Origins of the Monoceros Ring

Erin Conn, 2016-10-31

B. Conn et al. https://arxiv.org/abs/1205.3177
& response by M. López-Corredoira et al. https://arxiv.org/abs/1207.2749

What is the Monoceros Ring/Overdensity?

- Discovered in 2002 (Newberg et al.)
- Overdense stellar structure
- Observations consistent with ring structure at R~15-18 kpc from galactic center

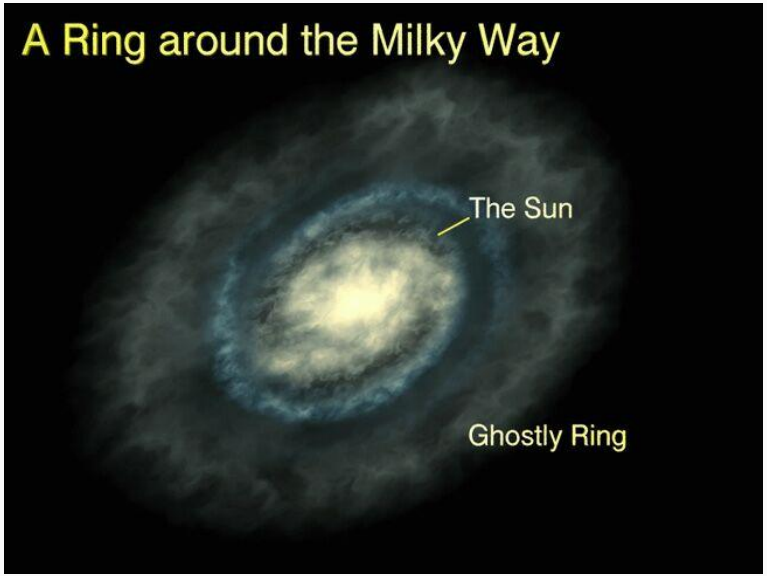


Image credit: Geraint F. Lewis (gfl@physics.usyd.edu.au)

Where did it come from?

Several theories!

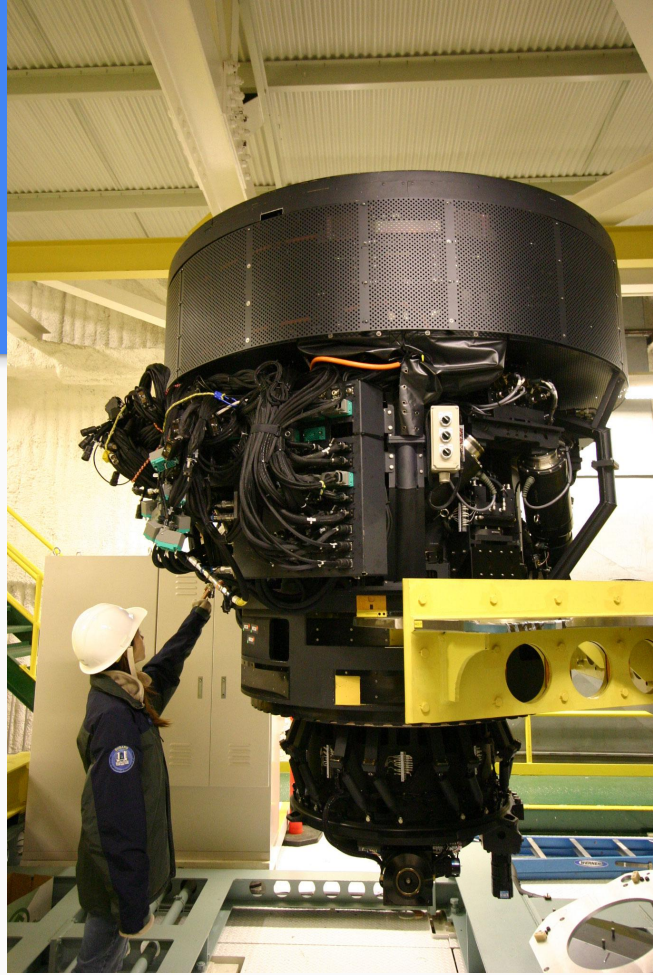
- Perturbation by dark matter
- Feature of the galactic disk
- Tidal stream accretion from Canis Major dwarf galaxy

