Pucon, December 11th 2018

# GEMINI/GeMS Observations of GCs in the Galactic Bulge


**Sara Saracino**

Department of Physics and Astronomy - University of Bologna

INAF - Bologna Astronomical Observatory

Collaborators:

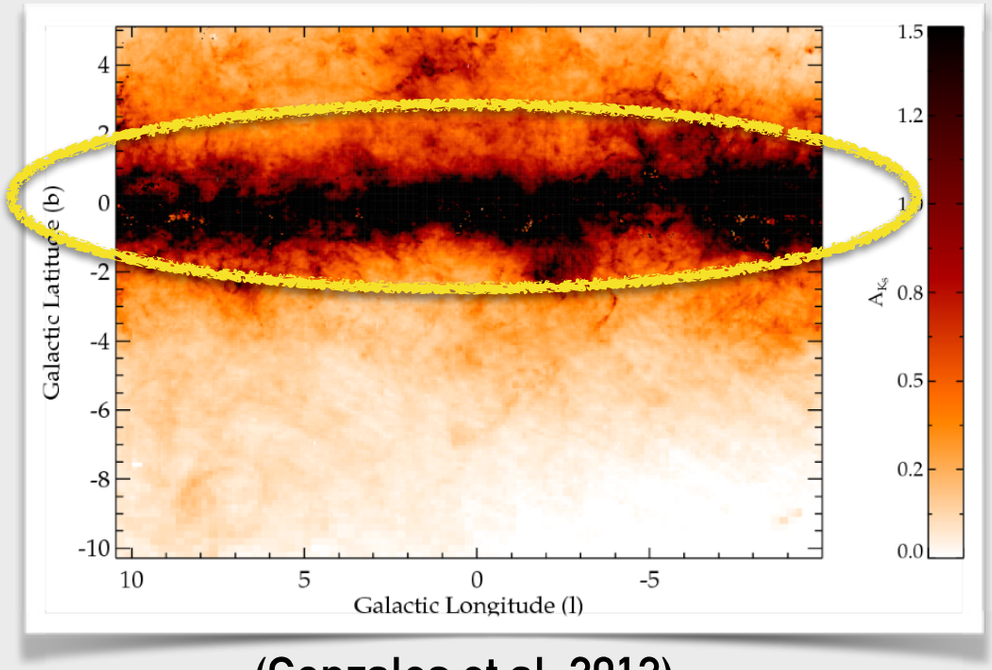
F.R. Ferraro, E. Dalessandro, L. Origlia, B. Lanzoni, D. Geisler, R. Cohen, M. Salaris, A. Bellini

Globular clusters in the Galactic Bulge are:

1. very dense. → HIGH ANGULAR RESOLUTION

Space-based instruments (es. HST)

2. highly reddened. → NEAR INFRARED




(Gonzales et al. 2012)

Ground-based MCAO instruments (es. GeMS+GSAOI)

