University of Hertfordshire

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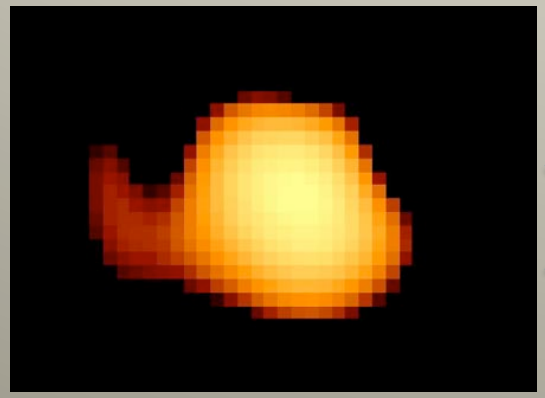
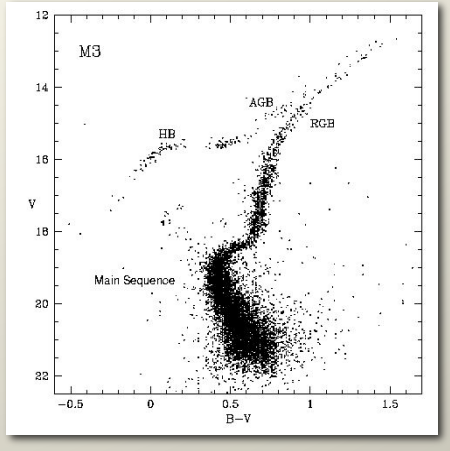
AGB stars in M33



UV Photosphere of Mira
700 x Sun

Arcetri, 19 September 2009

Introduction

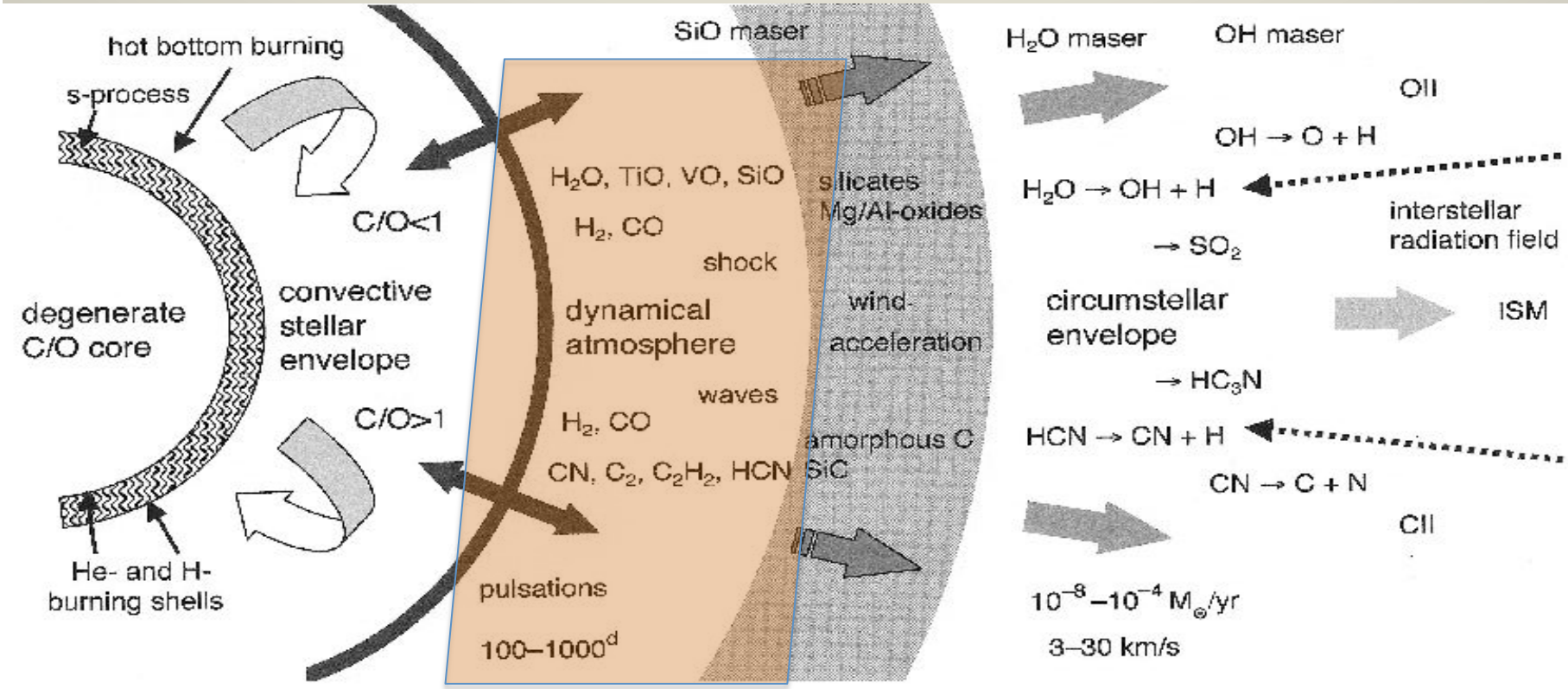


All stars with 0.8-8 M_{sun} become AGB stars; the AGB phase is brief (<0.01 Gyr)

- AGB stars are the most luminous stage for low and intermediate mass stars
- AGB stars are loose mass and pulsate

- AGB stars exist in large number in M33
- AGB stars indicate structure, distance and metallicity

