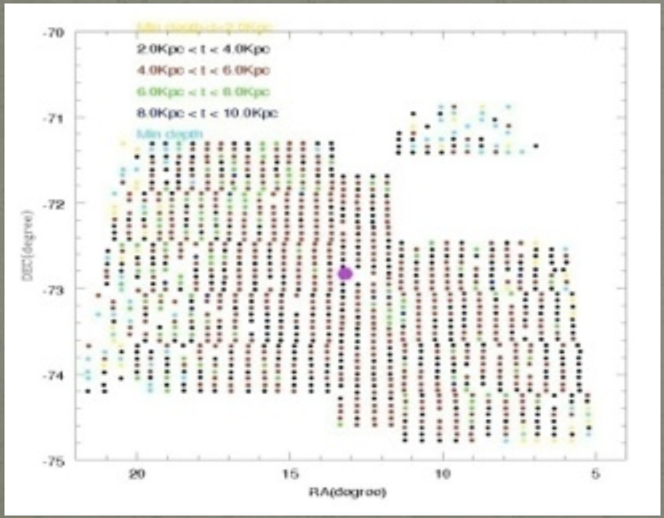


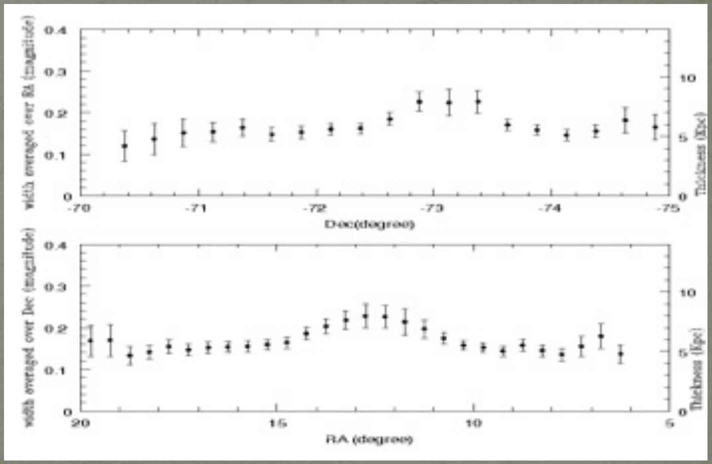


SMC – Central Nucleus





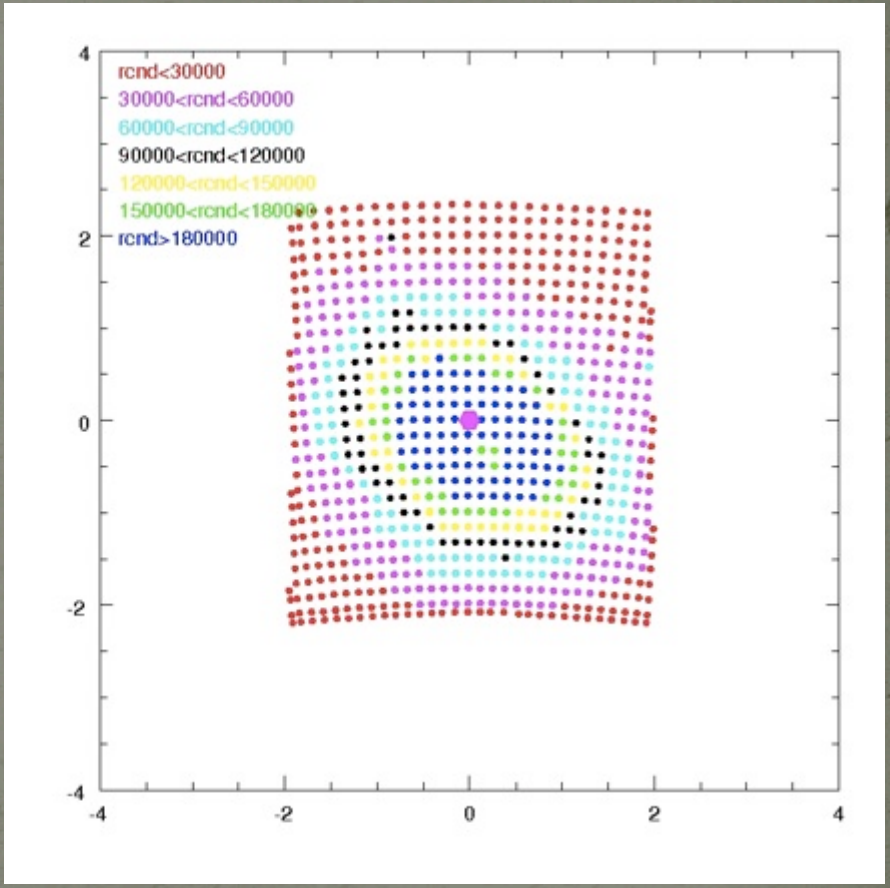




- Subramanian.S & Subramaniam.A 2009 A&A 496, 399
- Subramanian, S & Subramaniam, A., 2011, to appear in ApJ

Structure of the SMC

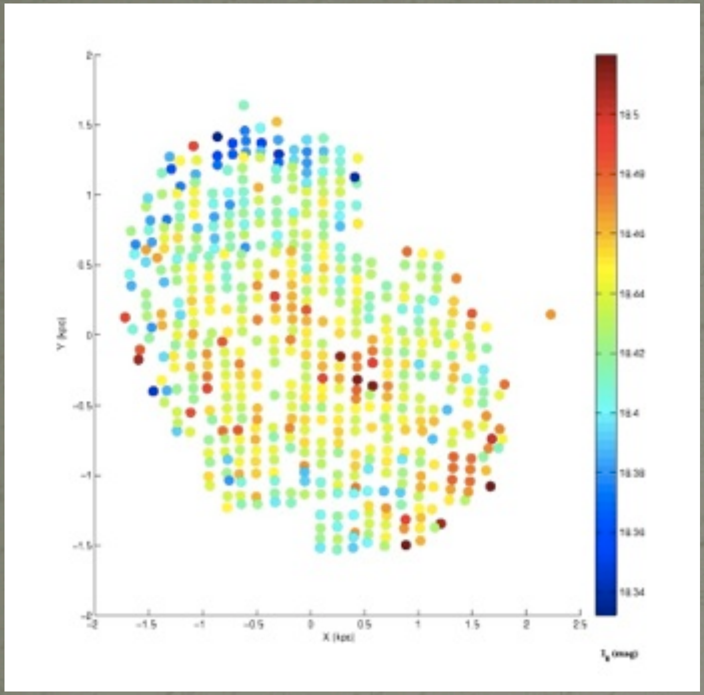
- Density distribution of red clump stars in the SMC are plotted for both MCPS and OGLE III data. The distribution looks regular, smooth with an elongation towards the LMC (NE-SW) direction.
- Based on previous studies structure of the SMC (intermediate age) can be approximated to a triaxial ellipsoid.
- Depth estimates of SMC shows a large depth near the center, which is expected for an ellipsoidal structure.
- The covariance matrix of the coordinates is constructed and the eigen values and eigen vectors are determined.

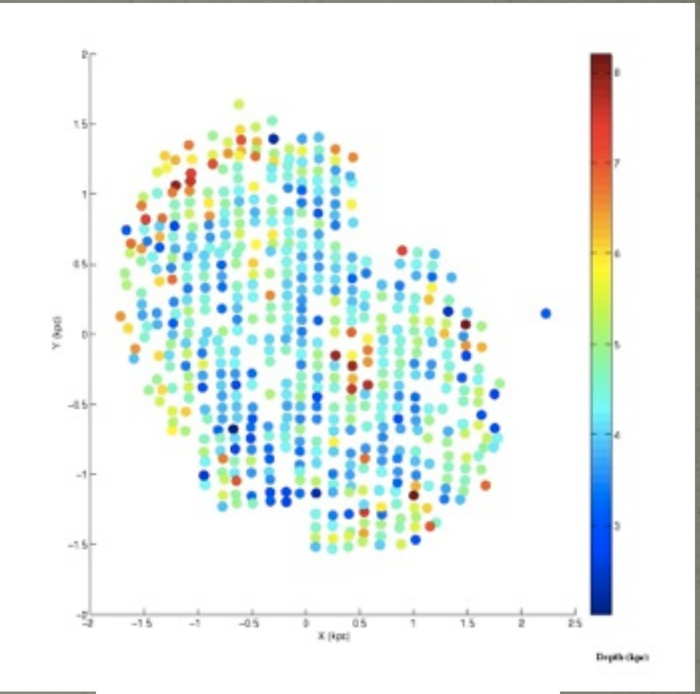


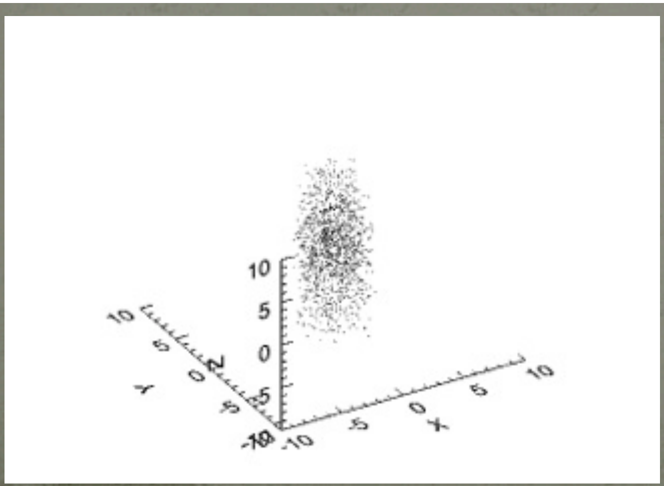
Subramanian, S & Subramaniam, A., 2011, to appear in ApJ

