Strömgren survey for Asteroseismology and Galactic Archaeology

www.mso.anu.edu.au/saga

Luca Casagrande

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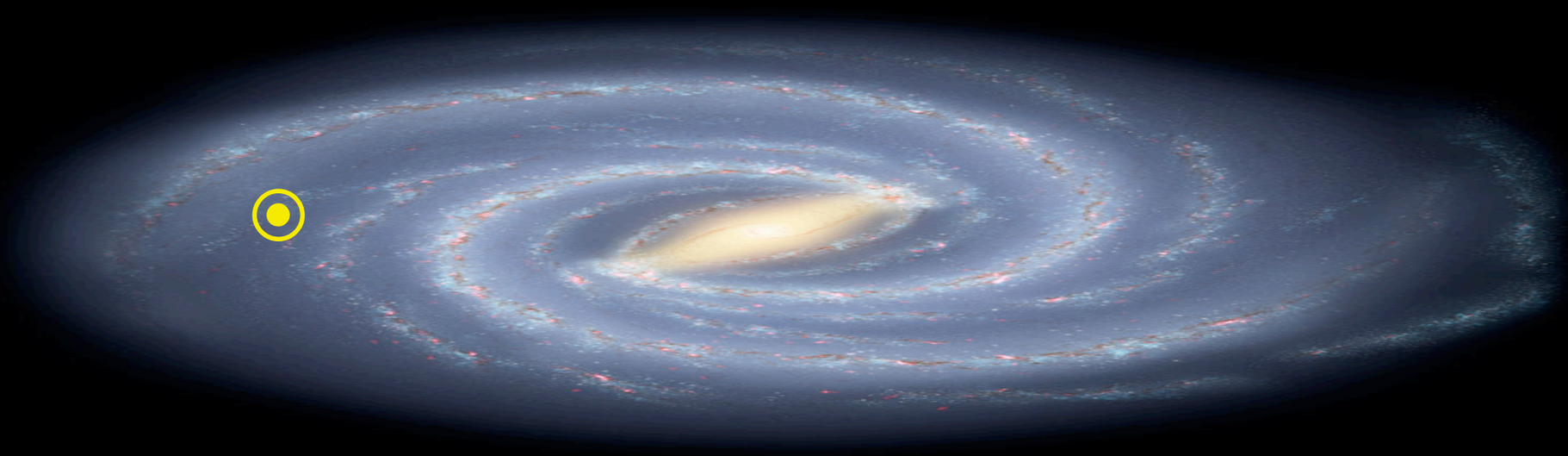
A.P. Milone, S. Hodgkin, A.F. Marino,
A. Pietrinferni, M. Asplund, S. Feltzing,
C. Flynn, F. Grundahl, P.E. Nissen,
R. Schönrich, K.J. Schlesinger, W. Wang

Galactic Evolution (=baryons!)

e.g. Lynden-Bell 1975, Tinsley 1980, Matteucci & Francois 1989, Chiappini et al. 1997, Schönrich & Binney (2009)



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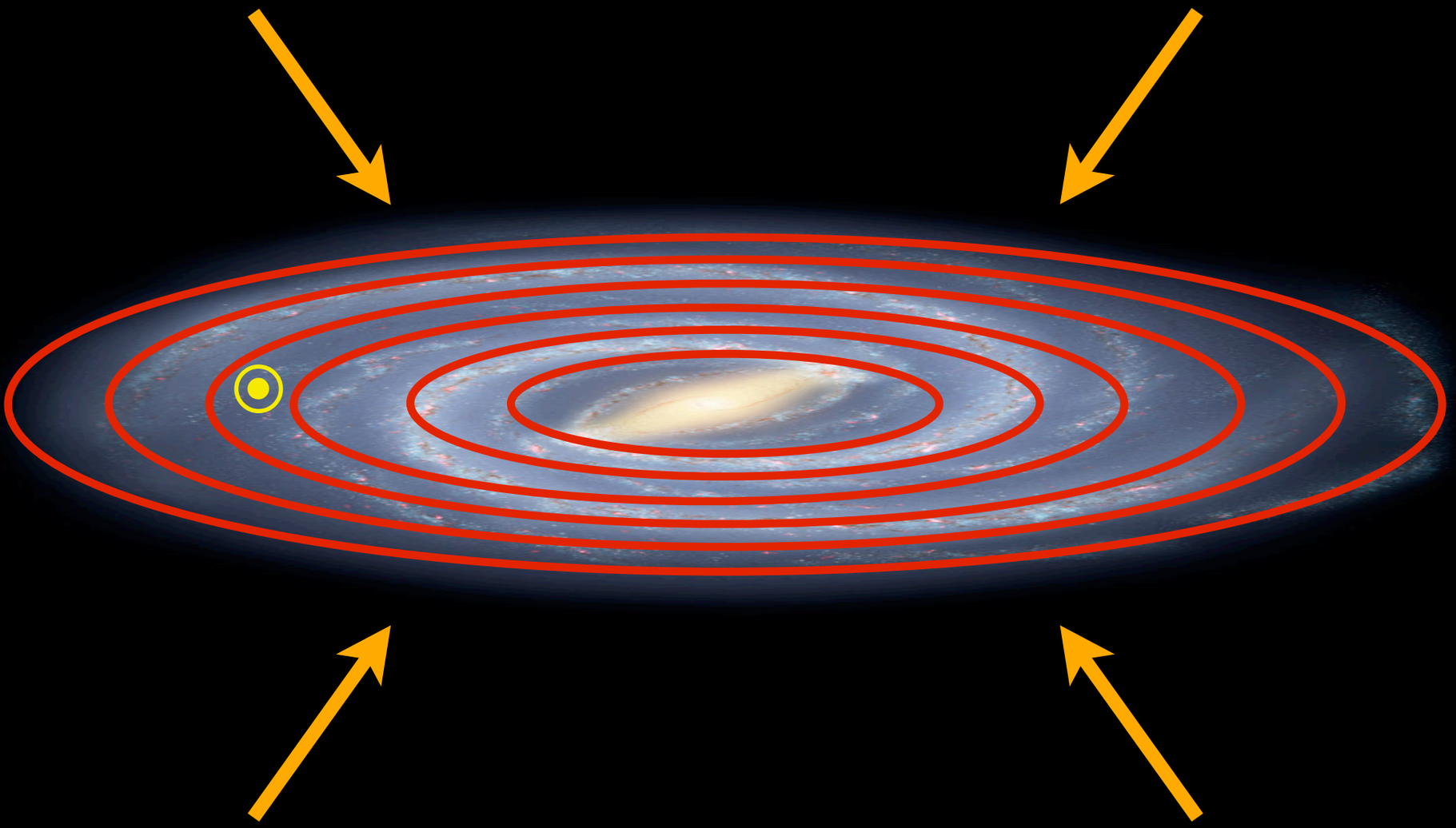

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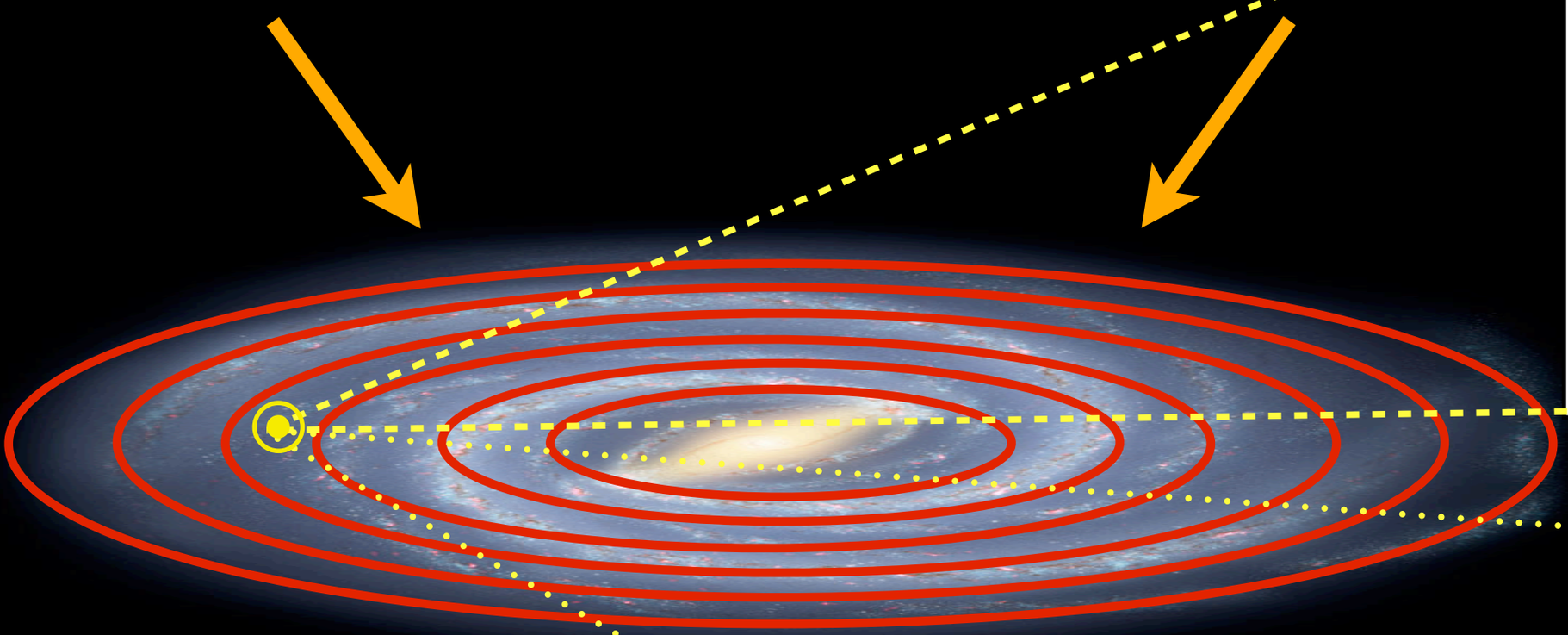

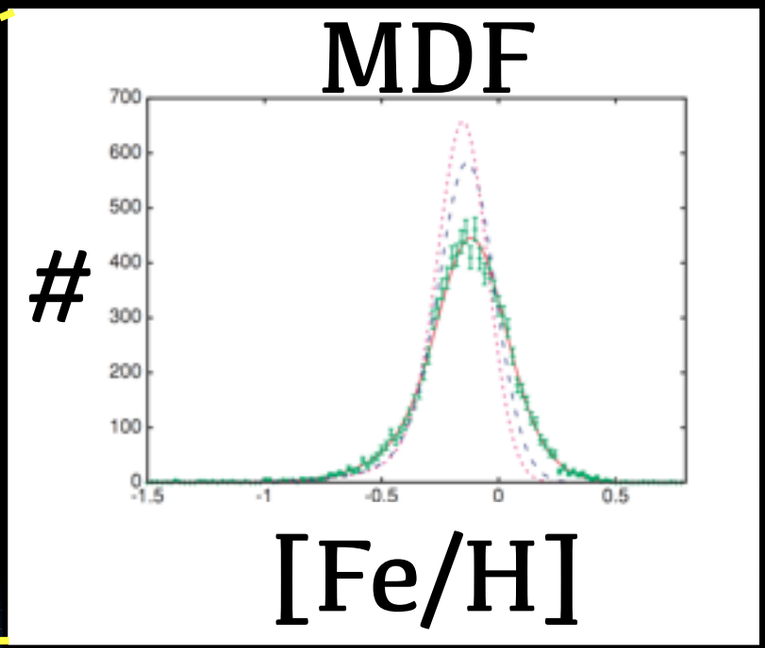

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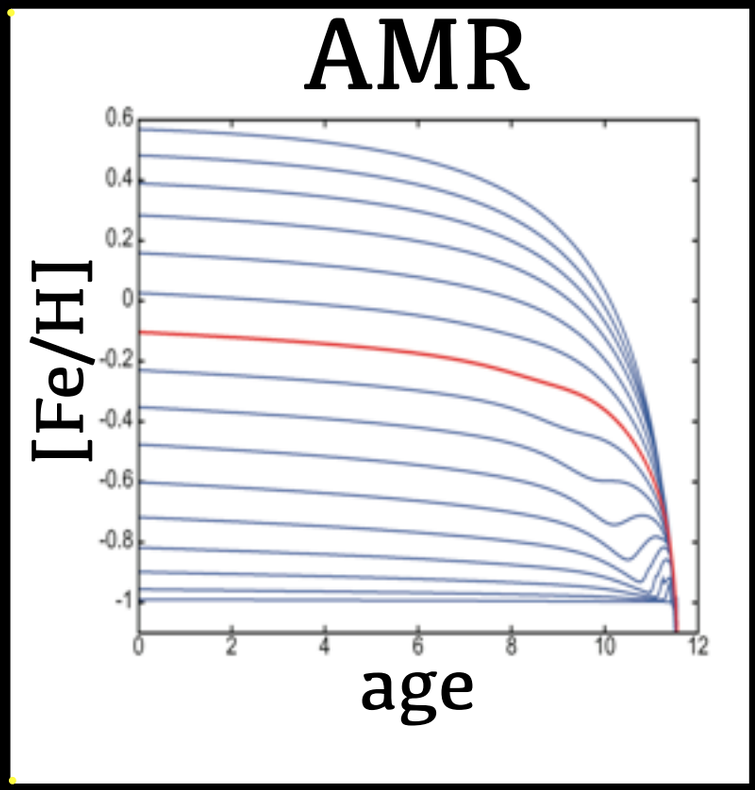

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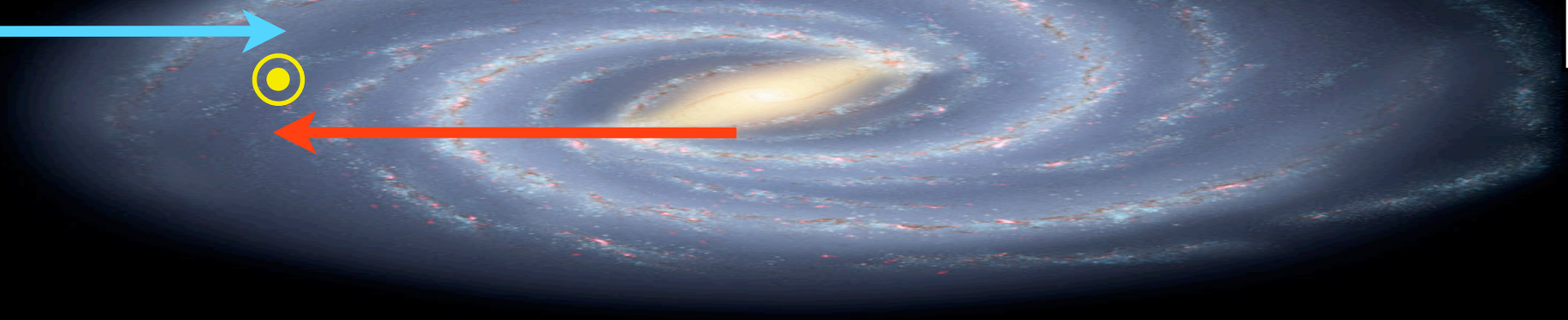

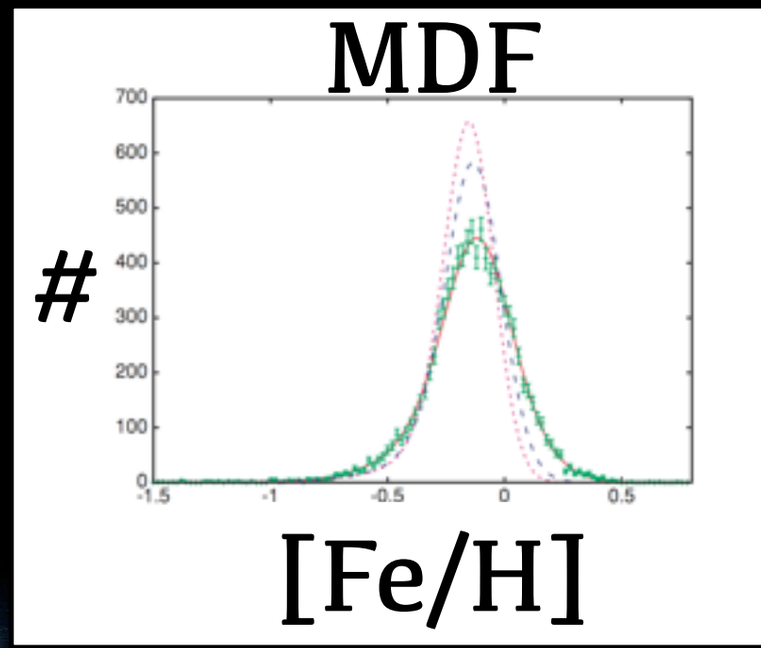

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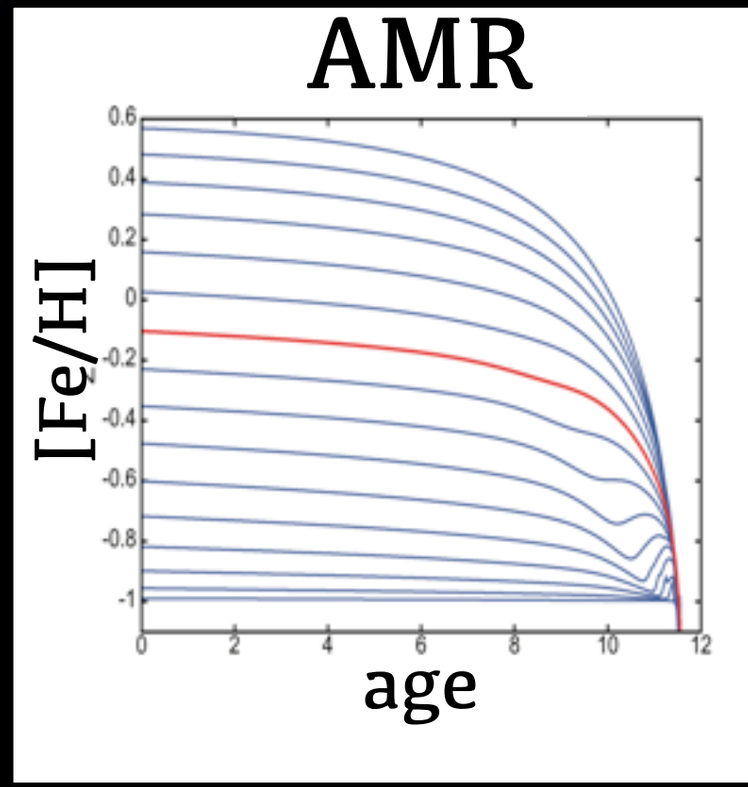

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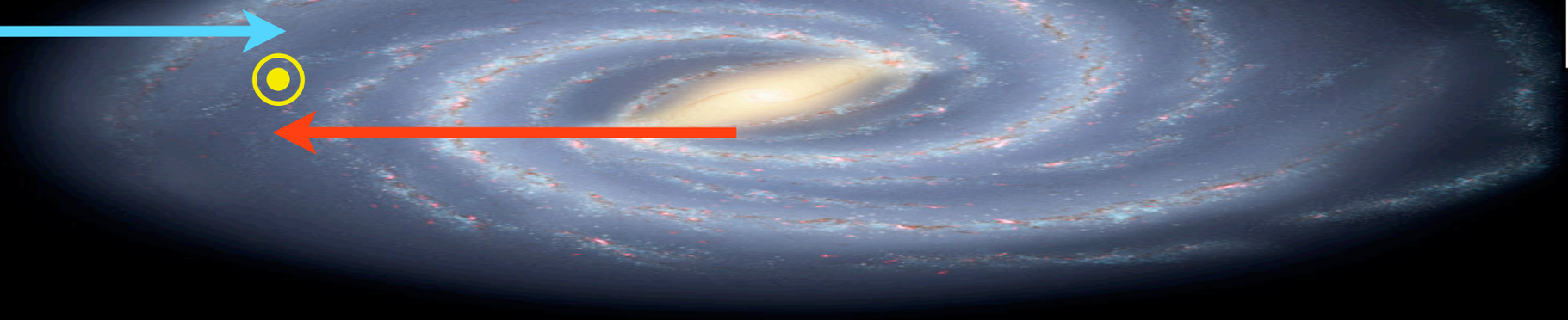