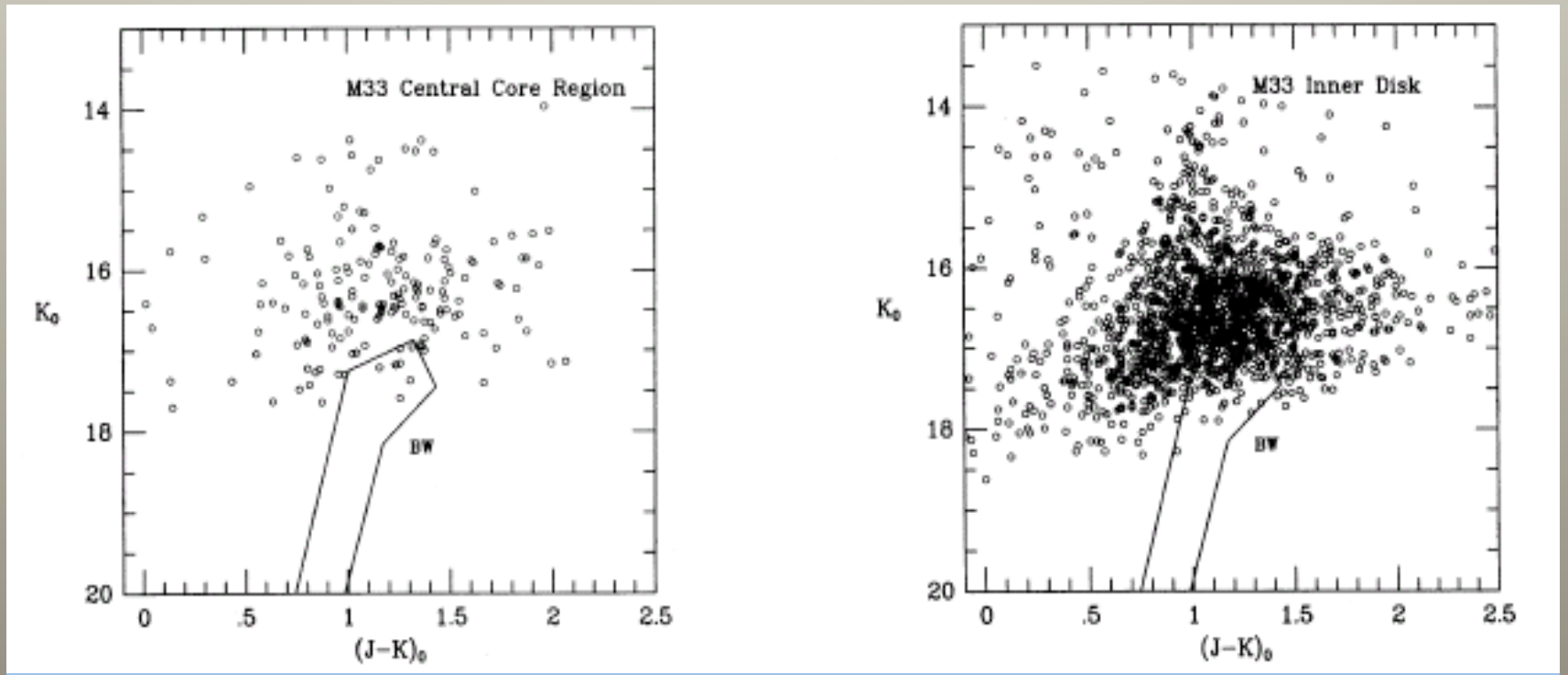
“Metallicity tracers”



(book “AGB stars”, Eds. Habing & Olofsson 2003)

Previous near-IR observations

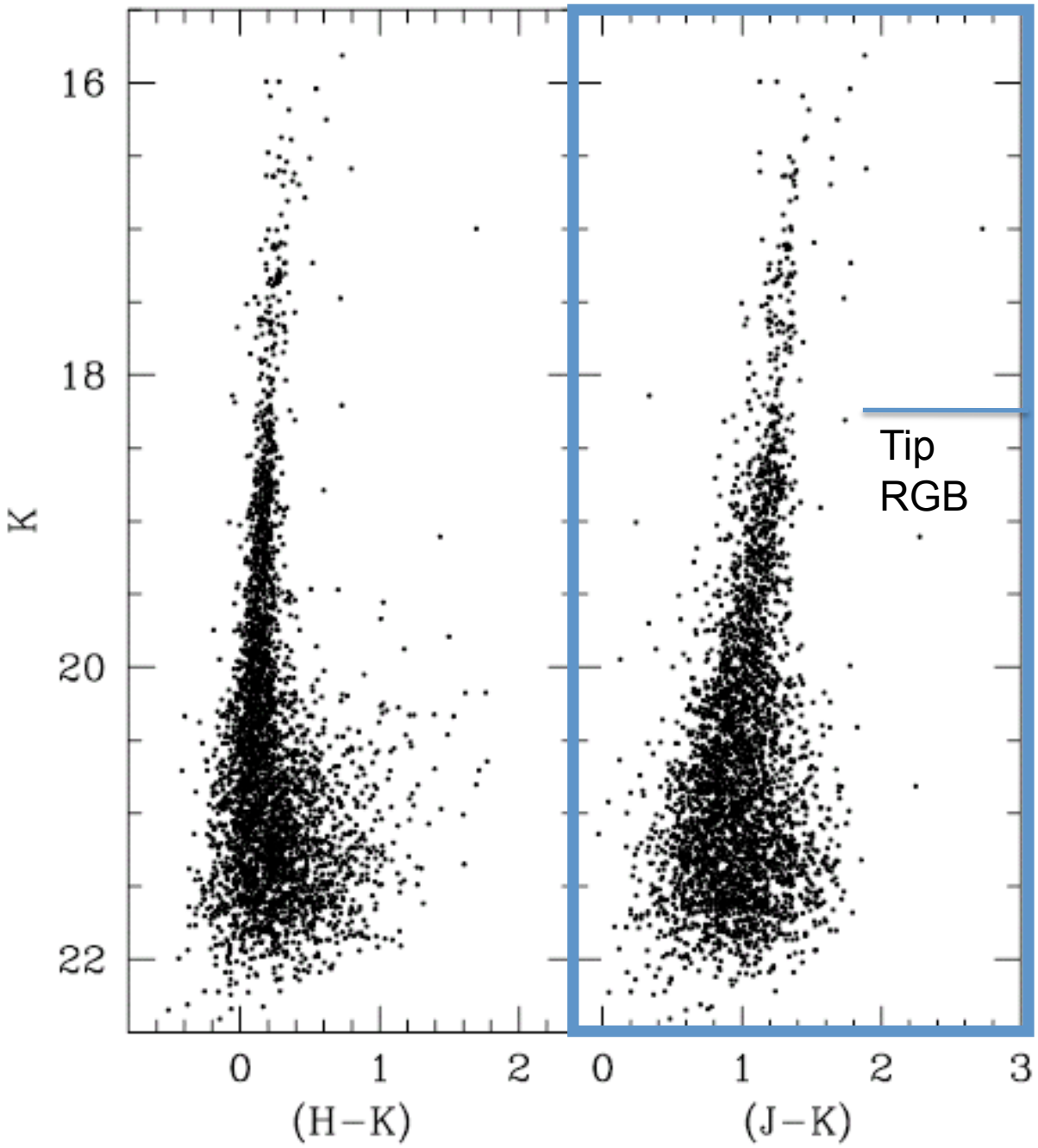
- McLean & Liu (1996)
  - Central 7.6', K~17-18
  - Numerous intermediate-age, no bulge