SMC structure – spheroidal/ellipsoidal

Subramanian, S & Subramaniam, A., 2011, to appear in ApJ





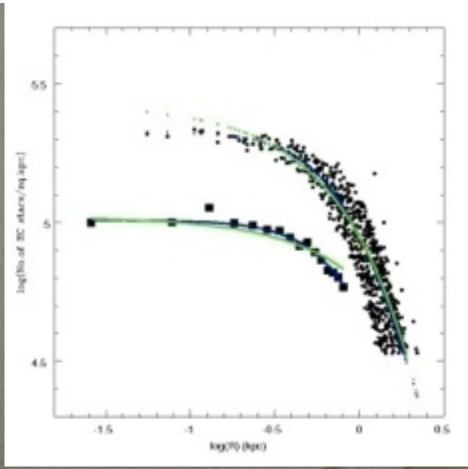


_X:Y:Z_

1:1.3:1.6

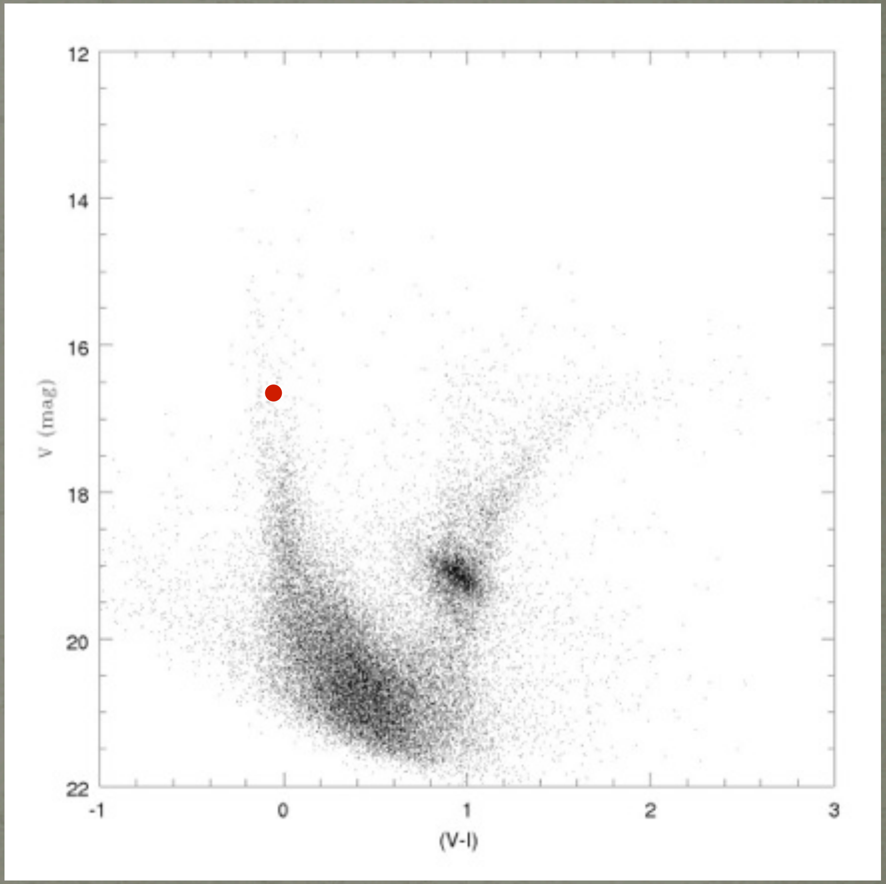
_i_ =2.6

_PA_=70.2



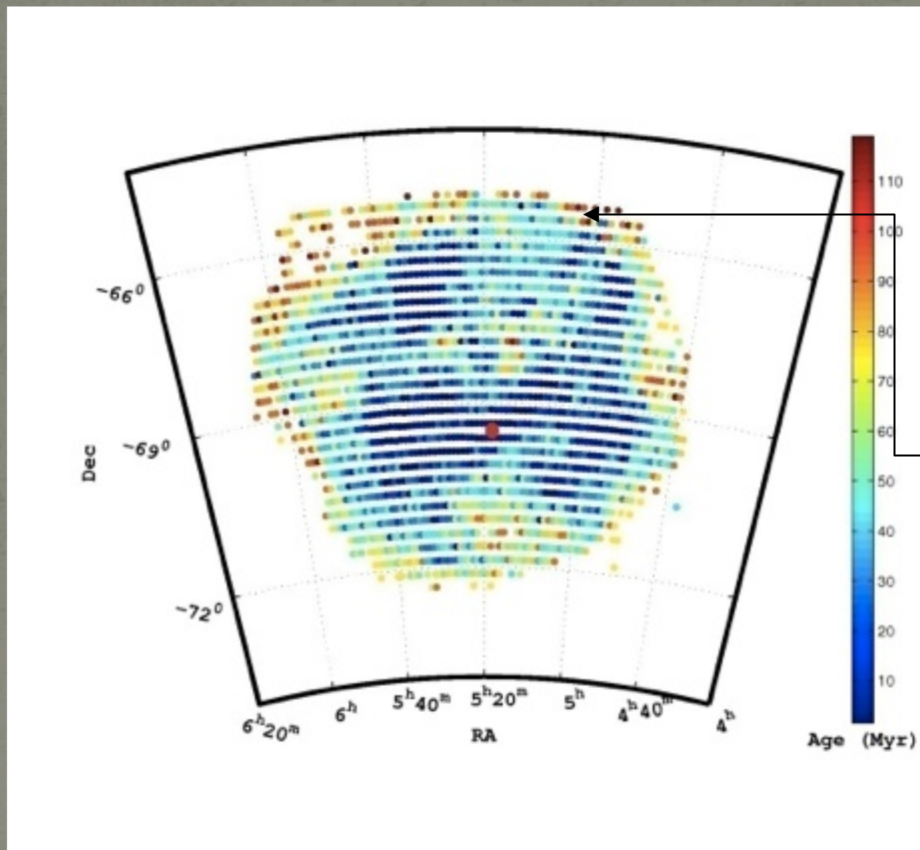
Recent star formation history

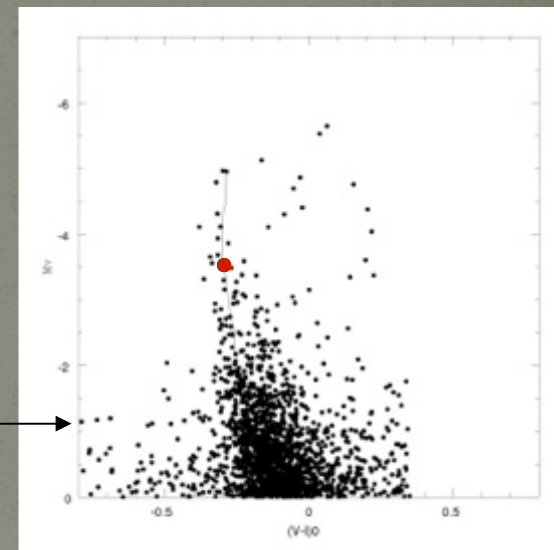
- Method is the identification of Main Sequence Turn-Off (MSTO)
- The turn-off magnitude is corrected for extinction, *an extinction map is estimated for the bright young stars in the L&SMC.*
- The absolute turn-off magnitude is converted to age *with estimated linear log(age) – Mv relations.*
- The turn-off age is the age of the LSFE



The LMC LSFE Map (*using MCPS*)

Indu, G. & Subramaniam, A., 2011, to appear in A&A (highlighted paper)

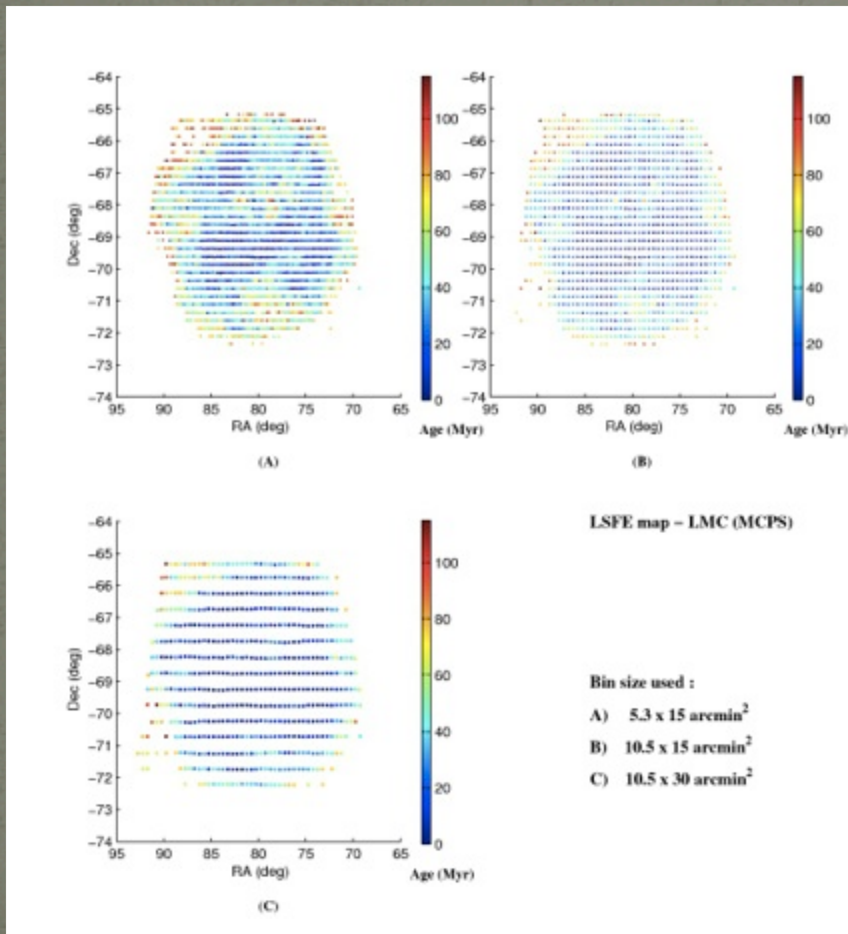


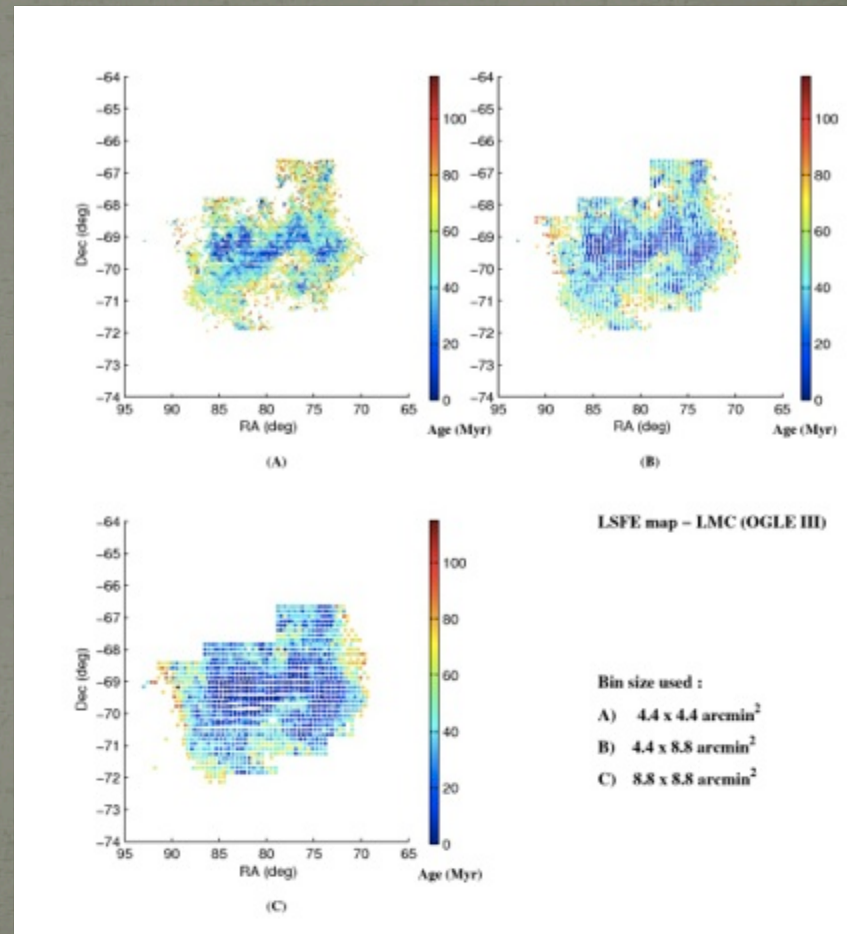


Area 5' x 15'

- **Out side to inside quenching of star formation which propagates radially inward**
- **A lopsidedness of young star forming regions with respect to optical center**

