DECam and the Magellanic Clouds

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DECam Community Workshop

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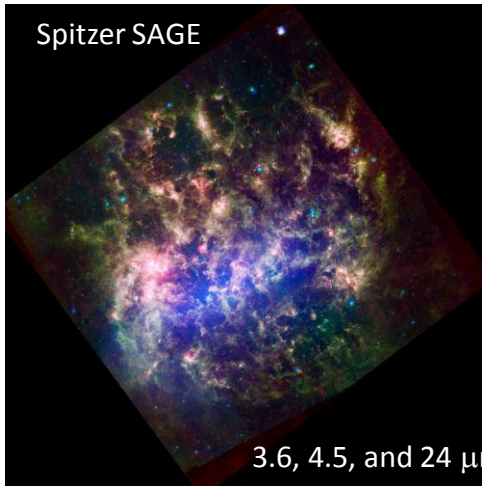
Motivation

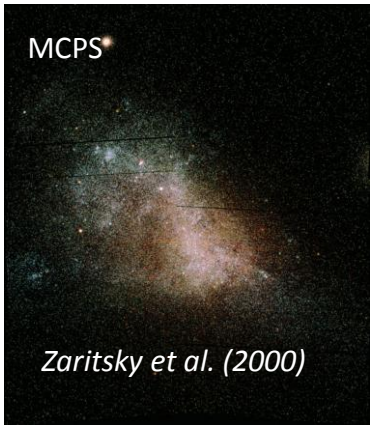
- The Magellanic Clouds are rich laboratories of astrophysical phenomena
- Their structure and stellar populations allow us to explore their evolution and history of interaction
- The DES will allow us to map Magellanic structure over a huge area, tens of degrees away from the galaxy centers
- We wish to build on the DES by adding imaging of areas that are of great interest for Magellanic Cloud structure
- This survey will be of great value to the stellar populations community

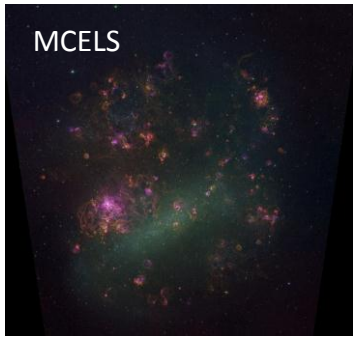
Magellanic Cloud Surveys

- MCPS (*UBVI*)
- DENIS (*IJK*)
- 2MASS (JHK_s)
- SAGE (IRAC+MIPS)
- HI 21cm (ATCA, Parkes)
- CO (NANTEN)
- OGLE, OGLE-II, OGLE-III (*BVI*)
- MACHO (*BR*)
- SuperMACHO (*V+R*)
- VMC (YJK_s)
- Various optical spectroscopic surveys

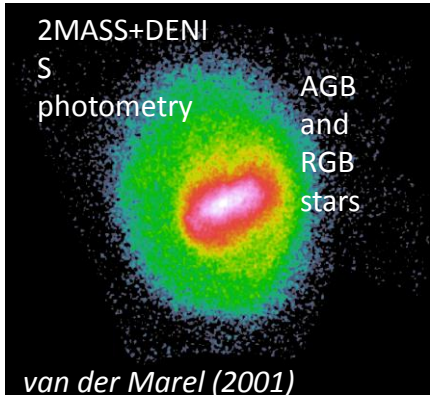


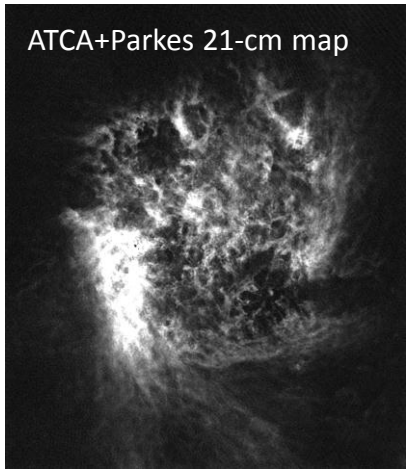
Meixner et al. (2006); courtesy of K. Gordon





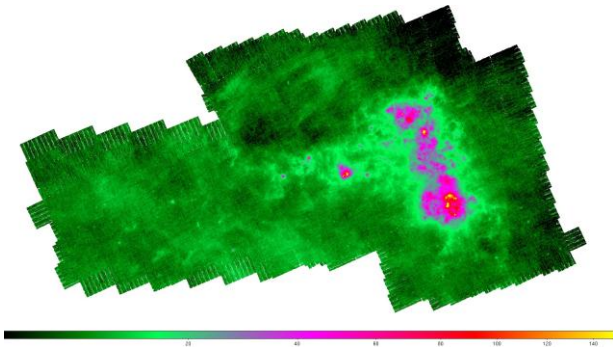
C. Smith and S. Points





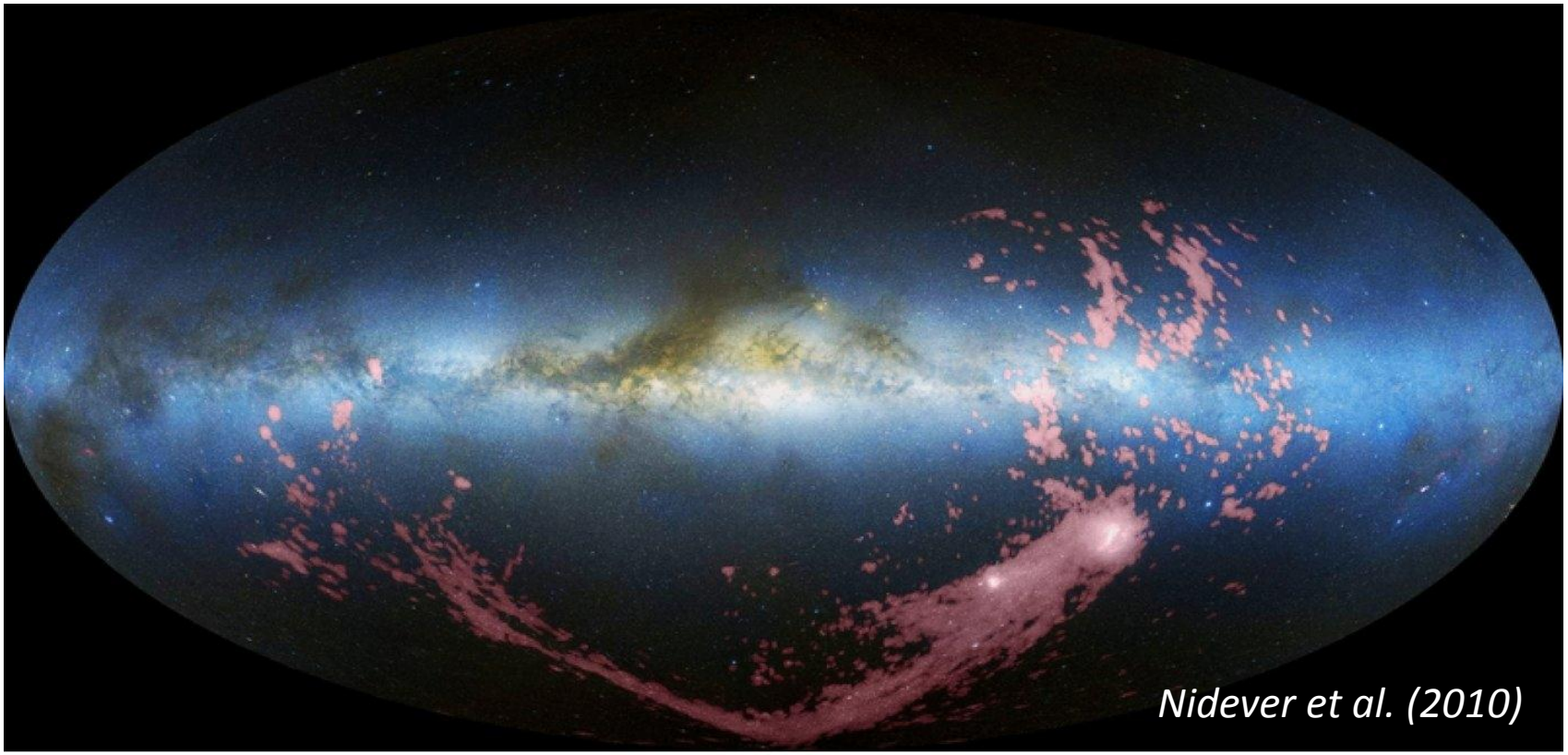
Kim et al. (1998); Staveley-Smith et al. (2003)

Spitzer 160 μm



Gordon et al. (2011)