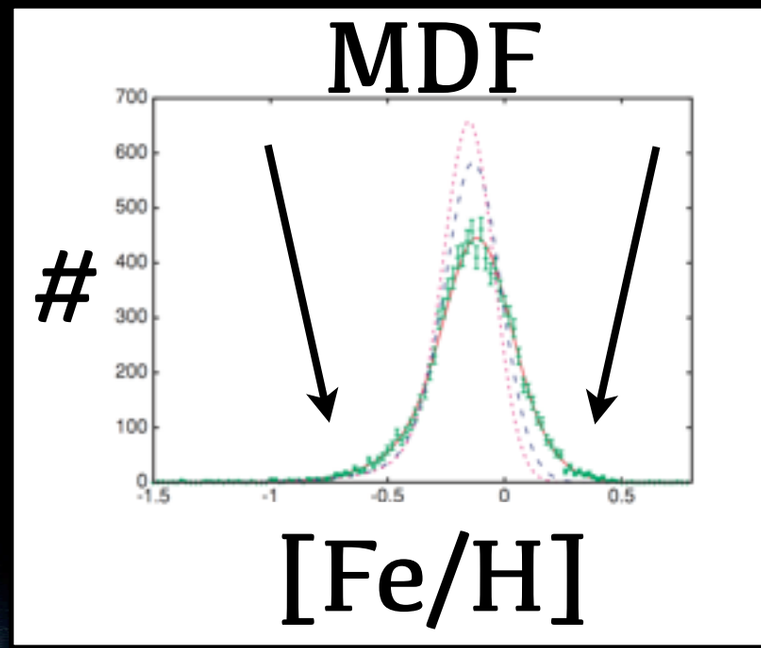

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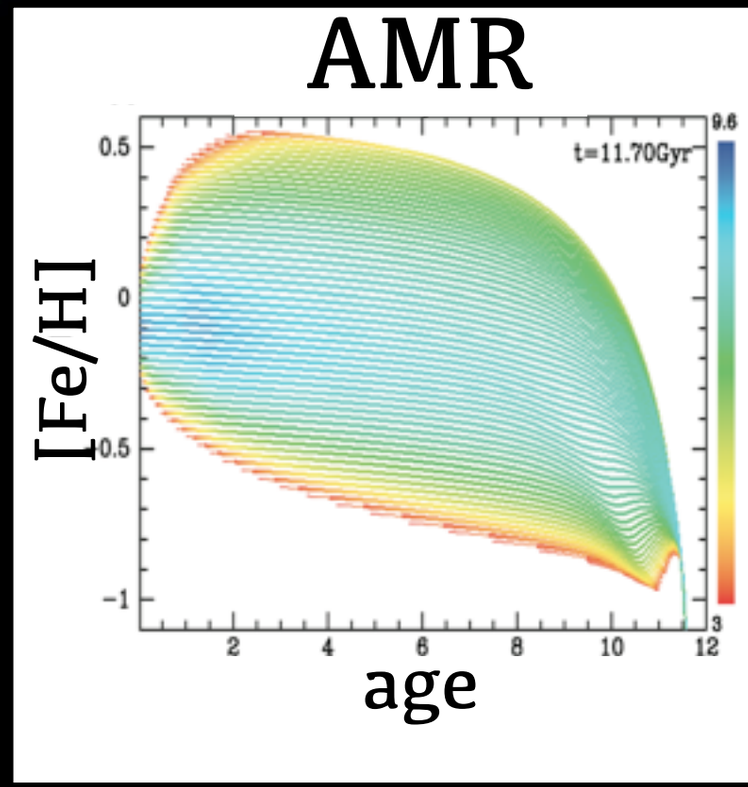

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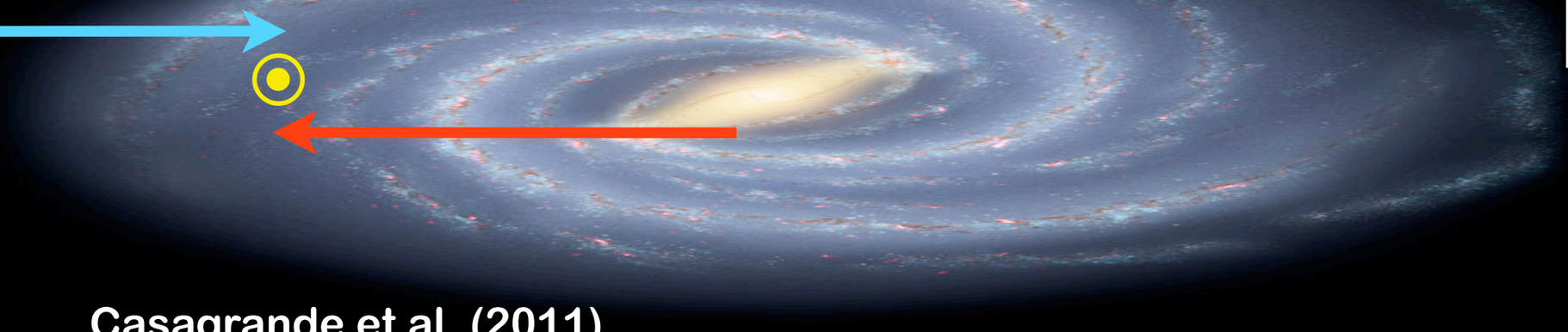

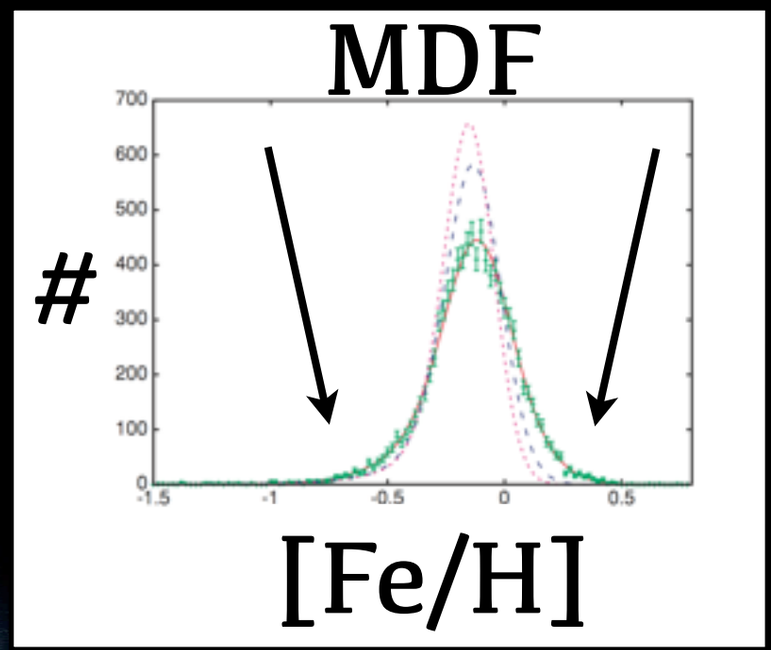

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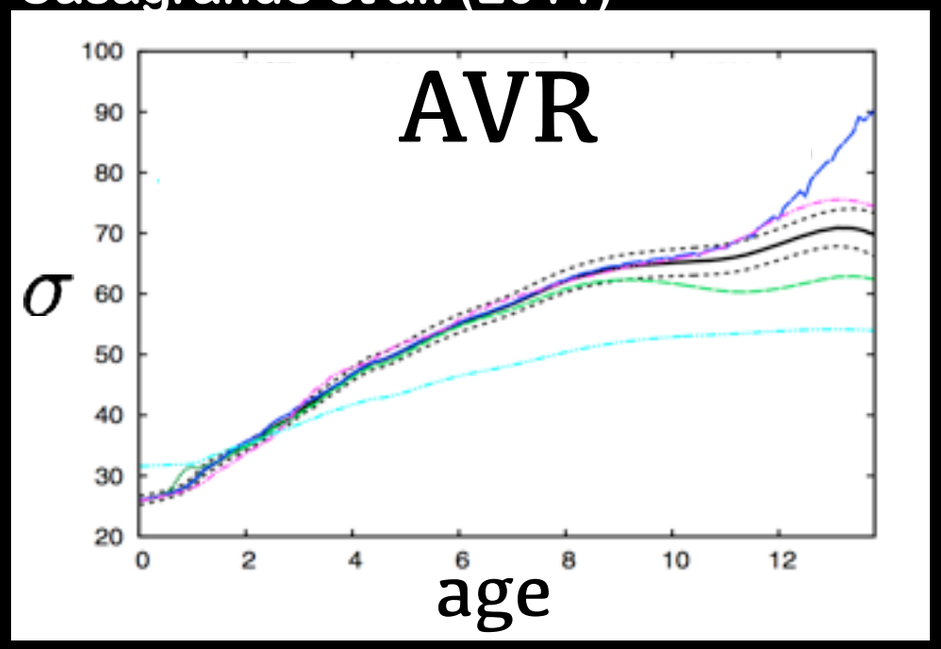
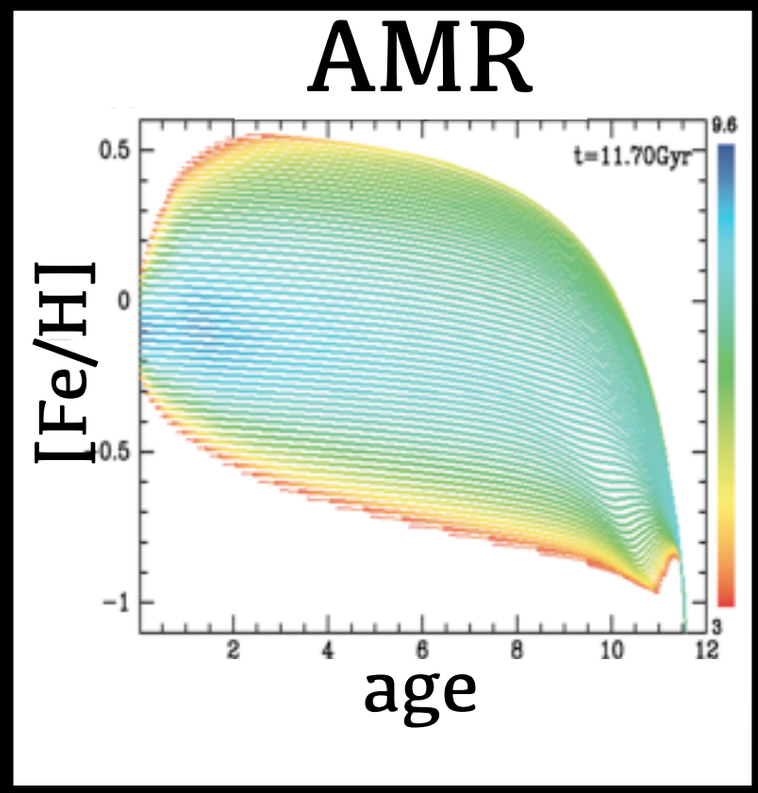
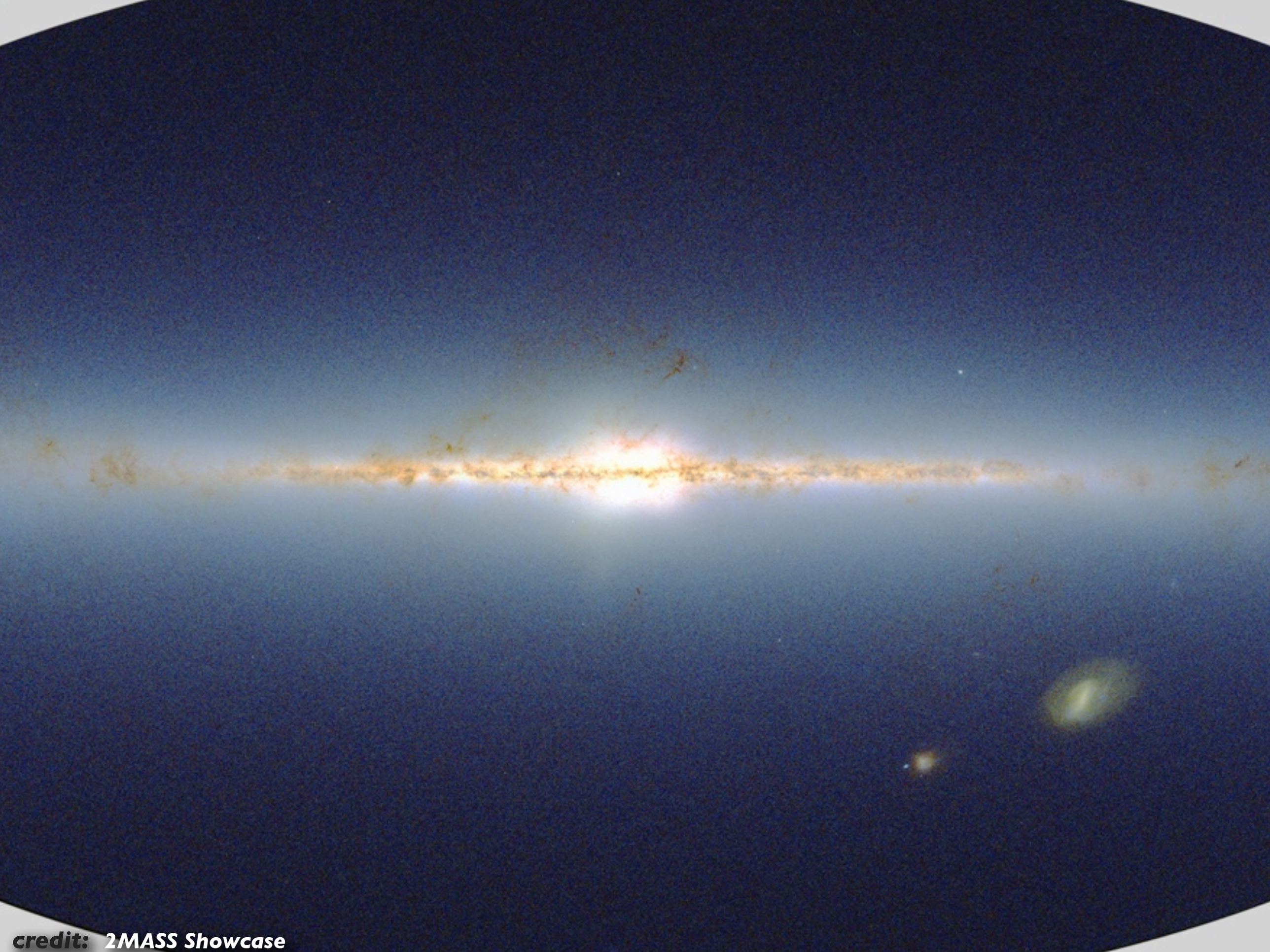
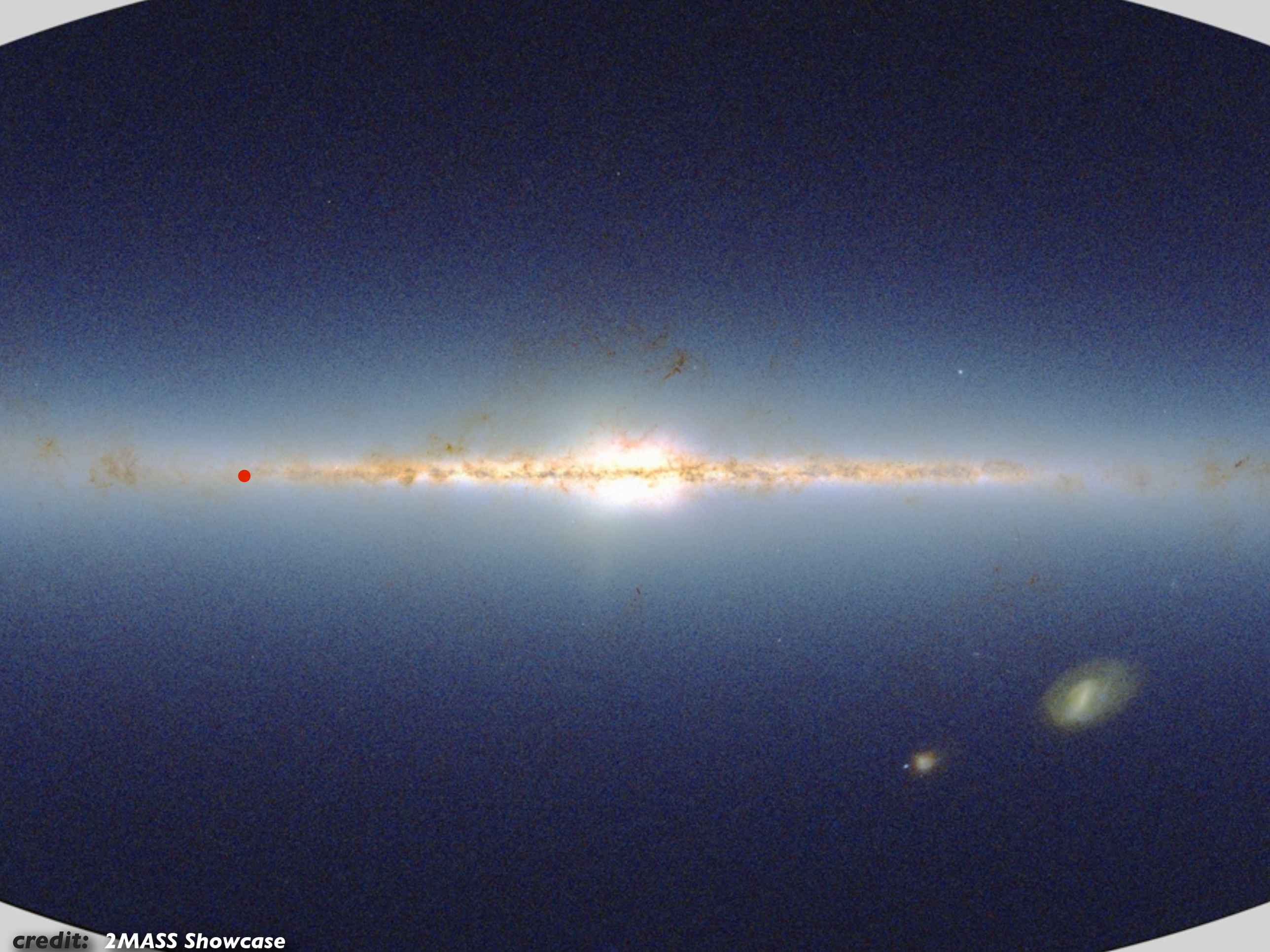
Casagrande et al. (2011)







credit: 2MASS Showcase



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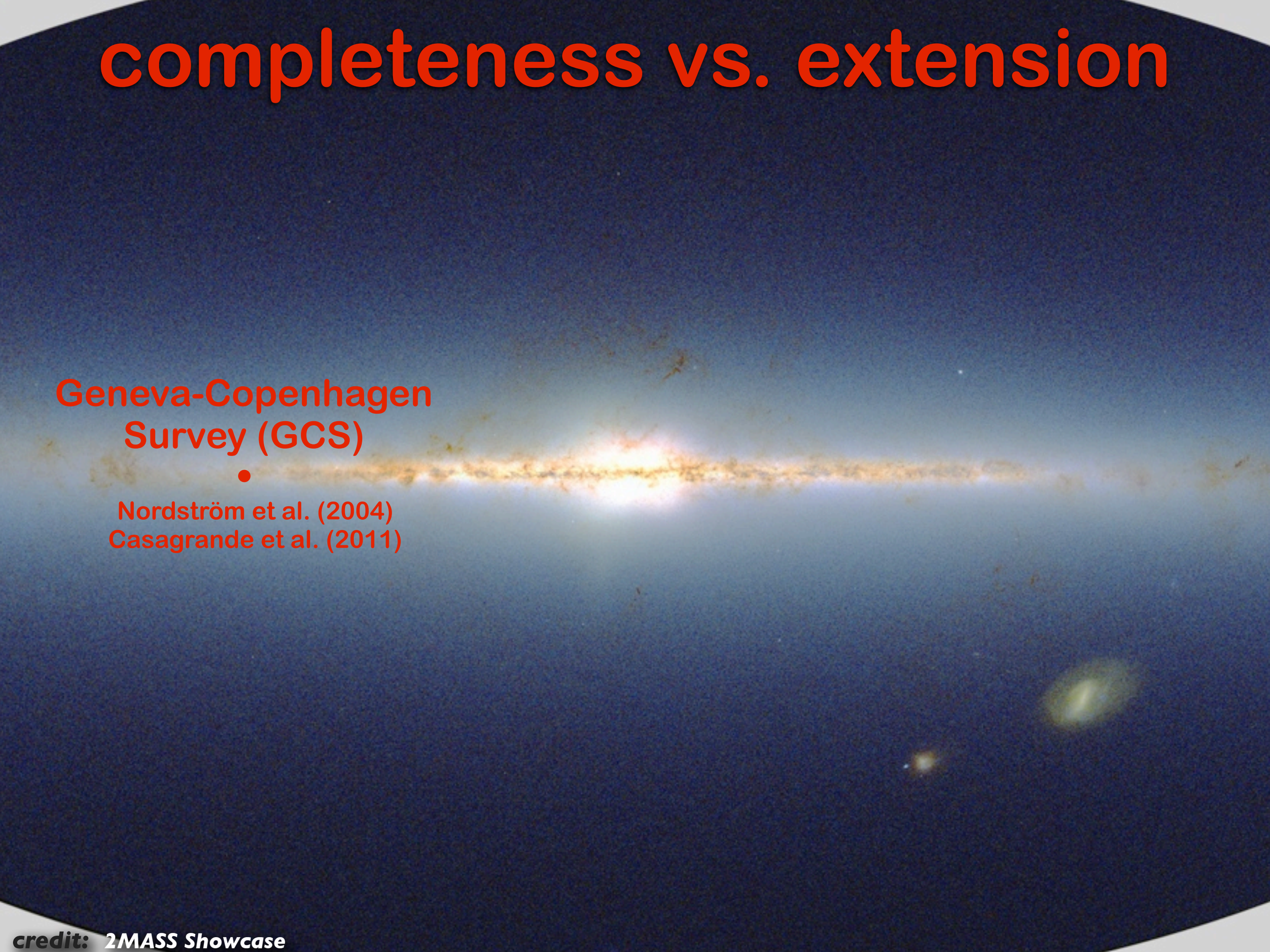
completeness vs. extension

Geneva-Copenhagen Survey (GCS)

Nordström et al. (2004)
Casagrande et al. (2011)