Observations

SUPRIME-CAM Wide Field Imager on the Subaru Telescope in Hawaii

Chosen for deep observations across wide area in short time

180 frames taken in 3 stripes across galactic disk (longitudes 130°, 150°, 170°) in latitude range [+15°,+25°], Nov. 2007 & Jan. 2008



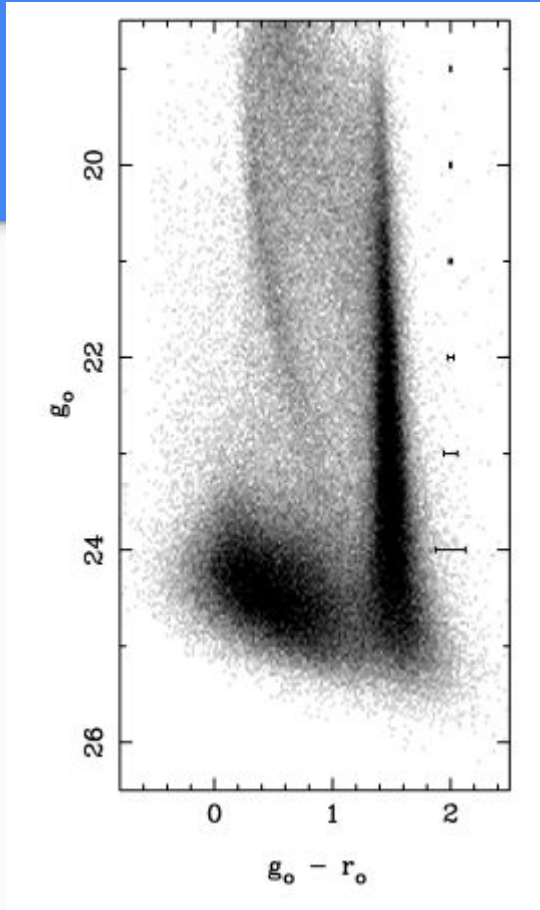
http://www.subarutelescope.org/Introduction/instrument/SCam.html

Observations

Photometry corrected with SDSS cross-matching and dust extinction maps (Schlegel, Finkbeiner, & Davis 1998, adjustment Bonifacio et al. 2000)

Magnitude completeness estimated by finding fraction of stars detected in overlapping frames & fitting logistic curve

Stars separated from background galaxies w/multiple flux estimates



Analysis

Used MATCH (Dolphin 2002) in distance-fitting mode to fit CMDs

Following de Jong et al. (2010), cut off age at [10.1<log(t/yrs)<10.2], used SDSS *g* & *r* isochrones, Saltpeter IMF, 30% binary fraction, & binned metallicities to describe halo & thick disk: [Fe/H]=−0.7, [Fe/H]=−1.3, [Fe/H]=−2.2