The Larger Scale Environment



Example results from surveys

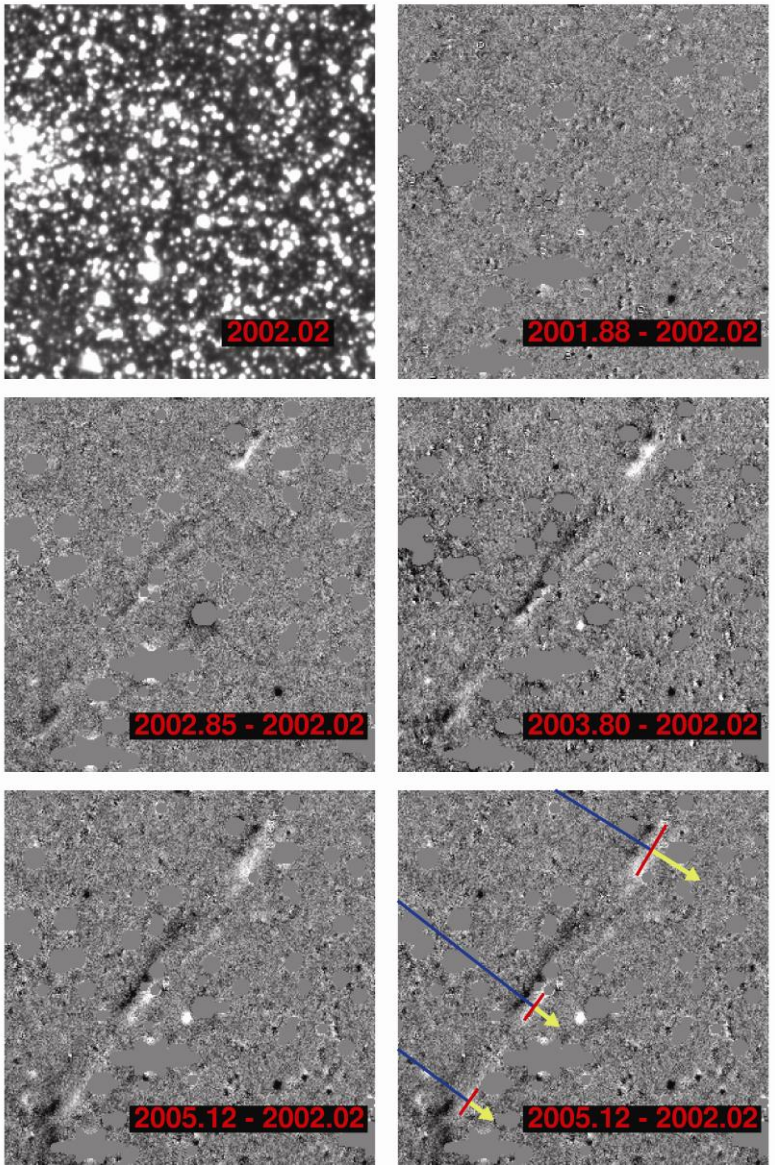
Supernova light echoes!

For Type Ia SN, assuming:

- Perpendicular dust sheet at z=150 pc
- $V_{max} = V_{max,1987A}$ - 3.5 mag

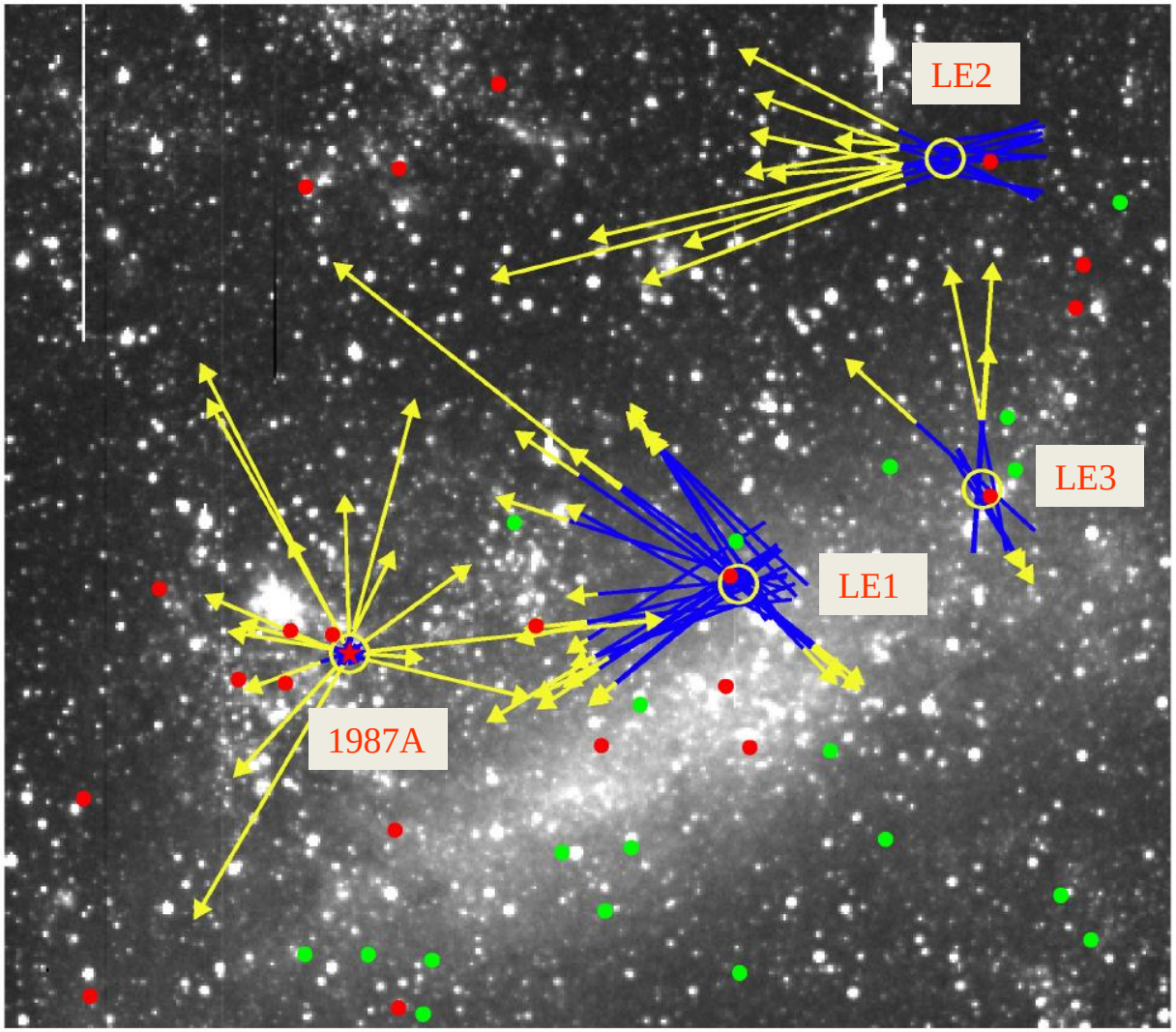
At 500 yr, Σ_V = 22.5 mag arcsec^{-2}, ρ = 0.29 (250 pc)

At 1000 yr, Σ_V = 24 mag arcsec^{-2}, ρ=0.5 (420 pc)



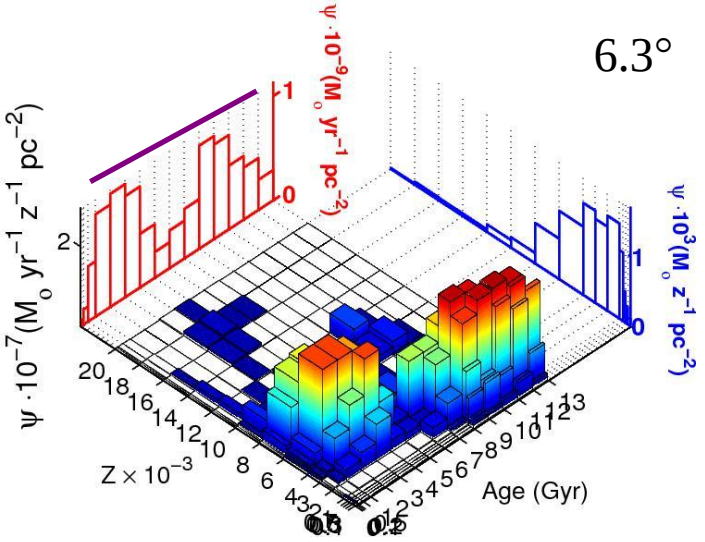
Light Echoes from “Ancient” SNe in the LMC

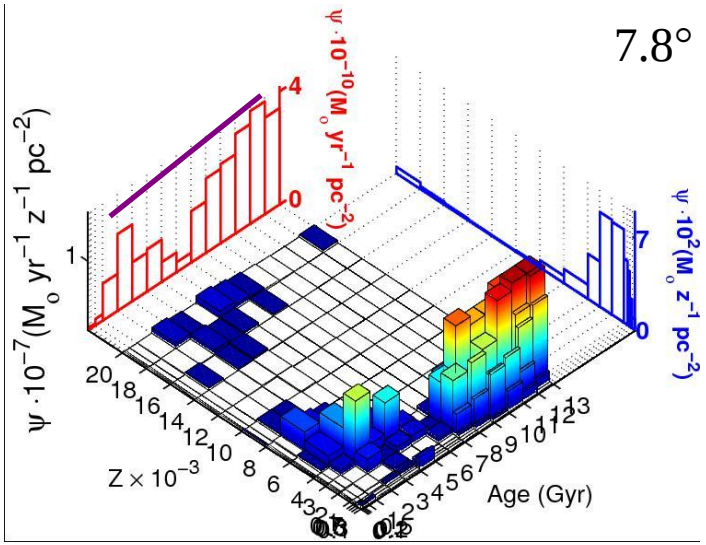
- Four distinct light echo groups besides SN1987A
- Surface brightness between 22.5 and 24 mag arcsec^{-2} in “VR”
- Apparent proper motion between 0.7*c* and 1.8*c*