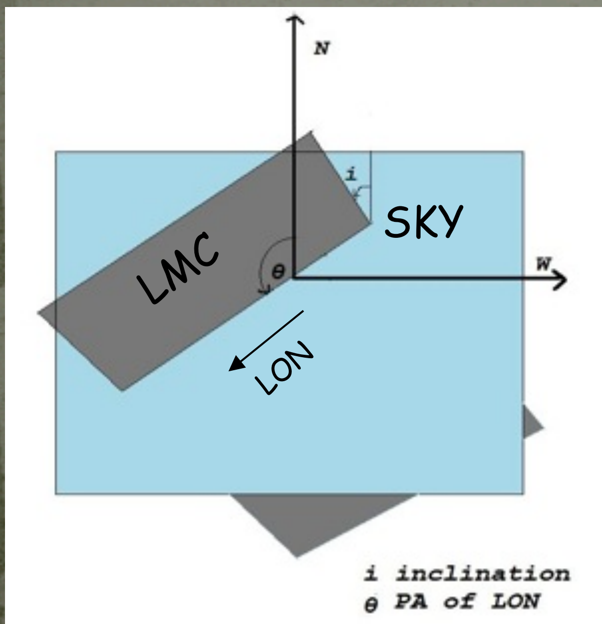
The LMC LSFE MAP *MCPS & OGLE III*

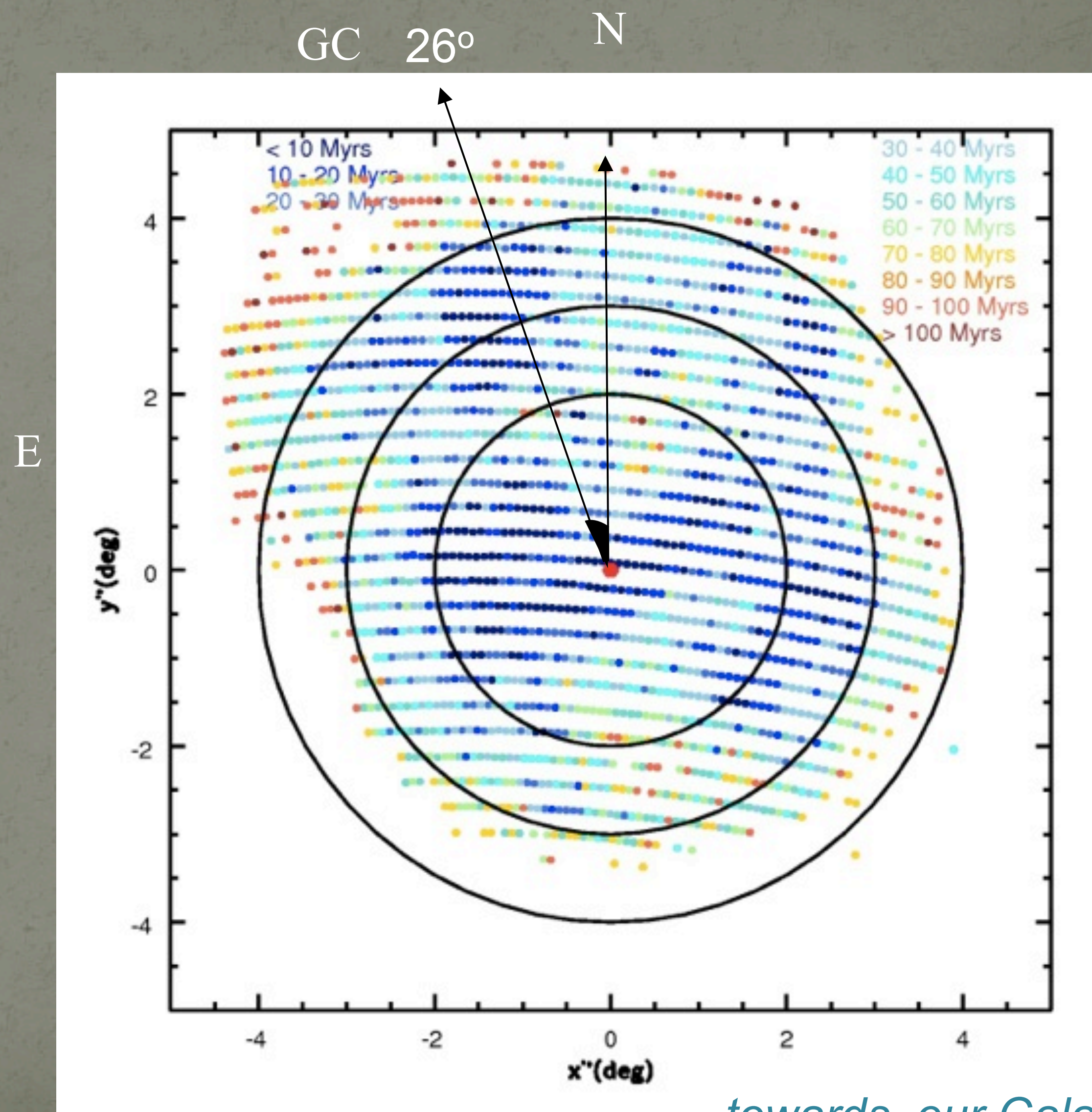




Indu, G. & Subramaniam, A., 2011, to appear in A&A (highlighted paper)

Deprojection to the LMC plane, *free from viewing perspectives*





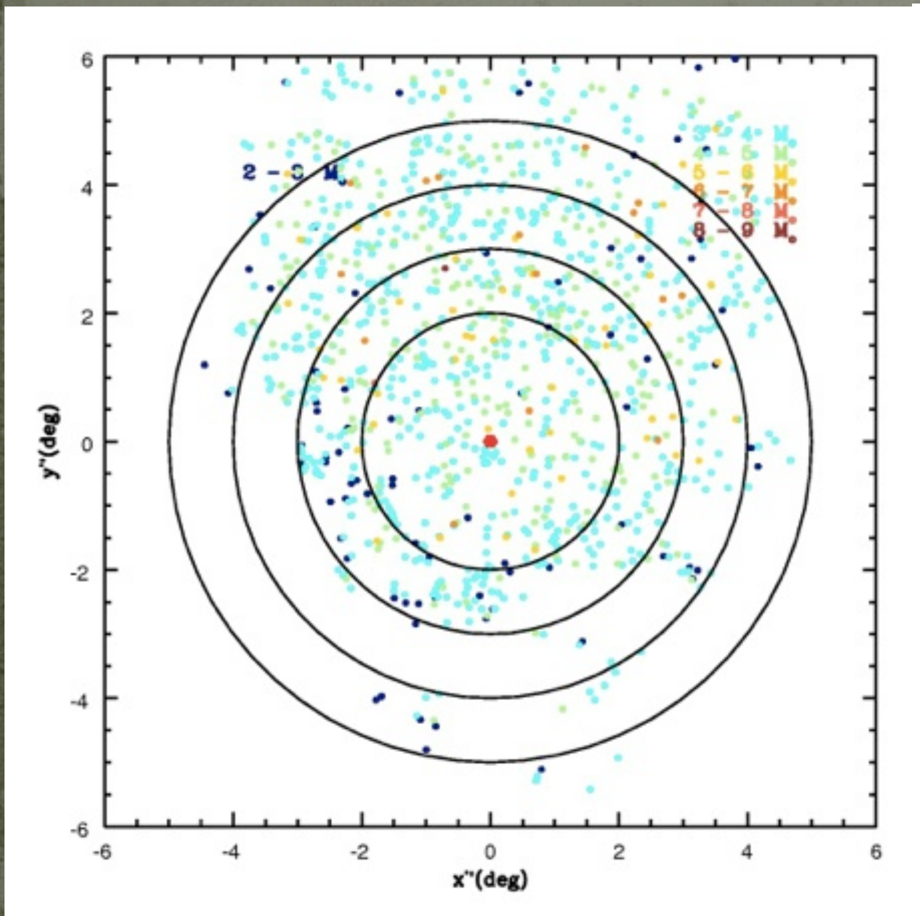
An extension of younger star forming regions towards the N-NE

towards our Galaxy ?

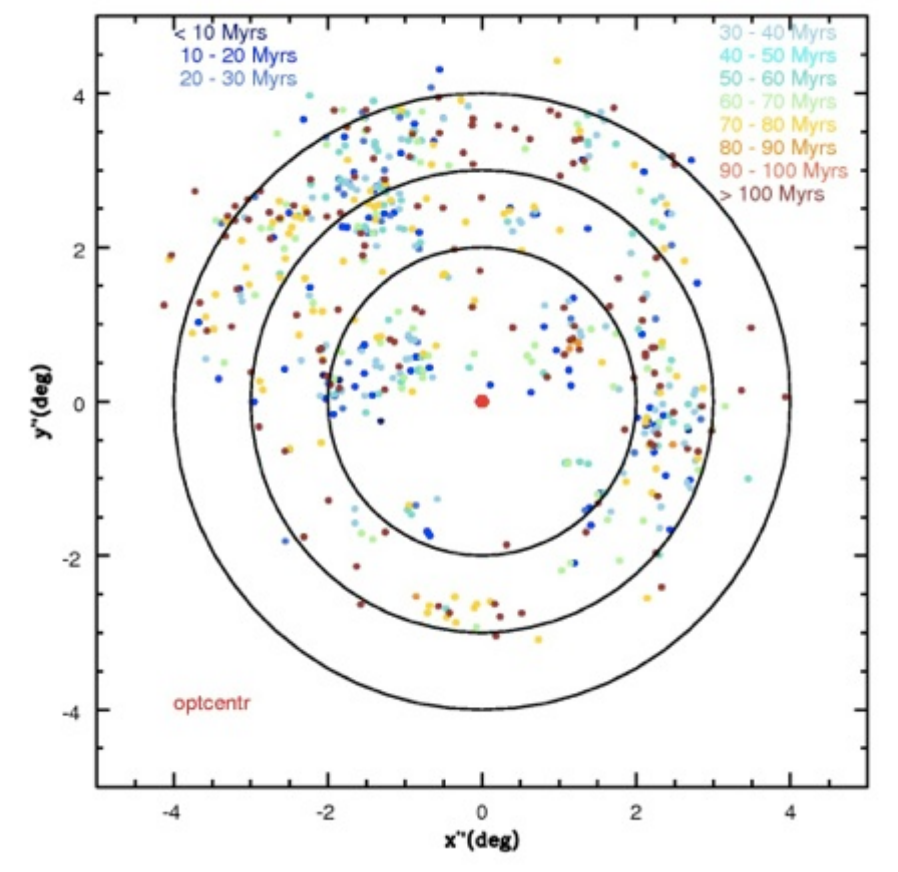
Indu, G. & Subramaniam, A., 2011, to appear in A&A(highlighted paper)

HI clouds & Young clusters comparison in the LMC

log mass (M☉)



Age (Myr)



" Gas is preferentially located in the North ! "

" The young (≤ 40 Myr) clusters seems to accumulate in the NE-N Direction "

(data : Kim et al 2007: ApJ, 669, 1003K *)*

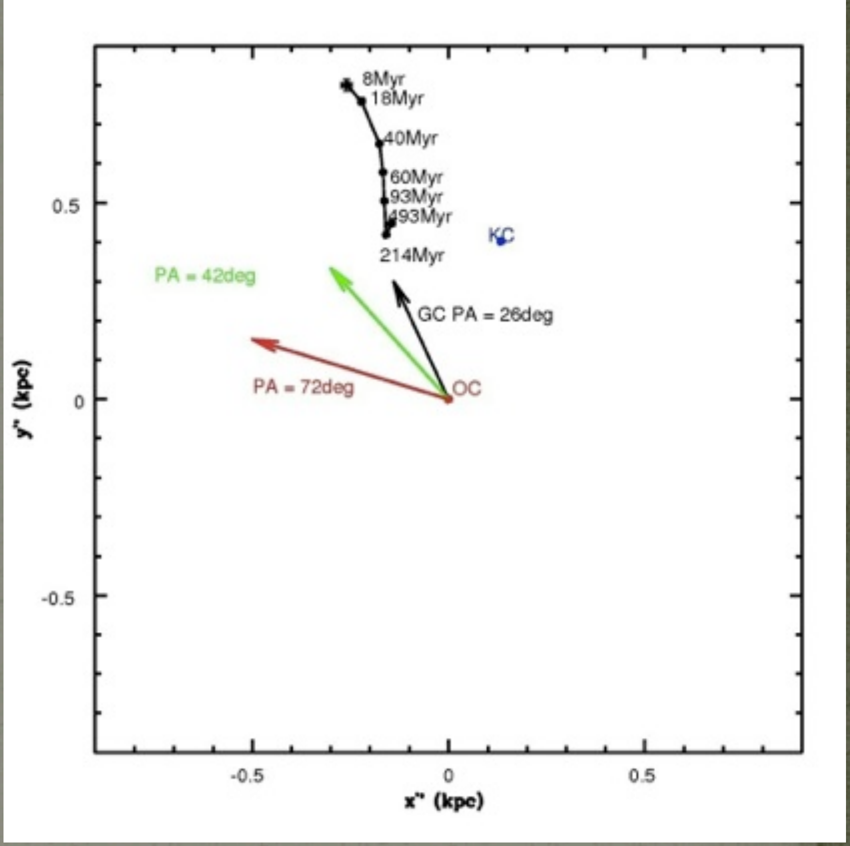
(data : Glatt et al 2010: A&A, 517A, 50G *)*

Shift in the center of the young stellar distribution in the LMC

Indu & Subramaniam: Star formation history of the Magellanic Clouds

Table 1. The centers of the stellar population in the LMC for various ages, using MCPS data.