Templates created to avoid edge effects

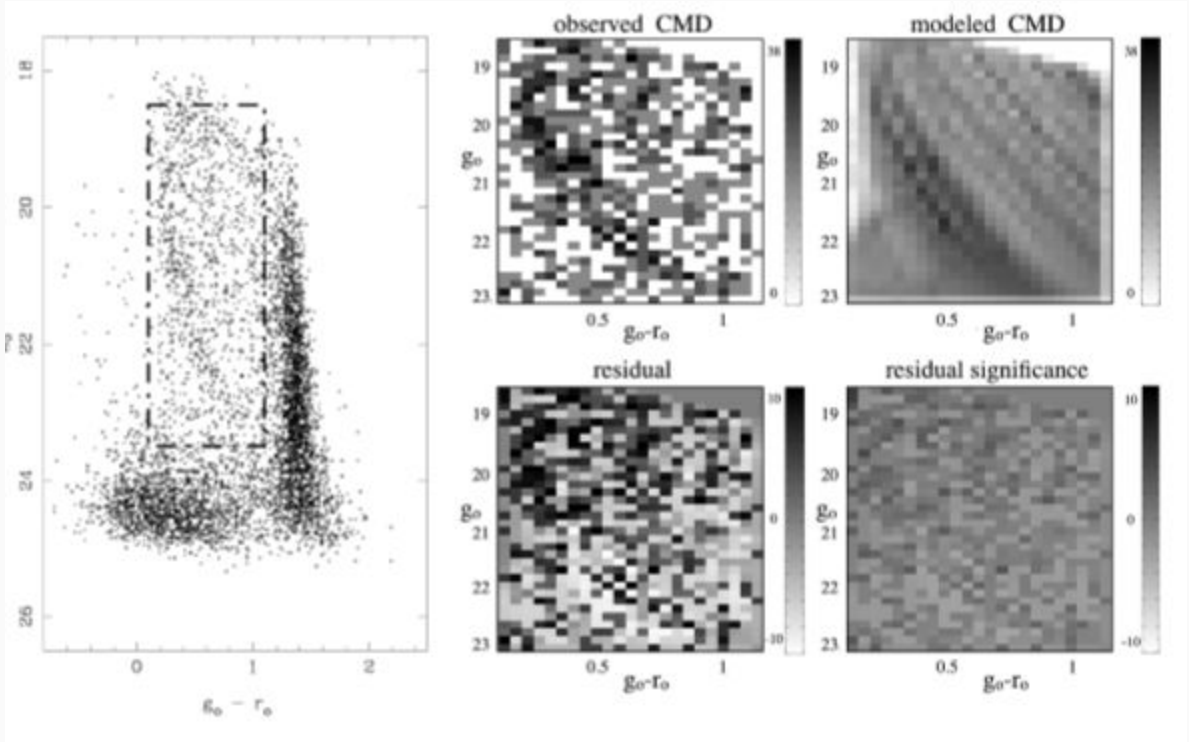
Set magnitude & color cutoffs to remove spurious objects & faint red thin disk stars

Analysis

MATCH builds Hess diagram for data, then synthetic diagrams for age & metallicity ranges assuming 1 M⊙/yr SFR (scaled & combined to match observed diagram)

Synthetics convolved with photometric errors & completeness profile. Poisson MLE used to determine best single or linear combination of models.

Analysis

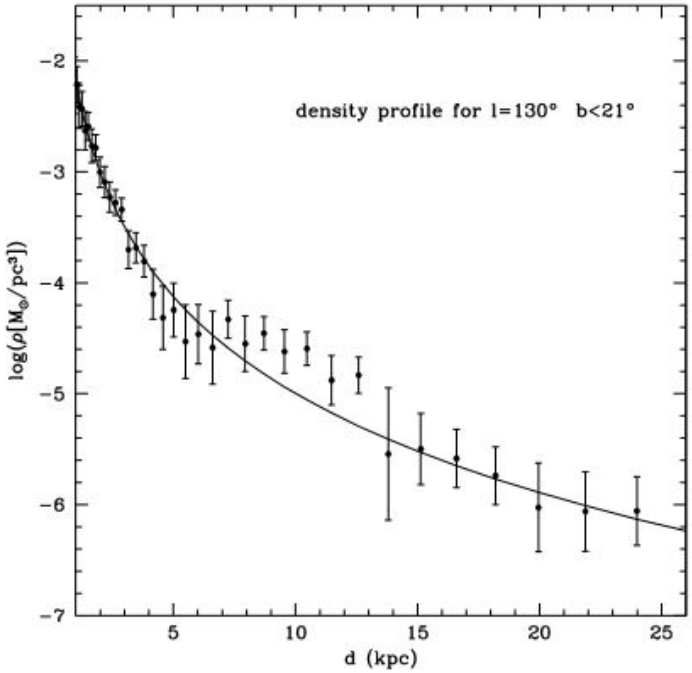

observed CMD
modeled CMD
residual
residual significance
$g_o - r_o$
g_o

Analysis

MATCH ouputs SFR corresponding to each population template, transformed into stellar mass density.