# THE PROJECT

**WHAT?** Obscured and massive Bulge GCs

**HOW?** By using ground based MCAO imaging in the NIR
+ HST in the optical

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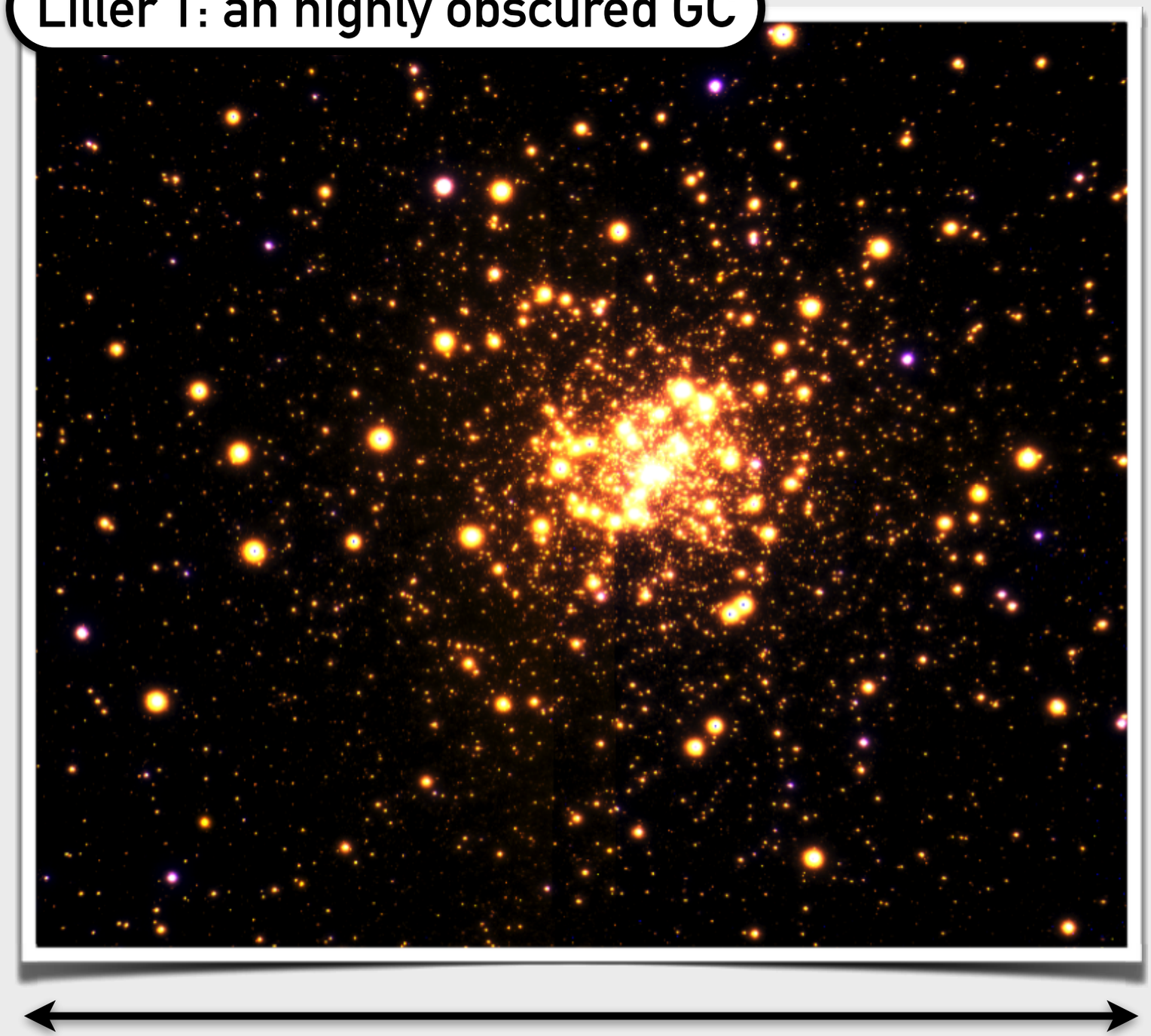
**WHAT?** Obscured and massive Bulge GCs

**HOW?** By using ground based MCAO imaging in the NIR
+ HST in the optical

**WHY?**

- To unveil unexplored systems → Liller 1
- For TO ages and low MFs studies → NGC 6624
- To measure PMs with ground-based observations → NGC 6569

# Liller 1: an highly obscured GC



93″

GeMS@GEMINI images

## Main properties:

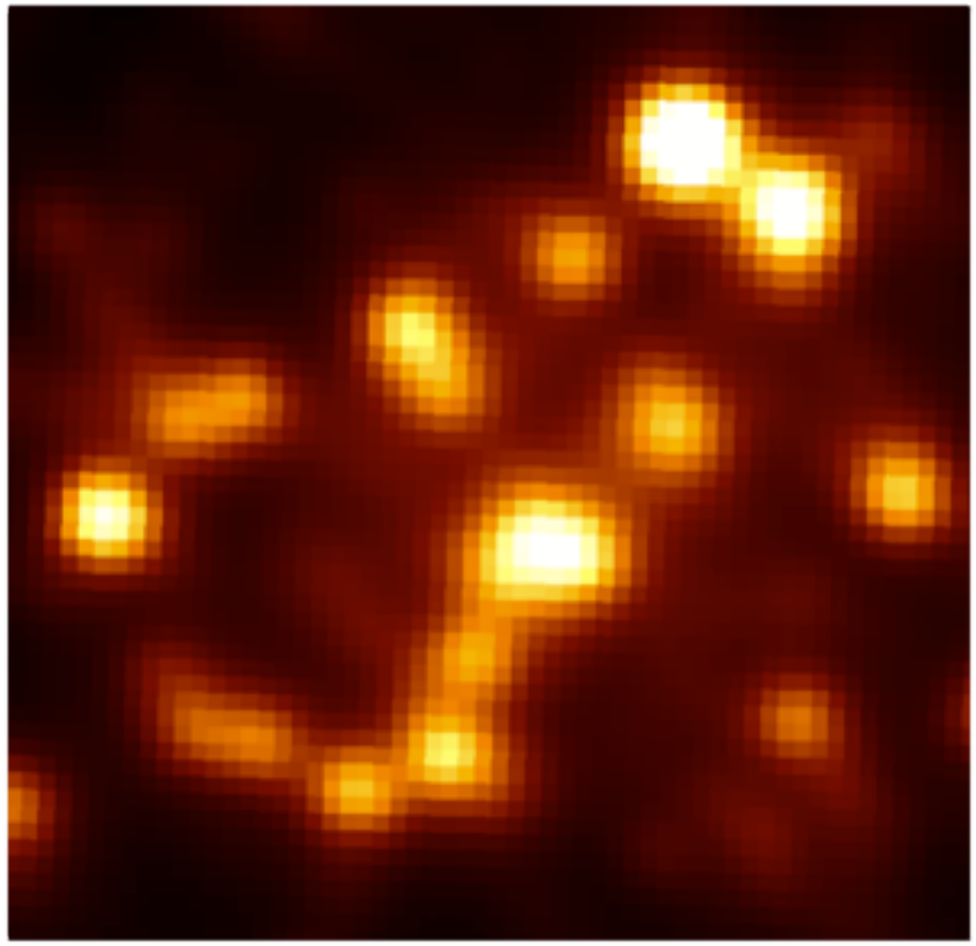
1. $D_{Gal.center} = 0.8$ Kpc
   (Harris 1996, 2010 edition)