Age (Myr)	RA(deg)	Dec (deg)	x'' (kpc)	$\sigma x''$	y'' (kpc)	$\sigma y''$	N#
8	80.5303	-68.5728	-0.2598	-0.0137	0.8000	0.0160	13327
18	80.4294	-68.6190	-0.2218	-0.0080	0.7584	0.0094	36536
40	80.3217	-68.7290	-0.1756	-0.0046	0.6505	0.0052	107243
60	80.3163	-68.8027	-0.1666	-0.0034	0.5780	0.0038	192619
93	80.3297	-68.8768	-0.1632	-0.0025	0.5051	0.0027	353207
214	80.3542	-68.9608	-0.1589	-0.0014	0.4184	0.0015	1141153
493	80.3146	-68.9201	-0.1451	-0.0009	0.4470	0.0010	3151134



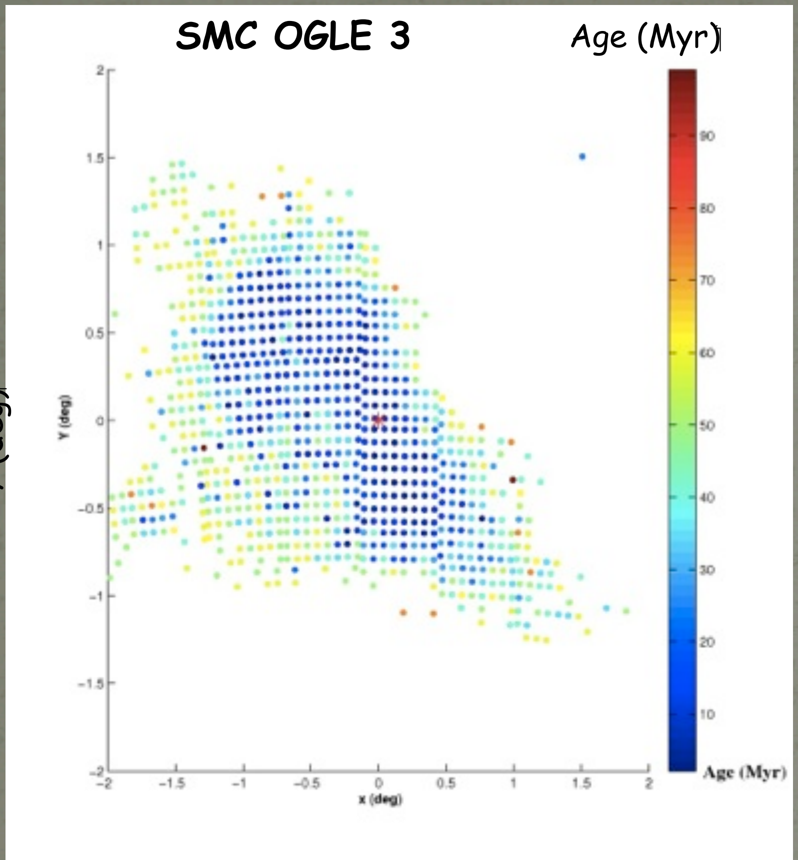
Age (Myr)	Shift to North (pc/10Myr)	Shift to East (pc/10Myr)
500 - 200	-	-
200 – 100	7	-
100 - 40	27	-
40 - 10	50	28

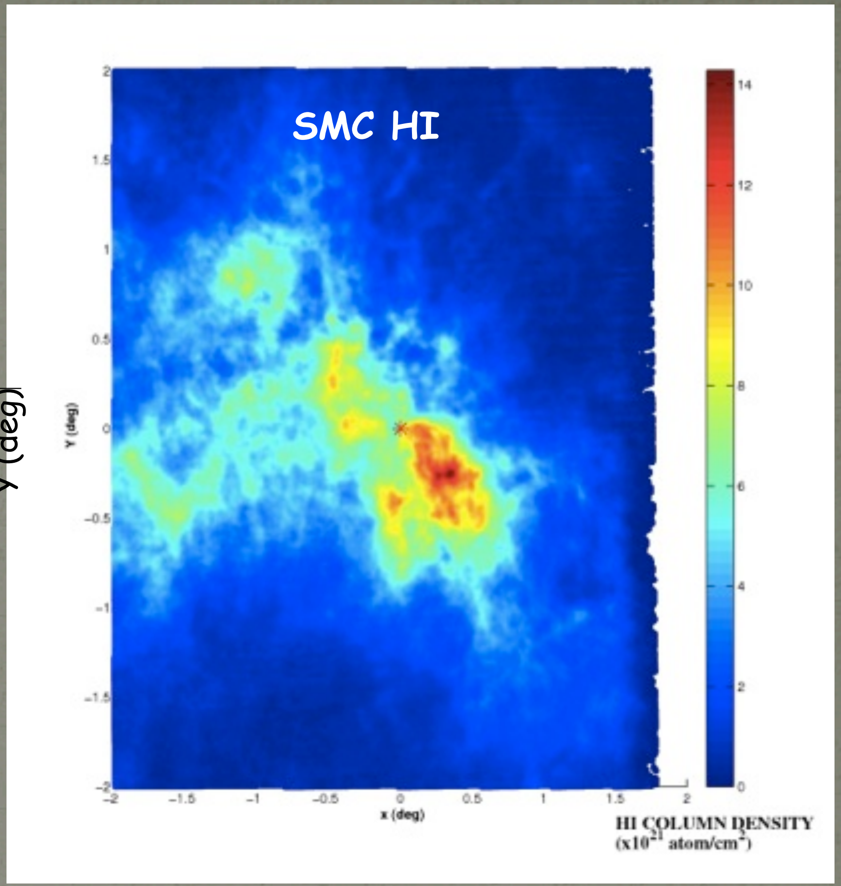
The NE center shift in 200 – 40 Myr can be due to, **tidal interaction with the Galaxy**

The enhanced NE shift in < 40 Myr may be, **the result of compression due to the movement of the LMC**

Indu, G. & Subramaniam, A., 2011: to appear in A&A(highlighted paper)

Spatial distribution of LSFE vs. HI in the SMC





(Stanimirovic et al 2004)

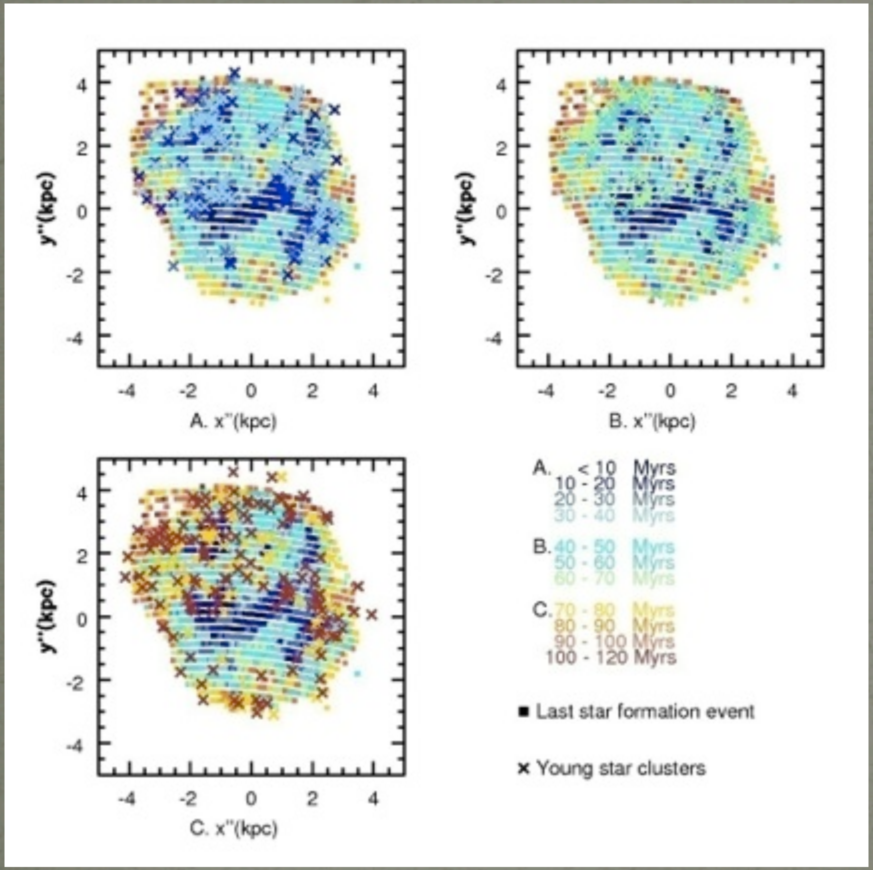
- No gradation in age, but outer regions have older age
- Eastern wing with more star forming regions
- The NE, SW substructures are identified in both the maps

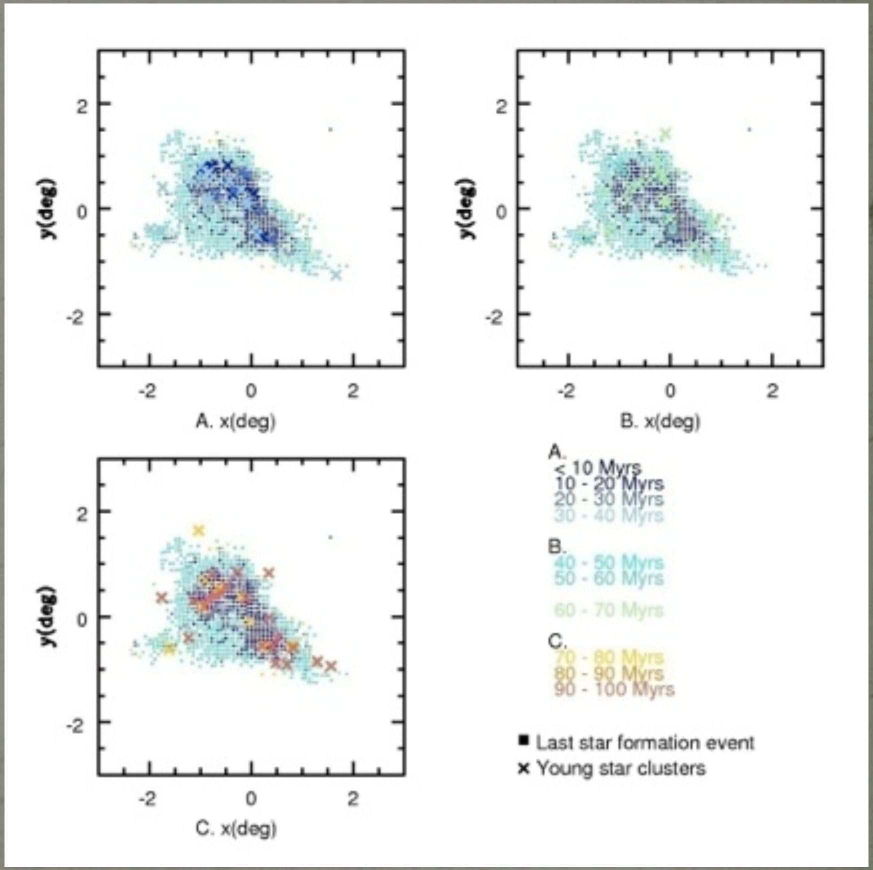
Indu, G. & Subramaniam, A., 2011, to appear in A&A (highlighted paper)

Correlation with *young clusters* the LMC & the SMC

Indu, G. & Subramaniam, A., 2011, to appear in A&A (highlighted paper)

COVER PAGE PICTURE





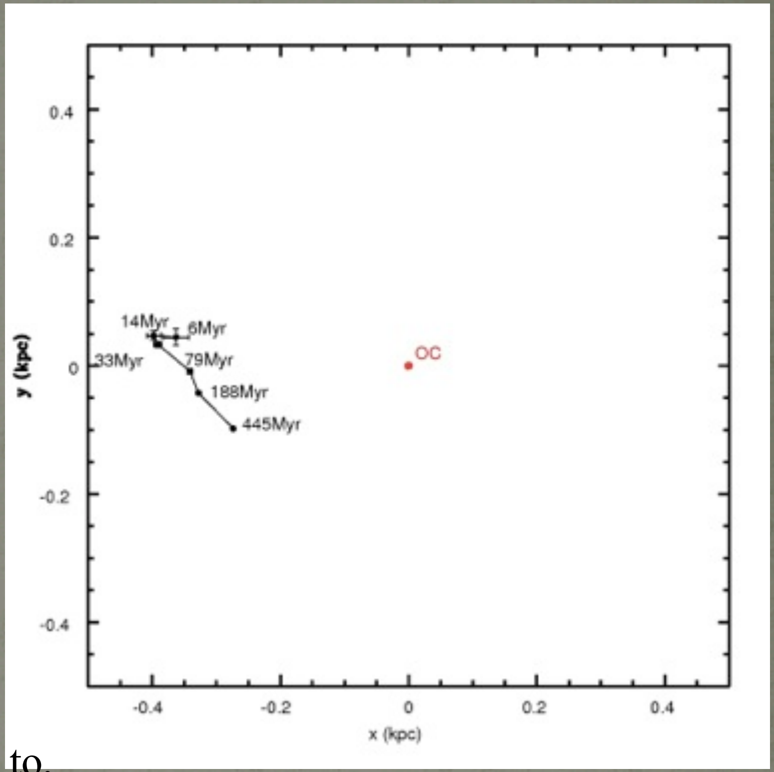
Star forming regions correlate with the location & age of young clusters pretty well.

Cluster data from Glatt et al. 2010: A&A, 517A, 50G

Shift in the center of the young stellar distribution the SMC

Table 2. The centers of the stellar populations in the SMC for various ages using OGLE III data.