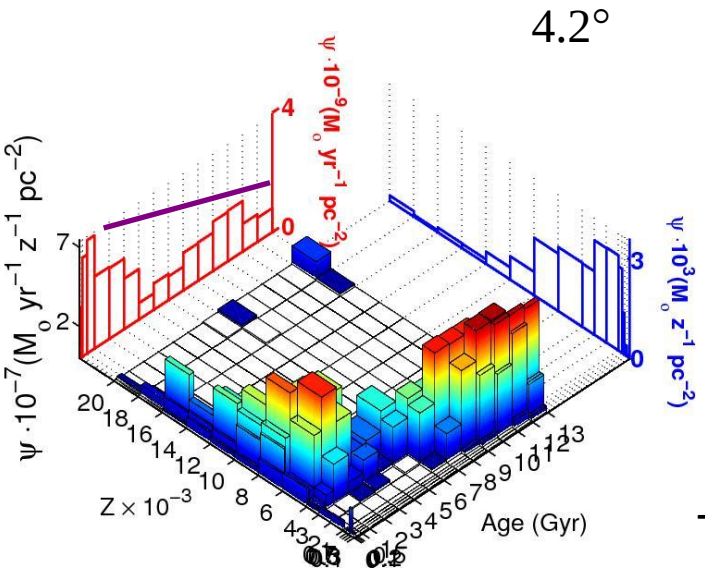


Rest et. al. (2006)

Population gradients





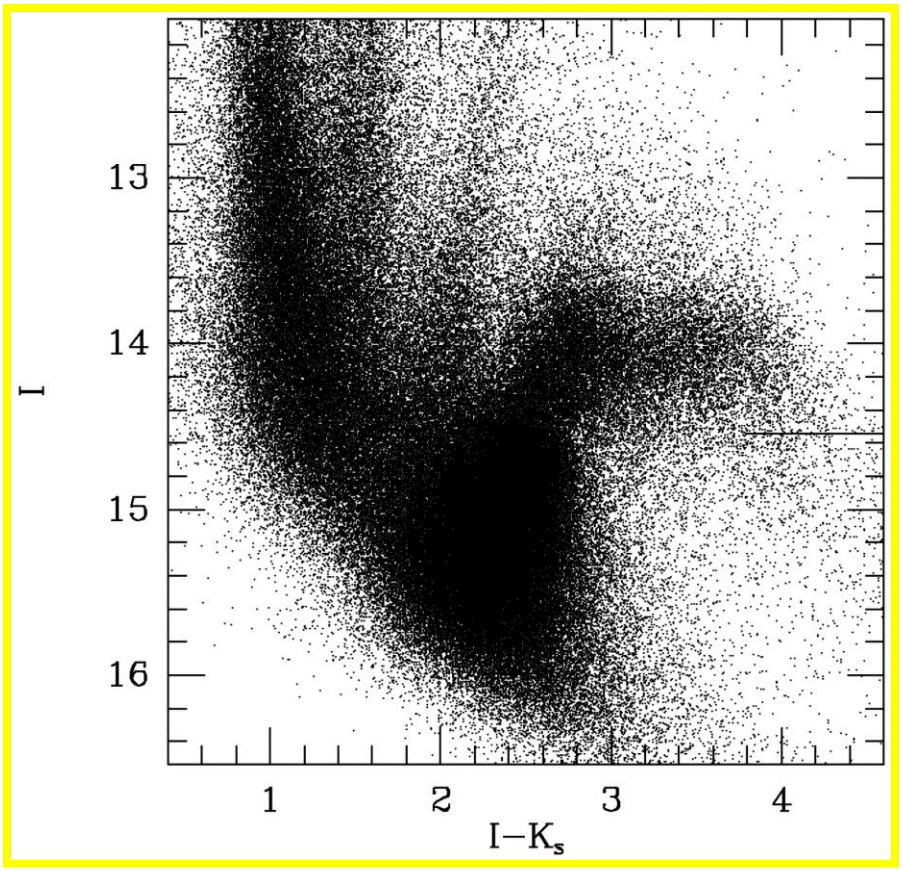


From I. Meschin PhD thesis, in prep.

- Two main events of SF at 8-12 Gyr and 2-5 Gyr ago, at all radii
- depressed SF between 5 and 8 Gyr
- the ratio young/old decreases with radius
- the mean metallicity decreases with radius

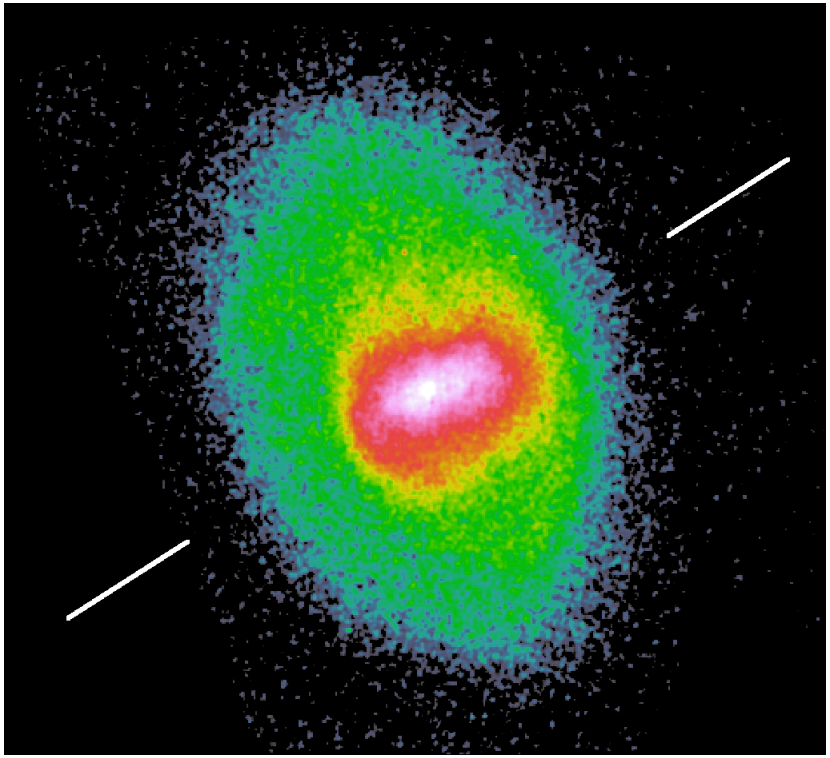
Thanks to Matteo Minelli and Alistair Walker for this slide

The LMC's Geometry



2MASS + DENIS color-magnitude diagram

van der Marel & Cioni (2001)



Deprojected stellar density distribution

i=34.°7 ± 6.°2 Θ=122.°5 ± 8.°3

The SMC's Geometry

- Individual SMC Cepheids
- End-to-end depth of ~20 kpc

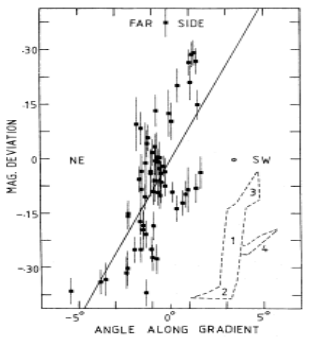


Figure 7. As Fig. 6 but for SMC. The dashed outline sketches in miniature (1) the main bar (2) the near arm (3) the far arm and (4) the material extending from the centre to the SW and overlapping in projection against the far arm.

abscissa is angle in degrees and the ordinate is magnitude in units of 0.0389 mag, such that the x- and y-axes correspond to equivalent scales of linear distance. The angle is measured positively from the coordinate centre in the direction of the maximum distance gradient, which points roughly SW in each case. In effect, Figs 6 and 7 show the Clouds as they might appear viewed from along their line of nodes in the plane of the sky. The filled circles in each plot show Cepheids in the solution. The error bars (Appendix A) appear large because of the large magnification of the y-coordinate to match the x-coordinate in linear scale, and especially in the case of the LMC because of the method of data analysis. One Cepheid preceding the SMC (R Hyi = HV 6320) has excellent data but was excluded from the solution for being too inconsistent with a planar approximation, although it is no doubt a member of that galaxy (*cf.* open circle in Fig. 7).

Despite the apparent 'thickness' of the LMC Cepheid distribution, error analysis indicates that the spread is less than 2σ different from zero, if all estimated errors are uncertain by 20 per cent. Our model for the LMC is thus an inclined plane of insignificant thickness, tipped by $29 \pm 6°$ with the closest part at PA $52 \pm 8°$. The SMC appears to consist of a 5-to-1 central bar seen edge-on, a near arm (NE) and far arm (SW), and a mass of material pulled out of the centre of that galaxy, perhaps by the LMC, and seen in projection in front of the far arm in the SW (*cf.* sketch in Fig. 7). A model of a single inclined plane is obviously inadequate and error analysis shows that the residual line-of-sight scatter about the inclined-planar solution is very significantly different from zero. The size and direction of the maximum distance gradient is thus not a very meaningful quantity. An average of the results from the three solutions gives an inclination of $70 \pm 3°$ with the closest part at PA $58 \pm 10°$.