Sérsic profile fit to underlying stellar population & overplotted

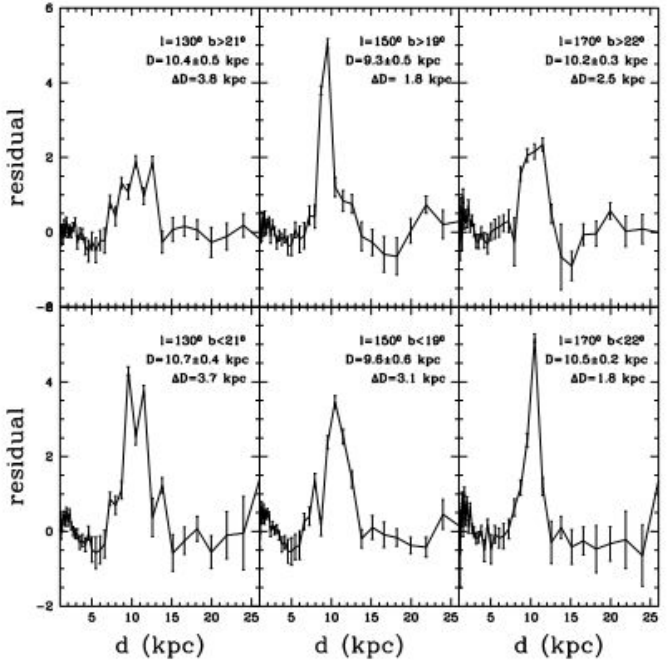
Able to clearly delineate density of MO



Analysis

Removed bulk Milky Way components & computed residuals from Sérsic profile

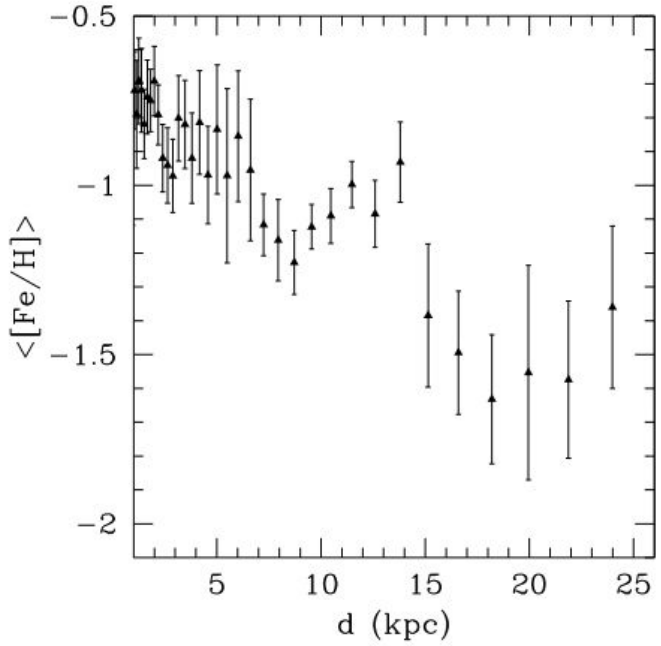
Fit Gaussian - width is FWHM



Analysis

Obtained metallicity profile from 3 stripes combined using isochrone fitting

MO clearly visible even without underlying MW population removed



Discussion - Perturbation by Dark Matter

Interaction with massive DM sub-halo migrates disk stars into ring structure

Difficult to distinguish from tidal stream accretion without chemistry or detailed velocities

BUT - only existing matter is moved. MO should have corresponding *under*density, not seen in data

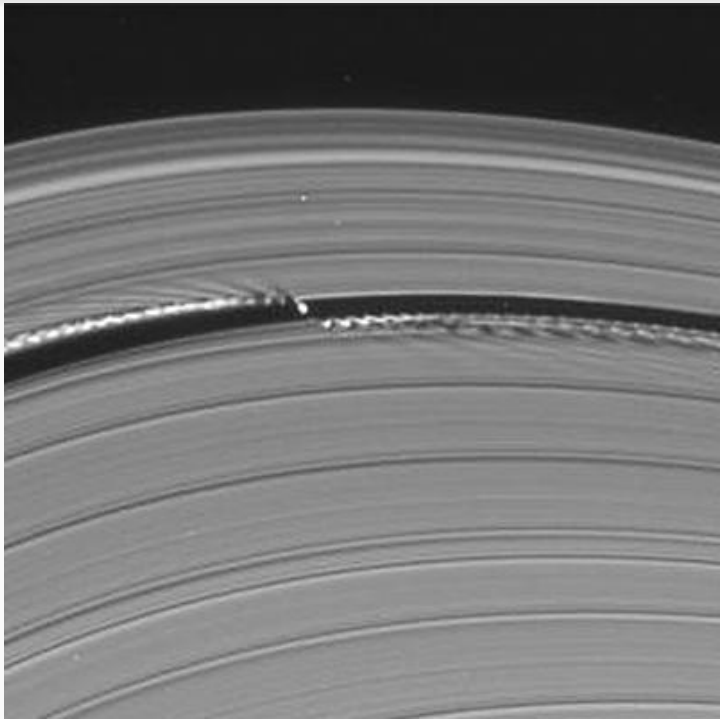


Image: Cassini

Discussion - Disk Feature

Milky Way disk is warped

Disk may also flare - rapid thickening with radius

Hammersley & López-Corredoira (2011) showed stellar counts compatible with disk flare