Age (Myr)	RA(deg)	Dec (deg)	x (kpc)	σx	y (kpc)	σy	N#
6	14.2007	-72.7345	-0.3631	-0.0197	0.0445	0.0128	2430
14	14.3156	-72.7533	-0.3981	-0.0109	0.0472	0.0069	7968
33	14.2957	-72.7728	-0.3916	-0.0063	0.0334	0.0041	23377
79	14.1303	-72.8157	-0.3413	-0.0036	-0.0088	-0.0024	67919
188	14.0868	-72.8496	-0.3279	-0.0021	-0.0425	-0.0014	203383
445	13.9135	-72.9043	-0.2739	-0.0011	-0.0980	-0.0008	597714



Age (Myr)	Shift to North (pc/10Myr)	Shift to East (pc/10Myr)
500 - 200	2.2	2.1
200 – 30	5	4
< 30	-	-

The NE center shift in 500 – 200 Myr can be due to,

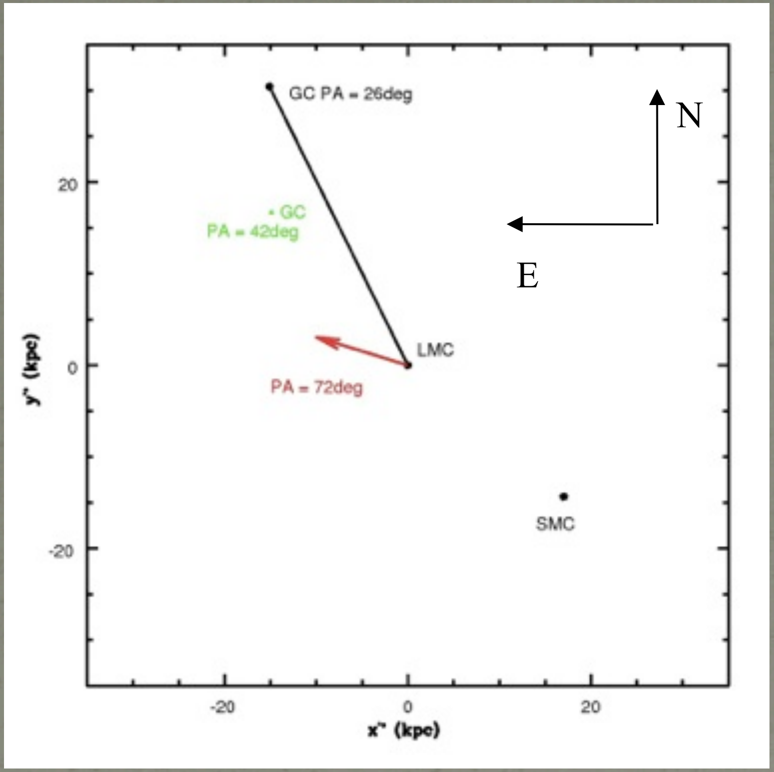
- **Interaction with the LMC and/or formation of the wing**

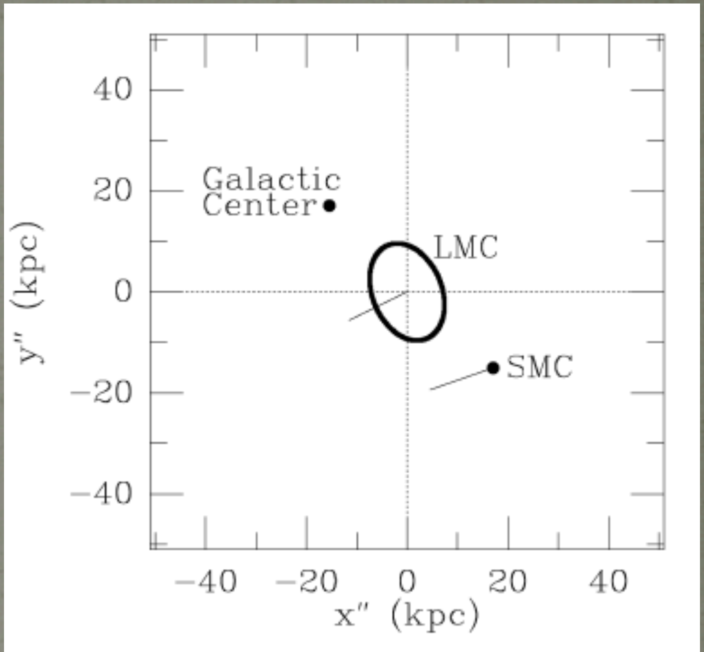
The enhanced NE shift in 200 – 30 Myr may be,

- **The result of the perigalactic passage**

Indu, G. & Subramaniam, A., 2011: to appear in A&A(highlighted paper)

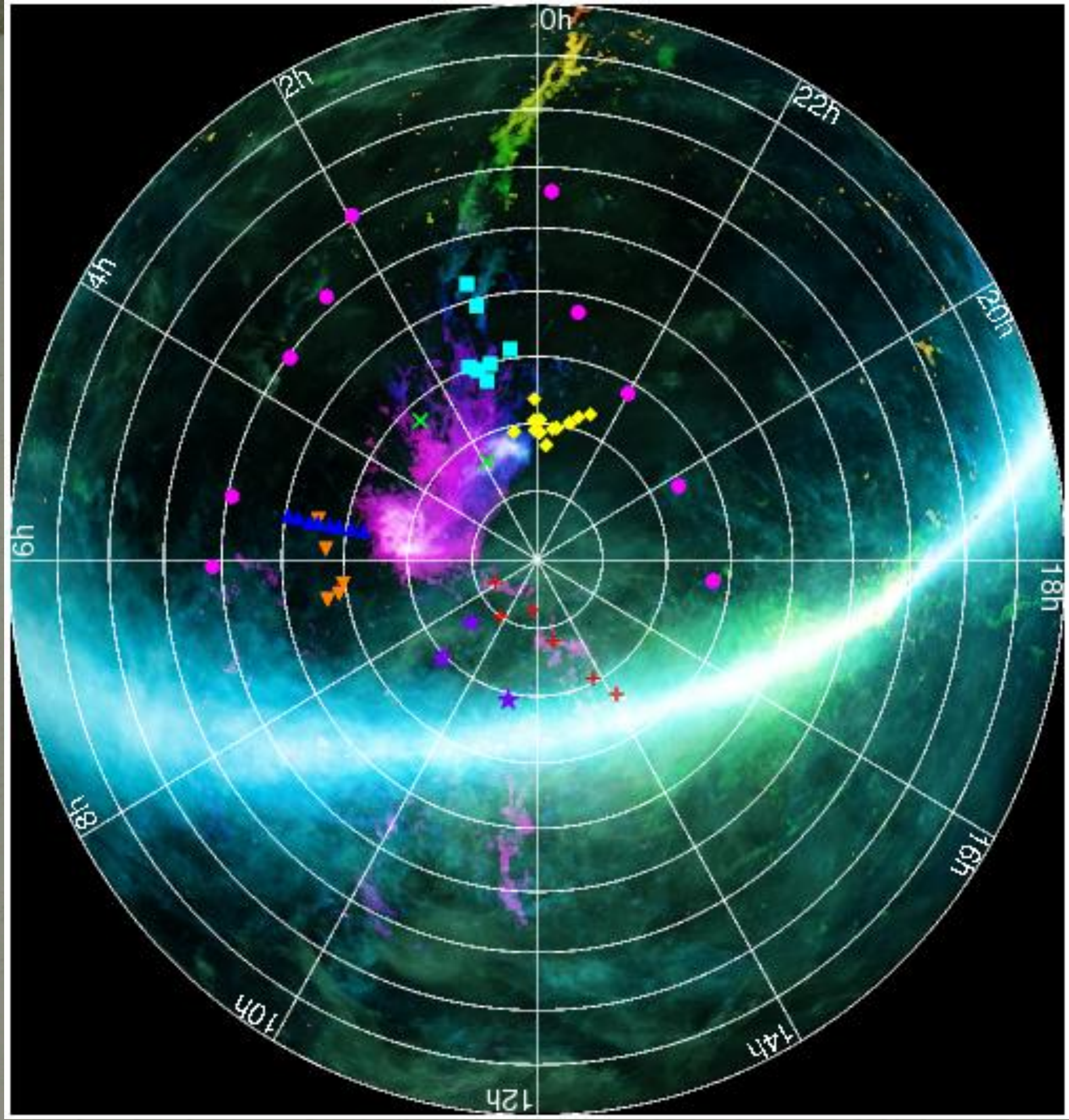
The Clouds & the MW in a single plane ..



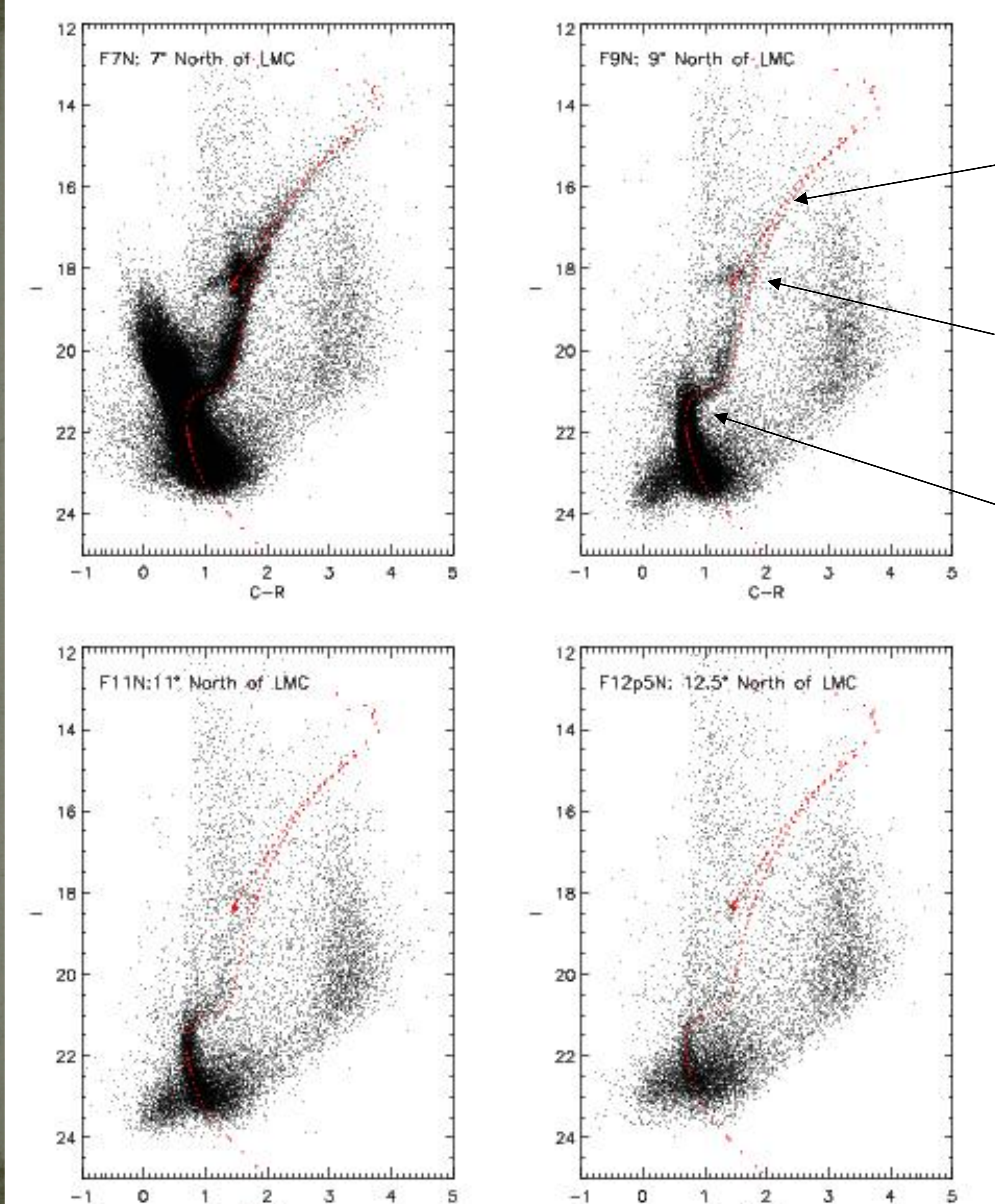


(*van der Marel 2001*: AJ, 122, 1827V)

- *The center shift in the LMC in the last 40Myr may be the result of the combined effect of*
- **The gravitational attraction of the Galaxy *(on the gas of the LMC disk)***
- **The movement of the LMC towards the East *(causing compression of gas and star formation in the East)***
- *There are difficulties in disentangling the effect of the LMC, and the Galaxy on the SMC*