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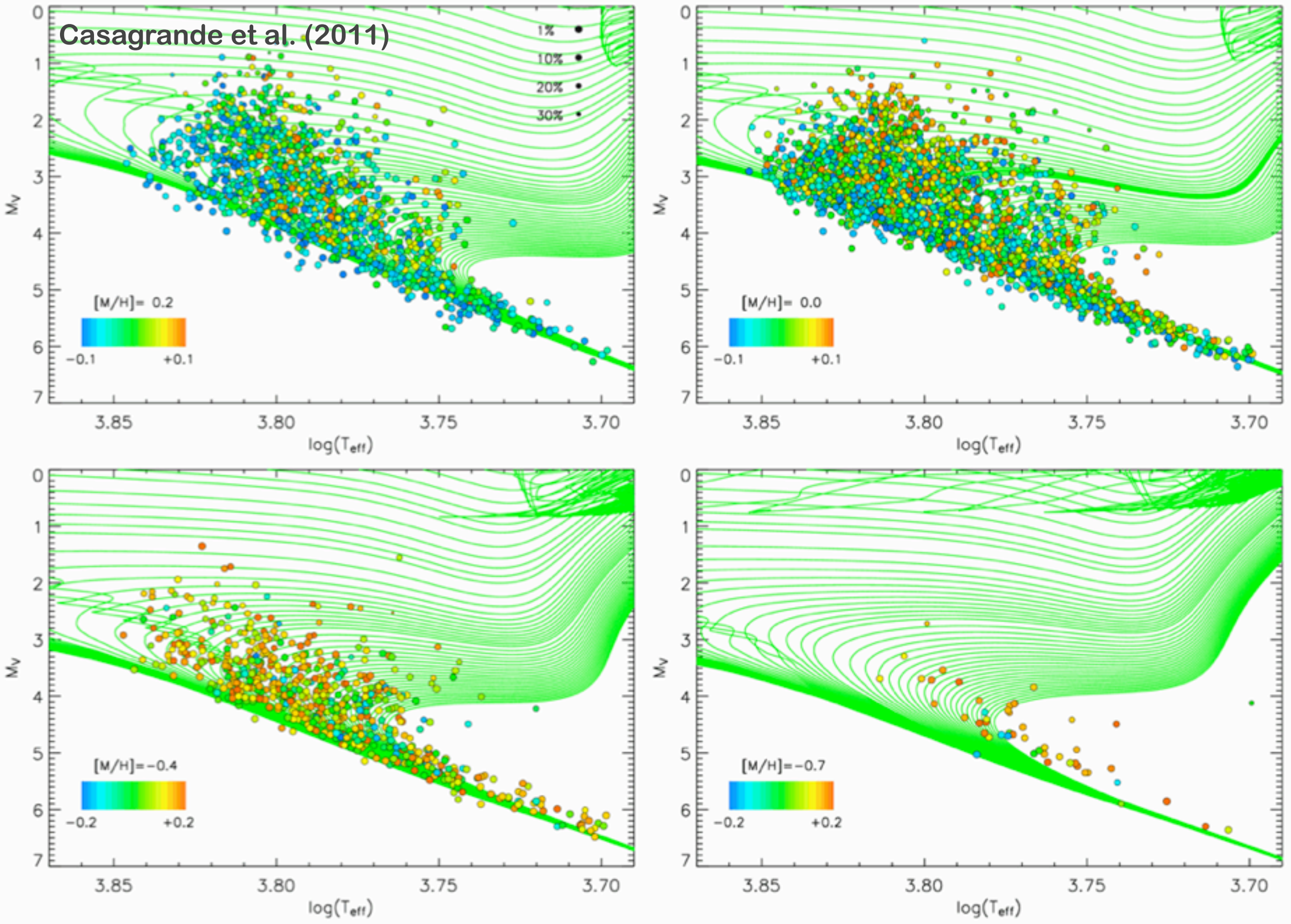
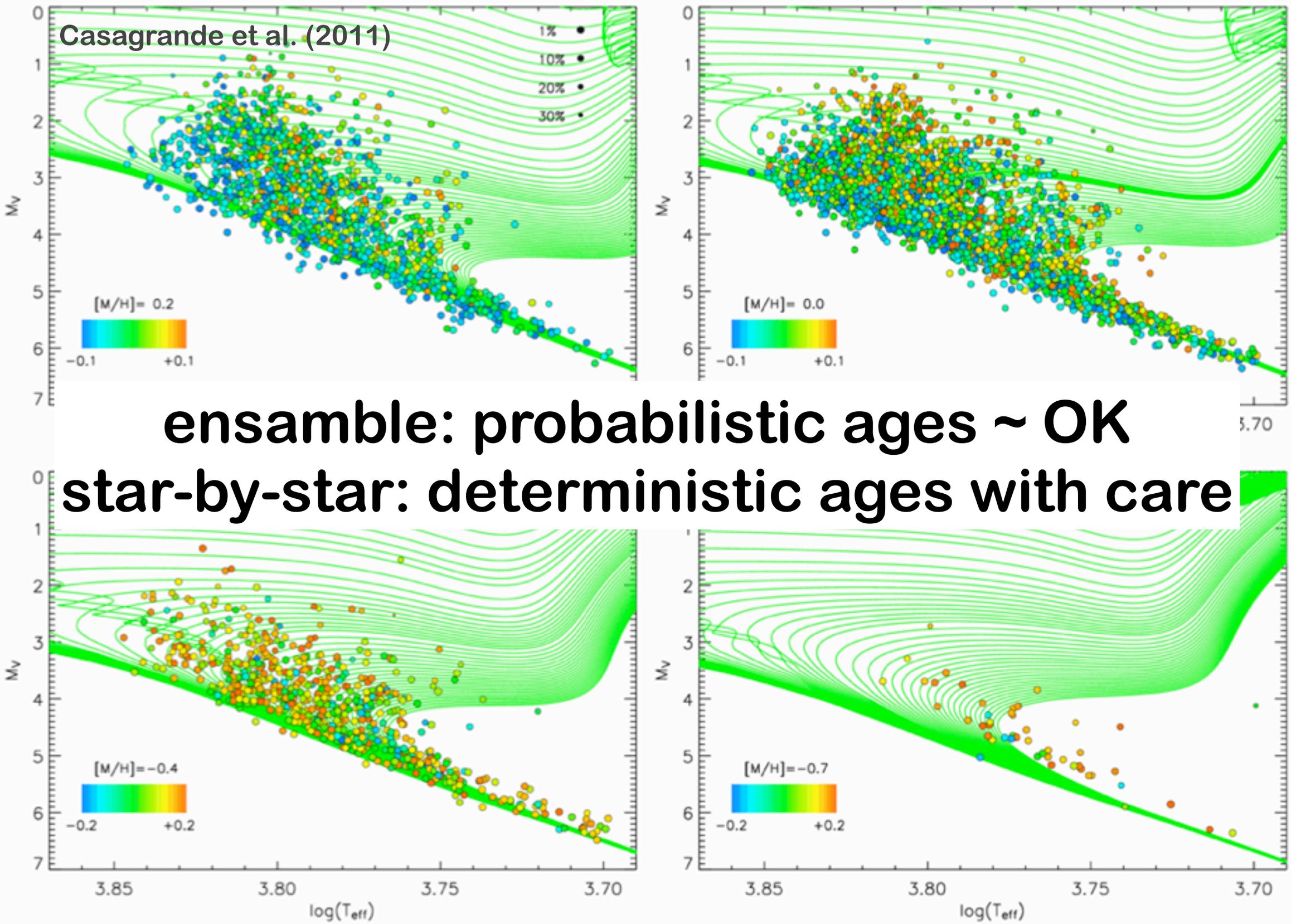


cf. e.g. Pont & Eyer (2004), Jørgensen & Lindegren (2005), Burnett & Binney (2010)

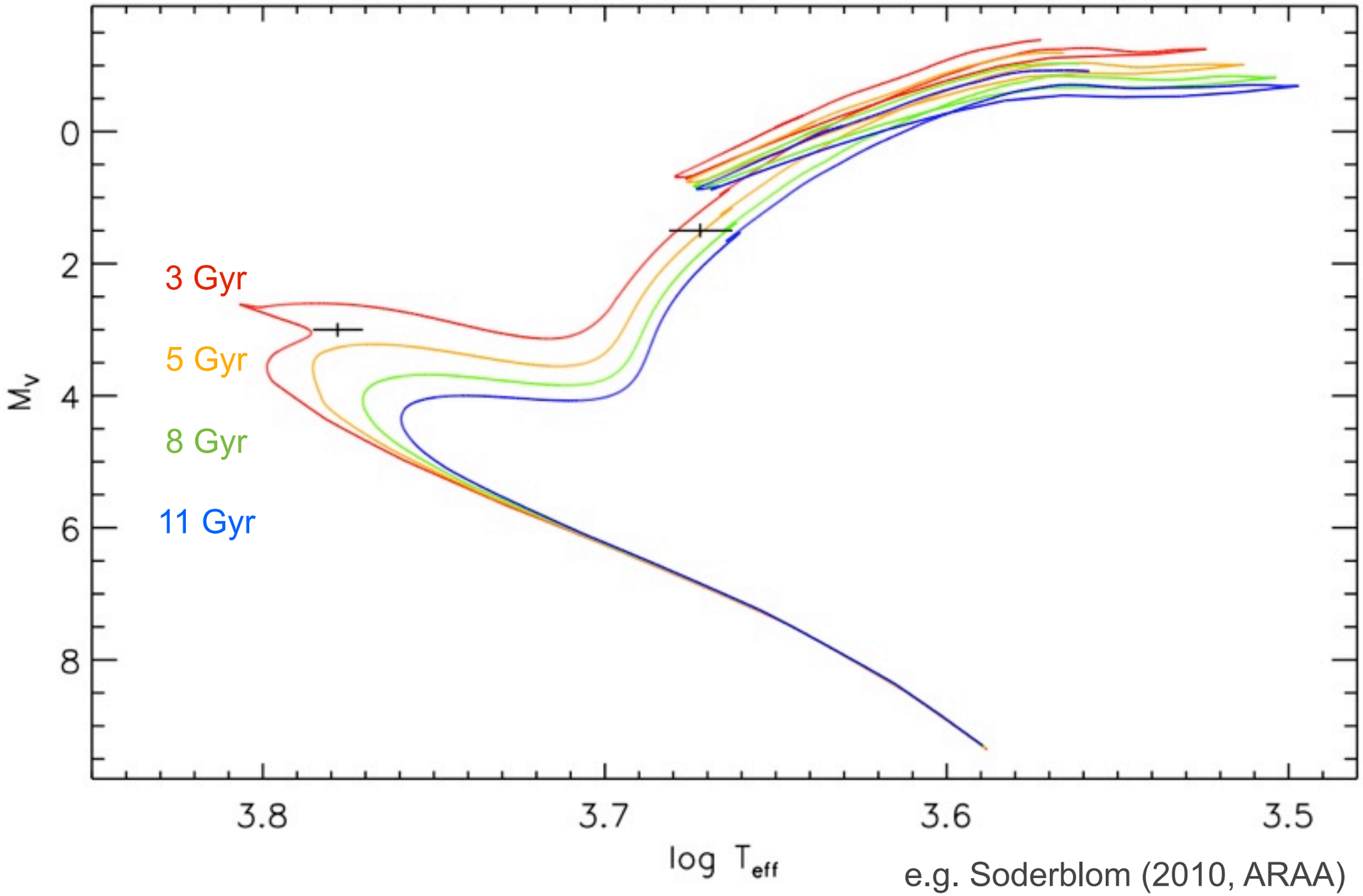
Sweeping (many things) under the rug



ensamble: probabilistic ages ~ OK

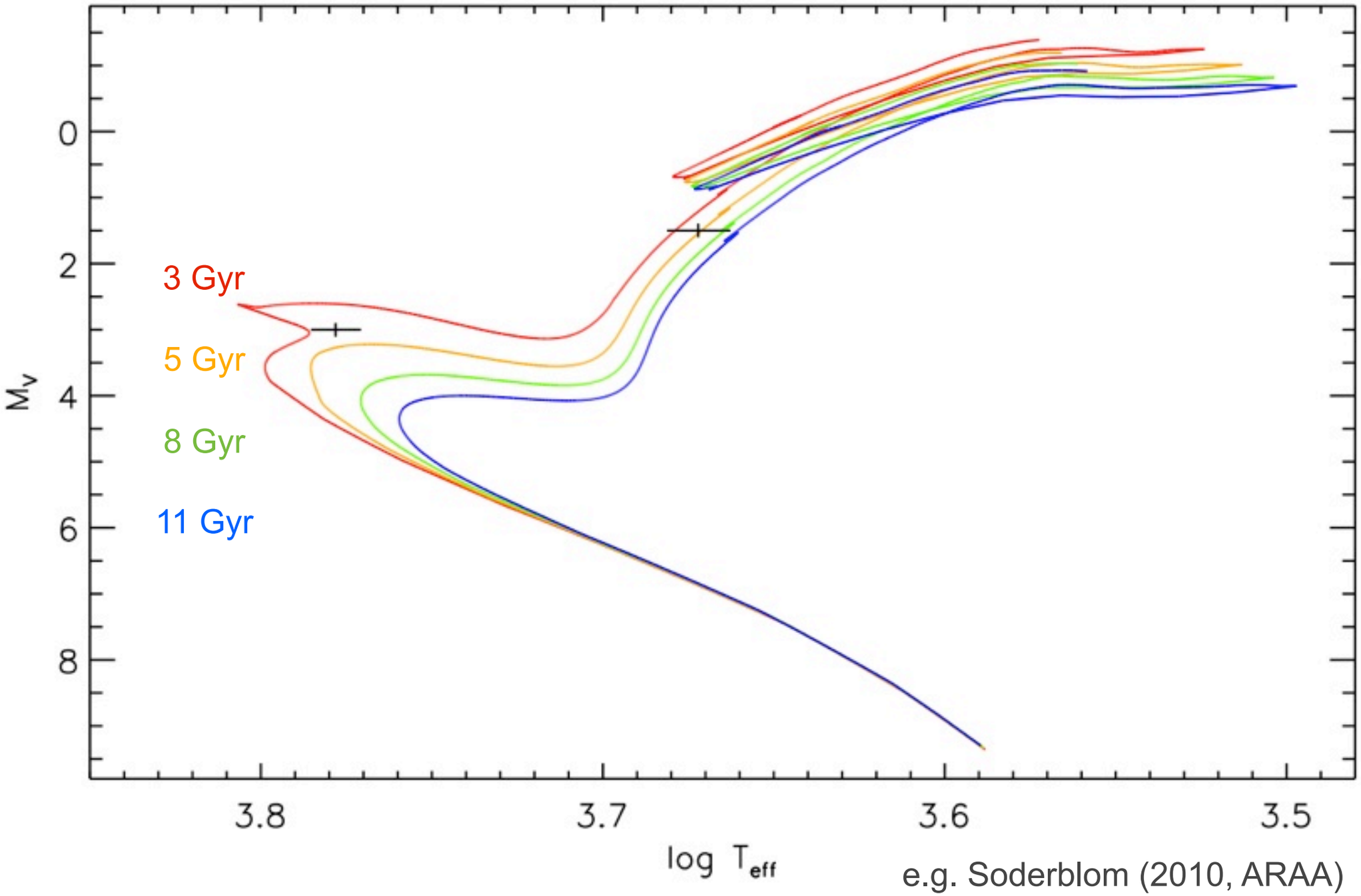
star-by-star: deterministic ages with care

cf. e.g. Pont & Eyer (2004), Jørgensen & Lindegren (2005), Burnett & Binney (2010)



e.g. Soderblom (2010, ARAA)

Ages of intrinsically bright and long lived stars



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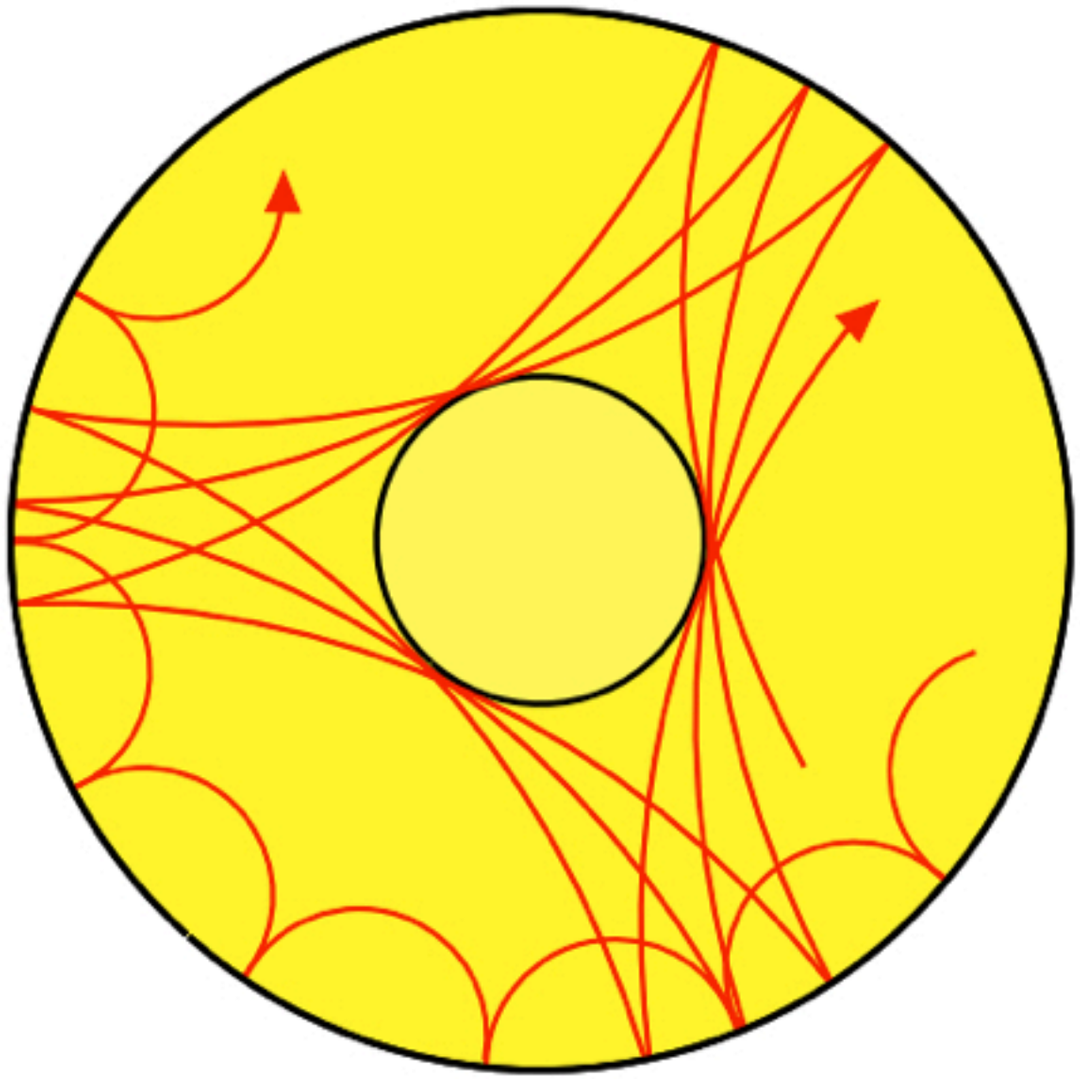
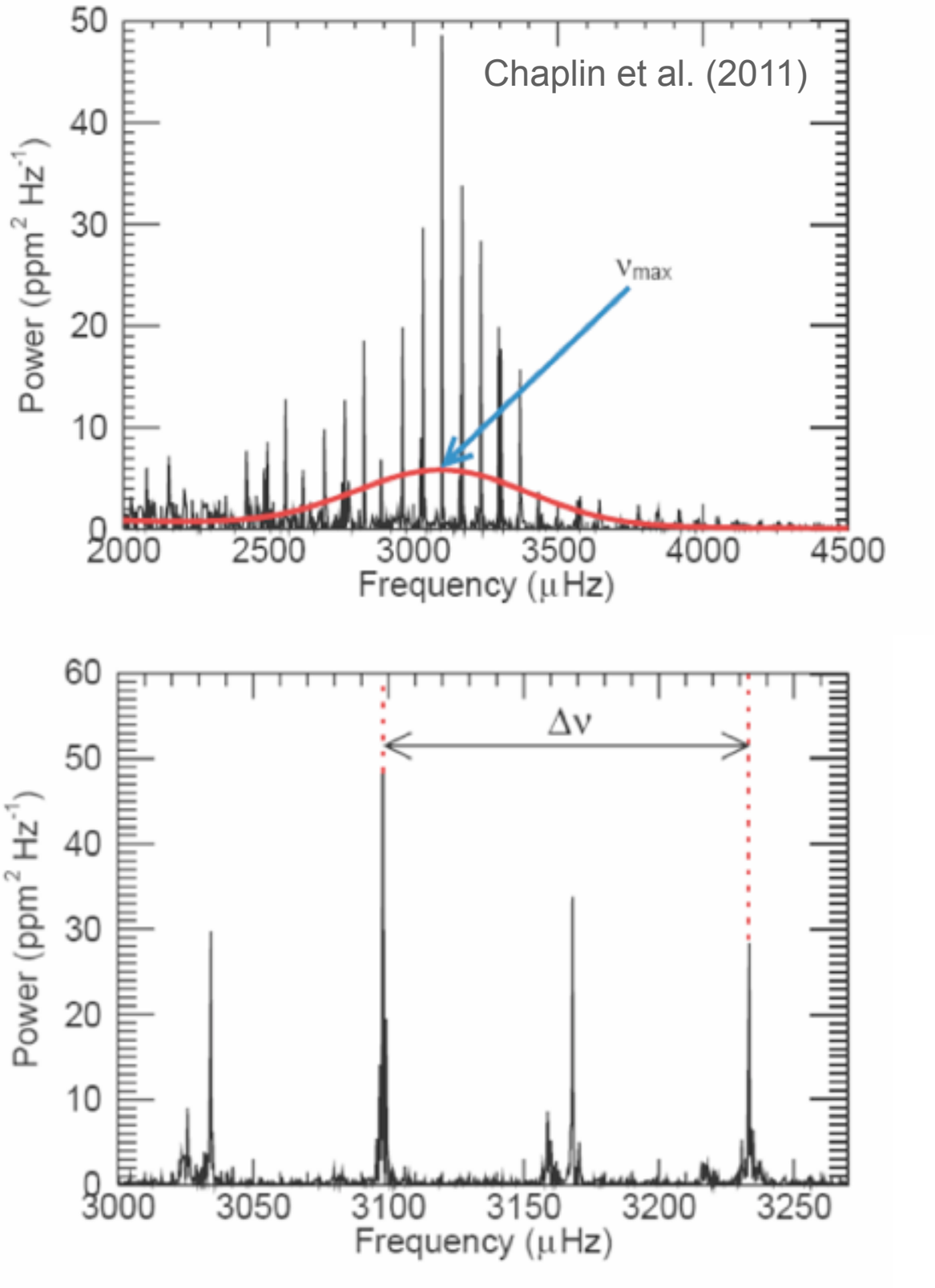