2. $E(B-V) = 3.09$
   (Valenti et al. 2007)

3. The second highest stellar encounter rate
   (Verbunt & Hut 1987)

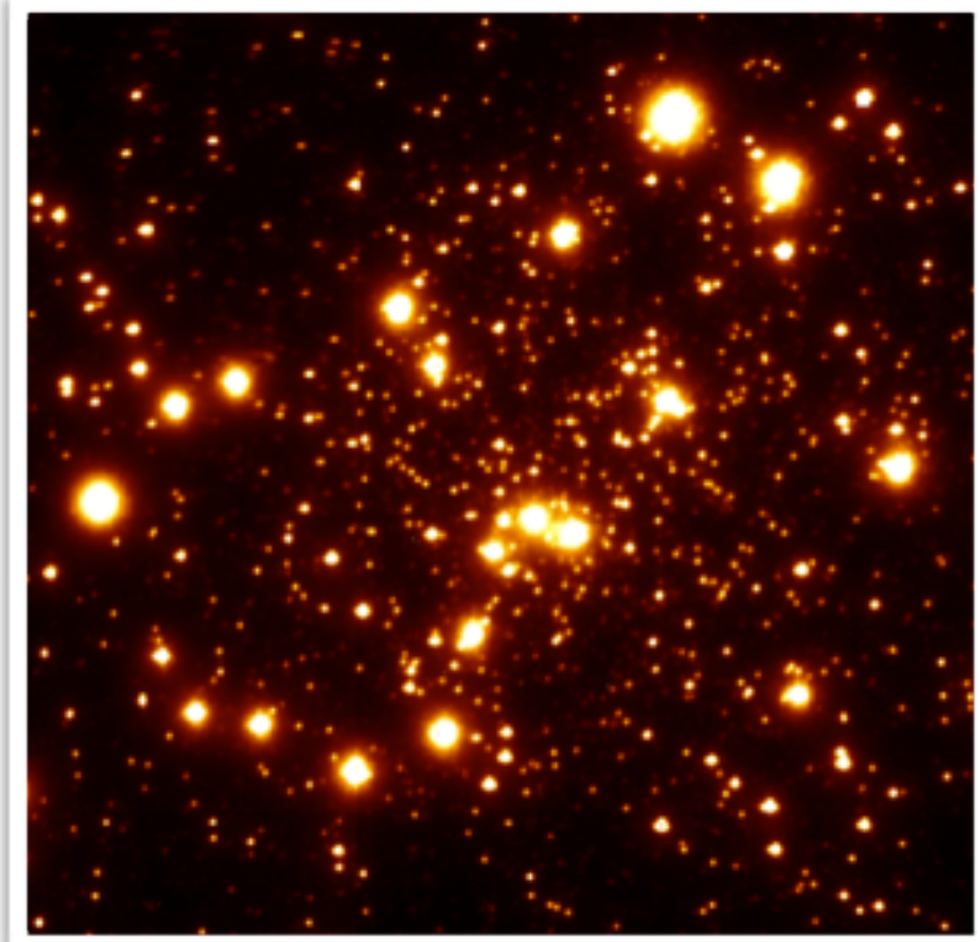
4. Intense γ-ray emission
   (Tam et al. 2011)