Outer Limits Survey – Search for the disk and halo Survey using 4m Blanco (Saha et al. 2010)



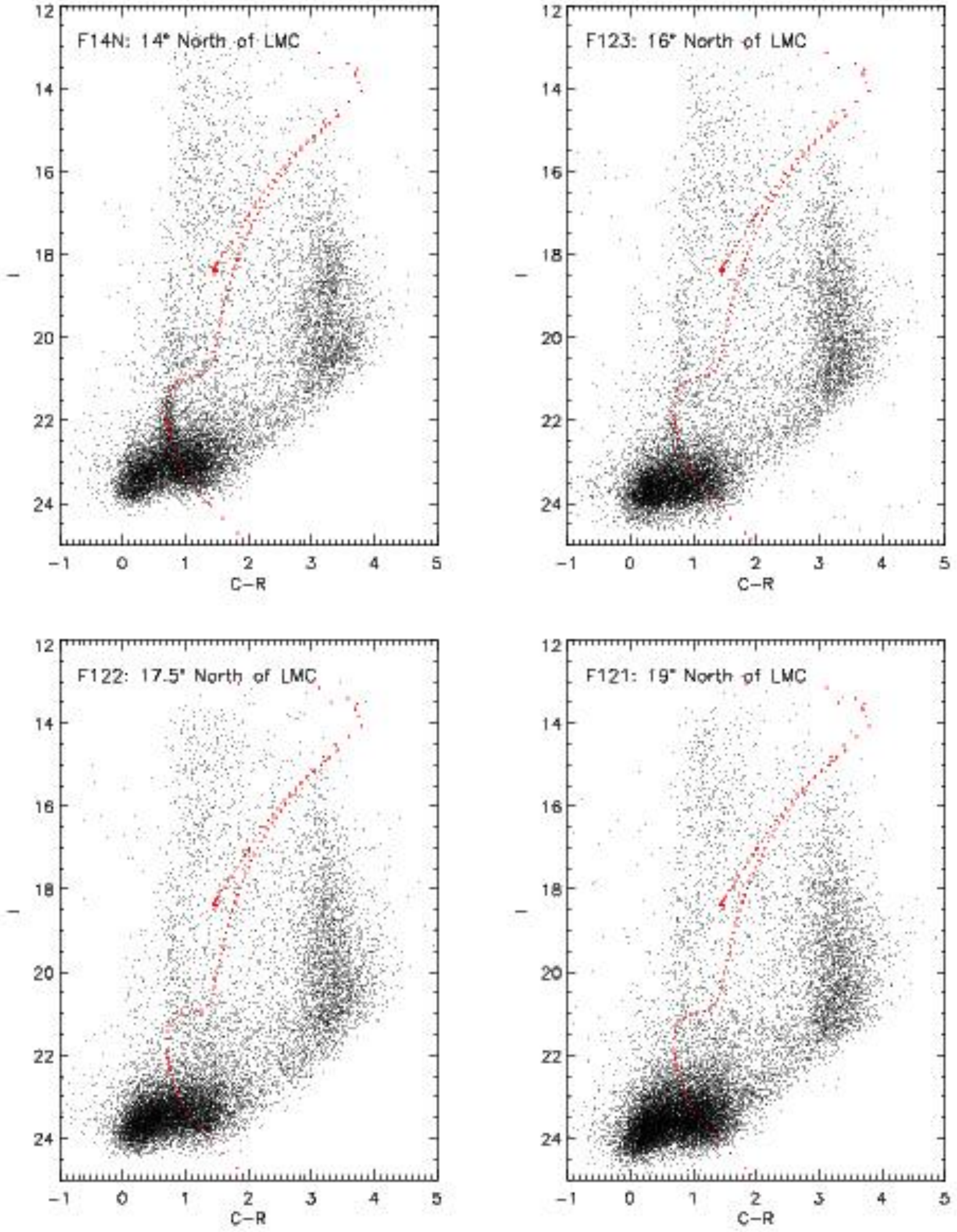
Red Giants -4m class

RR Lyrea – 8m class

MS Stars - GSMT

(Kinematics)

Saha et al. 2010



Disk till 16 degree North

No detectable Halo

Stellar density drops after 9 deg

Saha et al. 2010: AJ, 140, 1719S

Summary

- LMC – no prominent halo – a major merger formed the disk - 10 Gyr
- Early disk formation, structure of the disk more or less the same throughout (10,000Myr – 100Myr)
- Deviations, warps and thick disk – indicative of minor mergers, interactions
- SMC – no prominent halo
- Spheroidal/ellipsoidal structure : 1- 10 Gyr
- A major merger at 4 -5 Gyr
- Highly inclined disk of younger population and gas

- LMC & SMC formed separately and have different early evolution. Important to understand when and how they became binaries.
- Their recent star formation dictated by the proximity and motion in the Galactic halo

- **An off centred inward radial propagation of star formation in the LMC, within the last 100Myr**
- **A NE shift in the center of stellar distribution is present in the LMC, within the last 40Myrs. This can be the resultant effect of the gravitational attraction of the Galaxy & the movement of the LMC in the Galactic halo.**
- **In the SMC, we do see a shift in the center of density distribution of younger population towards the LMC. But it is difficult to differentiate the gravitational effect of the Galaxy & LMC on the SMC, can be a combined effect.**
- **Valuable to model the recent interactions between the clouds and the Galaxy. Also it provides constraints for the density of the Galactic halo in the direction of movement of the Clouds**

Inner kinematics of the MCs –AAOmega – spectra of 20,000 stars (Andrew Cole, UTAS)

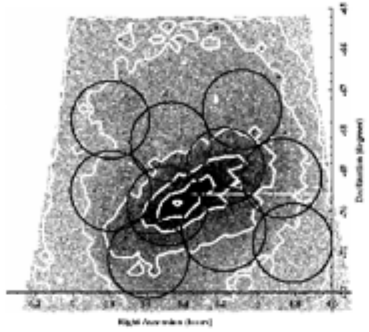
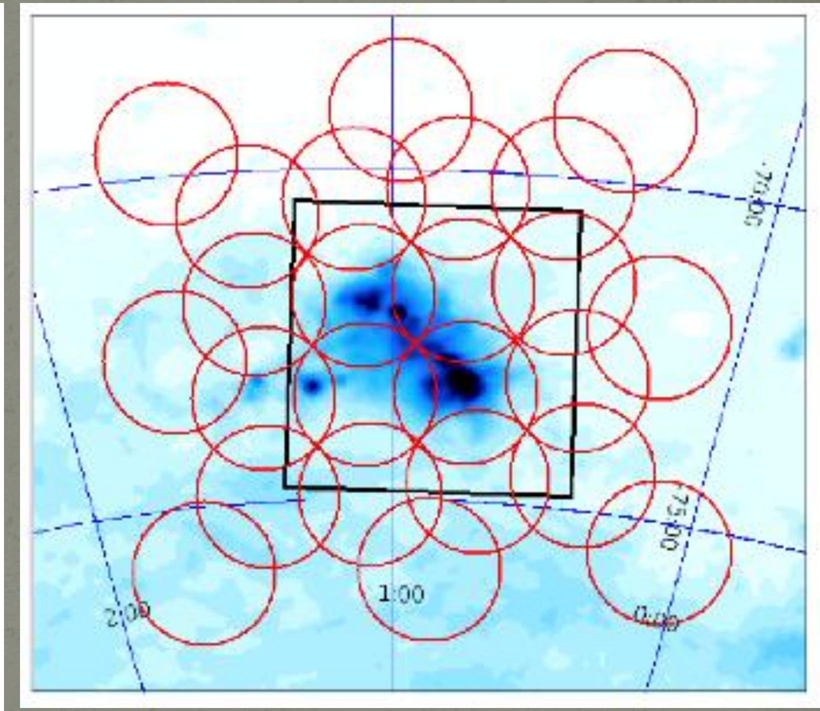


Figure 1: Density map of potential targets consisting of 1.7×10^5 stars with $1 \leq V-I \leq 3$ and $12 \leq I \leq 15$ from the catalogue of Zaritsky et al. (2004), binned to 2′ resolution. Contours show the (0.25, 0.5, 1.25, 2.5, 4.5, 6.5) arcmin^{-2} isopleths. Ten circles 2° in diameter are shown, indicating the placement of the 2dF fields to sample the bar with maximum efficiency. We will map the radial velocity of the inner LMC with a large enough sample to detect any differences in the rotation curve of the disk and bar.



Aiming to get chemo-dynamics of about 20,000 stars

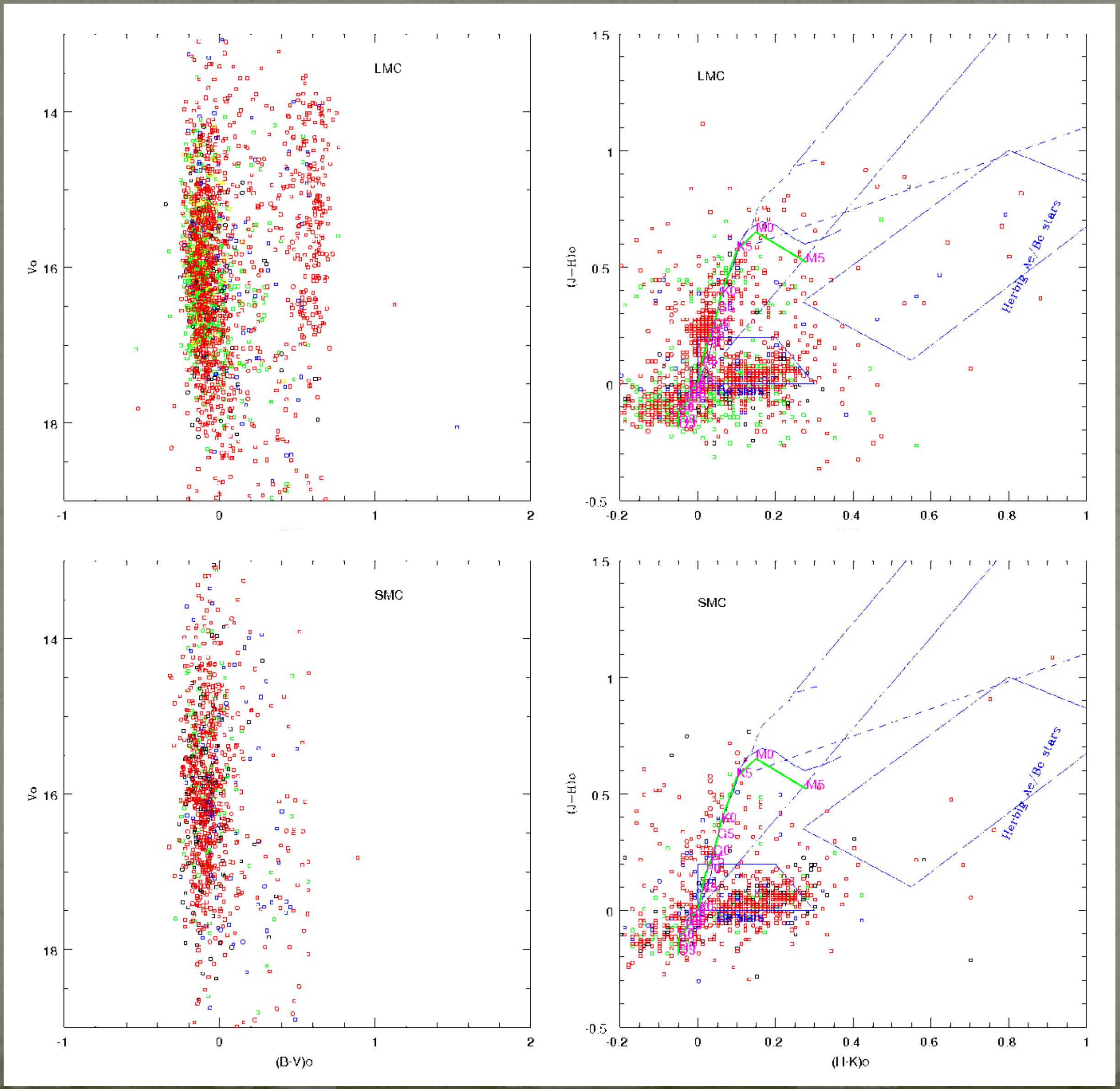
Cole, A. A. et al., 2005: AJ, 129, 1465C