Asteroseismology



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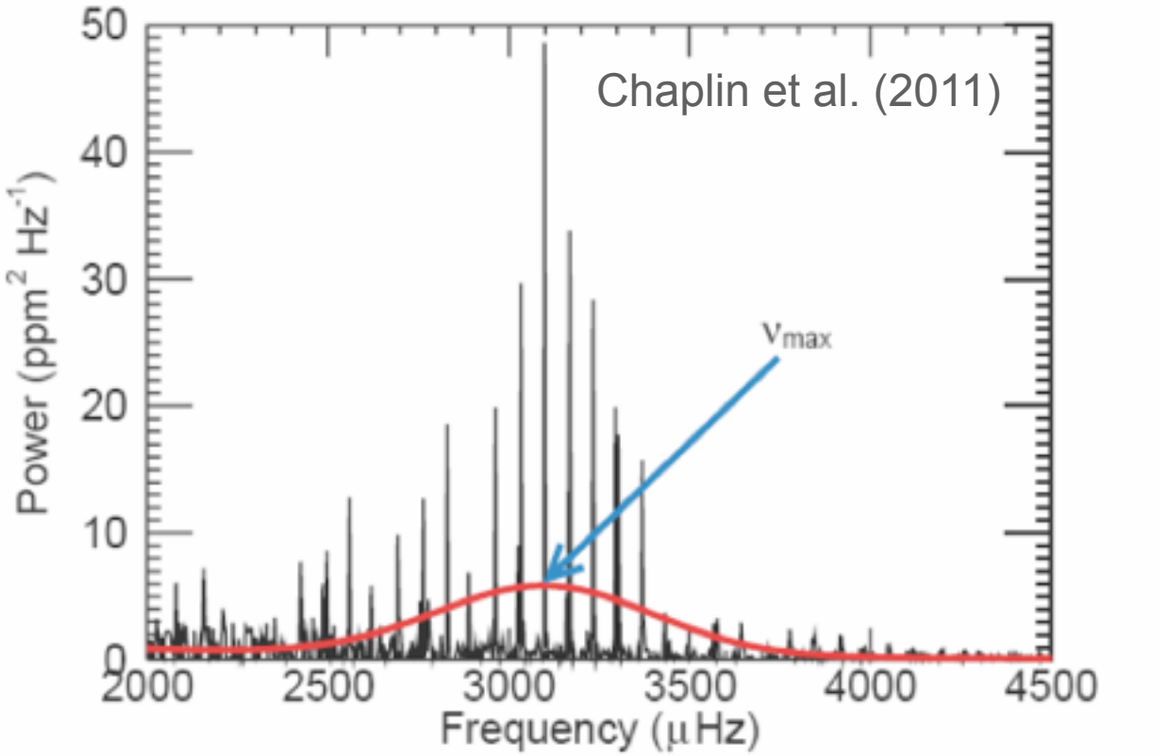
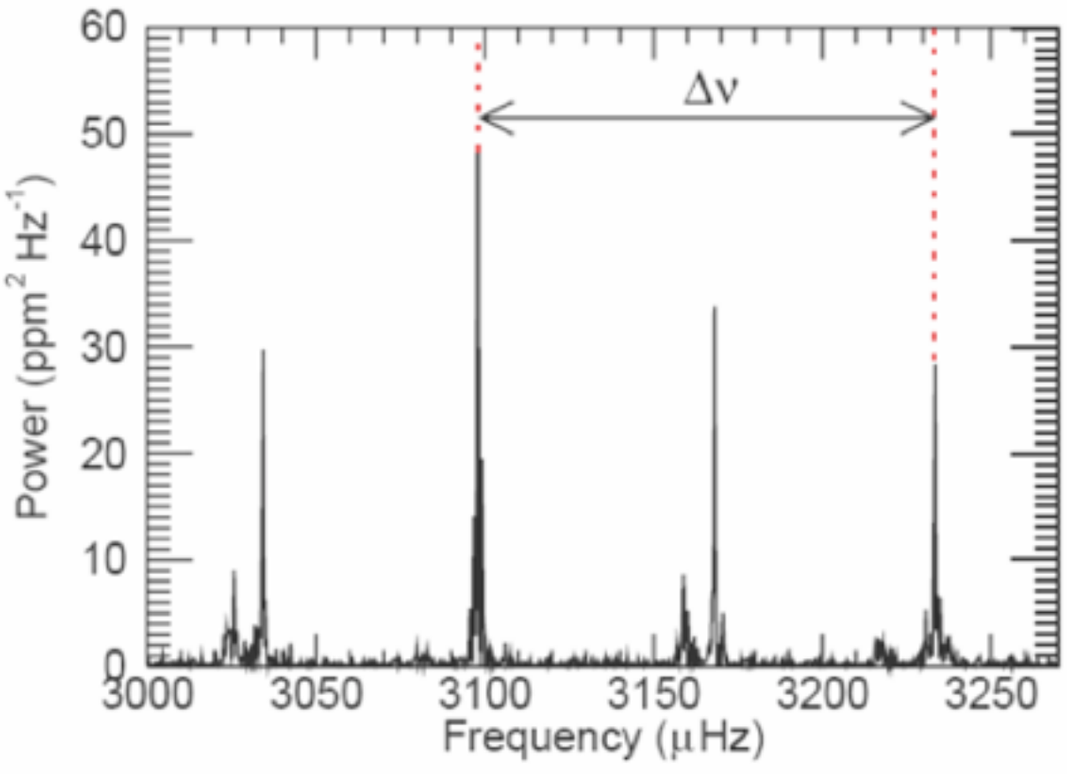




Ages

$$\frac{M}{M_\odot} \simeq \left(\frac{\nu_{\rm max}}{\nu_{\rm max,\odot}}\right)^3 \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{3/2}$$

Distances

$$\frac{R}{R_\odot} \simeq \left(\frac{\nu_{\rm max}}{\nu_{\rm max,\odot}}\right) \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2}$$

e.g. Hekker et al. 2009, 2011, Stello et al. 2009, and exceedingly precise log(g) values (e.g. Gai et al. 2011, Chaplin et al. 2014)

Asteroseismology + IRFM= distances

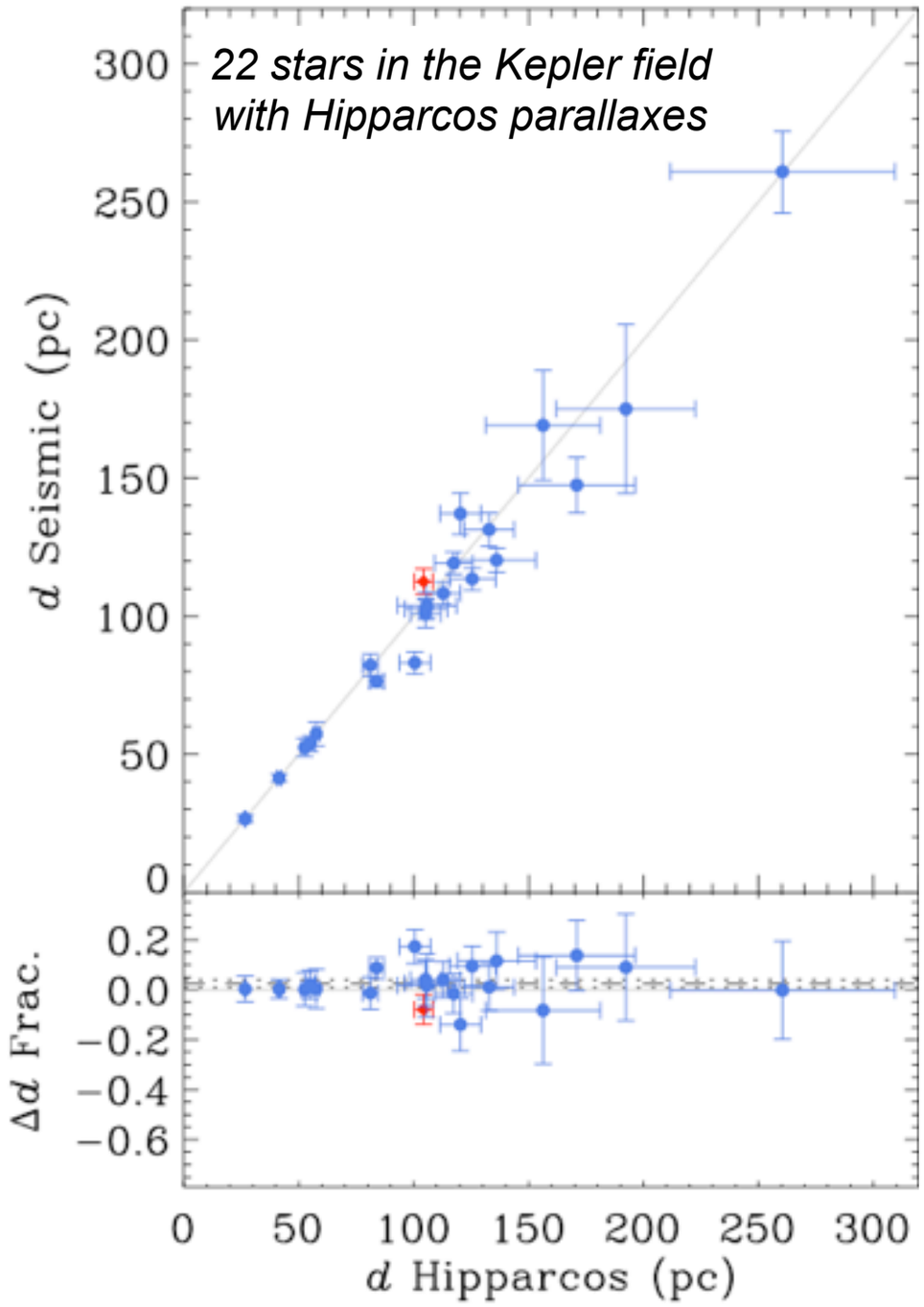
Asteroseismology + IRFM= distances

(Silva Aguirre, Casagrande, Basu et al. 2012; Miglio et al. 2013)

$$\frac{R}{R_\odot} = \left(\frac{\nu_{\rm max}}{\nu_{\rm max,\odot}}\right)\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2}$$

$$\mathcal{F}_{Bol} = \left(\frac{\theta}{2}\right)^2 \sigma T_{\rm eff}^4$$

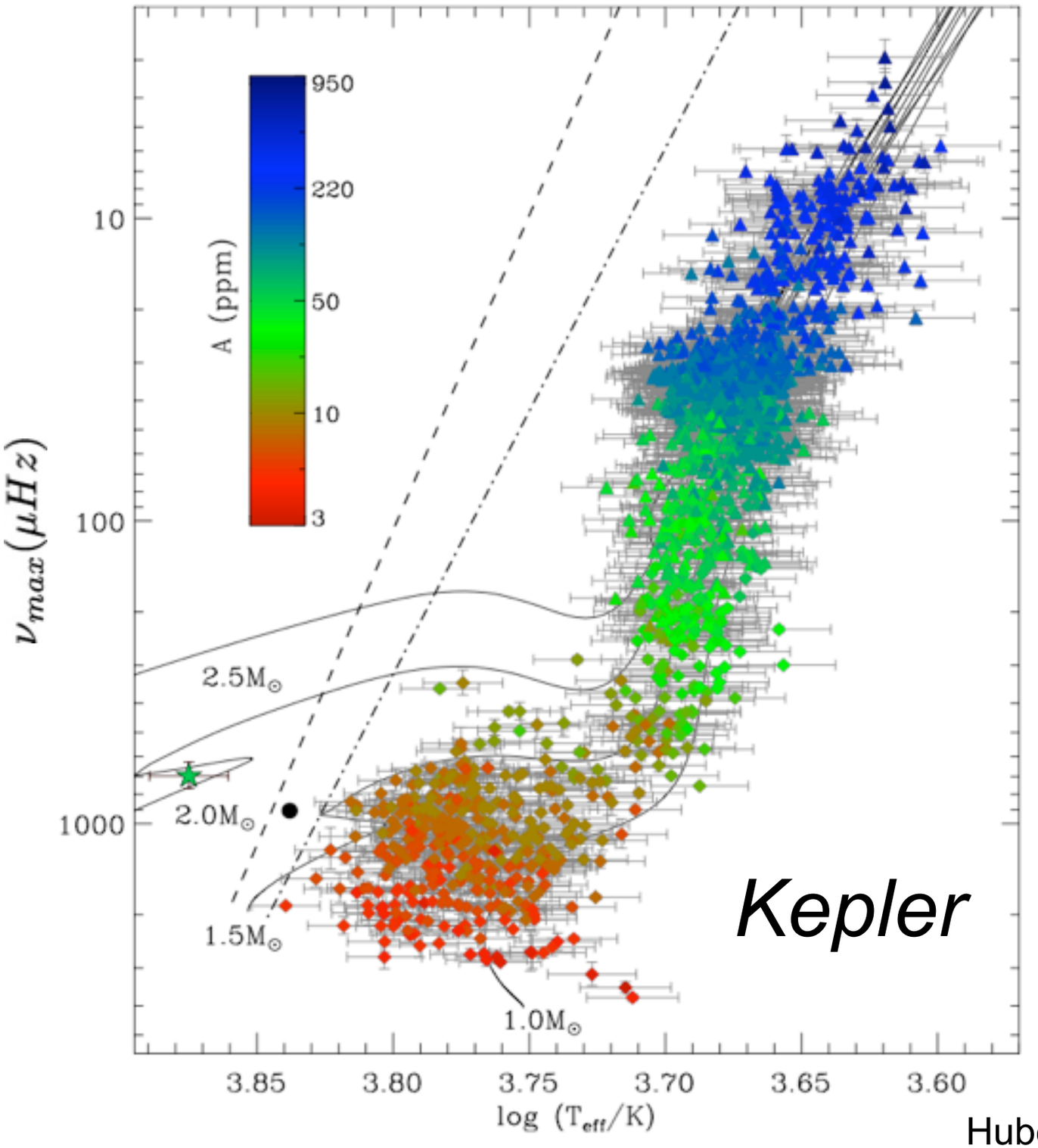
- Overall agreement: 2% ± 2%
- Considering *Hipparcos* parallaxes better than 5%: scatter 5% !



Revolution!

$\nu_{\rm max}$

$\Delta\nu$



$[\mathrm{Fe/H}]$

$T_{\rm eff}$

Huber et al. (2011)

DISTANCES

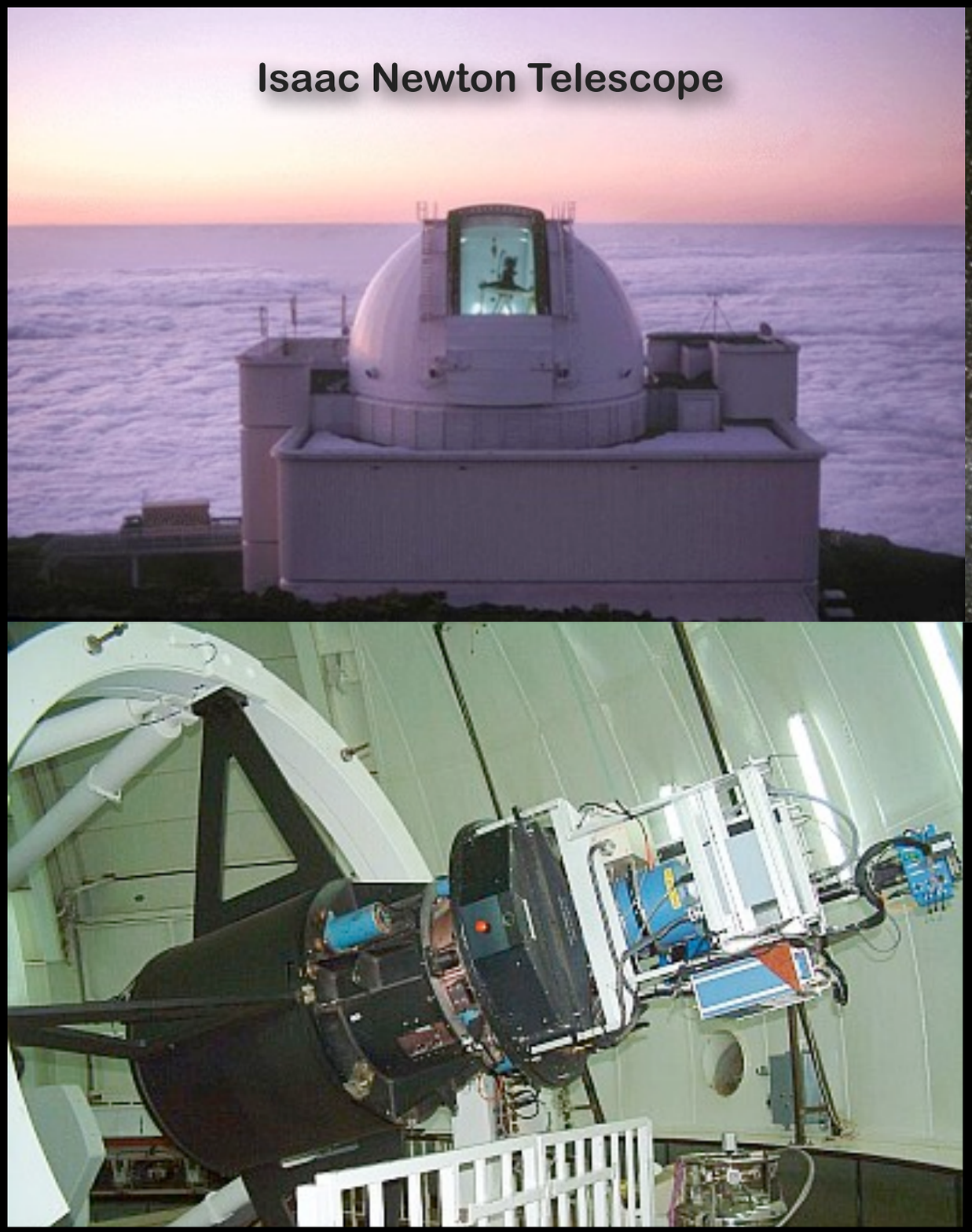
AGES

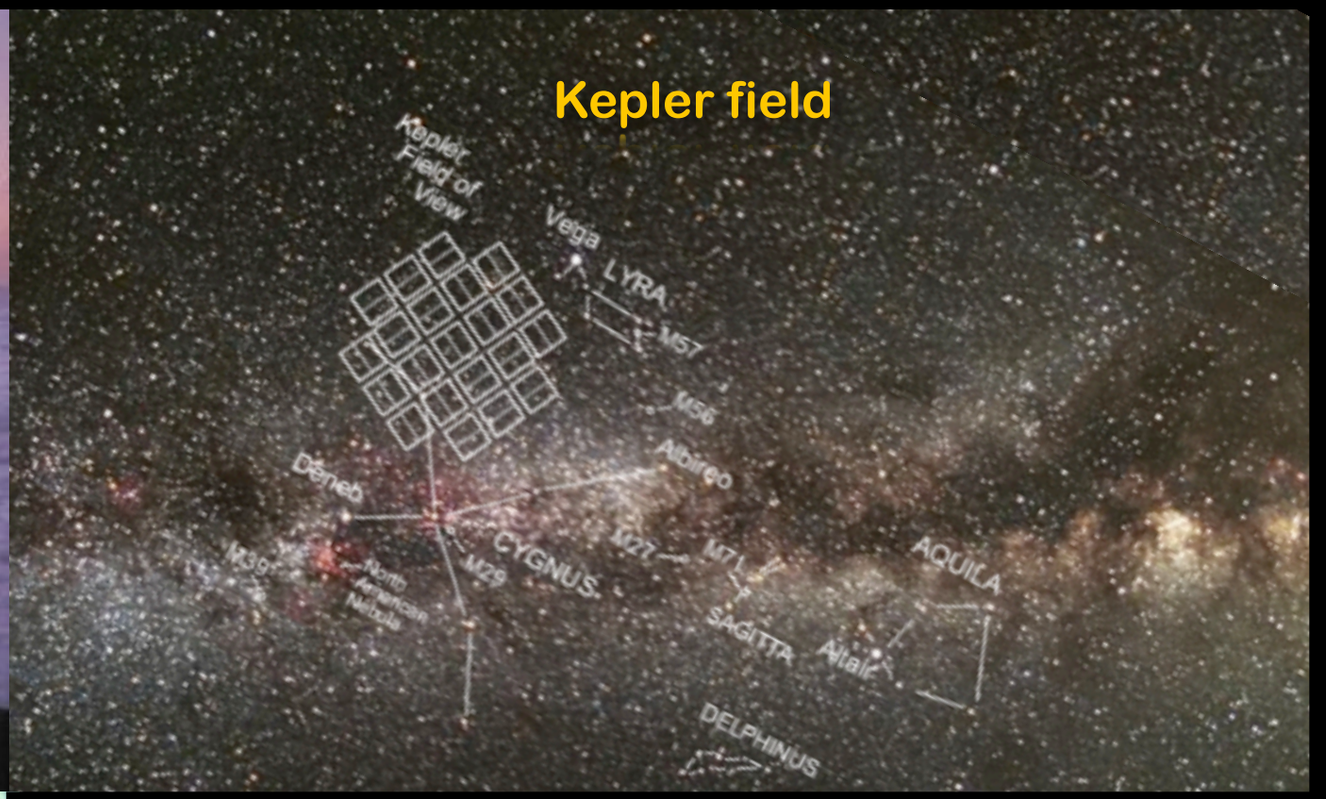
UNBIASED

in reality, forward modelling from theoretical models or bias correction are often needed, still