Near-infrared diagram for core and inner disk regions

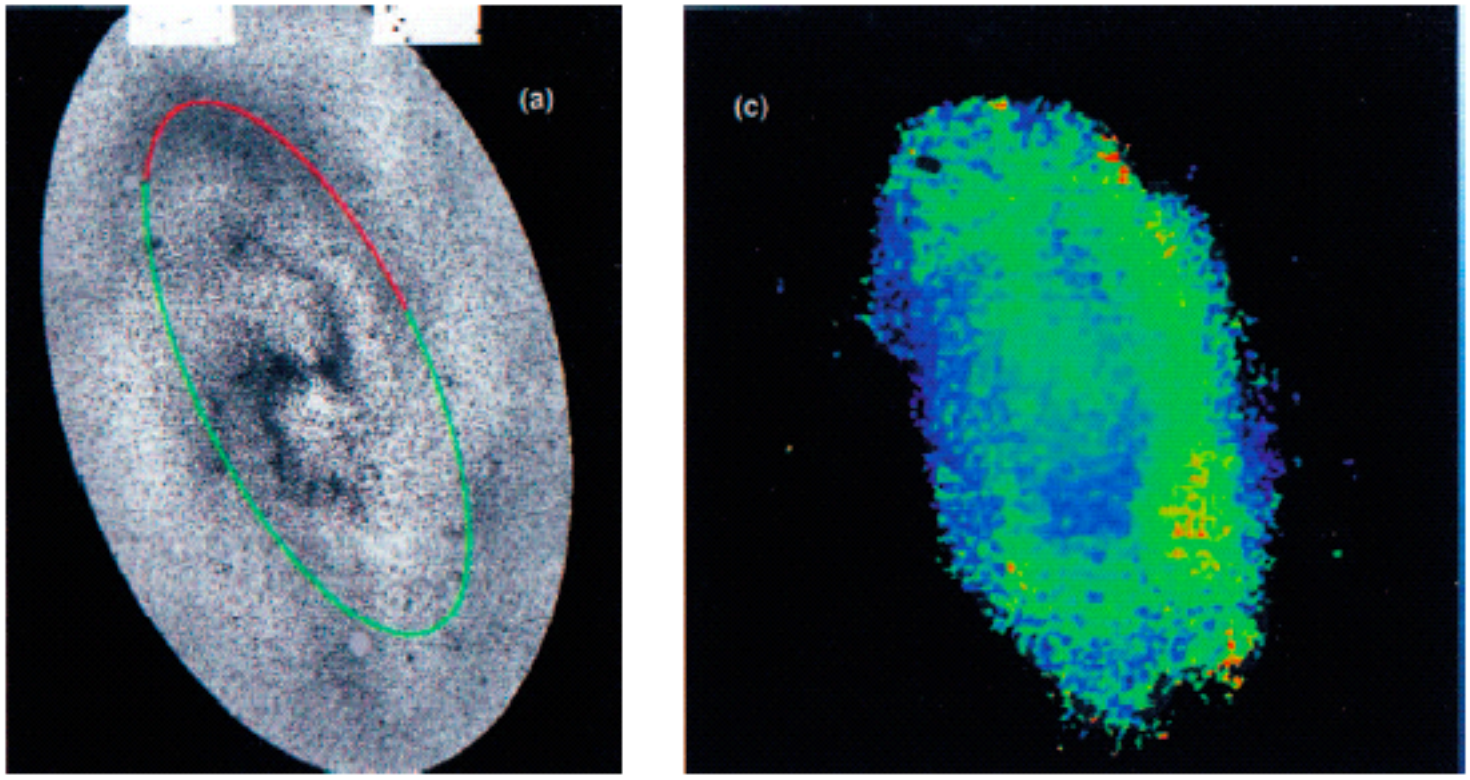
- Stephens & Frogel (2002)
  - Central 22”
  - K=22
  - RGB and AGB stars are well detected
  - The tip of the RGB is at K=18.15

Near-infrared diagrams of central region



- Block et al. (2004)
  - Wide-field, deep 2MASS, Ks~16
  - Arcs/ring of carbon stars

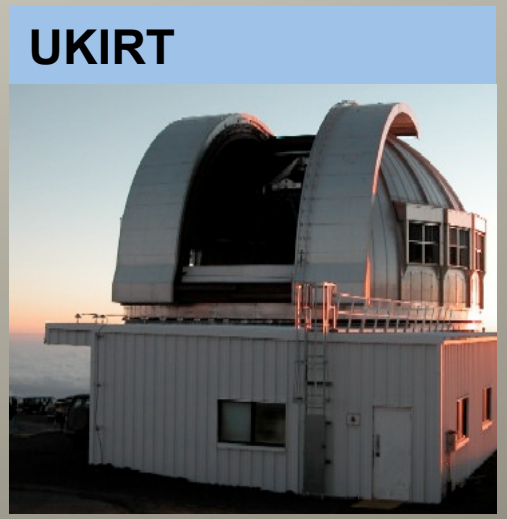
Number density of JHKs data and J-Ks colours, coded 0.5-1.5 blue-red-green



New near-IR observations

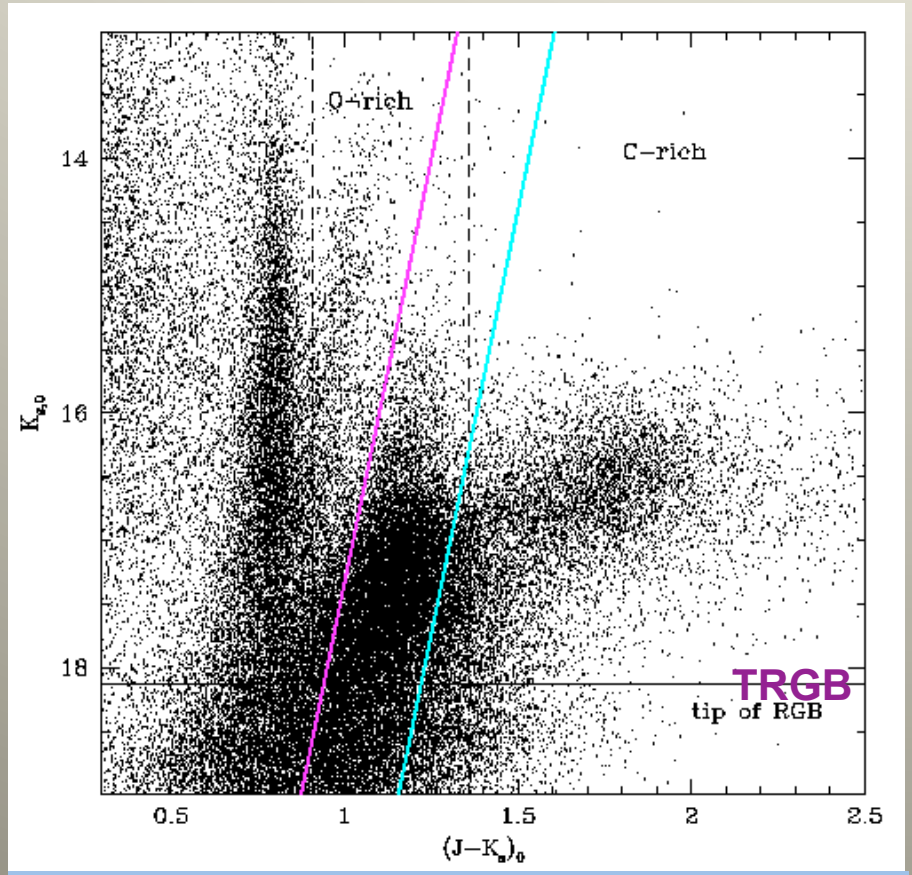
- A UKIRT programme (PI=Irwin) to survey luminous red stars in LGG*
- This program provides both a good sensitivity and a spatial coverage