Ongoing studies

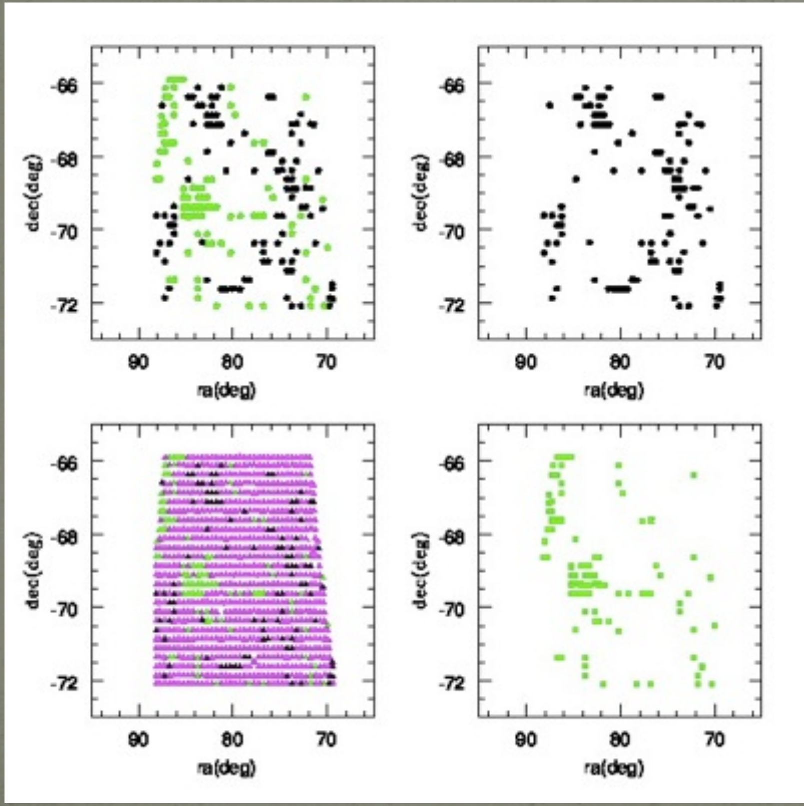
- Structure of the Clouds using IR data
- Kinematics of stars and gas
- Metallicity gradient across the Clouds Star formation history of the MCs between 1-9 Gyr
- Effect of metallicity on stellar evolution:
- 1. Properties of stars with fast rotation (Be stars)
- 2. Mass loss during Helium flash – fraction of
  red clump stars with IR excess

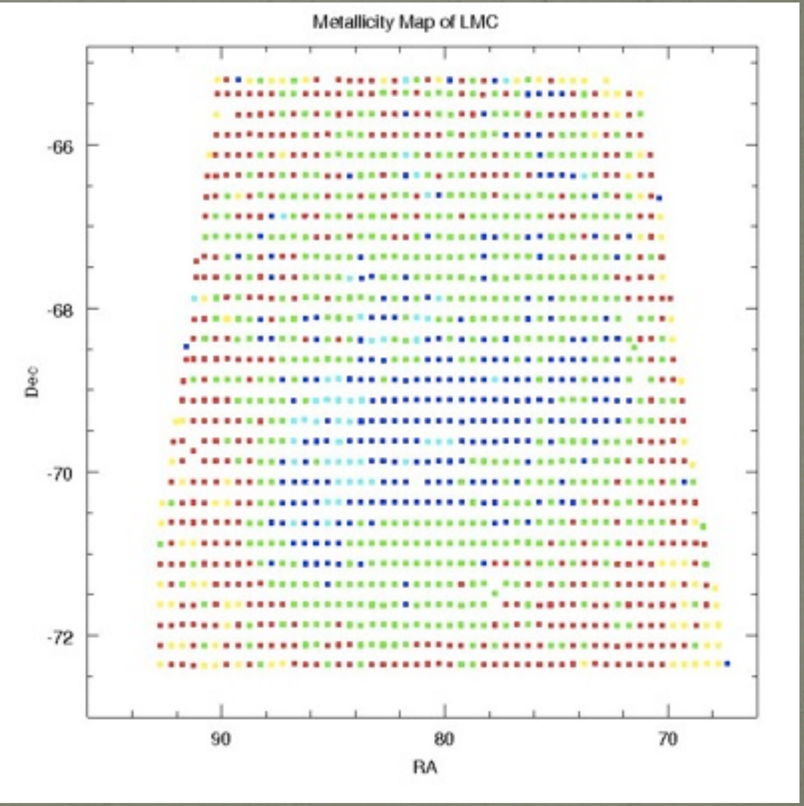
New Type of Be stars in the LMC (Galaxy-LMC-SMC)

Paul, Subramaniam, Mathew, Mennickent, Sabogal (to be submitted to MNRAS)

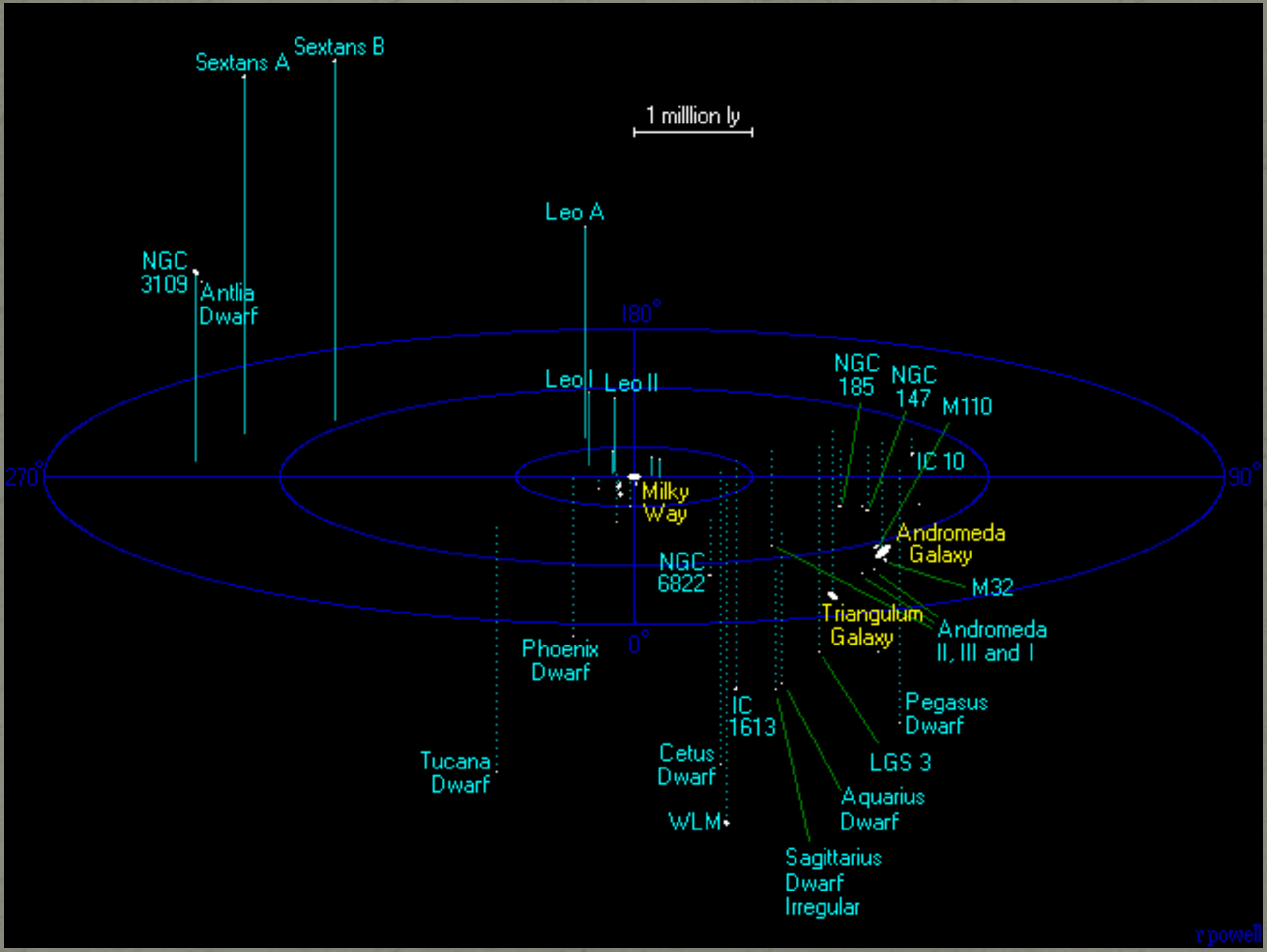


Variation in mass loss (LMC) – SFH or metallicity?





Local Group of galaxies



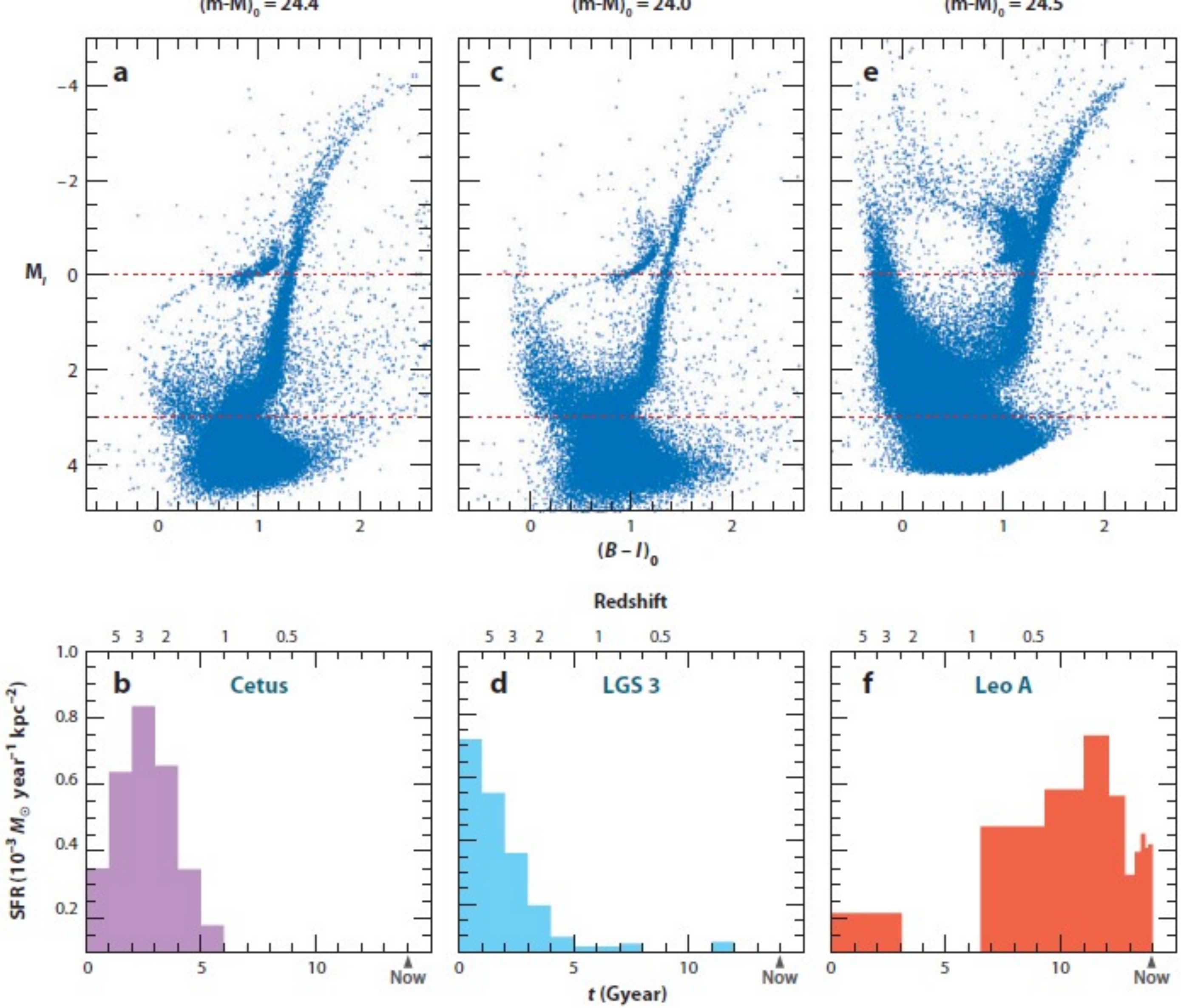
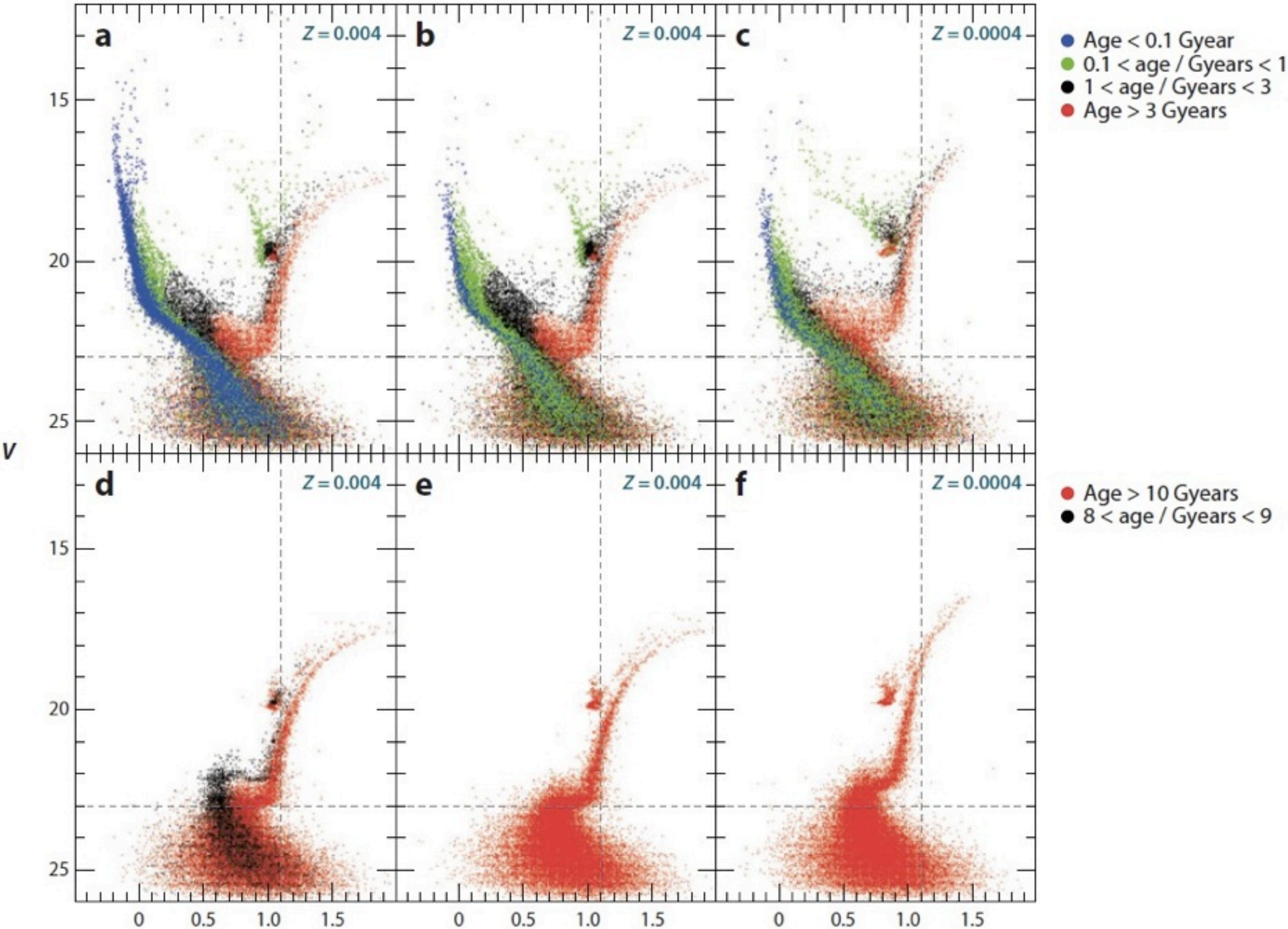