CLASSICAL PARAMETERS: [Fe/H] & T_{eff}

Strömgren survey for Asteroseismology and Galactic Archaeology

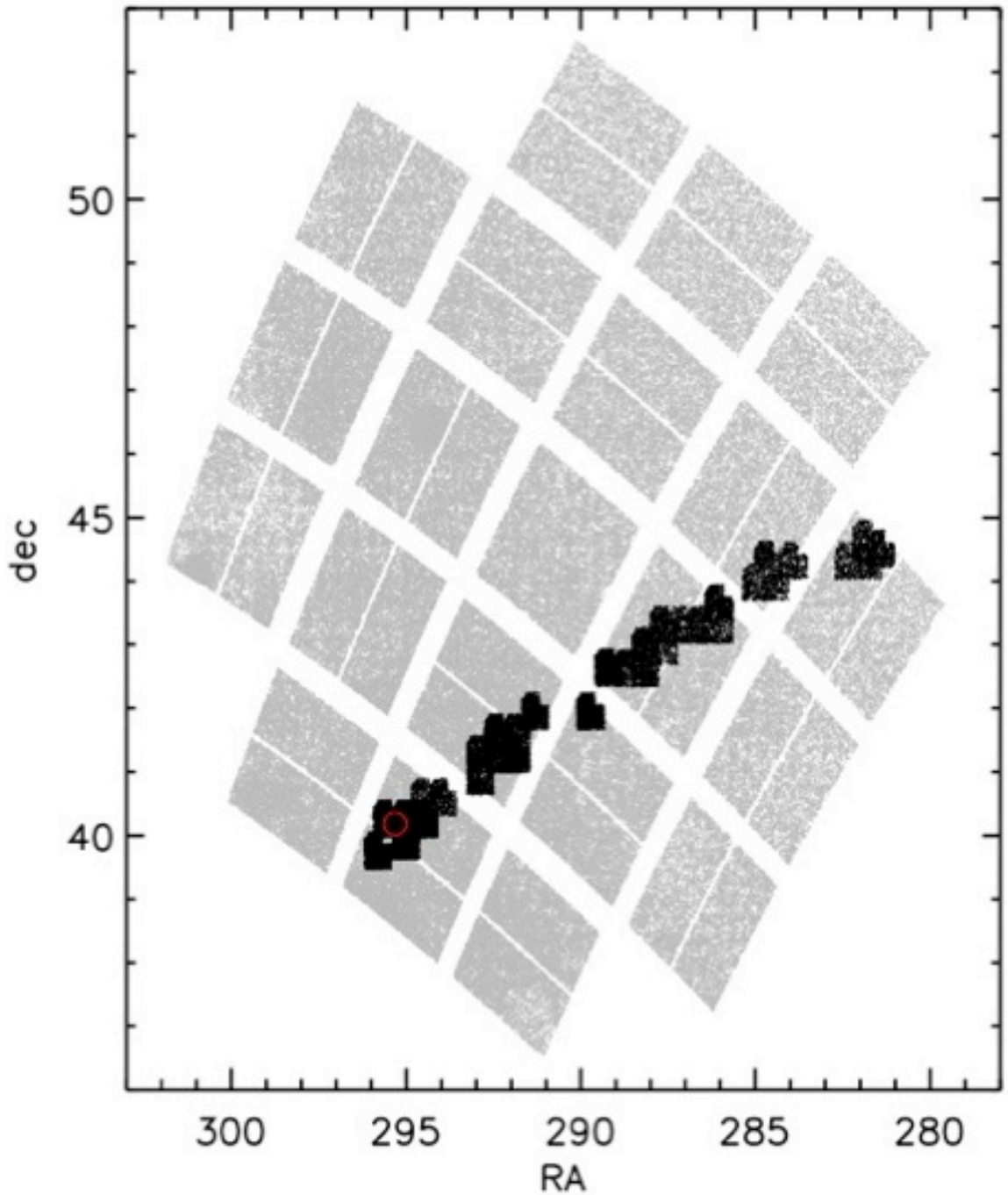


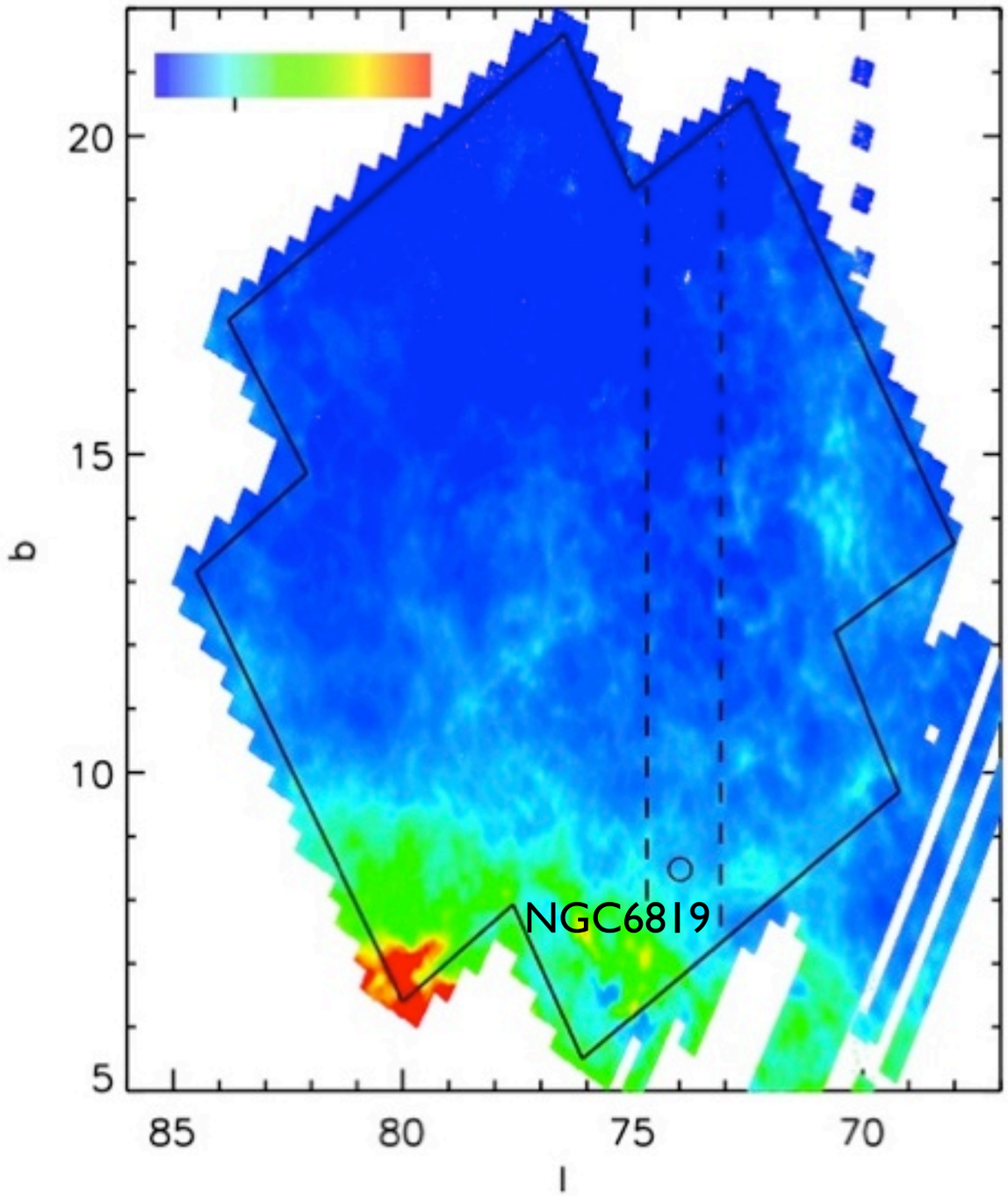


WFC @ INT:
- 2.5 m
- 34’ x 34’ FOV
- Strömgren *uvby*: [Fe/H]
- 21 nights (2012-2013) +
- 28 nights (2014-2015, Serenelli)

DR1

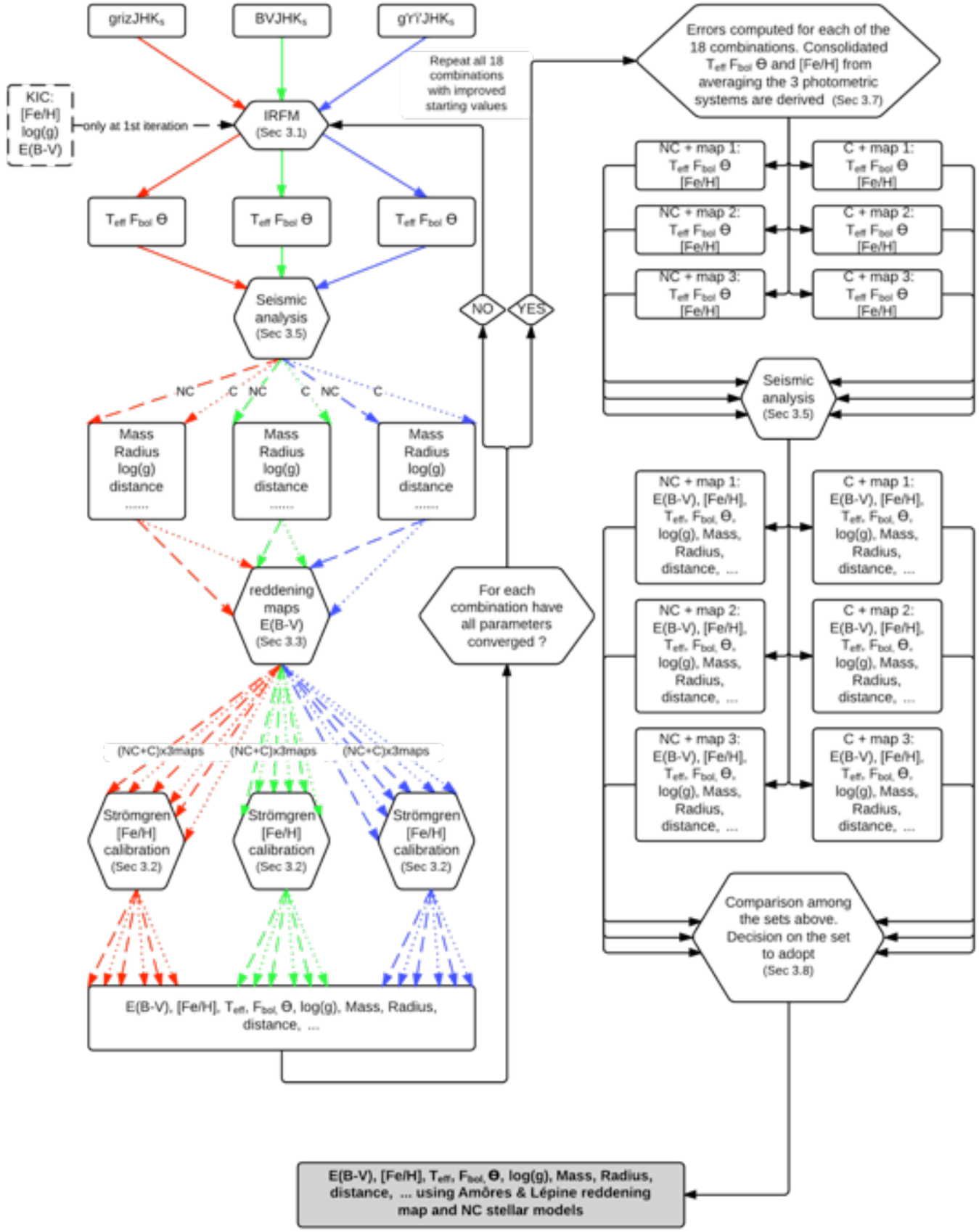
Casagrande, Silva Aguirre, Stello, Huber et al. (2014)





989 seismic stars

29000 stars



Casagrande, Silva Aguirre, Stello, Huber et al. (2014)

classical and seismic parameters derived self-consistently

Casagrande, Silva Aguirre, Stello, Huber et al. (2014)

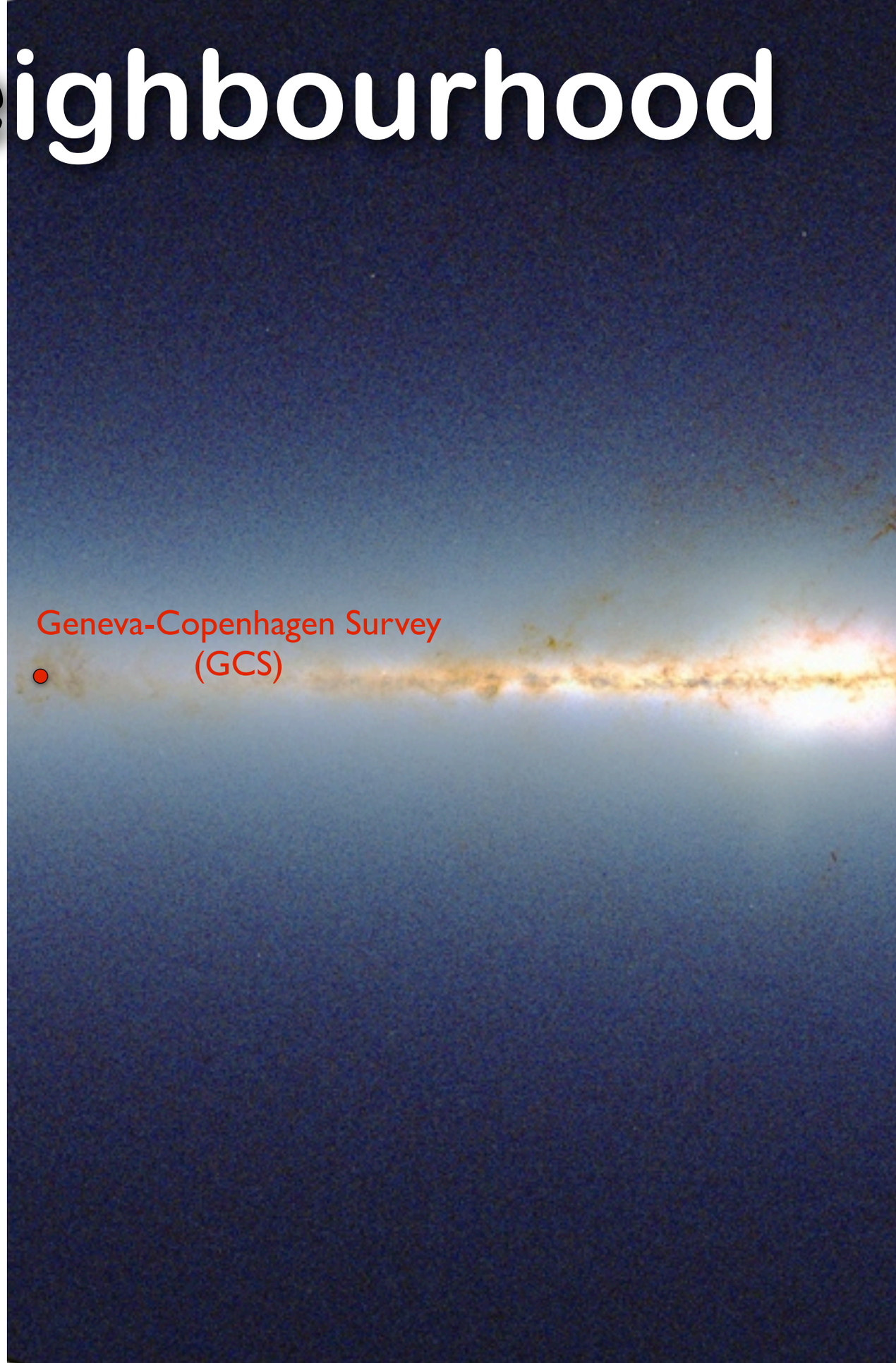
La Grande Bouffe

Effective temperatures: Infrared Flux Method
Reddening: 3D maps and 2MASS CMD
Metallicities: Strömgren photometry
Distances: seismology + IRFM
Masses: seismology + IRFM
Radii: seismology + IRFM
Ages: seismology

Casagrande, Silva Aguirre, Stello, Huber et al. (2014)

Leaving the Neighbourhood

Casagrande et al. in prep.