- M33:
  - A mosaic of 4 WFCAM tiles = 3 deg^2
  - Data reduction with WFCAM pipeline
  - Average seeing = 1.07”+/-0.06”
  - Ks=18.32 with S/N>10



* Including M31 and its satellites

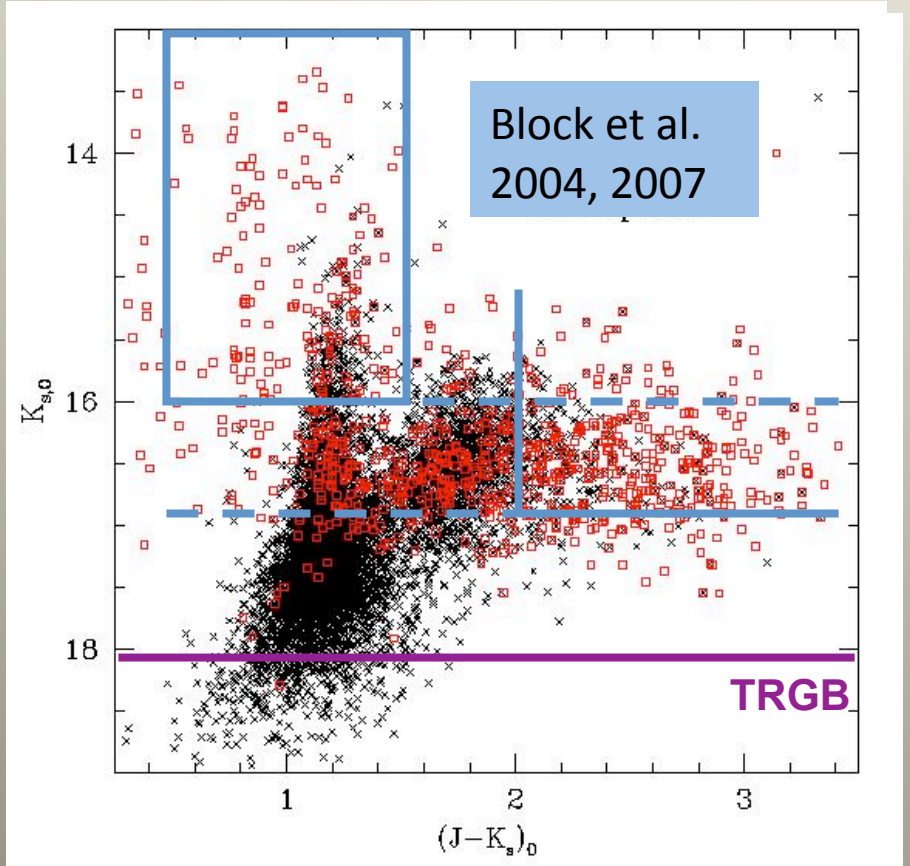
Selection of AGB stars



NIR colour-magnitude diagram

- Tip of the RGB @ Ks=18.15
- Foreground stars, supergiants, O-rich & C-rich AGB stars occupy clearly distinct regions

Selection of AGB stars



NIR colour-magnitude diagram

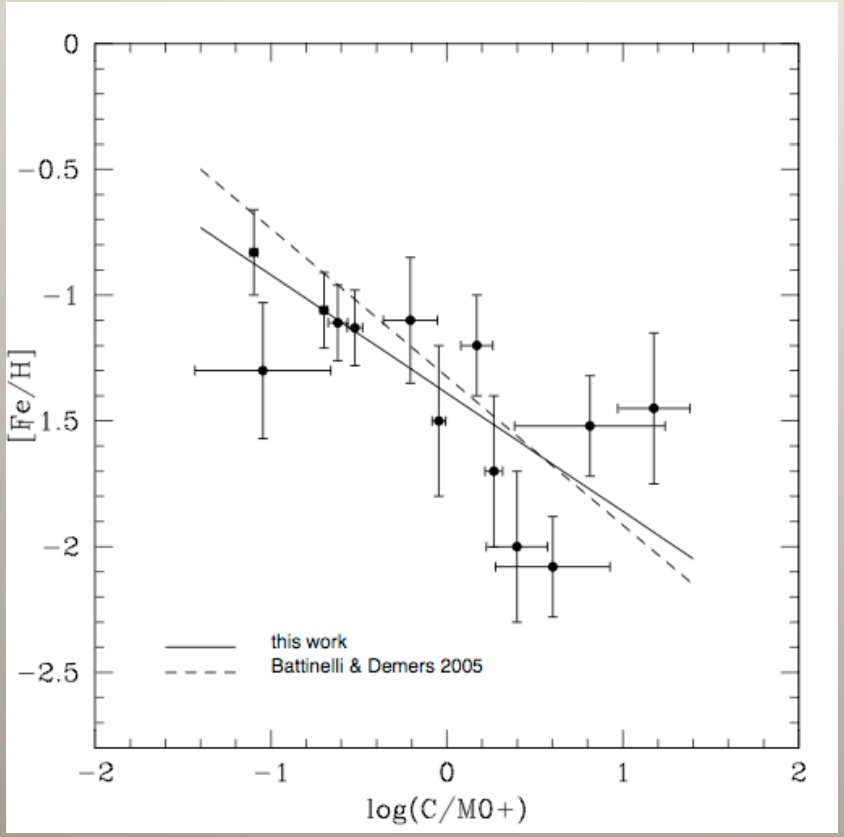
- LPV+IR+Spitzer published, thy are most secure AGBs
- Confirmed LPVs:

  Hartman et al. (2006)
- Dusty ones by Spitzer:
  McQuinn et al. (2007)

What can we use AGBs for?