ESO 3.6 m - NTT
Seeing limited



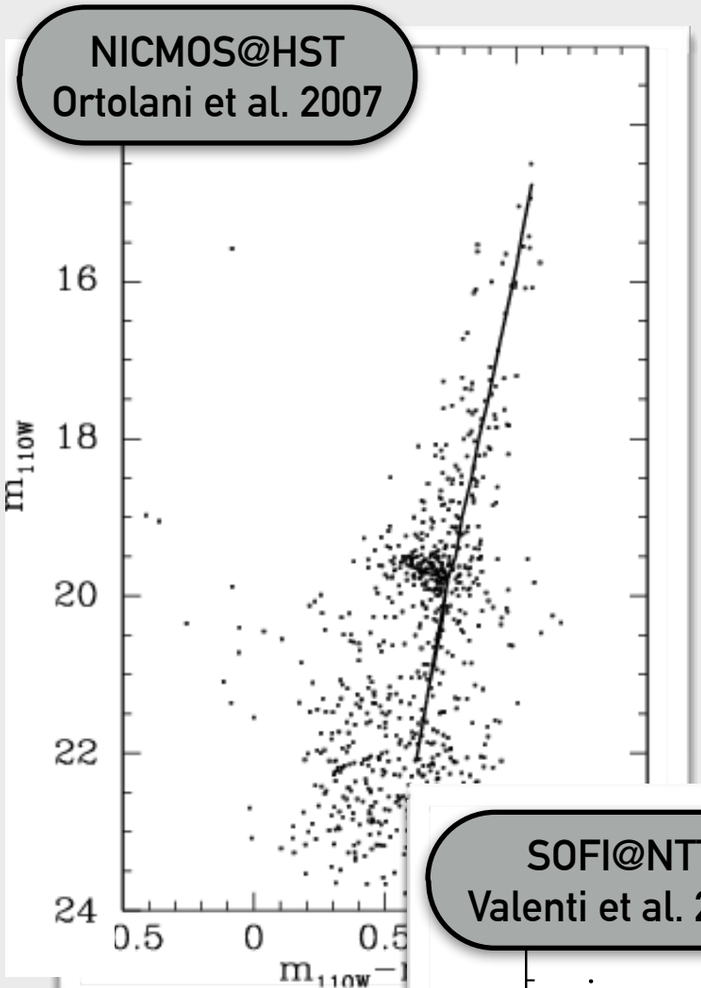
17”

GEMINI@GSAOI
MCAO-assisted



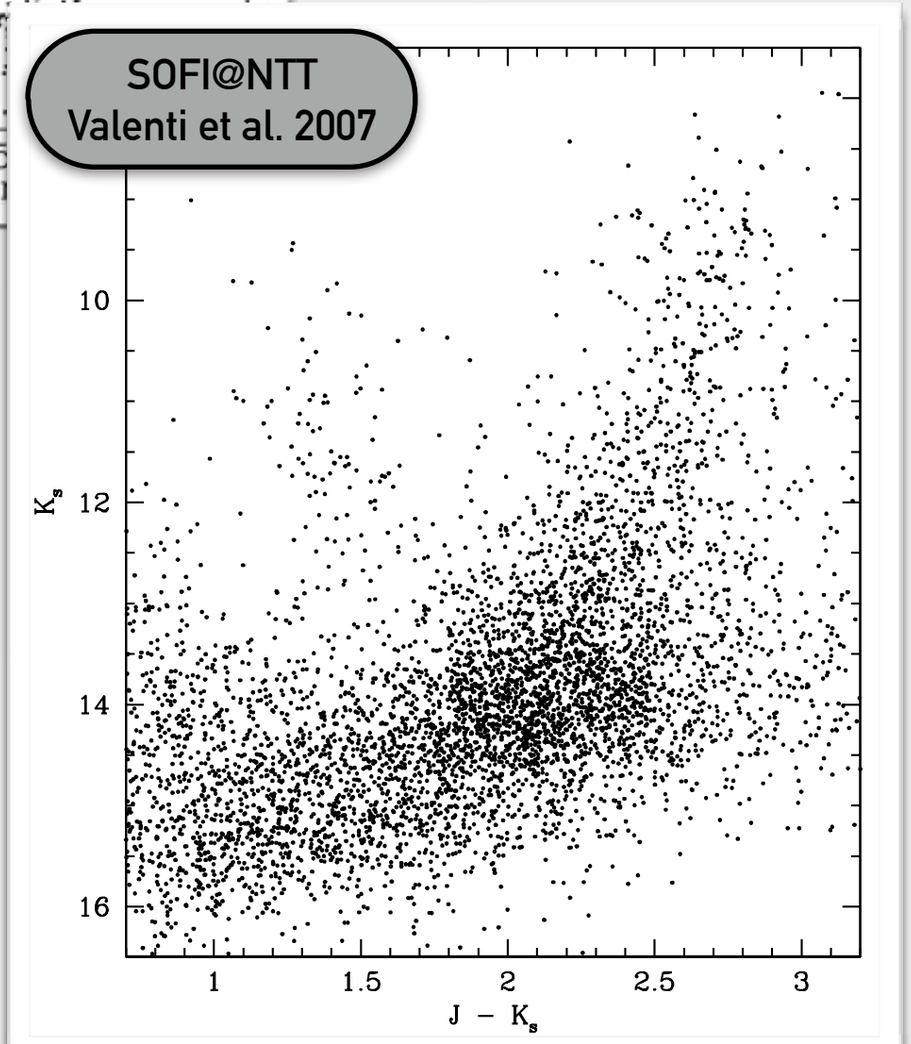
The improvement in terms of angular resolution is remarkable!