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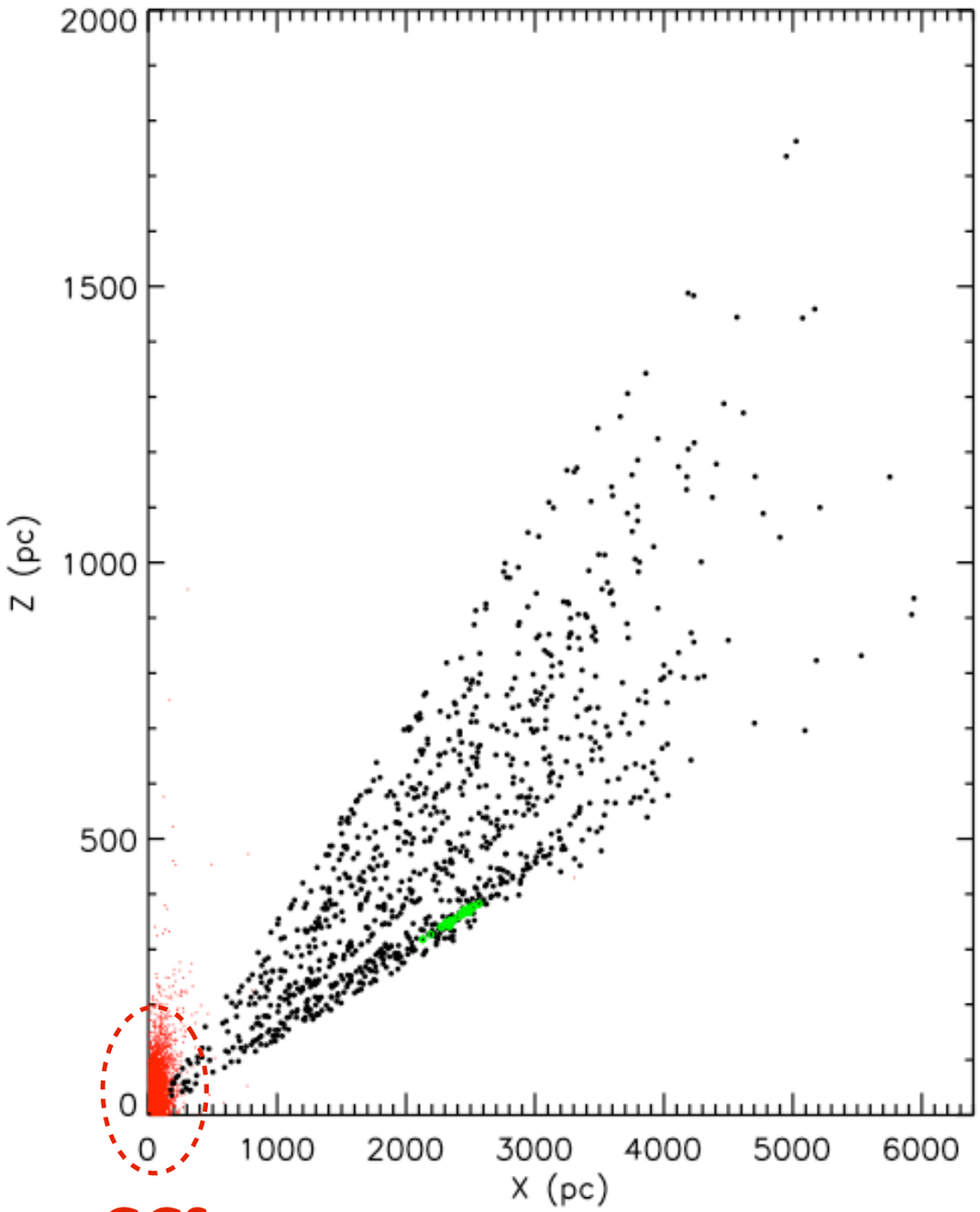
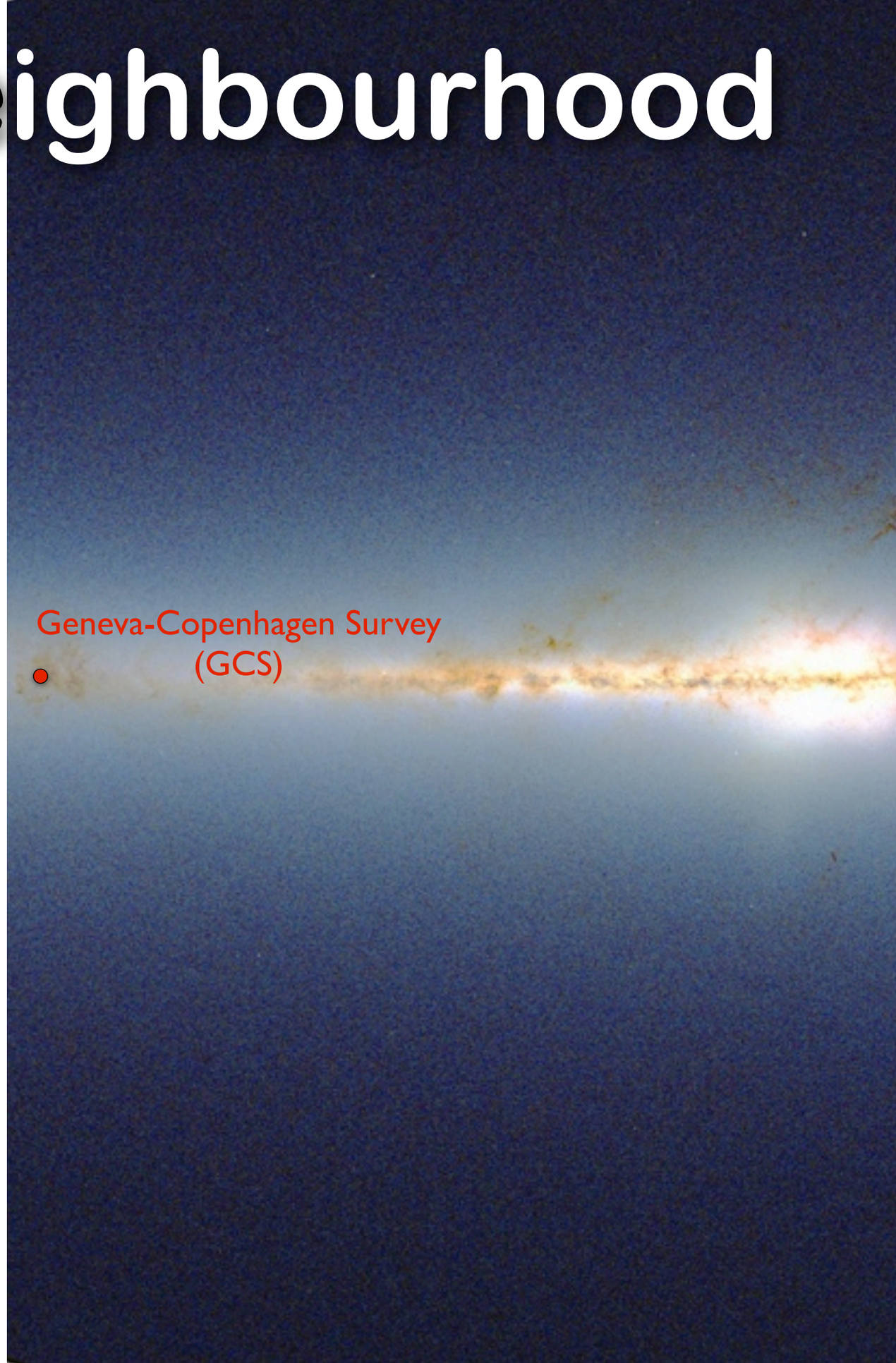


GCS

Nordström et al. (2004)

Casagrande et al. (2011)



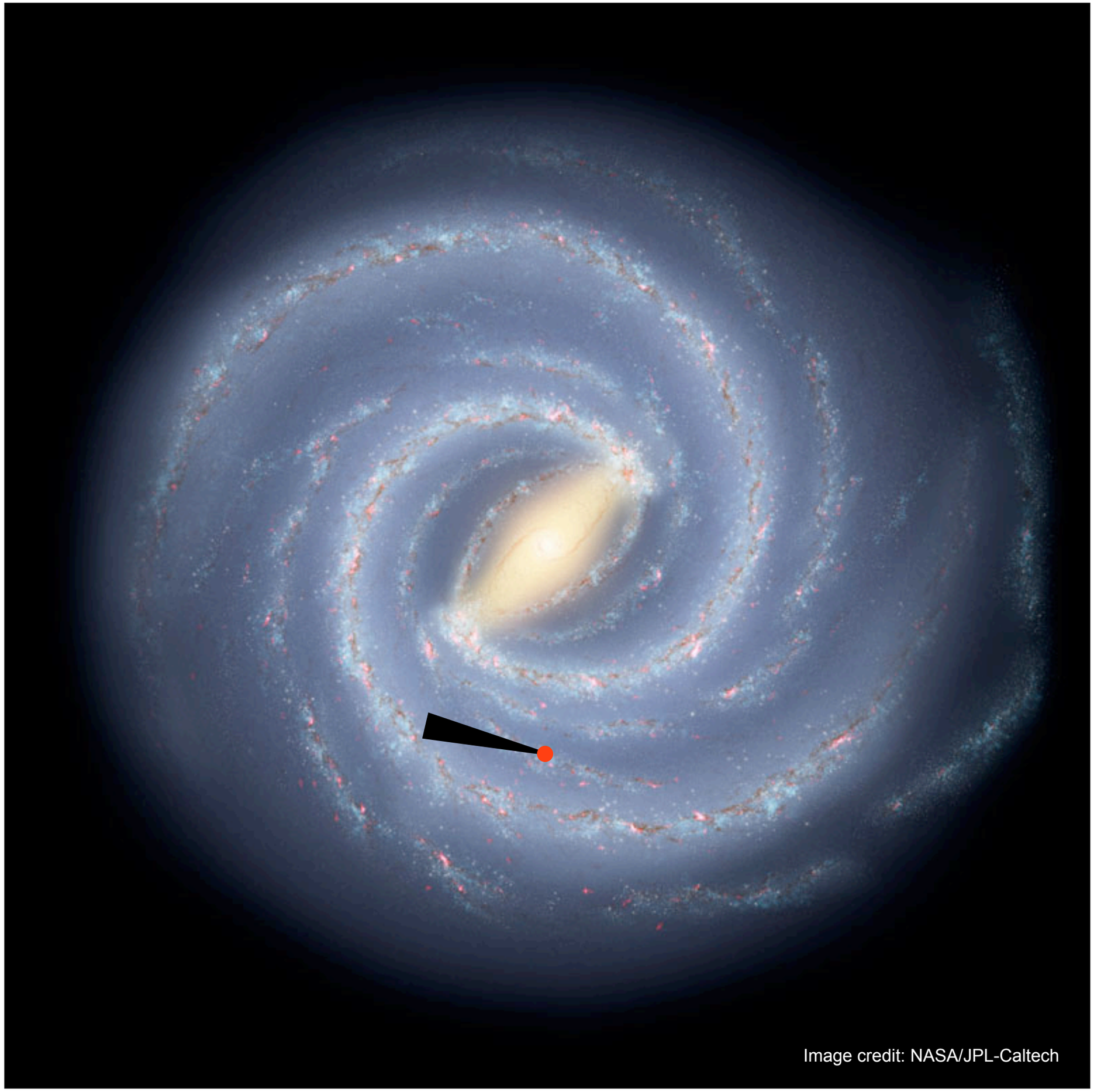
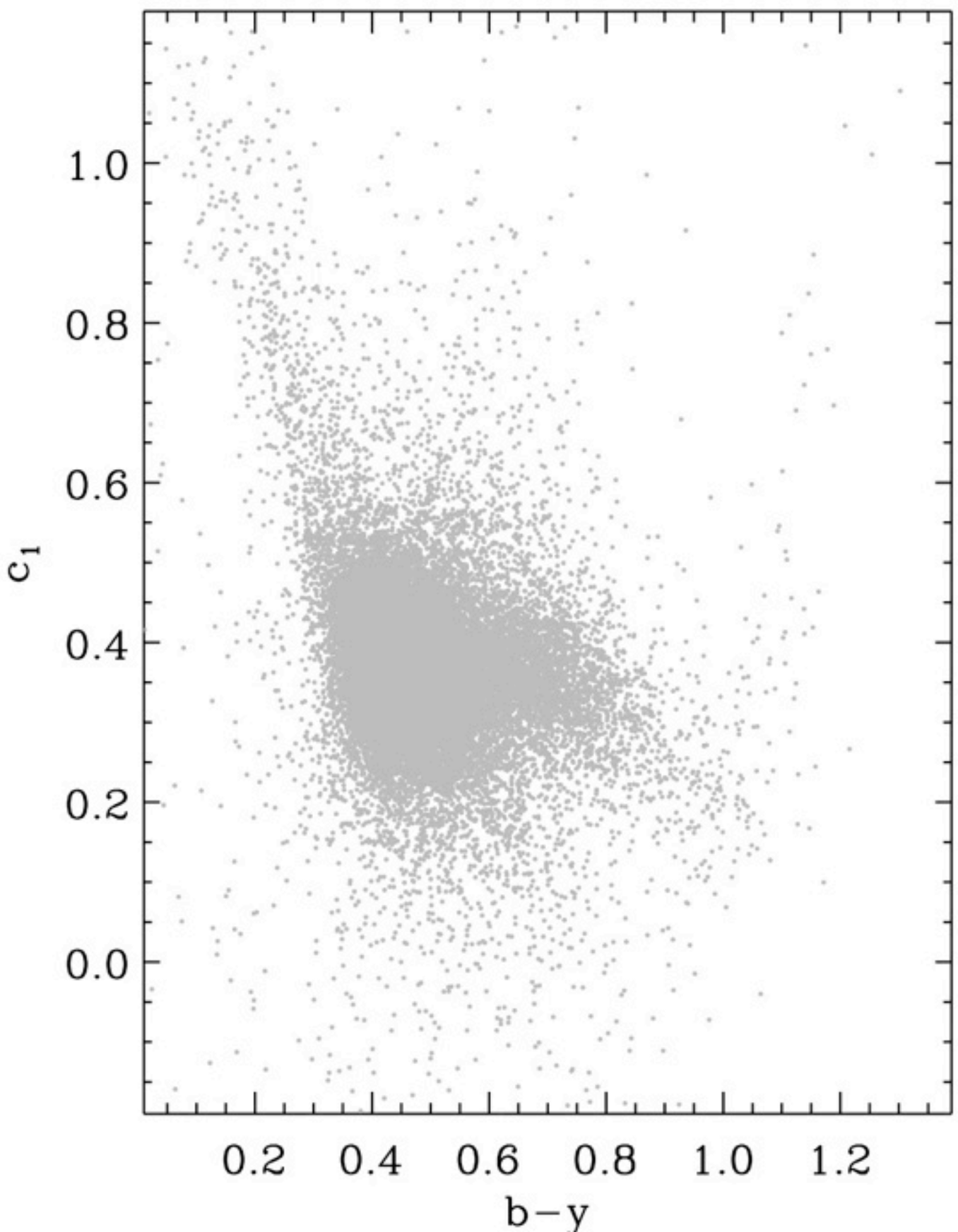


Image credit: NASA/JPL-Caltech

Benchmarking



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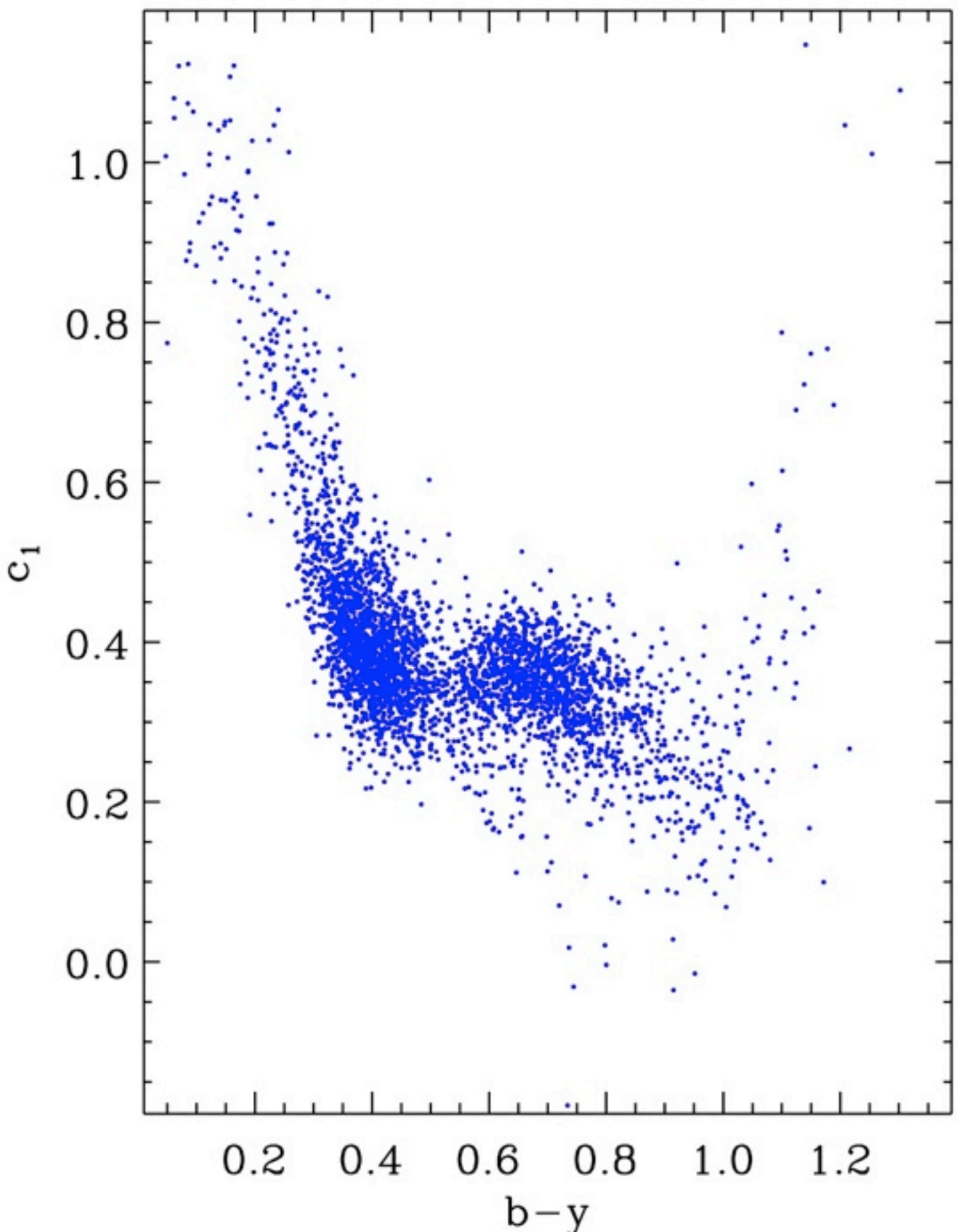
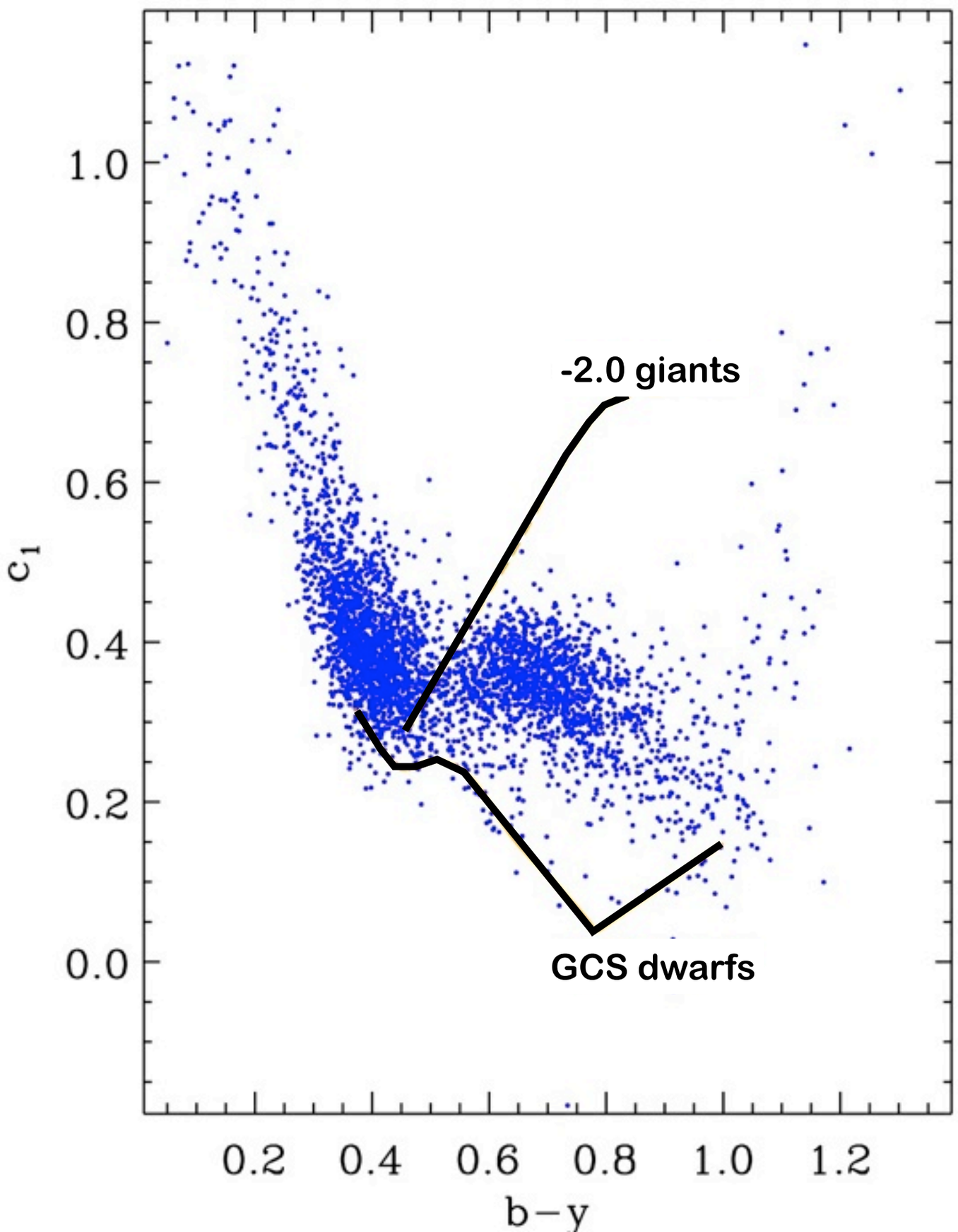