- Make the C/M ratio, convert it to [Fe/H] and investigate the metallicity gradient
- Investigate the morphology of C and M stars
- Make number density distributions of C and M stars and use stellar evolution models to derive the mean age and metallicity
- Investigate the structure of the galaxy from the mode of the C and M distributions

Calibration of C/M vs. [Fe/H]



Cioni 2009

Revised relation from Battinelli & Demers 2005:

- homogeneous [Fe/H] from (V-I) colours of RGB stars
- updated [Fe/H] values
- updated galaxies

RGB stars span a large age range

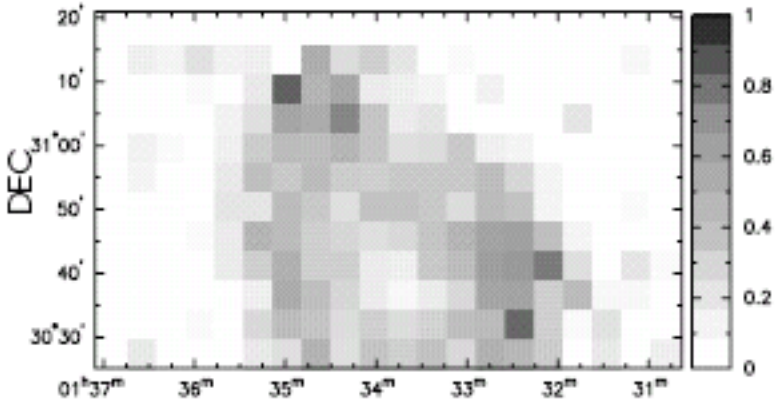
The metallicity of RGB stars is the closest approximation for that of AGB star progenitors

C/M values are from Battinelli & Demers

[Fe/H] = -1.39±0.06 - 0.47±0.10 × log(C/M0+)

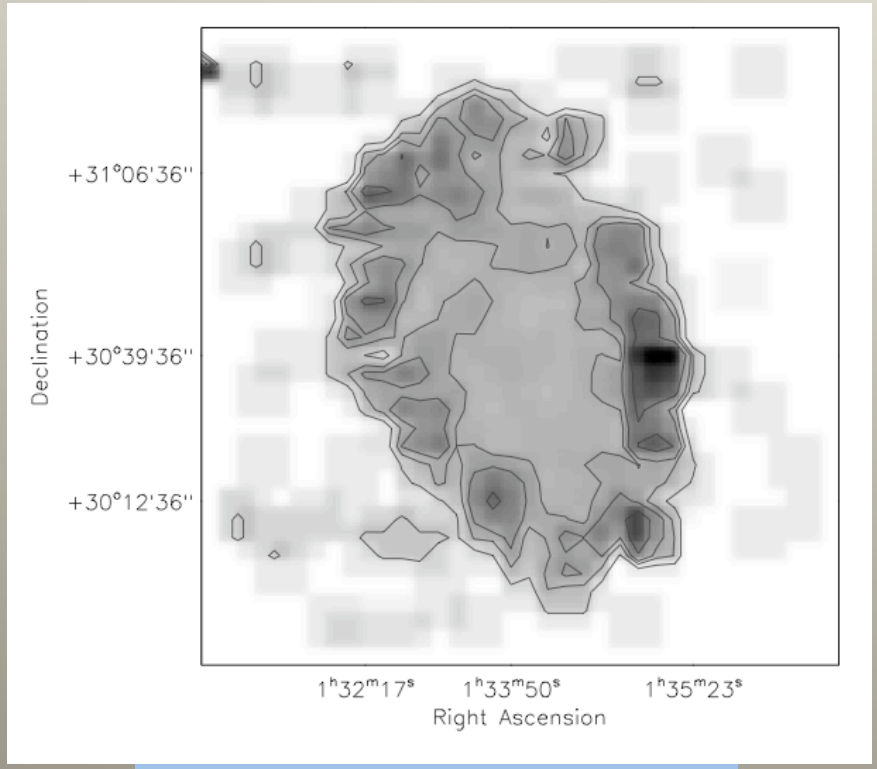
C & M stars selected using narrow band filters