The line-of-sight scatter inferred for the SMC Cepheids (0.10–0.13 mag, depending on the model) is reasonable given that a planar model looks barely adequate to describe the SMC. The

Caldwell & Coulson (1986)

Structure at large radius

Pointed CTIO Mosaic-2 observations:

- Magellanic Bridge (Harris 2007)
- Carina (Muñoz et al. 2006)
- SMC periphery (Nidever et al. 2011)
- Outer Limits (Saha et al. 2010)

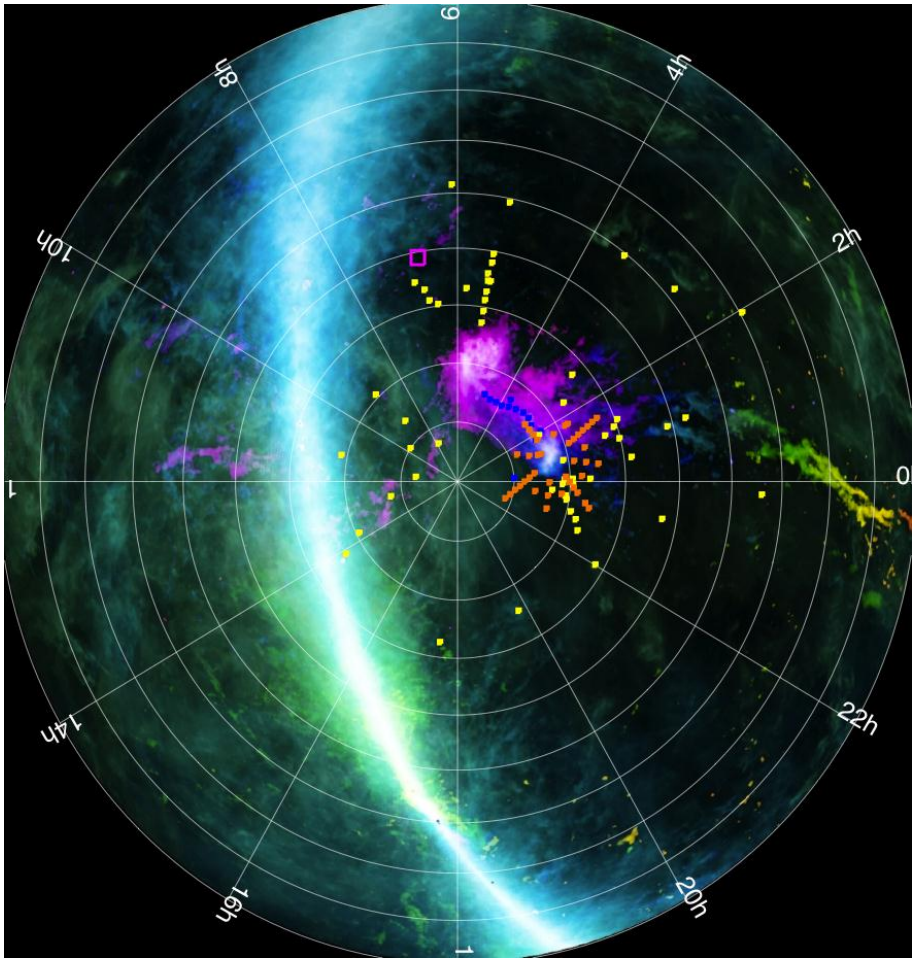
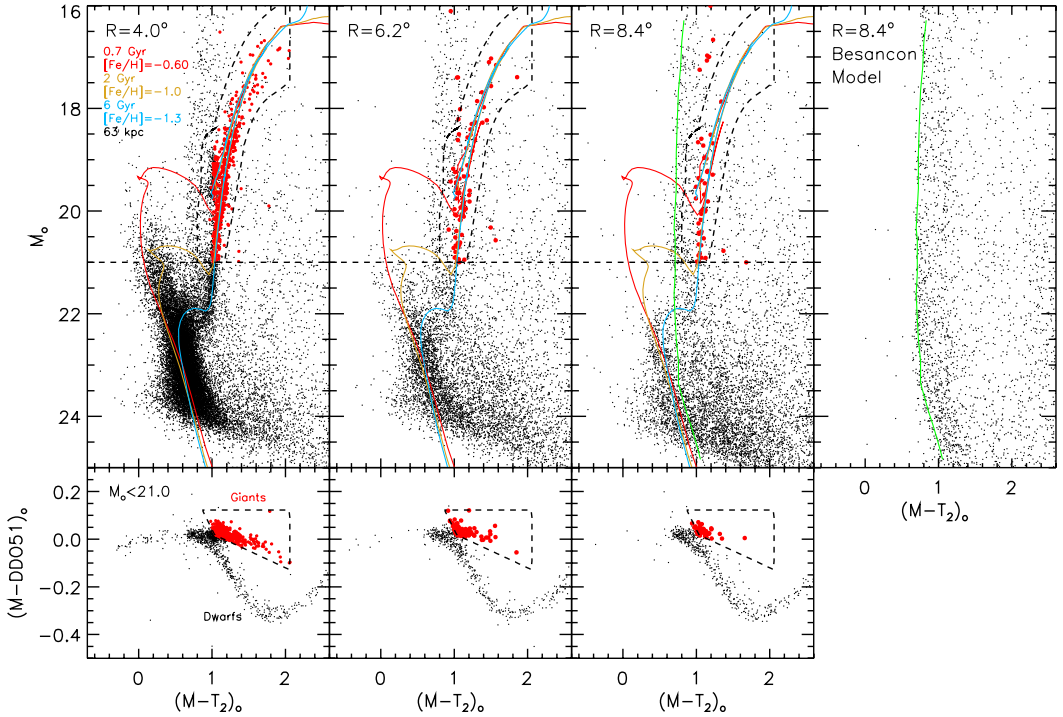
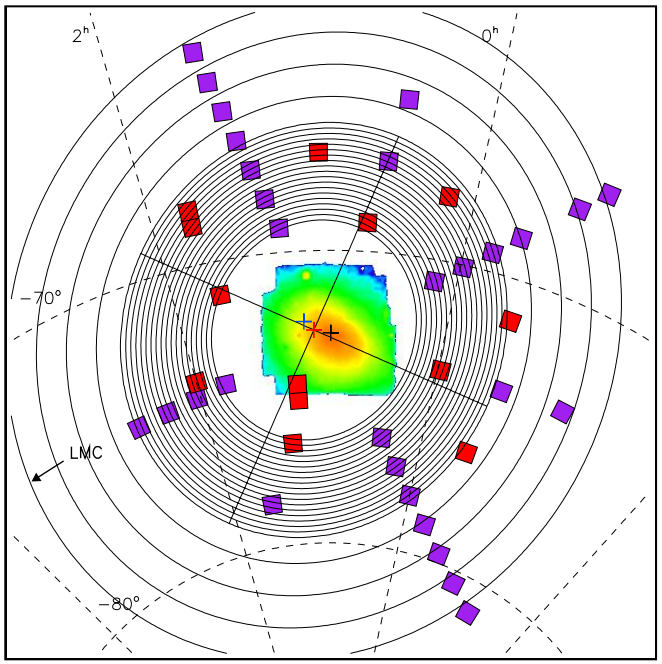


Image credit: S. Janowiecki and the Galactic All Sky Survey (McClure-Griffiths et al. 2009)