NICMOS@HST
Ortolani et al. 2007



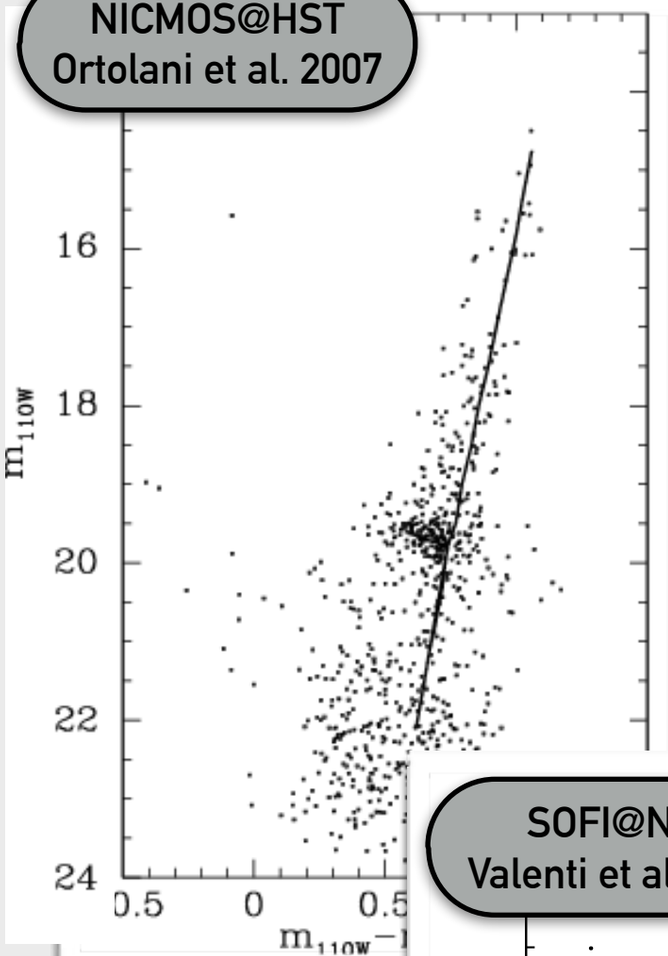

# From previous studies..

SOFI@NTT
Valenti et al. 2007

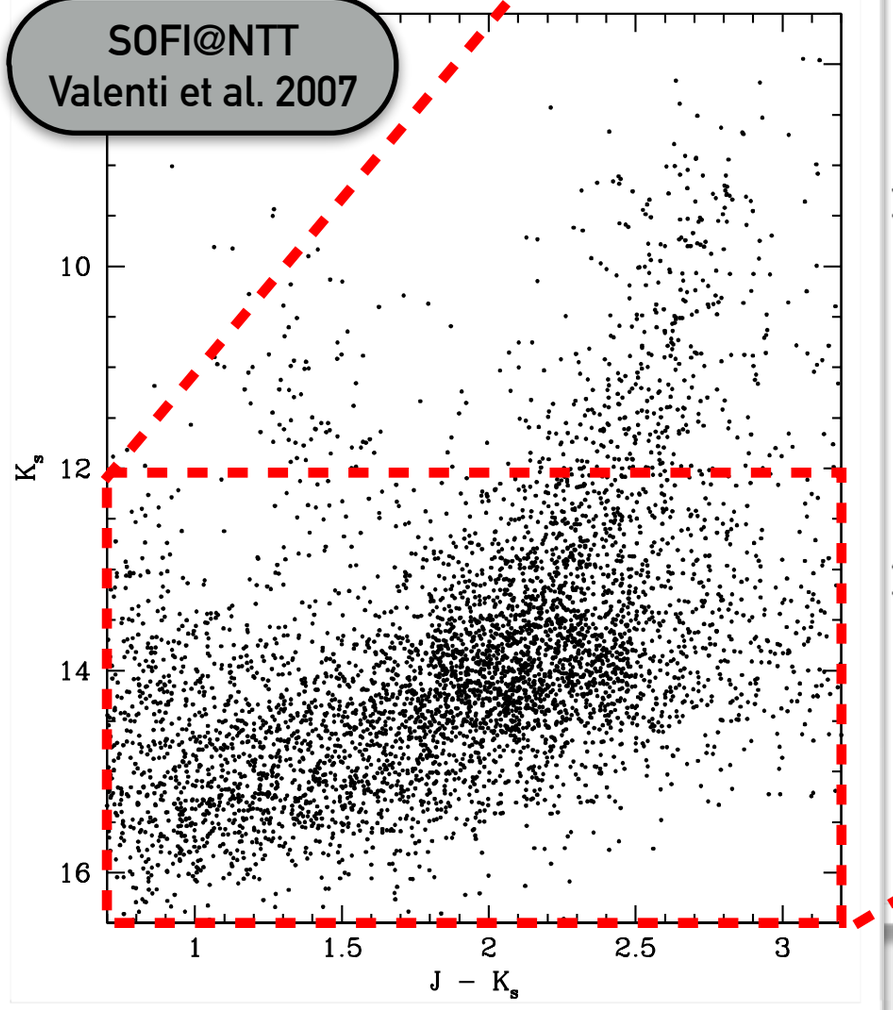