The C/M ratio



Rowe et al. 2005

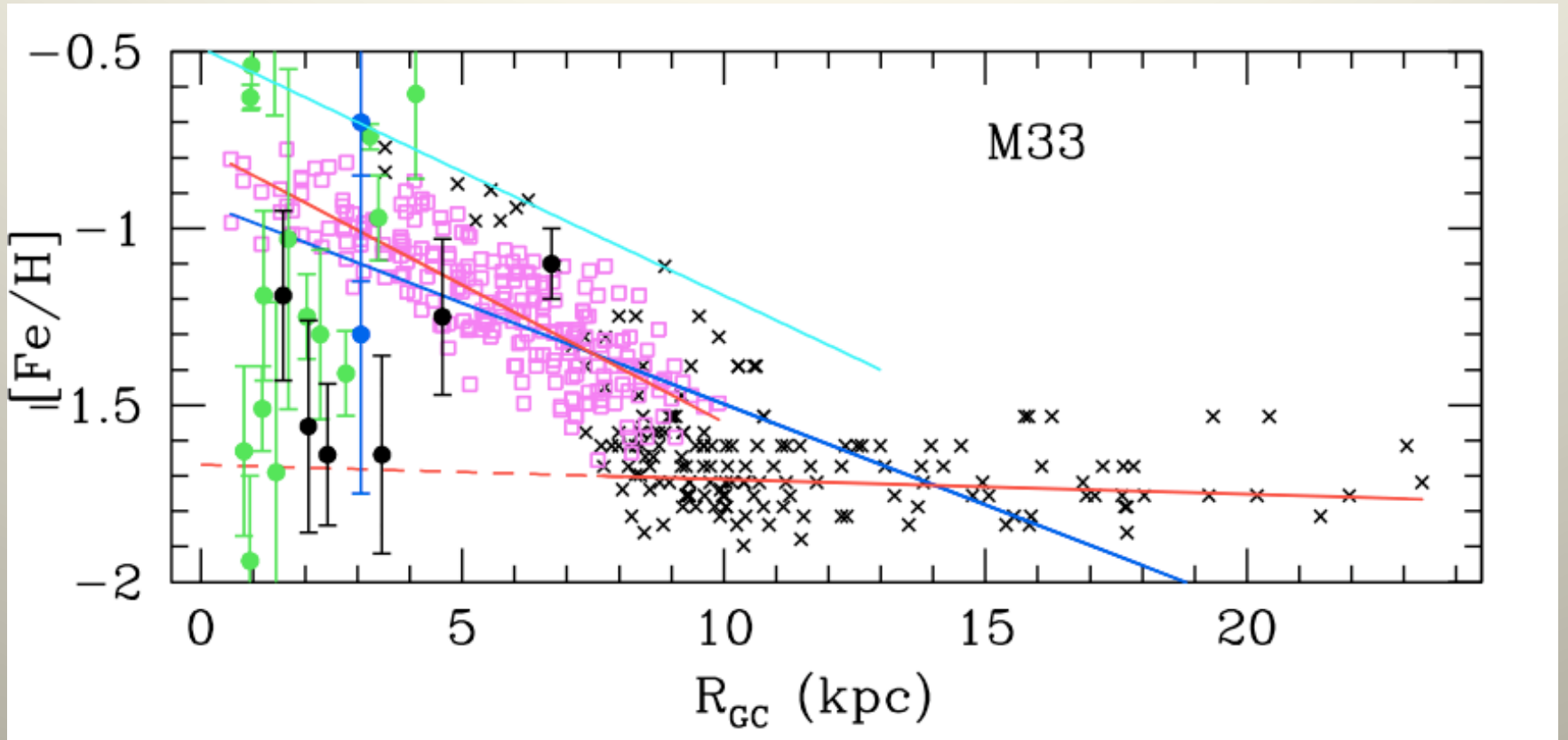
Cioni et al. 2009



Bins = 2.4'
Dark regions = high numbers

High ratio = low metallicity

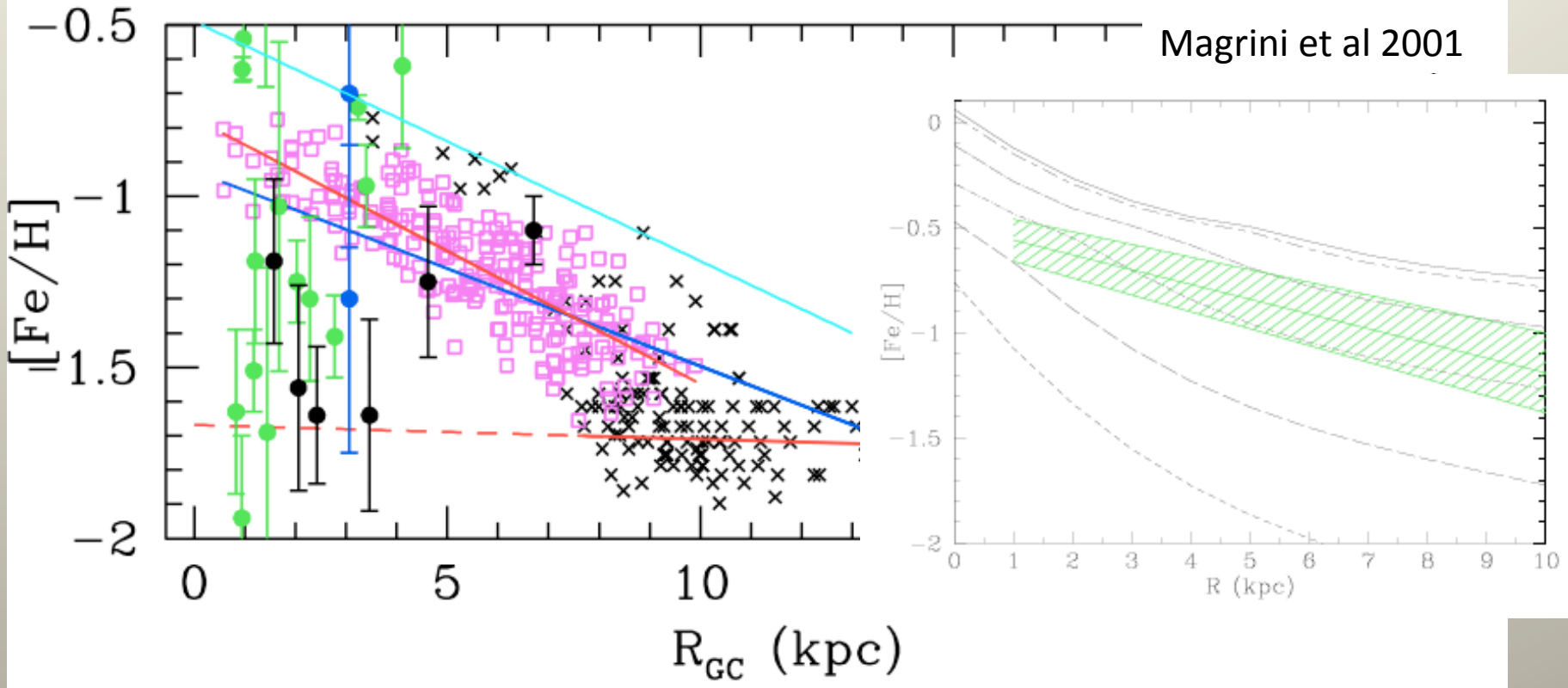
- Ring-like metal poor features
- The range of C/M values corresponds to a range of [Fe/H]~0.6 dex



Metallicity gradient across the M33

Cioni 2009

- Distribution of old **stellar clusters** and **AGB stars**
- [Fe/H] decreases in the inner disc and is constant in the outer disc/halo
- HII regions show a flat gradient (Rosolowsky & Simon 2008); compared with the AGB gradient it shows a flattening with time
- PNe show no gradient (Magrini et al 2009); they are younger than AGBs
- RGB gradient = AGB gradient = Blue Supergiants gradient



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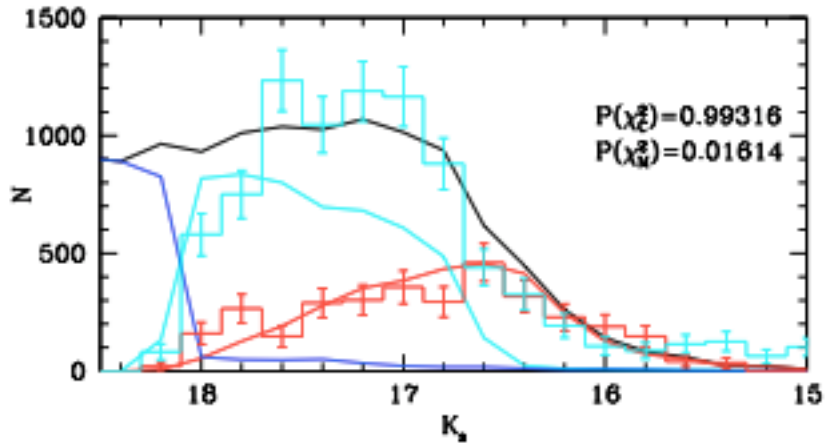
M33 age and metallicity

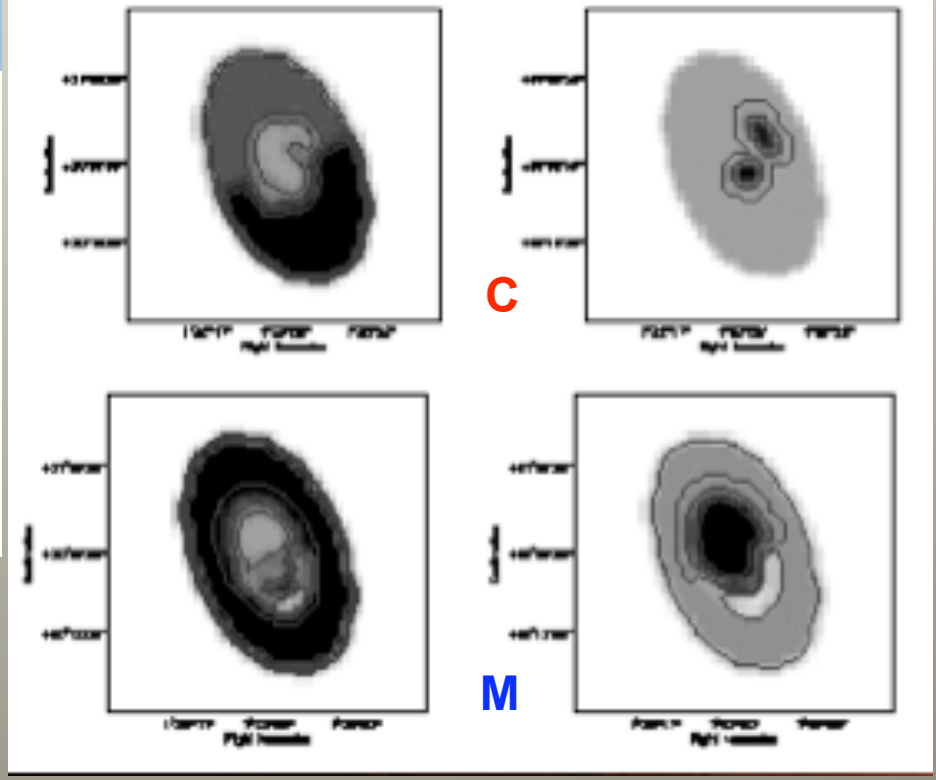
The disk/halo population is metal poor while the central regions are metal rich.
The outer ring of the galaxy is older (7-8 Gyr) than the centre (5-6 Gyr).