The Periphery of the SMC

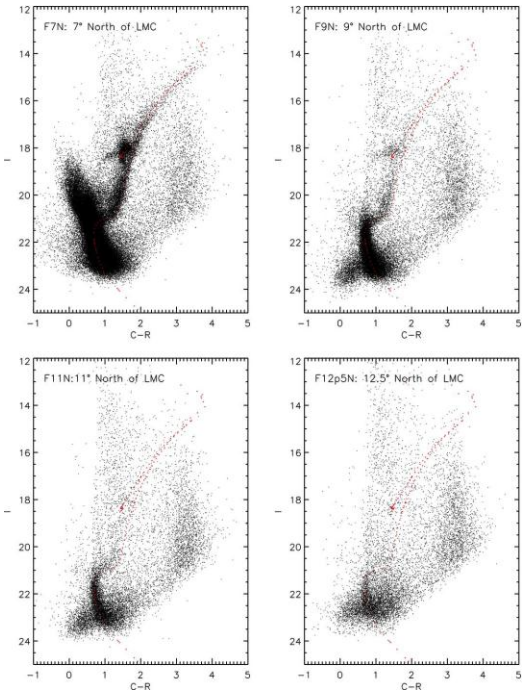


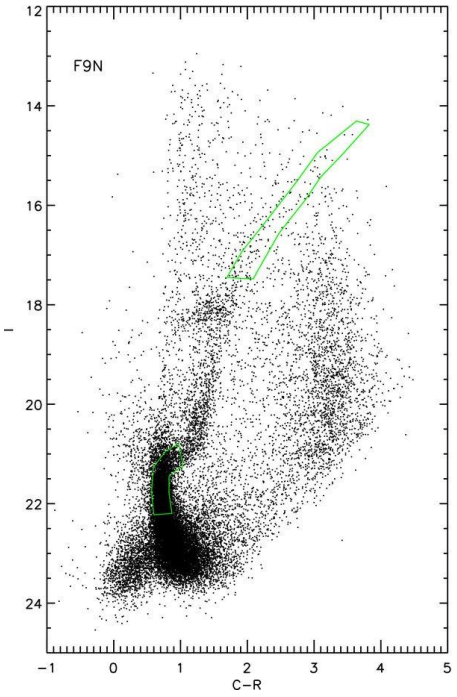


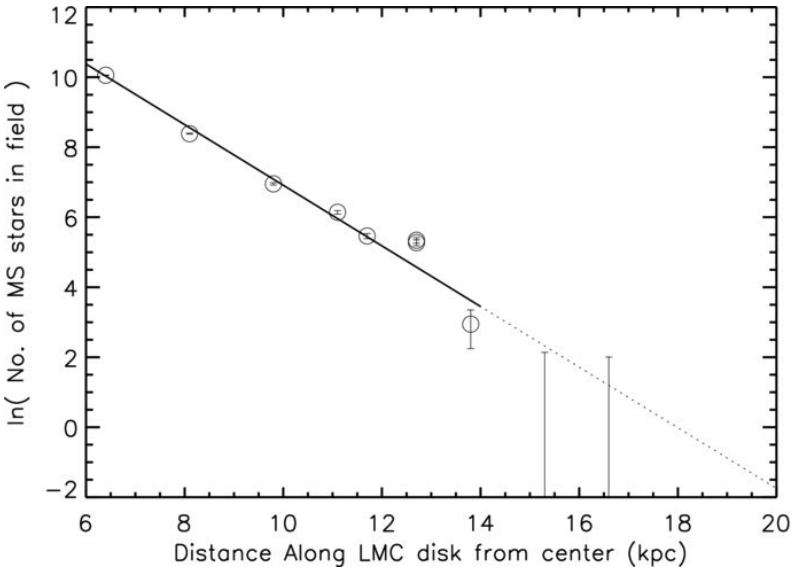
RGB stars as tracers

Nidever et al. (2011)

The Extended Disk of the LMC



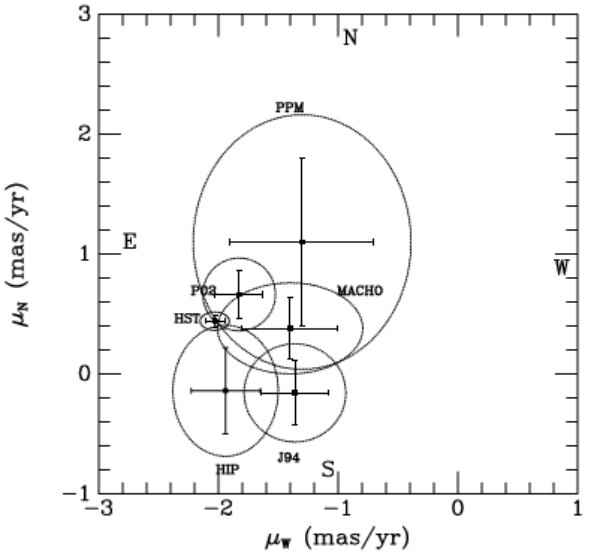




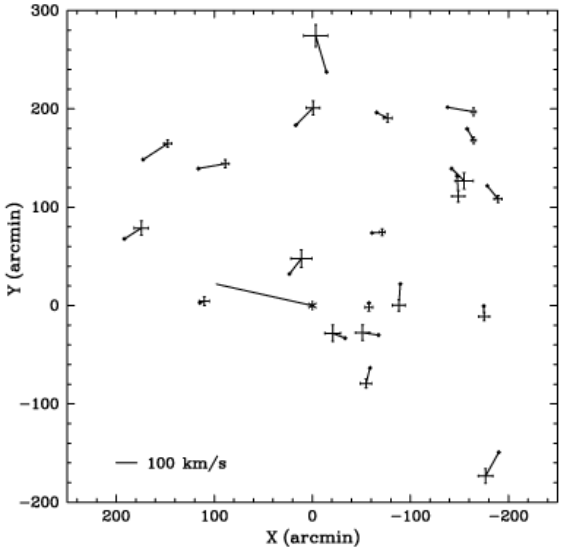
MSTO stars as tracers

Saha et al. (2010)

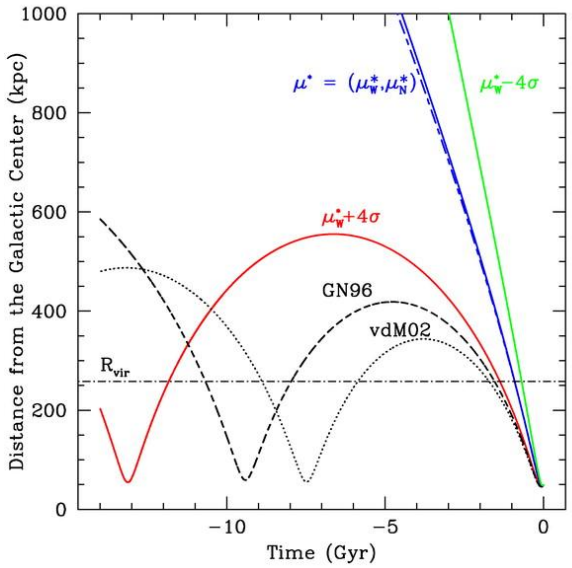
The Proper Motion of the LMC



Kallivayalil et al. (2006)



Piatek, Pryor, & Olszewski (2008)

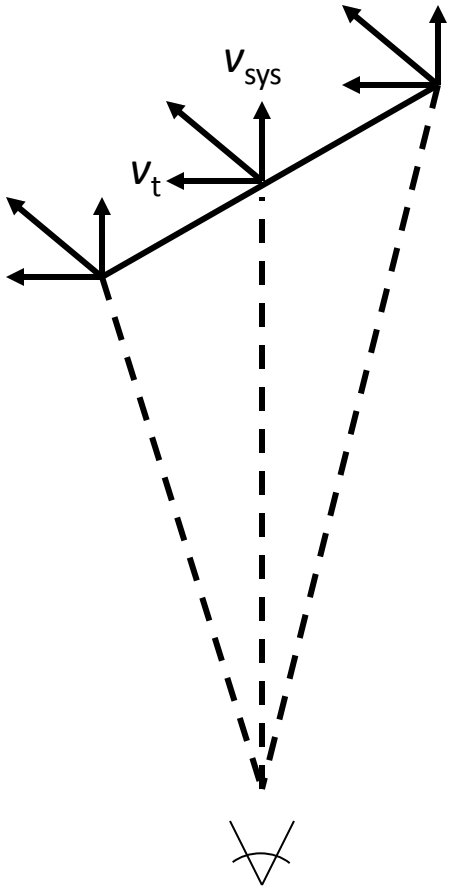


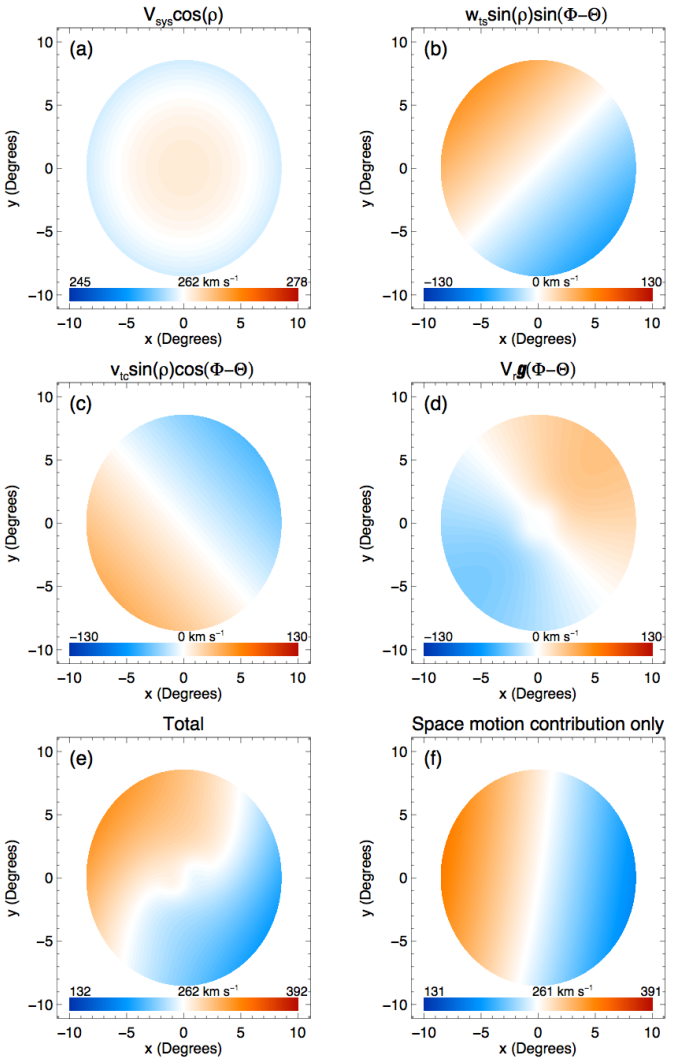
Besla et al. (2007)

The Magellanic Clouds on first infall…?