Image: Hubble, ESO 510-G13

Discussion - Disk Feature

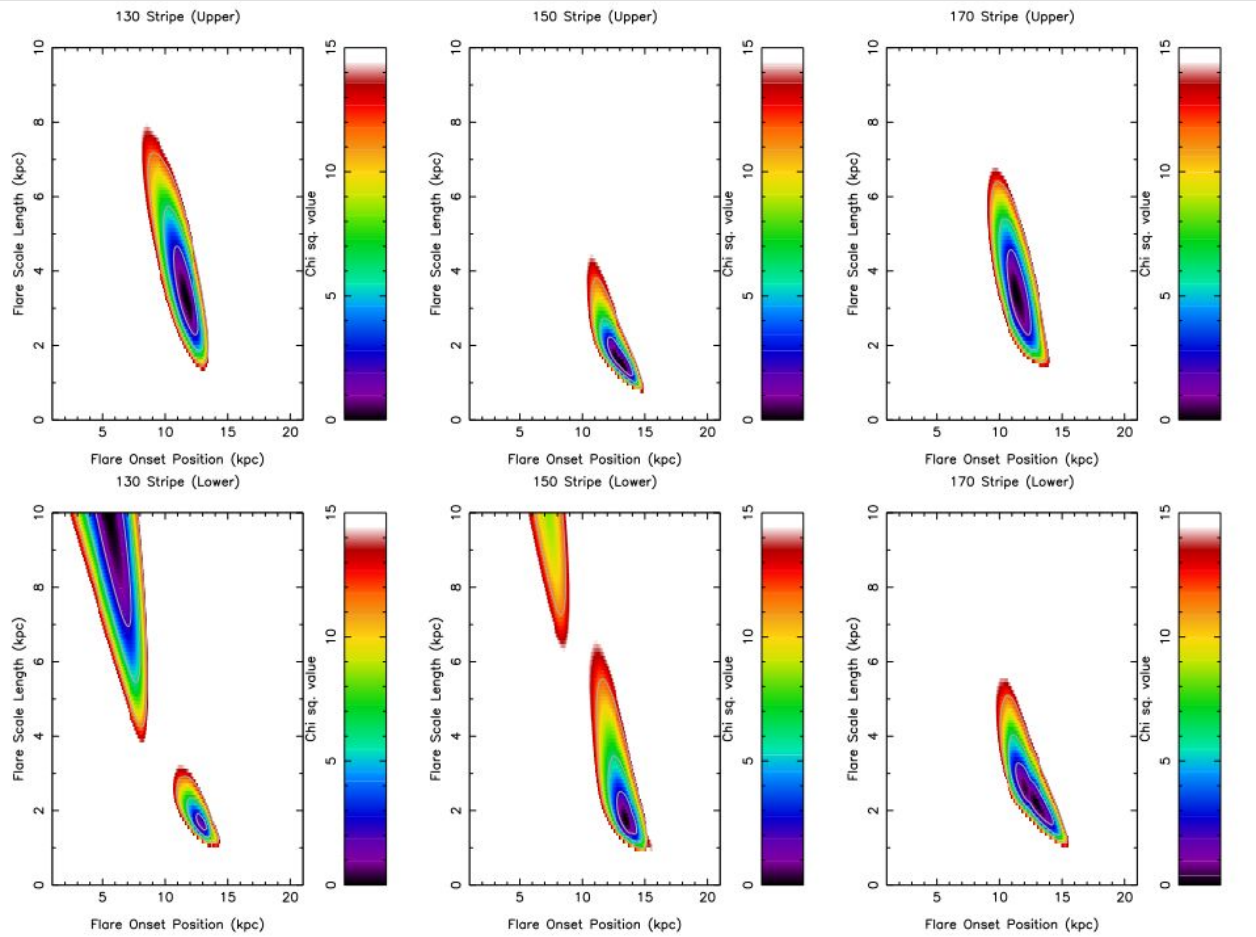
Fit Hammersley & López-Corredoira flare models to data set across scale length & offset position parameter space