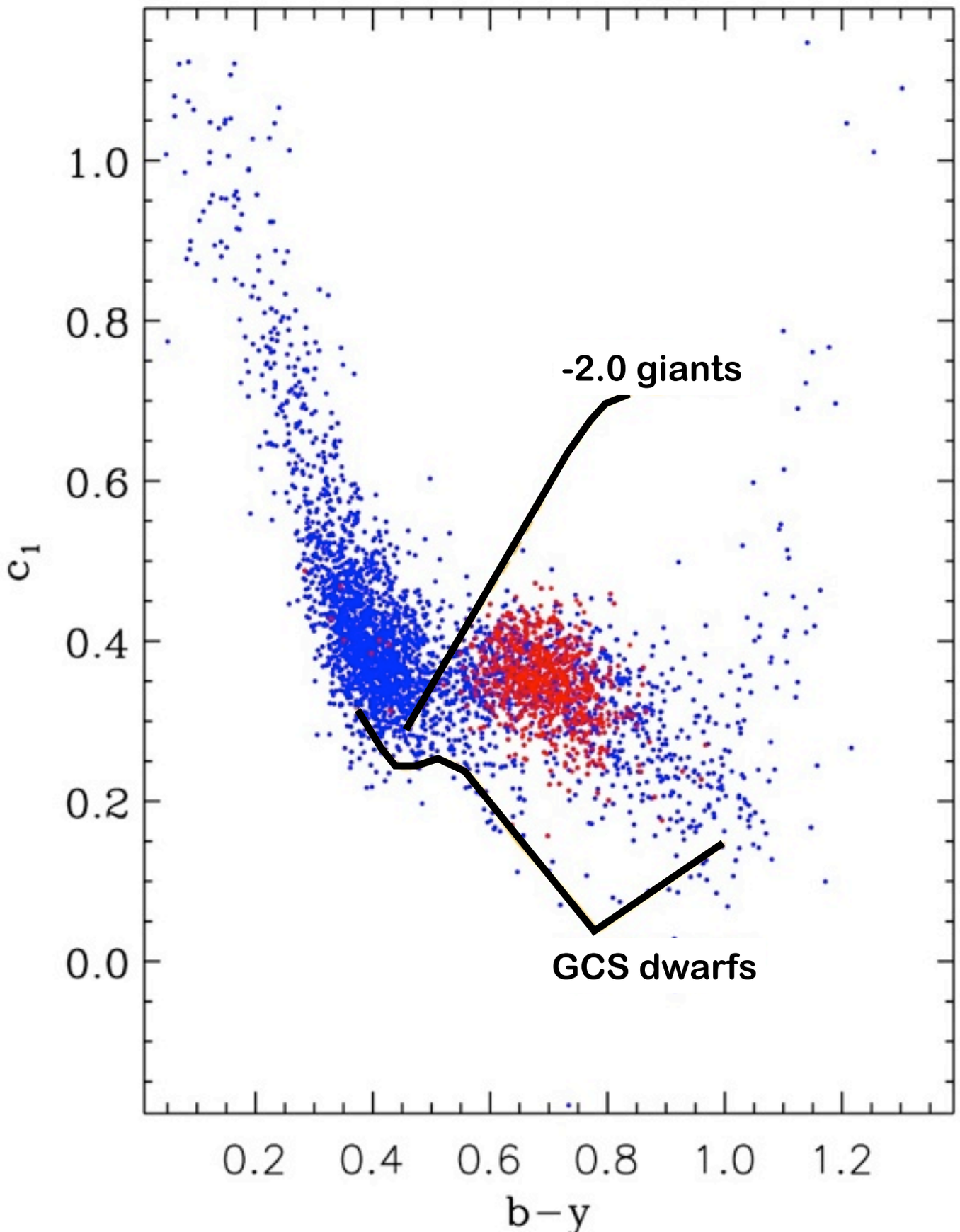
$V < 14$

Benchmarking



$V < 14$

Benchmarking

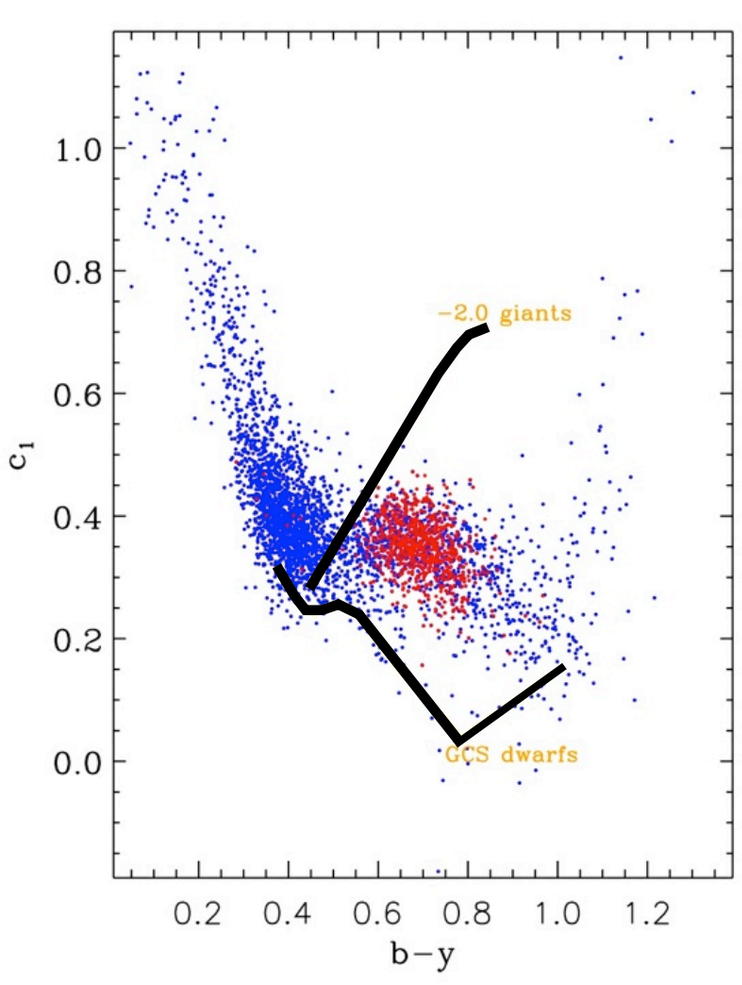


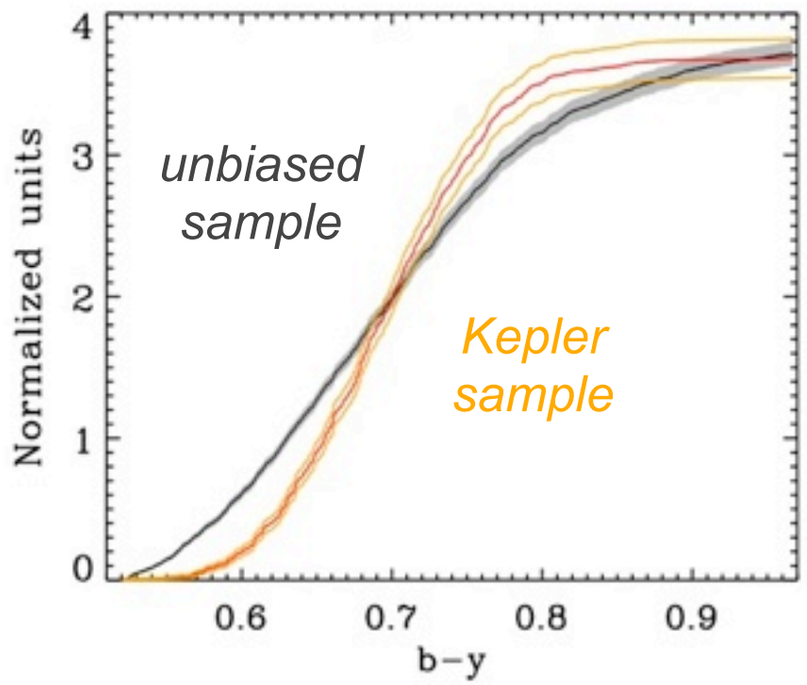
V < *14*

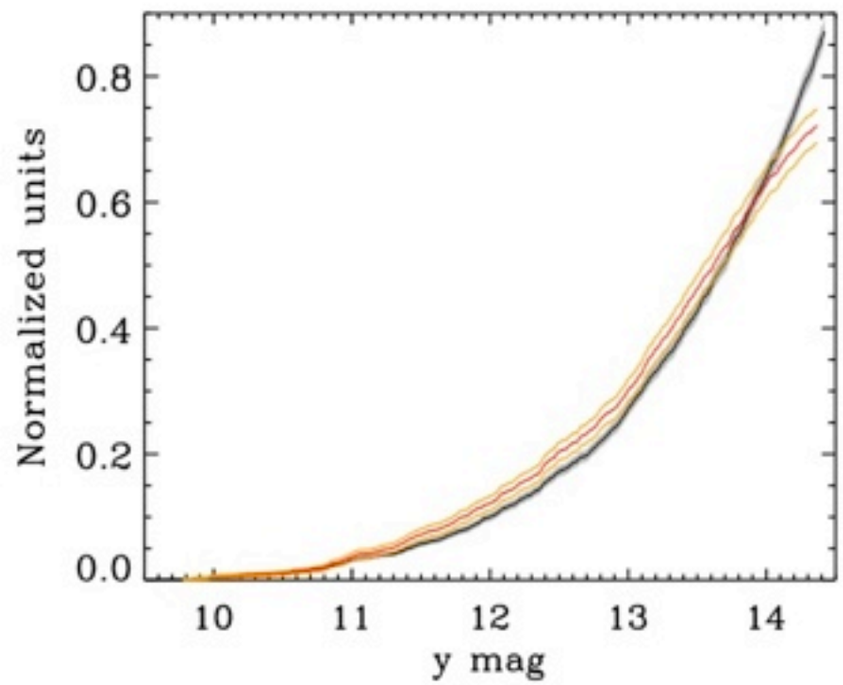
seismic

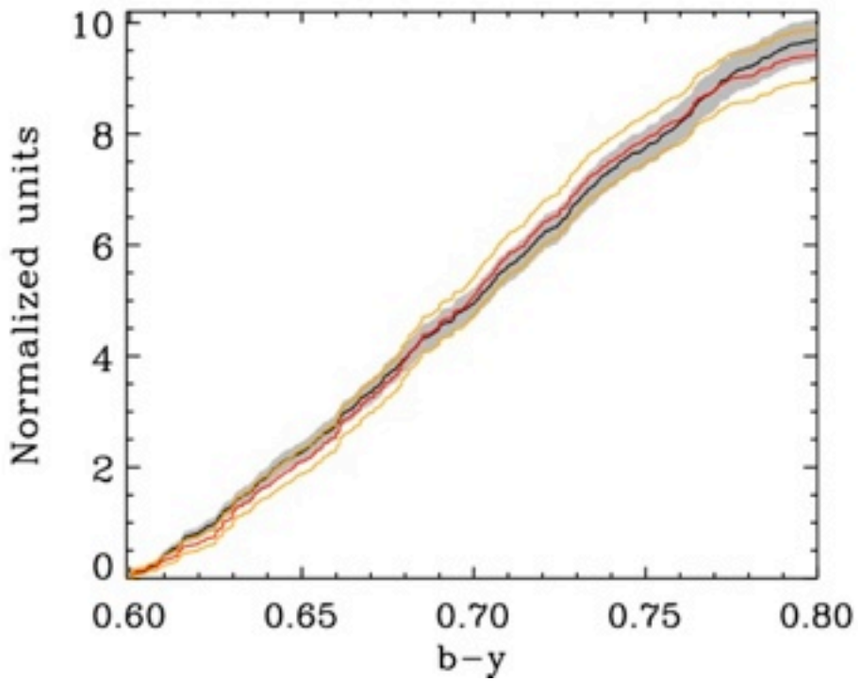
On the shoulders of giants

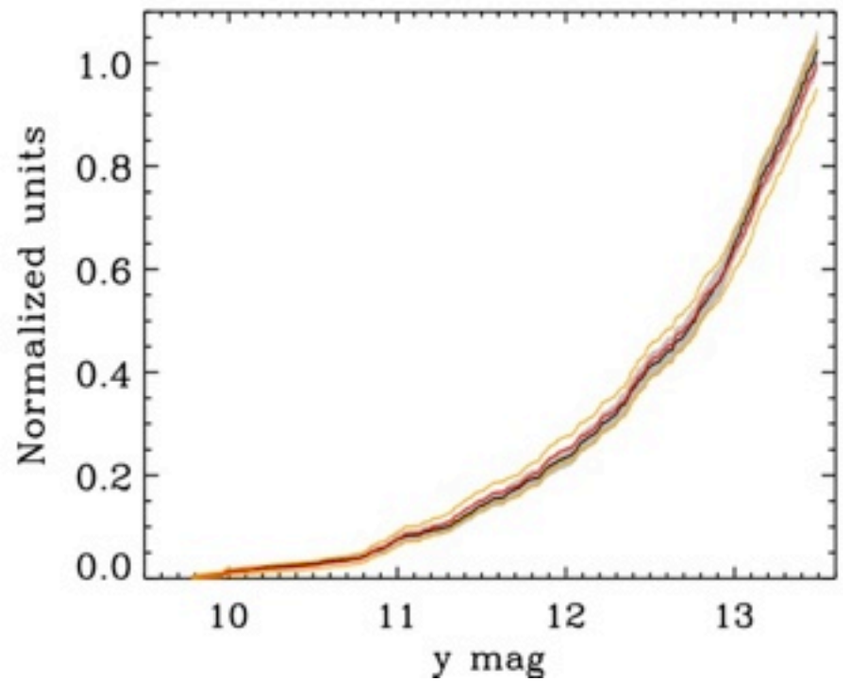
Benchmarking

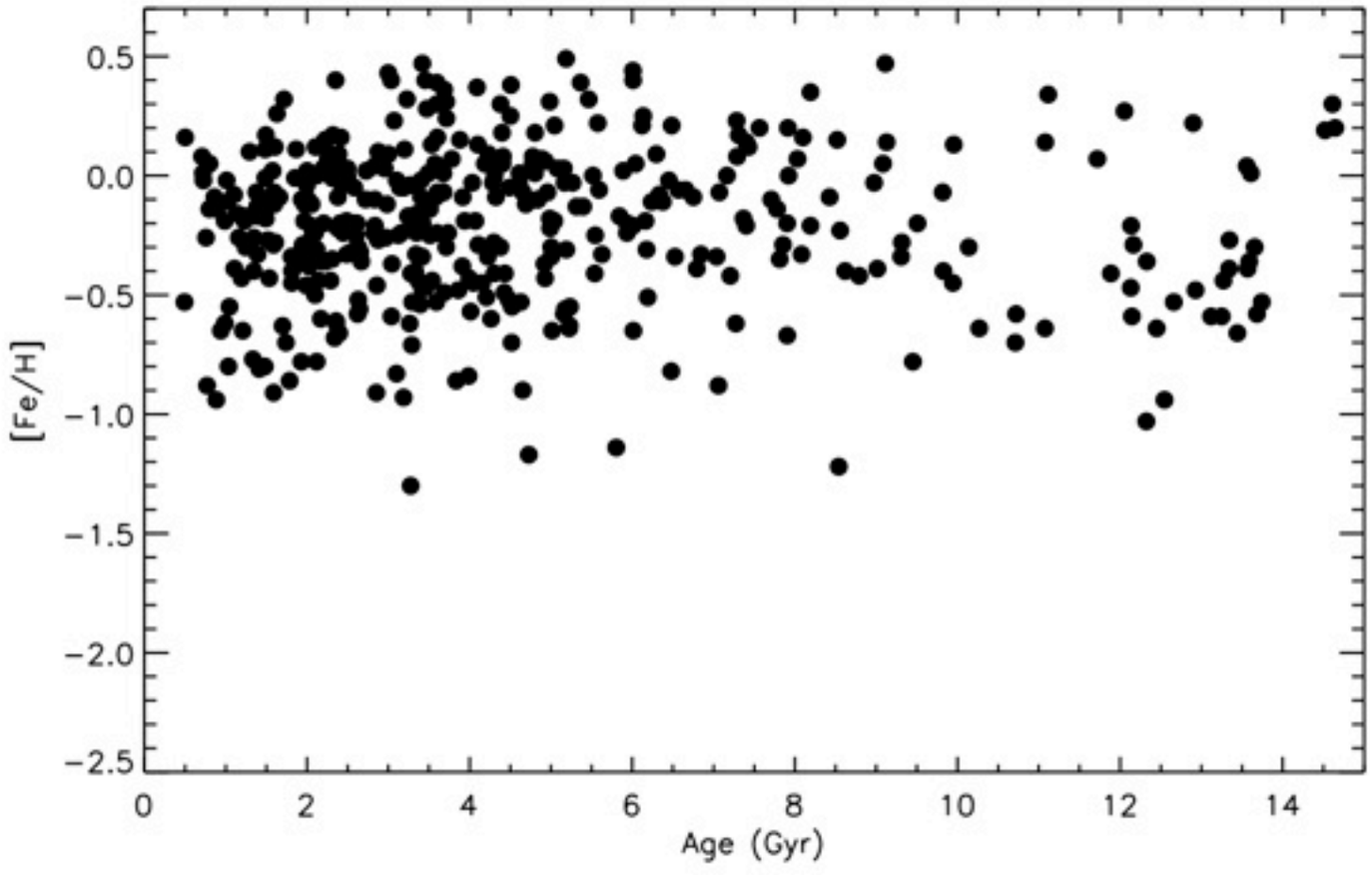






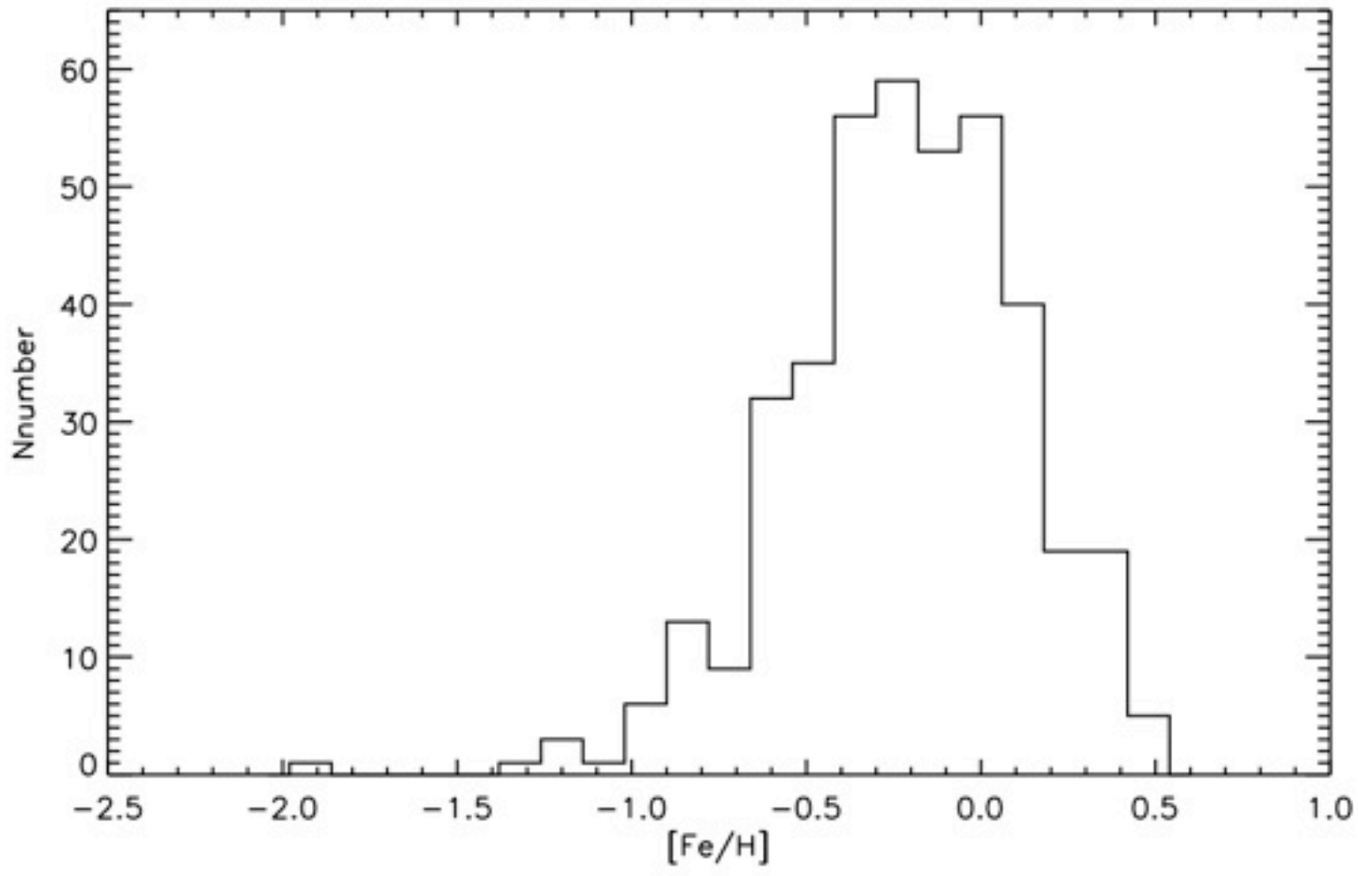





[Fe/H]
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
0
2
4
6
8
10
12
14
Age (Gyr)