# Unveiling the unexplored: Liller 1

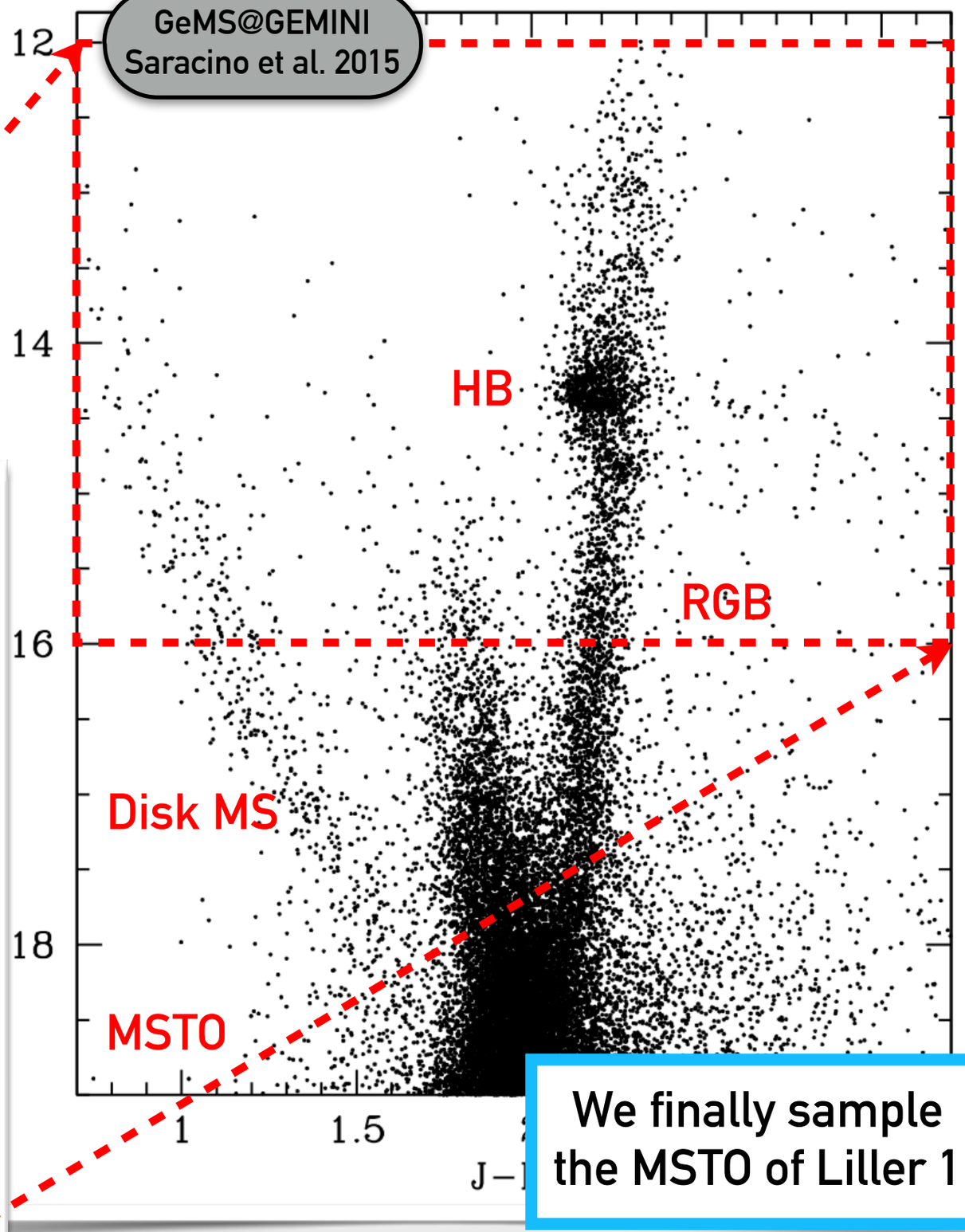
NICMOS@HST
Ortolani et al. 2007




SOFI@NTT
Valenti et al. 2007