AGB K distribution



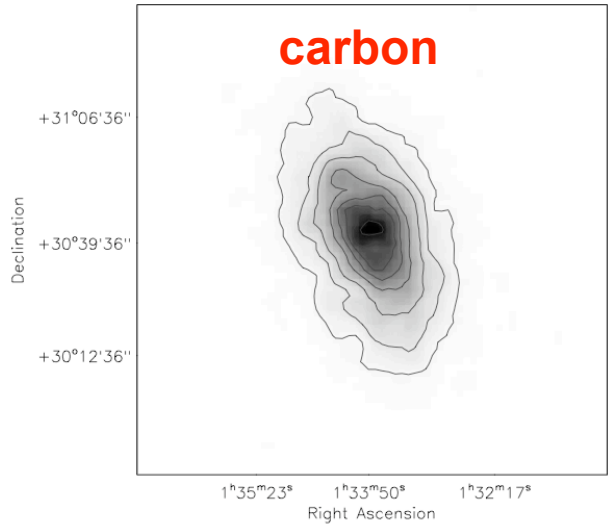
Theoretical magnitude distributions are created using stellar evolution models
The best fit is estimated using χ^2.

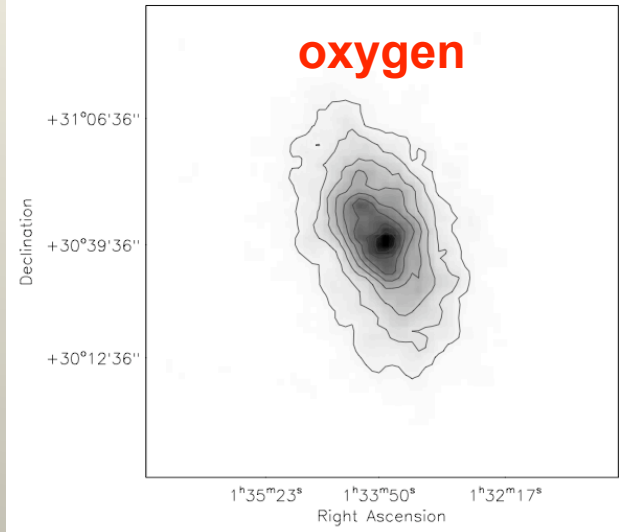
Mean age and total metallicity

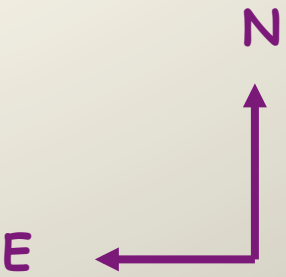


Cioni et al. 2008

Morphology

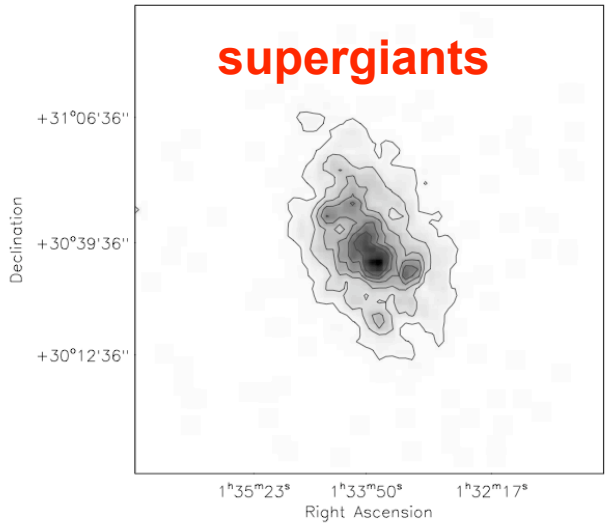


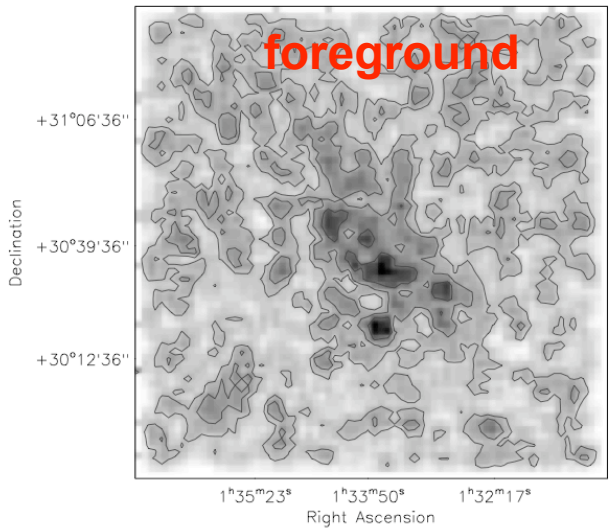




C & M show smooth contours with hints of spiral structure

Number density distribution of different stars



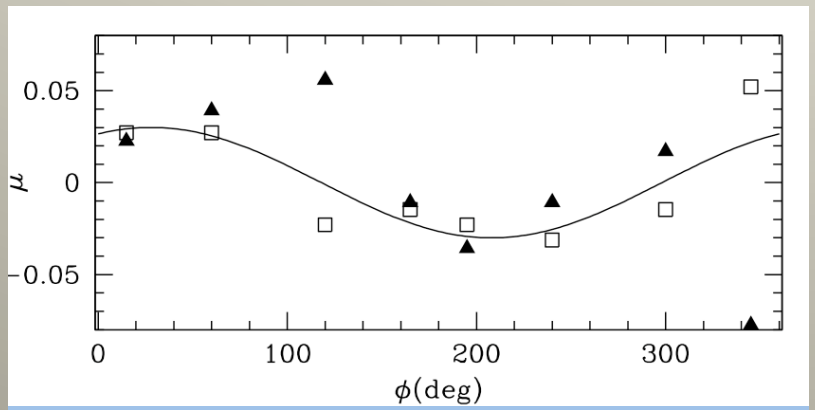


Supergiants, Cepheids and upper MS stars show clumps

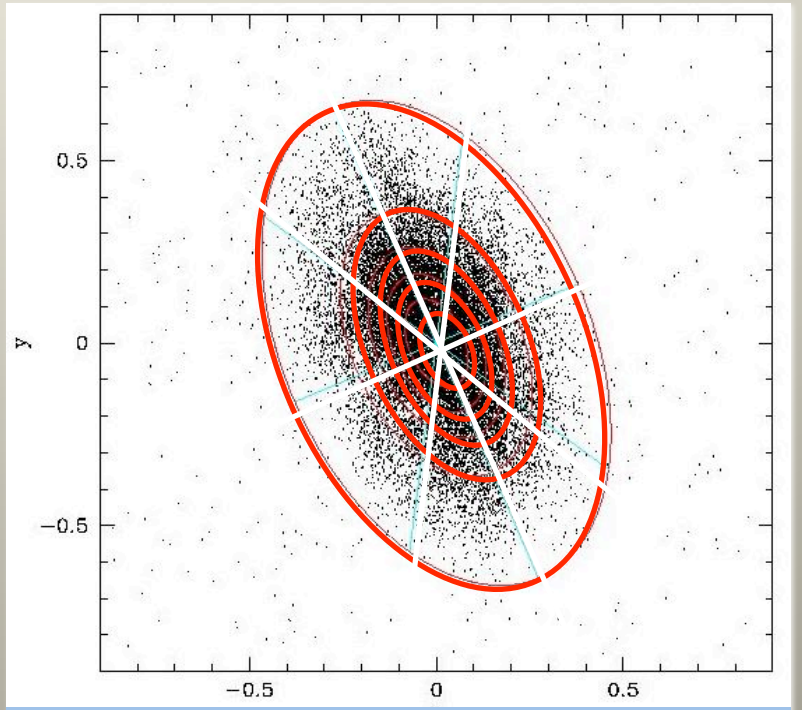
Orientation

SW stars are fainter than stars in the NE

Subdivision of area
3500 M-stars / ellipse
300 C-stars / ellipse



Sinusoidal variation