Figure 5

Hubble Space Telescope/Advanced Camera for Surveys (HST/ACS) color-magnitude diagrams (CMDs) and star-formation histories (SFHs) for three Local Group dwarf galaxies: (a,b) Cetus, a distant dwarf spheroidal galaxy (M. Monelli & the LCID team in preparation); (c,d) LGS 3, a transition-type dwarf galaxy (S. Hildago & the LCID team, in preparation); and (e,f) Leo A, a dwarf irregular (Cole et al. 2007). These results come from the LCID project (Gallart & the LCID team 2007, Cole et al. 2007), which is a large program designed to exploit the exquisite image quality of the HST/ACS to obtain uniquely detailed CMDs going back to the oldest main sequence turn offs for a sample of dwarf galaxies. The SFHs come from synthetic CMD analysis and the ages are also

Tolstoy et al.,2009:ARA&A..47..371T



SFH of the LG galaxies

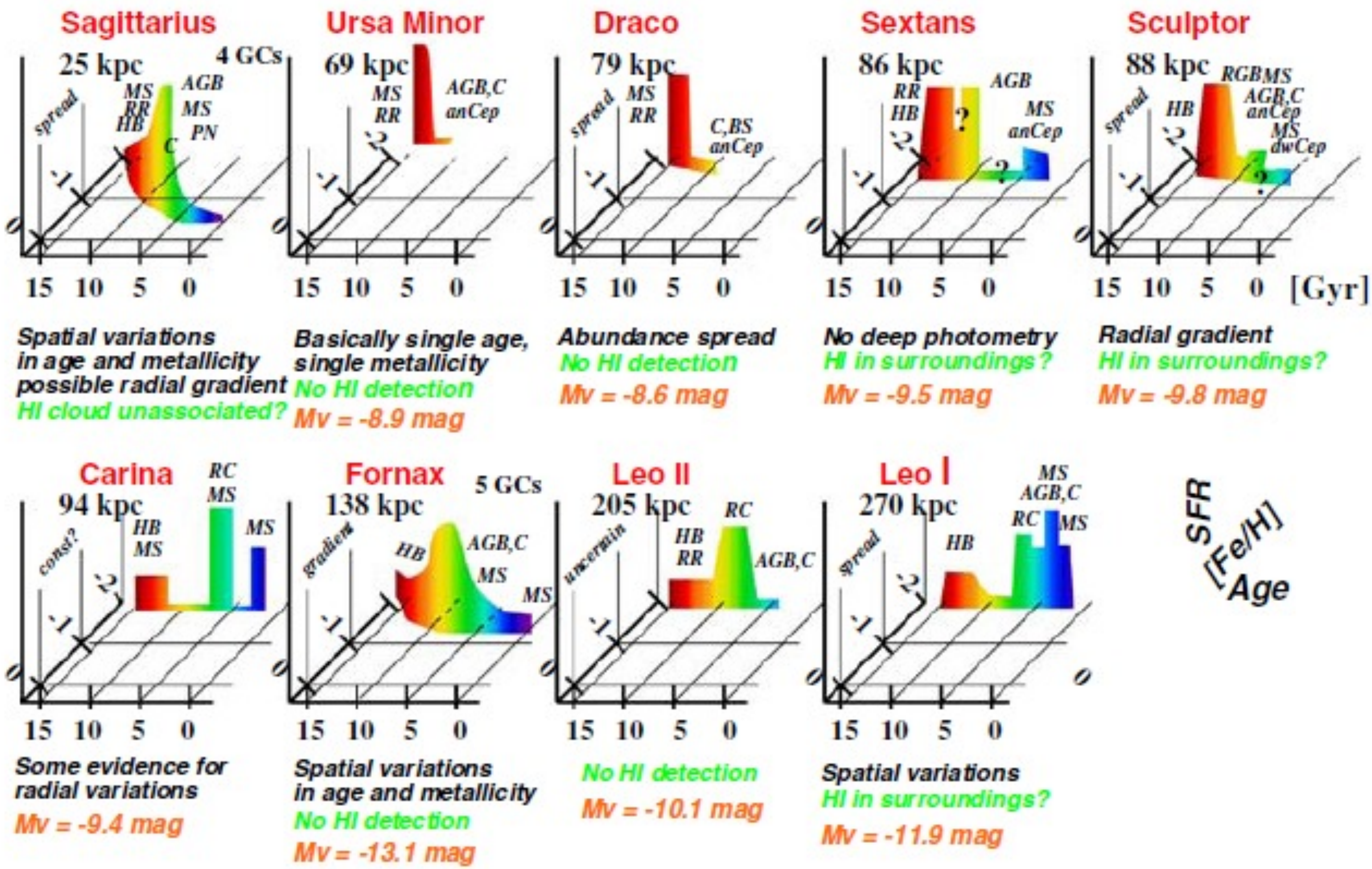
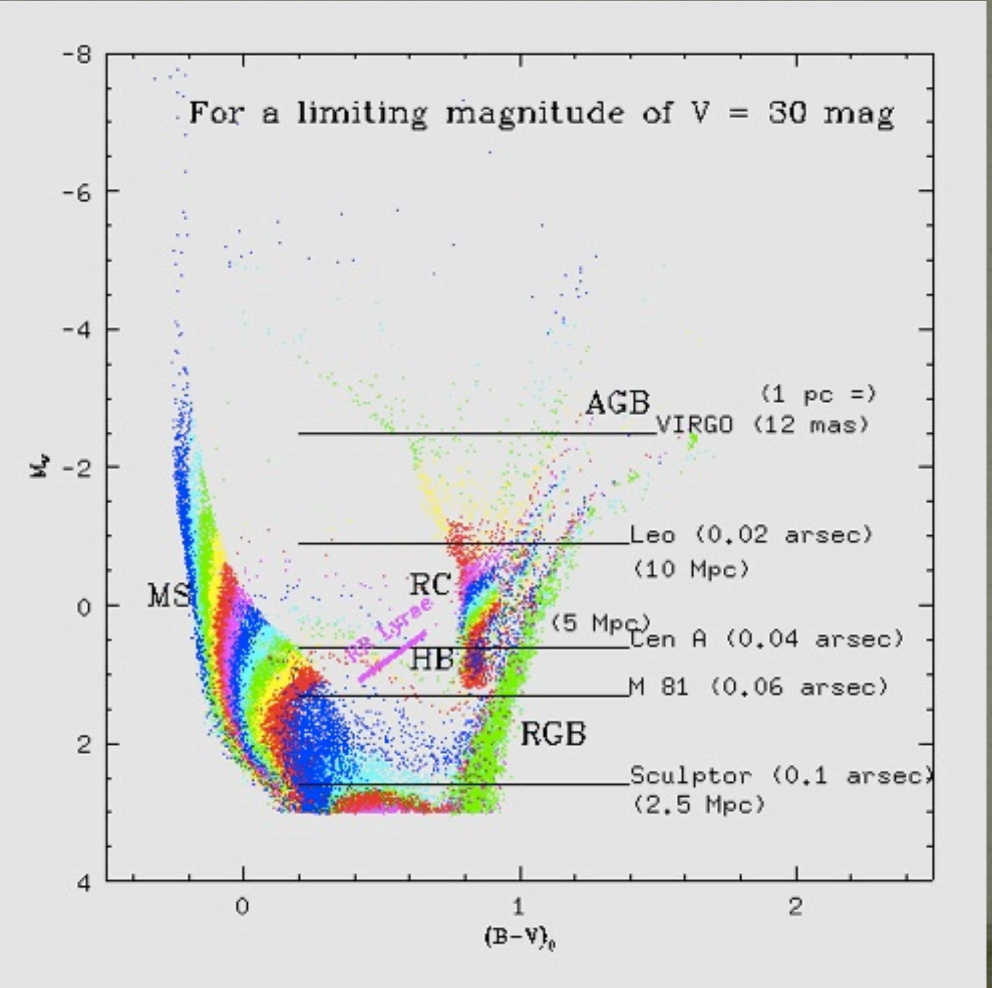


Fig. 13 Star formation histories of Milky Way dwarf spheroidal satellites. Each population box gives a schematic representation of star formation rate (SFR) as a function of age and metallicity. (From Grebel 2000. Courtesy of Eva Grebel, and Fabio Favata (editor))

Resolved Stellar populations in nearby galaxies

- Stellar IMF up to 0.5 M in the nearest galaxies
- Chemo-dynamics and structure of the nearby galaxies
- Complete census and properties of galaxies in the LG
- Direct detection of halo up to Cen A using RR Lyrae stars and Pop II stars
- Chemo-dynamics of M81/M82 systems
- AGB stars and upper MS in the Leo group
- Possibility of identifying stellar population in Virgo

Synthetic CMDs of heterogeneous resolved Stellar population in galaxies (Subramaniam 2005)



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