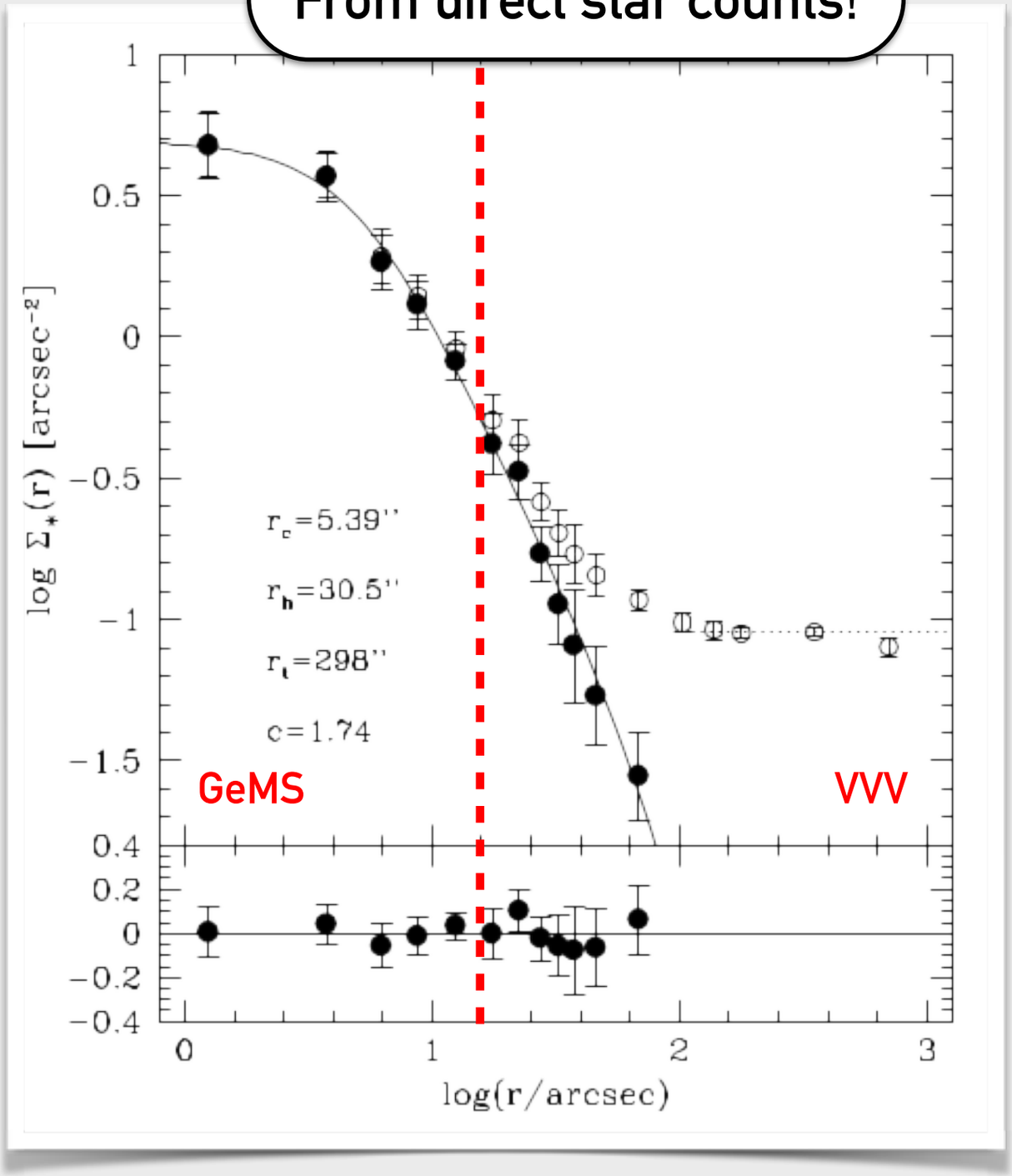



GeMS@GEMINI
Saracino et al. 2015




We finally sample the MSTO of Liller 1

From direct star counts!