…but note alternative scenarios (Diaz & Bekki 2011)

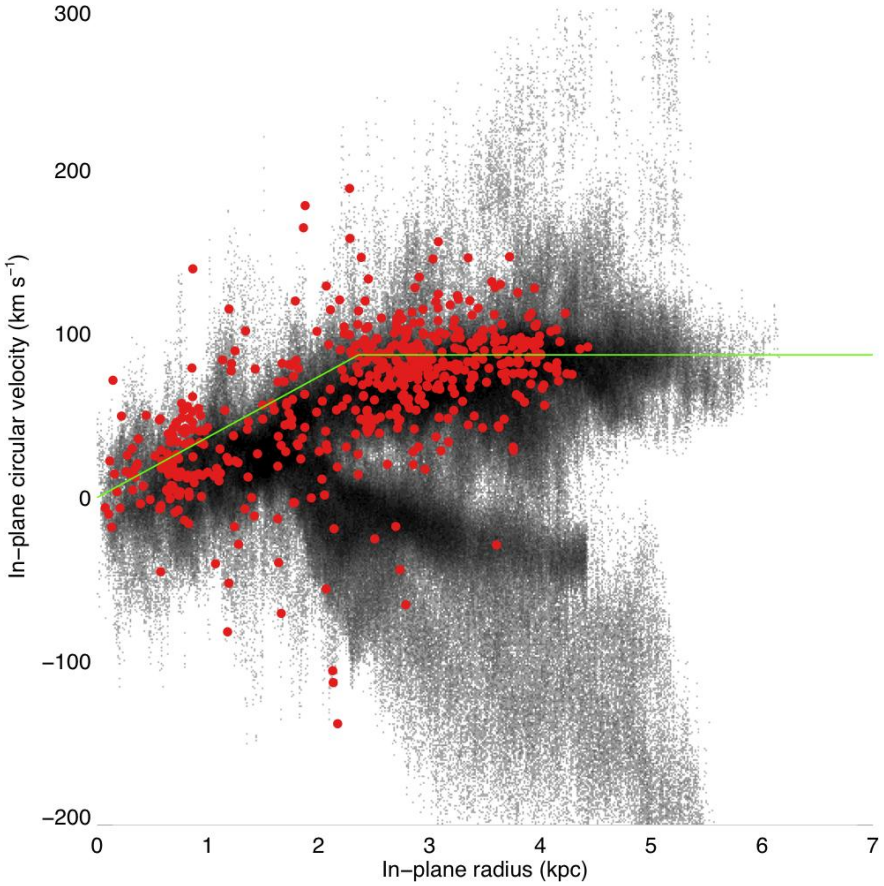
The Effect of the LMC's large angular extent on understanding kinematics



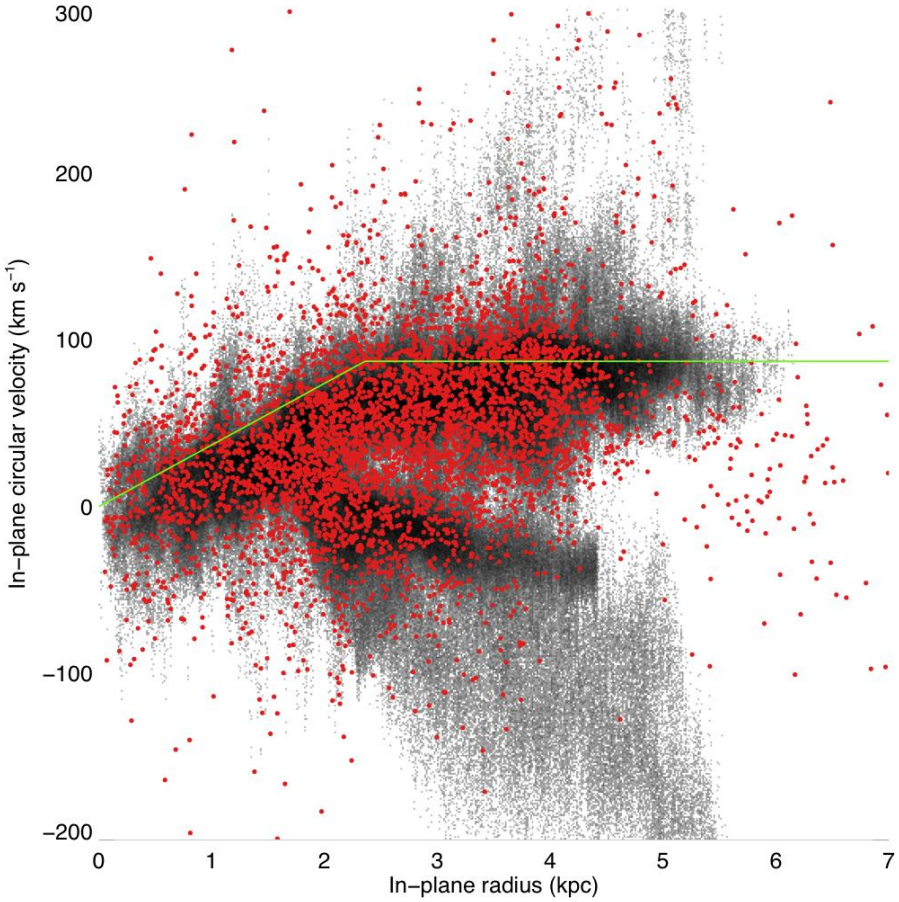


van der Marel et al. (2002)