AMR

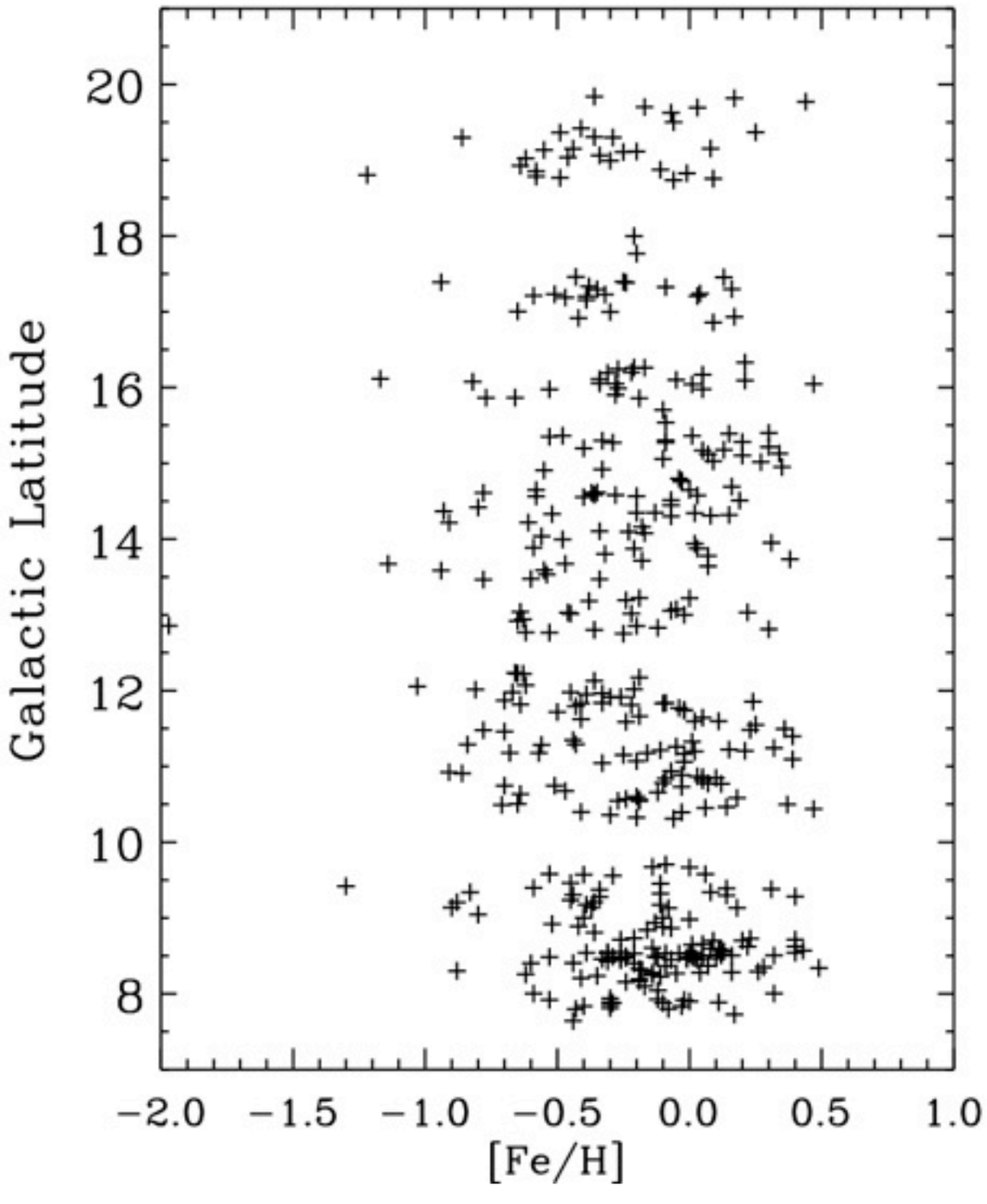
MDF

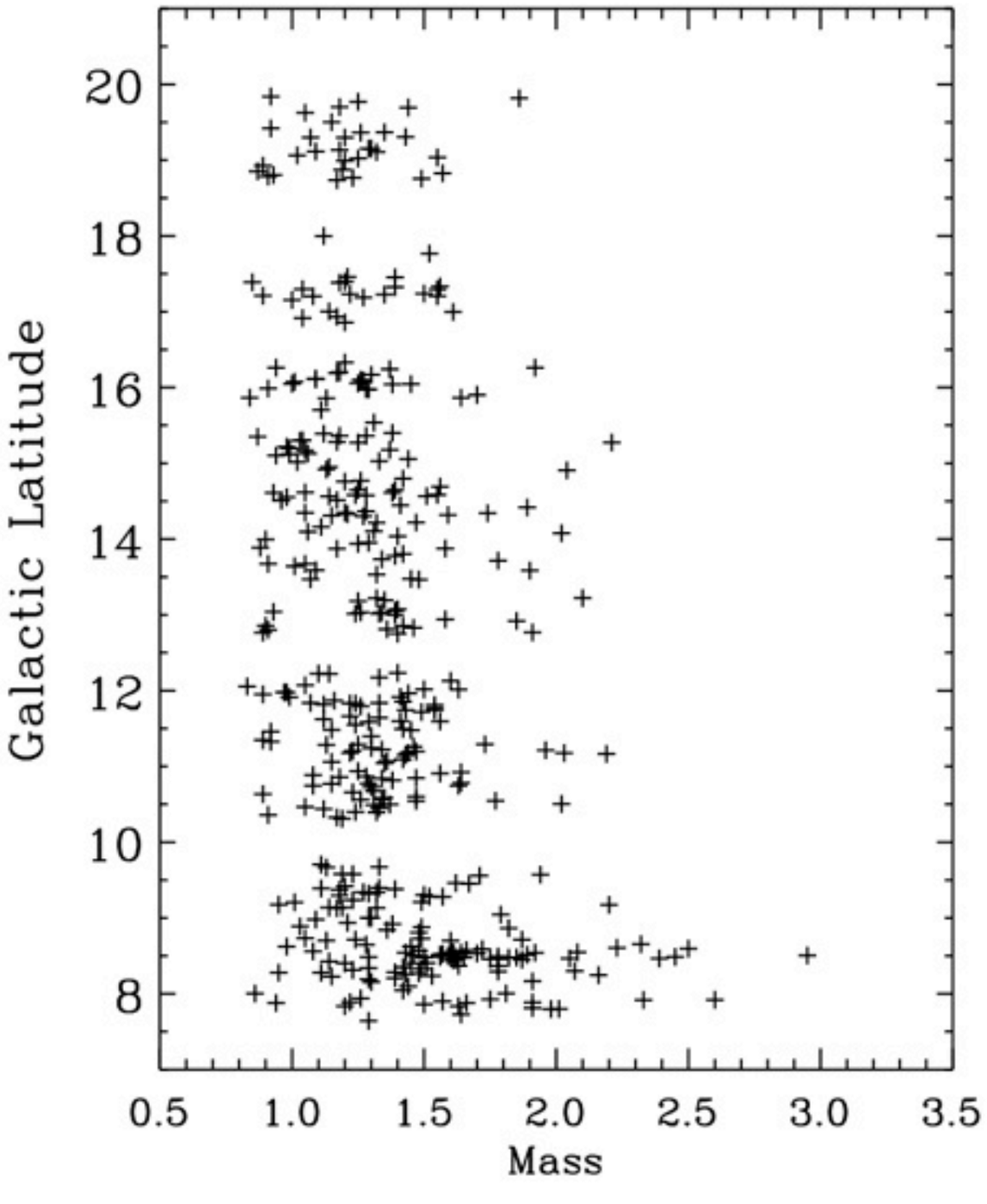

Nnumber
60
50
40
30
20
10
0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
[Fe/H]

Gradients in the disc

Casagrande et al. in prep.

see also Miglio et al. (2013) for mass gradients using CoRoT

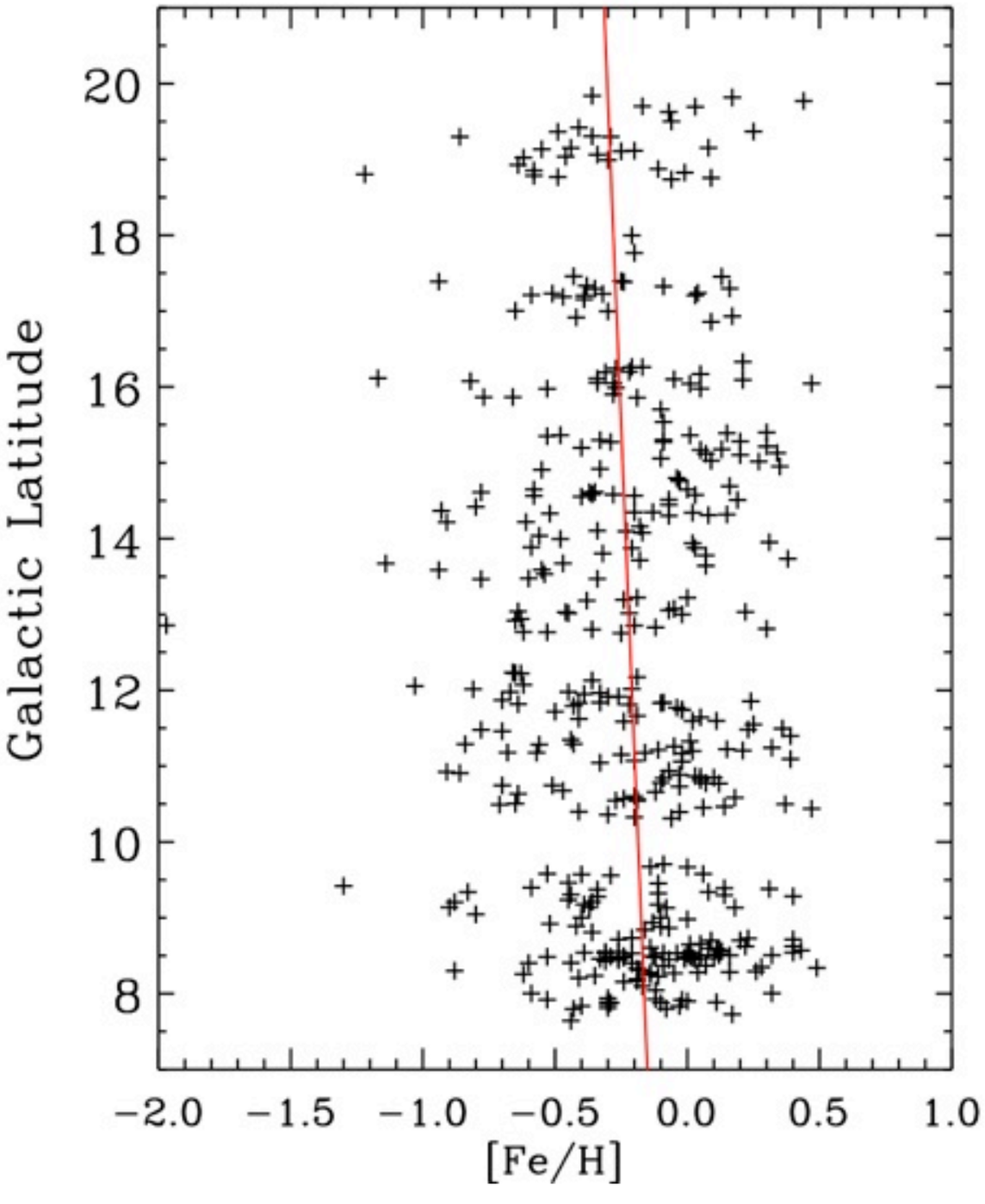


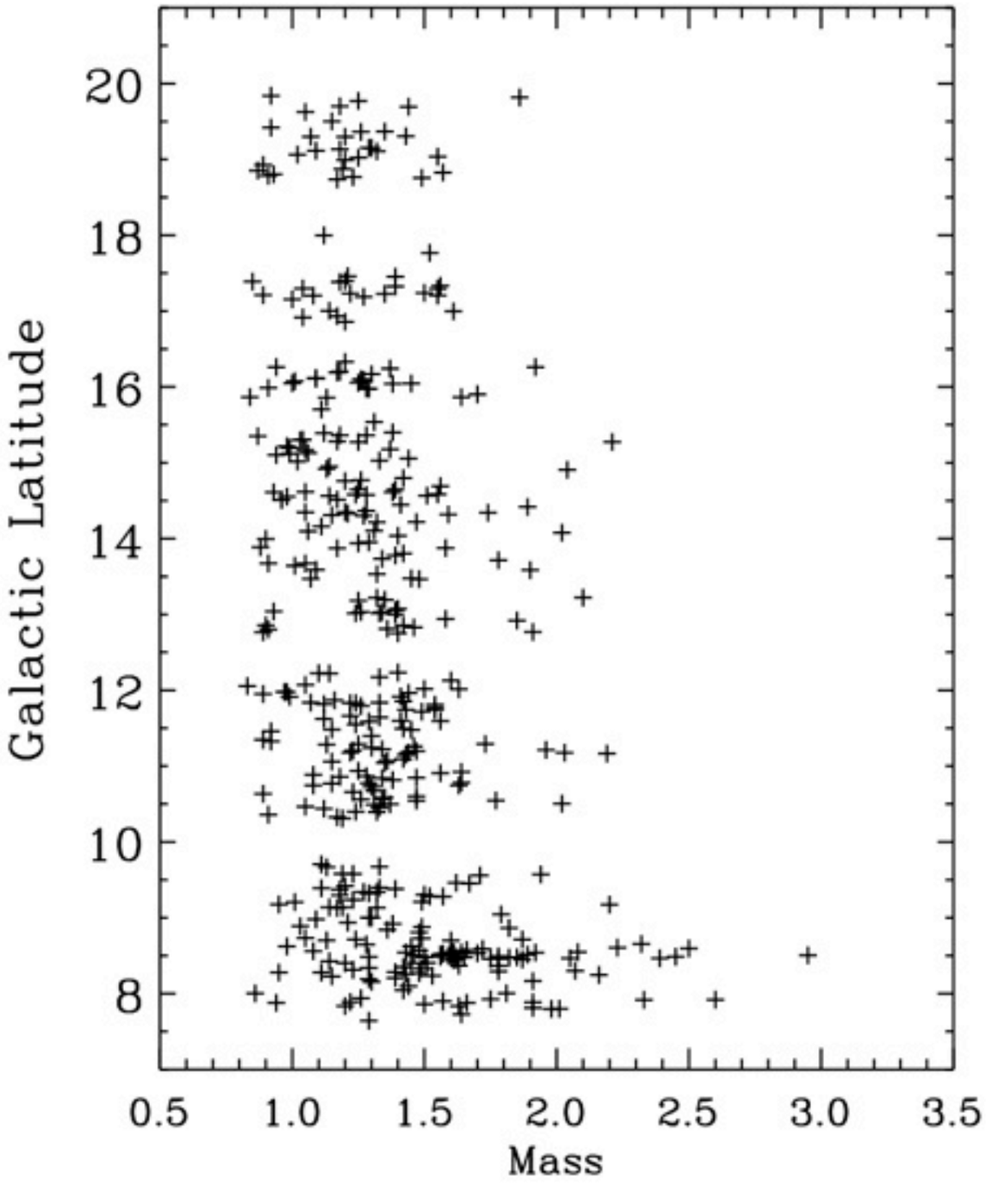


Gradients in the disc

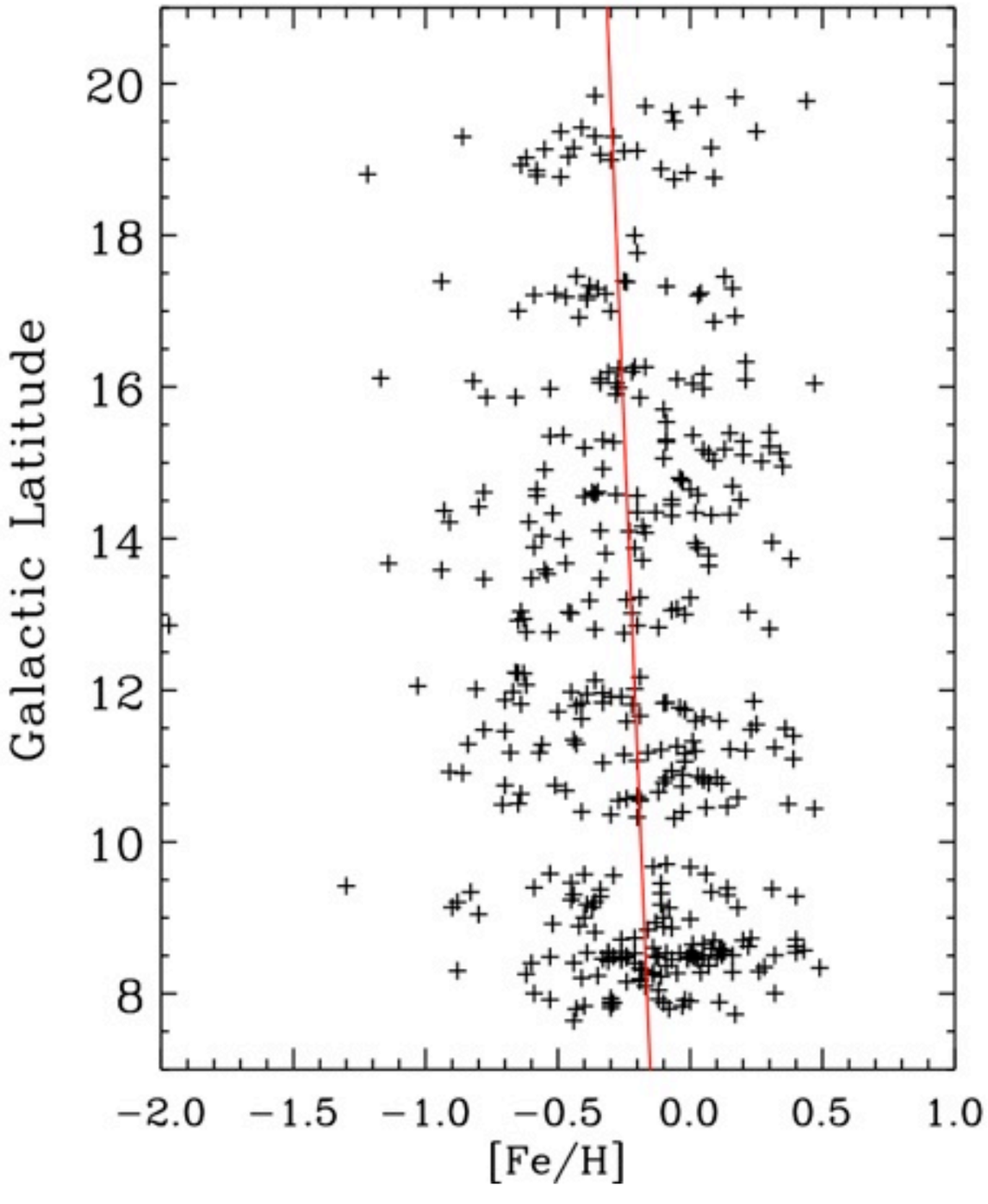
Casagrande et al. in prep.

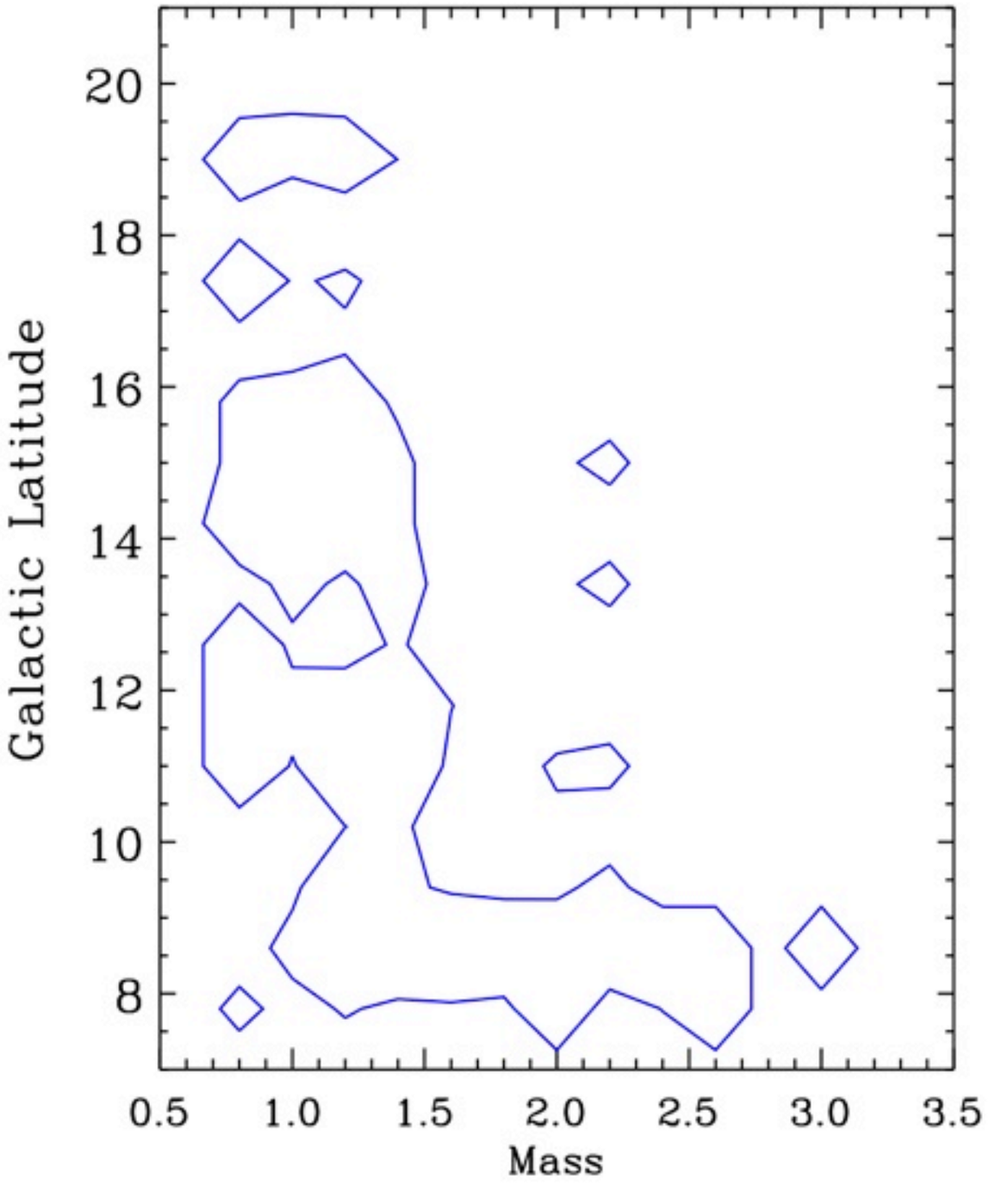
see also Miglio et al. (2013) for mass gradients using CoRoT





Gradients in the disc





The SAGA so far

- Power of asteroseismology for stellar population studies.

- Power of photometry for stellar parameter determination (bias correction!).

- It is now possible to derive constraints similar to those available for the Solar Neighbourhood (GCS) for other Galactic regions.

- Asteroseismology of stellar populations has just started (K2, TESS, + APOKASC, GAIA-ESO, GALAH)!