Models compared against data & chi-squared computed for each pt in parameter space

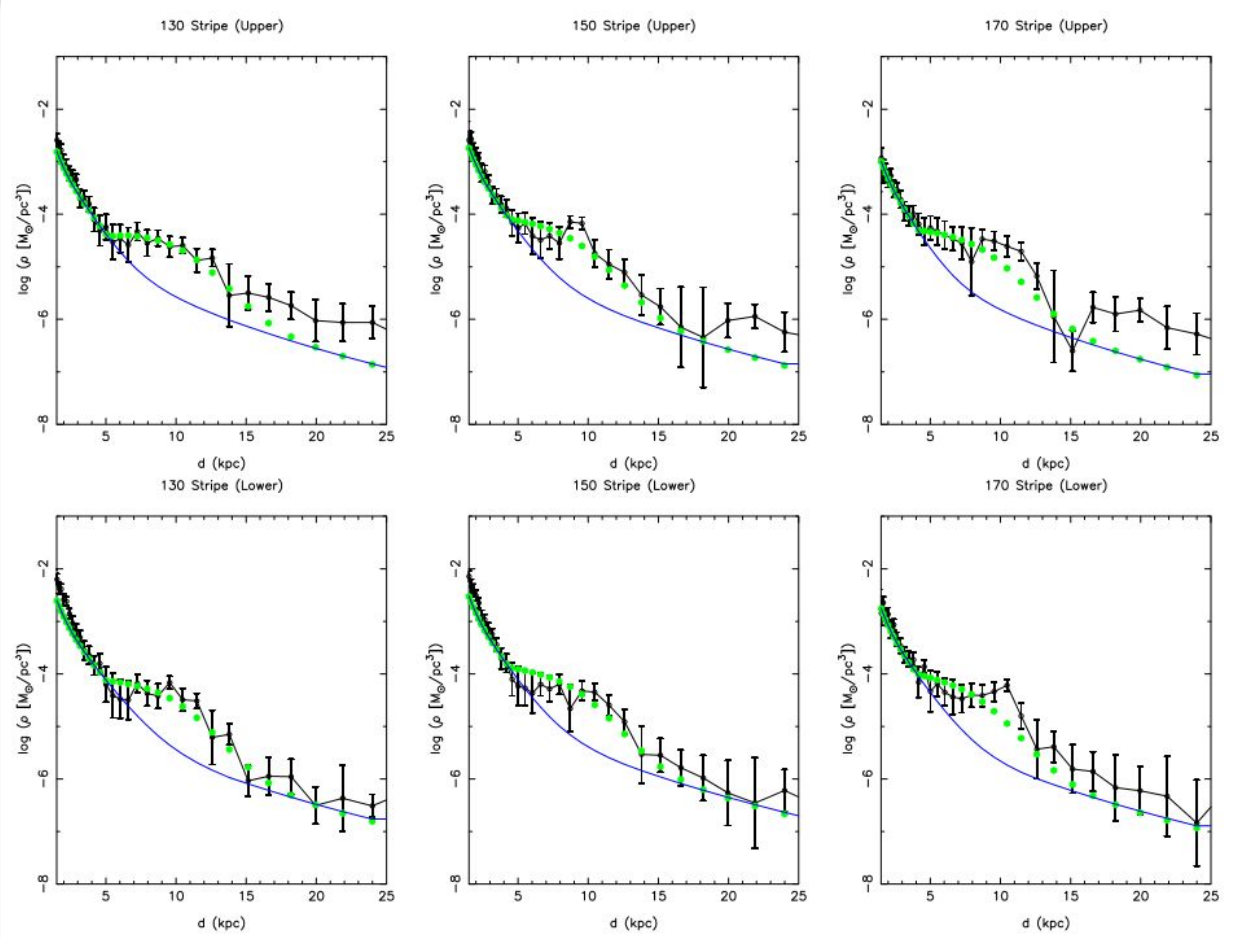
Fits show MO density profile requires very short scale length