A 5000-star LMC kinematic sample



RSGs only



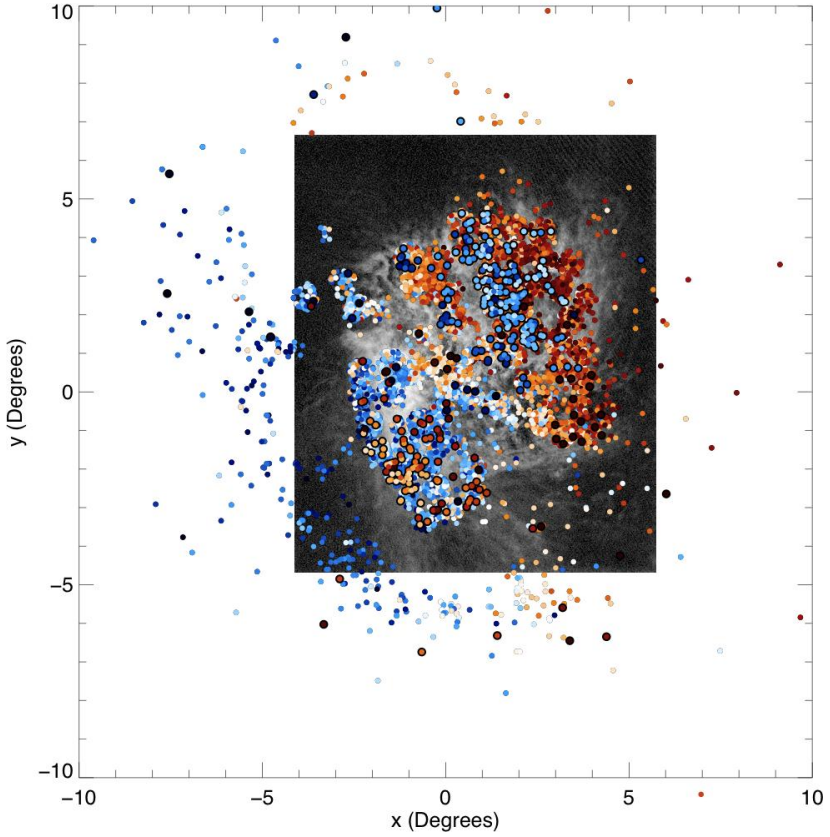
All stars

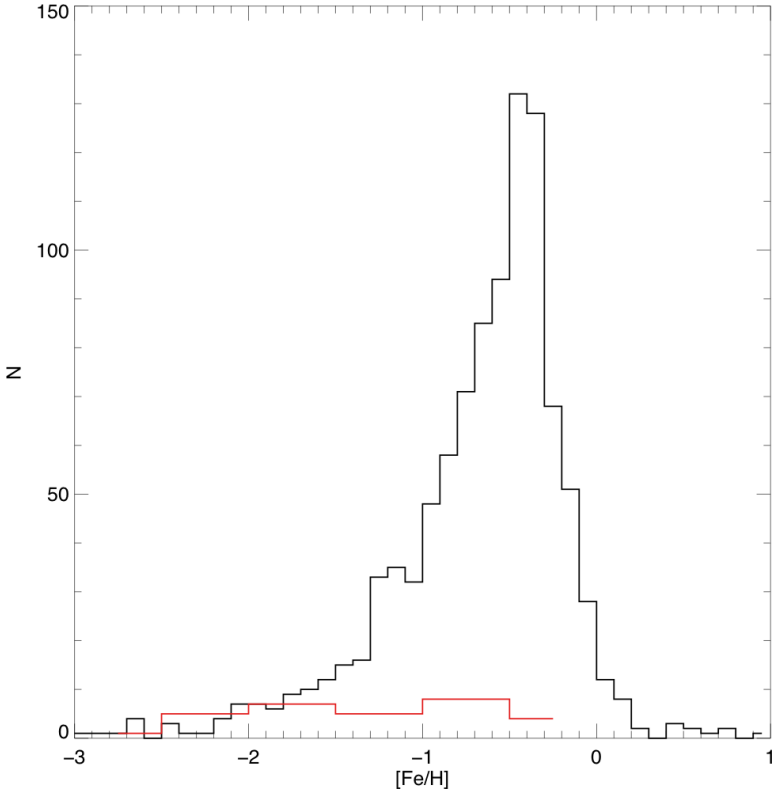
Fitting for v_{sys}, di/dt, θ, v_0, r_0

α=5h27m36s δ=-69 ˚52´ 12´´ i=34.˚7

Olsen et al. (2011)

An Accreted SMC population in the LMC

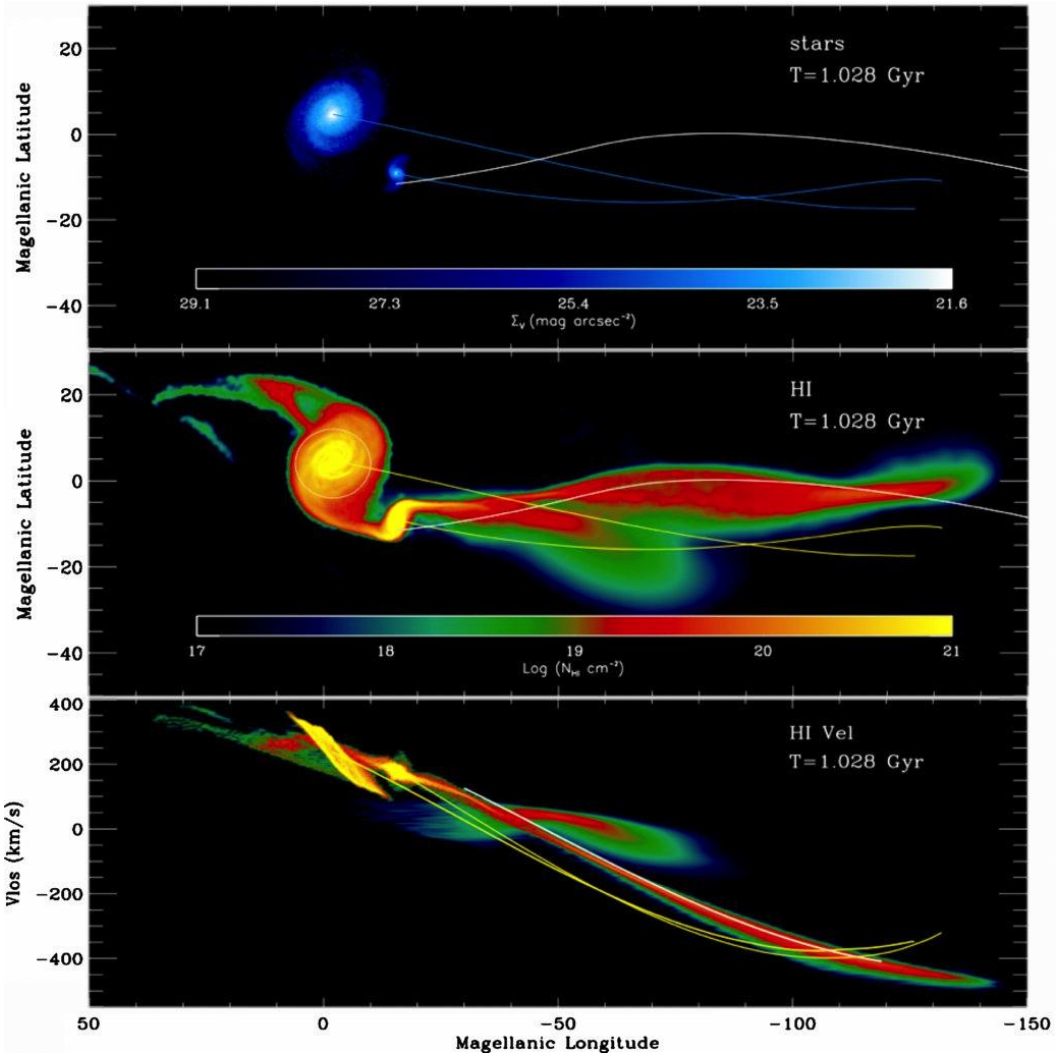




- Accreted population comprises ~5% of LMC stars
- Accreted stars share kinematic signature of HI streamers
- 30 Doradus as accretion-induced star-forming event?

A Formation Model for the Magellanic System

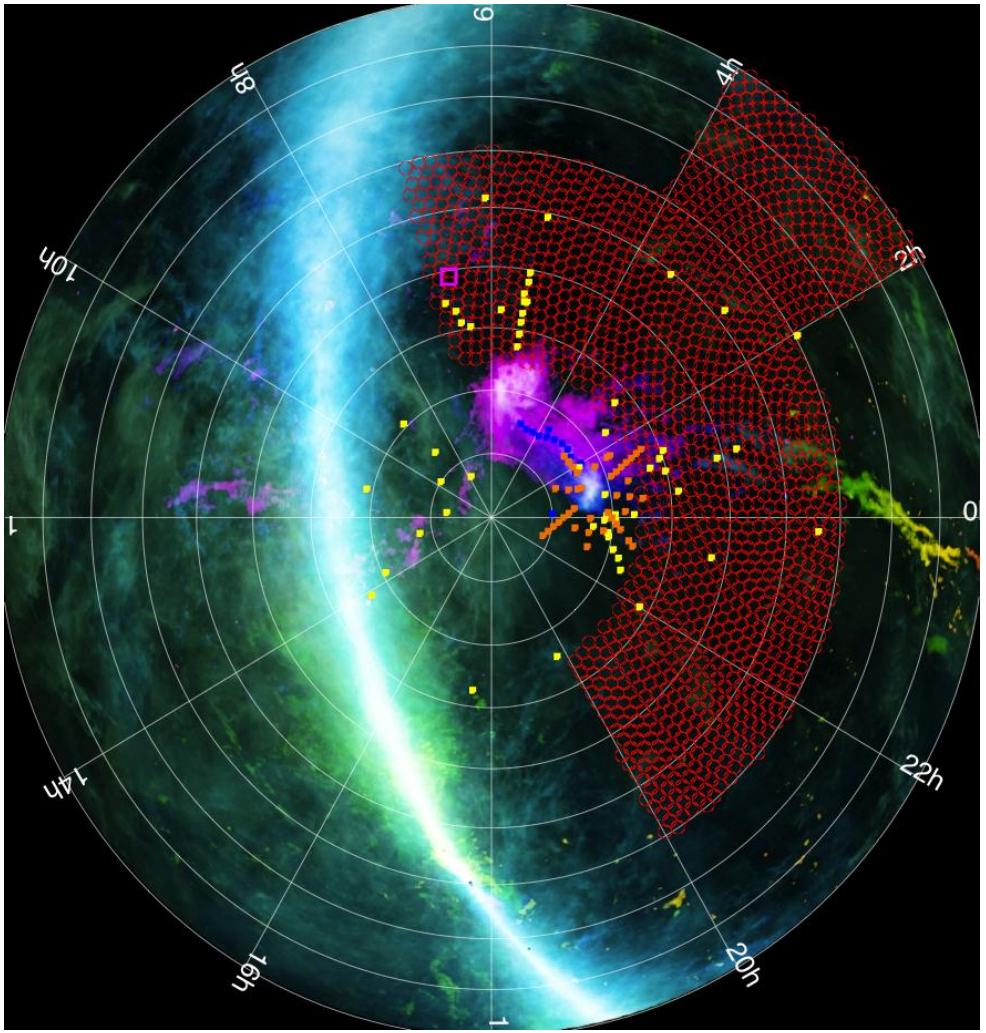
- Model of the LMC/SMC interaction only (no Milky Way)
- Magellanic Stream forms in close LMC/SMC passage ~1.2 Gyr ago
- SMC shredded, LMC left relatively undisturbed
- Model forced compact SMC stellar distribution, no stars in Stream
- Discovery of SMC stars in LMC means that there must be stars in the Stream if scenario correct
- Possible measurement of Galactic halo gas density?