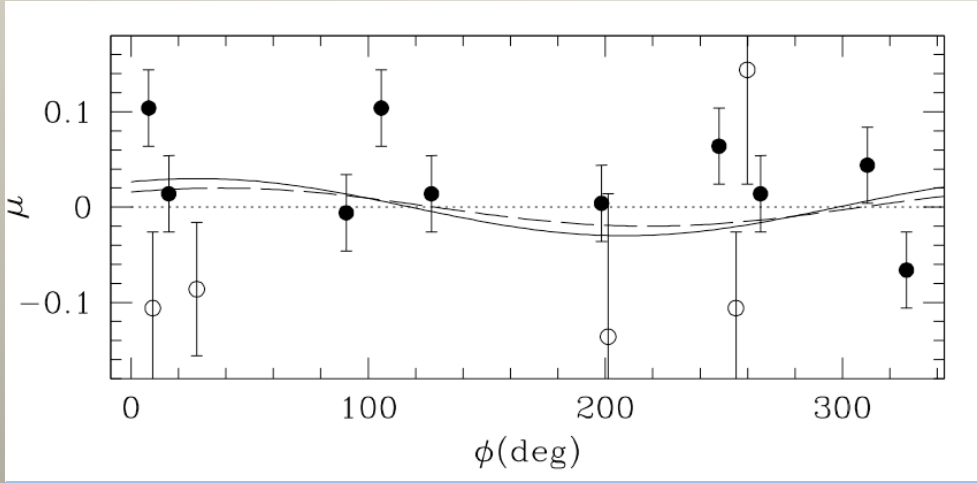


M33 area subdivision

The peak of the C star magnitude (▲) and colour (❑) distribution trace a sinusoidal variation

Structure (disk warp) ?

SW stars are fainter than stars in the NE

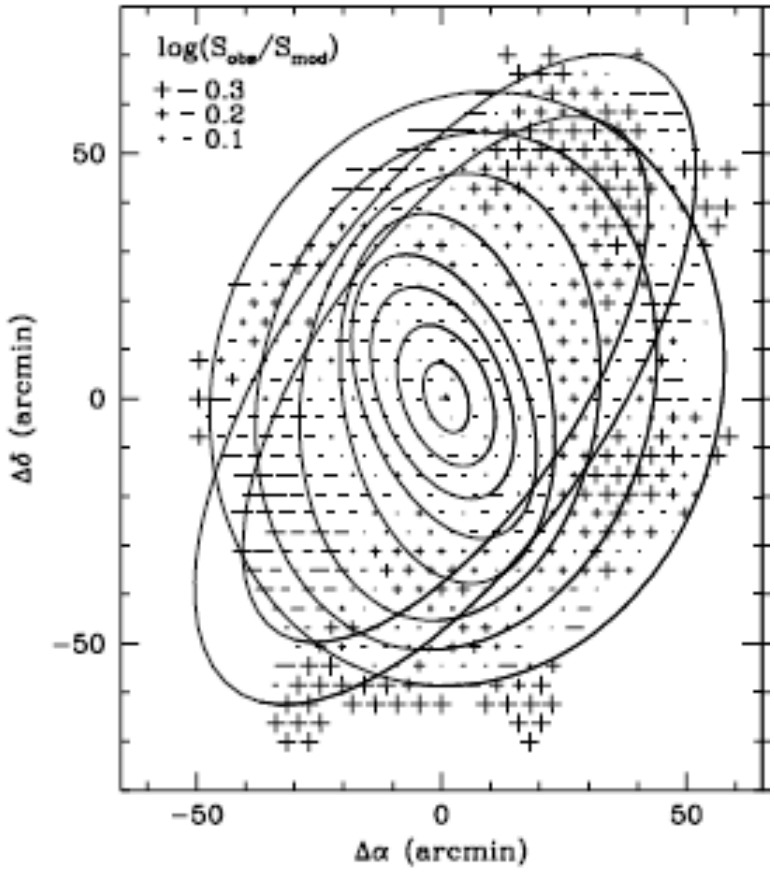


Sinusoid vs. literature data

(m-M) variation as measured by Kim et al. 2002 – filled symbols;

empty symbols refer to other authors

Corbelli & Schneider 1997



M33 warp model

Cioni et al 2009

Open questions

Why the AGB gradient is off set from that of RGB stars ?

What is the AGB kinematics?

What is the age distribution of AGB stars ?

What is the effect of differential extinction on the AGB selection?

Is the number of AGB stars produced consistent with the number expected?

The study of AGB stars can be extended to many other galaxies even in Virgo with the E-ELT.