Model can fit observed data within uncertainties of most of the data points

Discussion - Disk Feature



Discussion - Disk Feature



Discussion - Disk Feature

Explaining discrepancies:

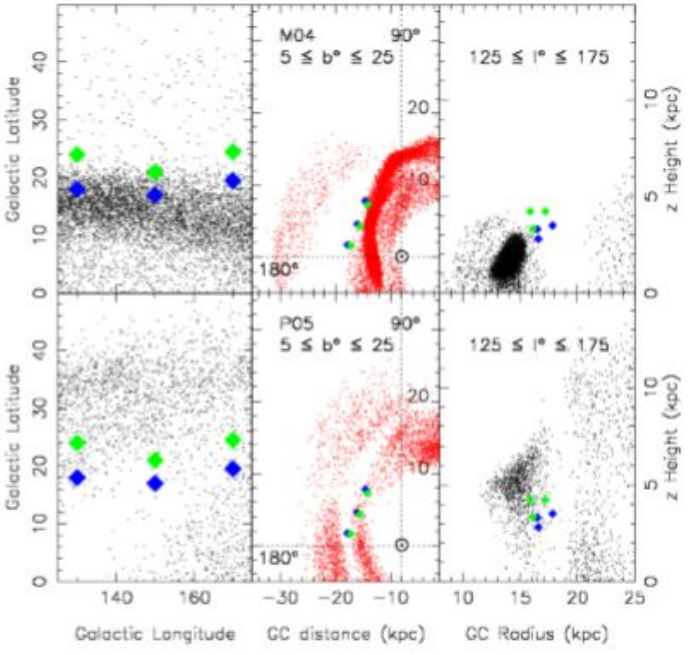
- Model does not account for disk warp - could explain at low heliocentric distances
- Unclear whether differences should be explained by data noise or intrinsic disk irregularity
- Improved statistics required

Discussion - Tidal Stream

Compared data with numerical simulations (Martin et al. 2004, Peñarrubia et al. 2005)

Data roughly matches models but change in density is incompatible.

Stream structure in data not compatible with either simulation, but a suitable model can likely be found by tuning parameters (is this the “true” model though?)



Discussion - Metallicity

Metallicity measurements (Fe/H) of MO in literature range from -1.6 to -0.8 photometrically, & -1.9 to -0.1 spectroscopically - MO is metal-poor

Due to distance, expected thin & thick disk metallicity profile must be extrapolated - used 5 studies (Coşkunoğlu et al. 2012, Lee et. al 2011, Cheng et al. 2012, Ivezić et al. 2008, Yong et al. 2005)

Consistently find that disk is expected to be more metal rich than MO

Discussion - Metallicity

Metallicity observations are closer to LMC or Sagittarius Dwarf type galaxies than Milky Way origin

Offset suggests extragalactic origin for MO stars

Disk flare model makes no metallicity predictions, but MO should be consistent with Milky Way population - disk appears too metal-rich to source stars in MO

Metallicity in perturbed disk model should be average of surrounding stars, it’s clearly not

Conclusions

Insufficient evidence to conclusively determine origin

Perturbed disk ruled out

Disk flare model consistent with observations, but not metallicity

Existing tidal stream models bracket, but do not fit data. Large parameter space assures a fitting model, but danger of not truly explaining data. Metallicity most consistent with tidal stream.

Response & Controversy

López-Corredoira et al. (2012)

Advise caution - extrapolations can be misleading, and don’t confuse models for the real thing

Disk flare has theory behind it (Momany et al. 2006), extragalactic stream is an ad-hoc hypothesis

Expected metallicities in Conn et al. are based on extrapolations of analysis of low *R* & |z| stars, Cheng et al. (2012) shows metallicity gradients consistent with MO.

References

Blair C. Conn, Noelia E. D. Noël, Hans-Walter Rix, R. R. Lane, G. F. Lewis, M. J. Irwin, N. F. Martin, R. A. Ibata, A. Dolphin, S. Chapman. Slicing The Monoceros Overdensity with Suprime-Cam. Submitted to arxiv.org 14 May 2012

M. Lopez-Corredoira, A. Moitinho, S. Zaggia, Y. Momany, G. Carraro, P. L. Hammersley, A. Cabrera-Lavers, R. A. Vazquez. Comments on the "Monoceros" affair. Submitted to arxiv.org 5 Jul 2012