Besla et al. (2011)

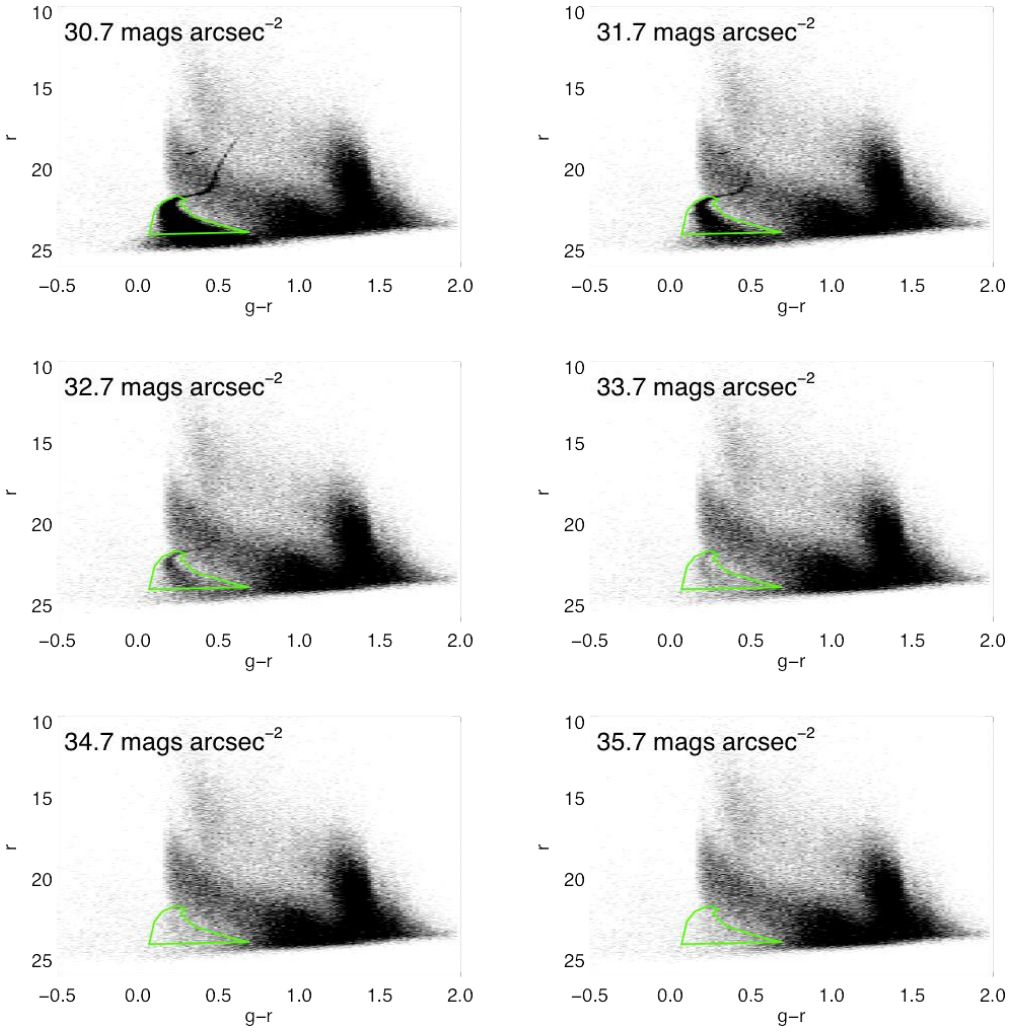
Magellanic Structure with DES

- DES fills in a large area of sky currently probed to ~1% fill factor
- Magellanic Cloud populations detected *already* within DES survey area

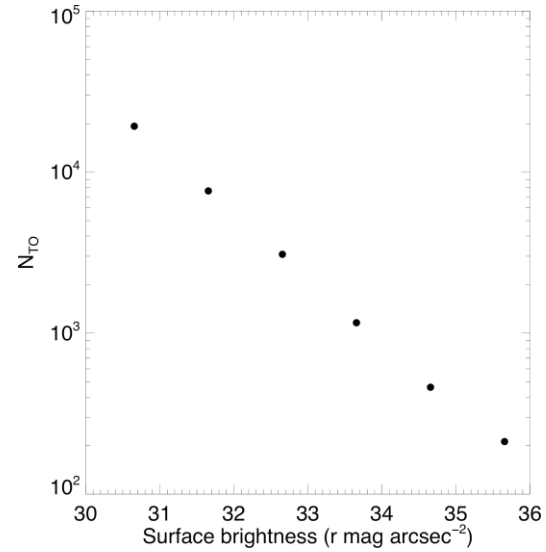


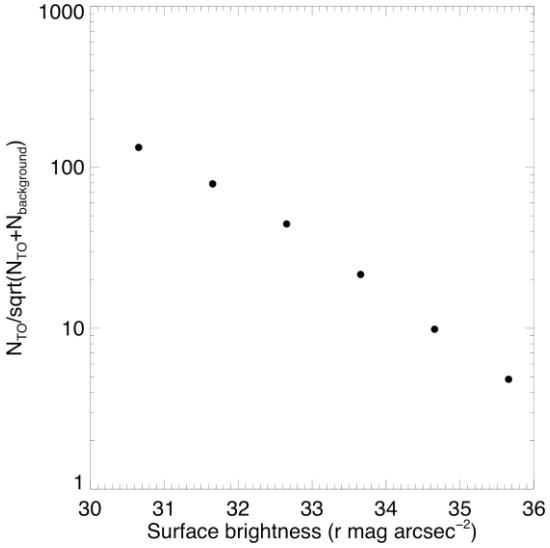
McClure-Griffiths et al. (2009)

Finding MC structure in DES



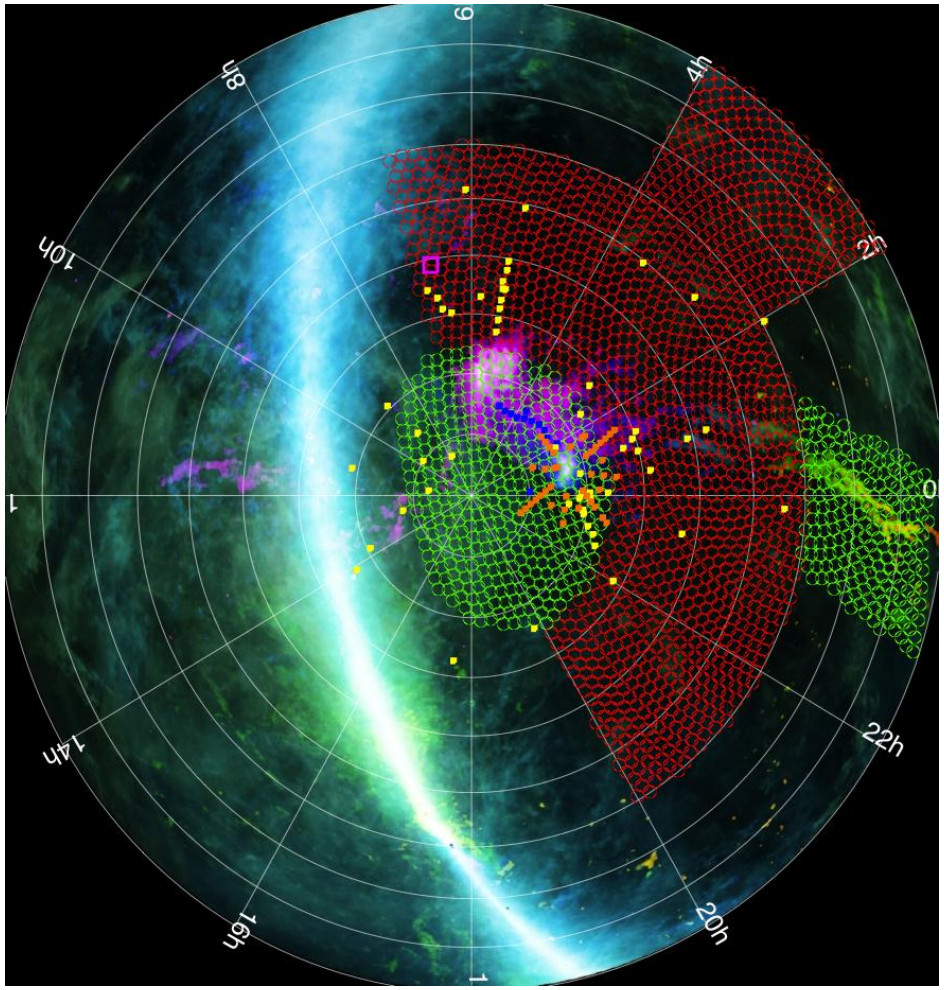
TRILEGAL (Girardi et al.) simulation





Proposing an extension to the DES

- Survey an area spanning a few hundred to ~1800 sq. deg.
- 10% - 100% fill factor
- gri filters at minimum
- z,u desirable additions
- DES survey strategy over sparse part of the coverage
- Adjust the strategy and filters when observing the main Cloud bodies, include transient detection
- Possible set-up of exposures to detect RR Lyrae
- 30-50 night Survey over 3-5 years
- Possibility of collaboration with DES?



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Guy Stringfellow
Alistair Walker
Dennis Zaritsky