significantly less concentrated
c = 1.74

more than 2 times smaller
tidal radius = 300”

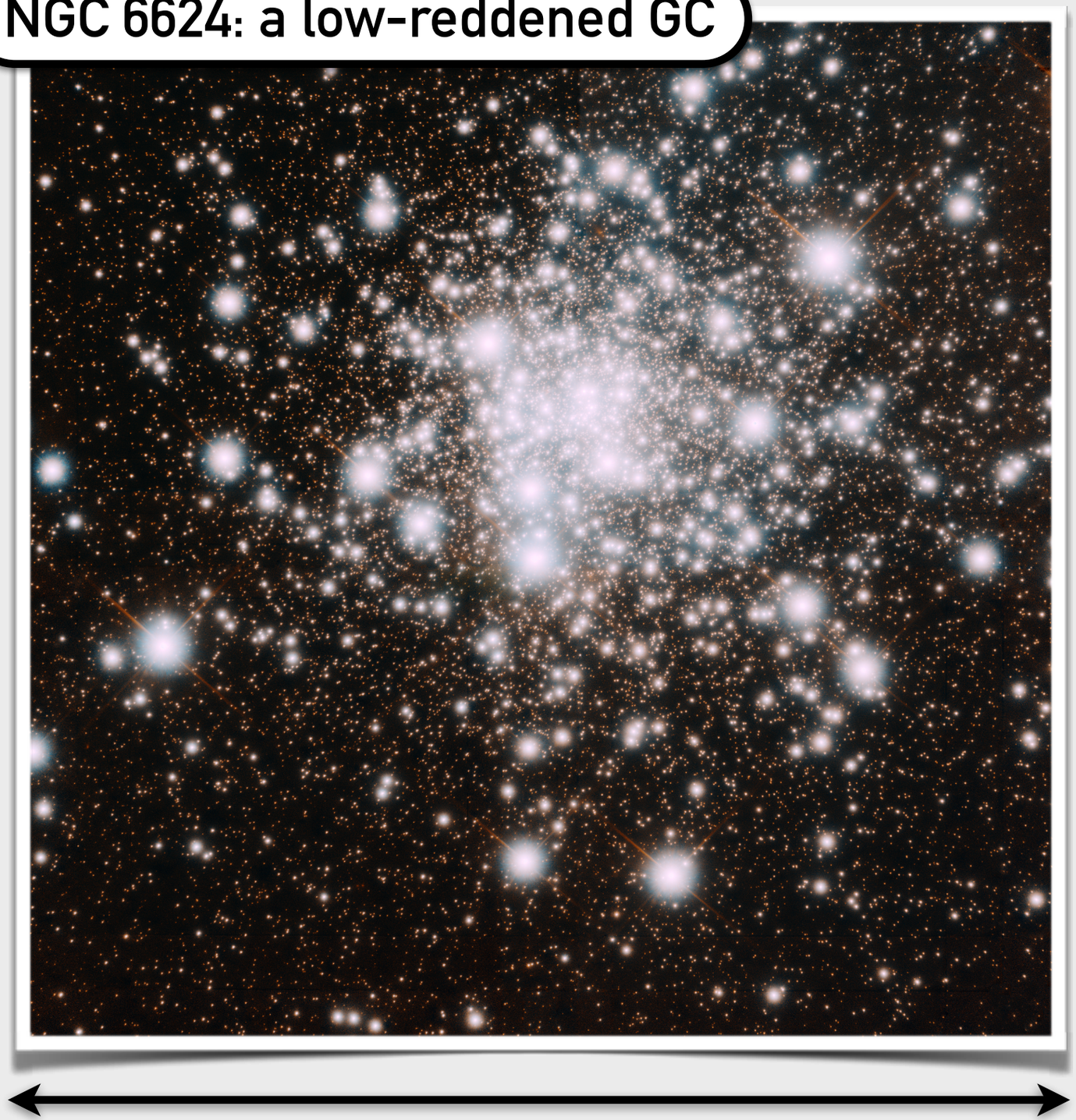
a very massive cluster
M = 1.5-2 *10^6 Msun

high stellar encounter rate
confirmed

Liller 1 is an ideal environment for the formation of collisional objects!

Saracino et al. 2015

# NGC 6624: a low-reddened GC



93”

GeMS@GEMINI images

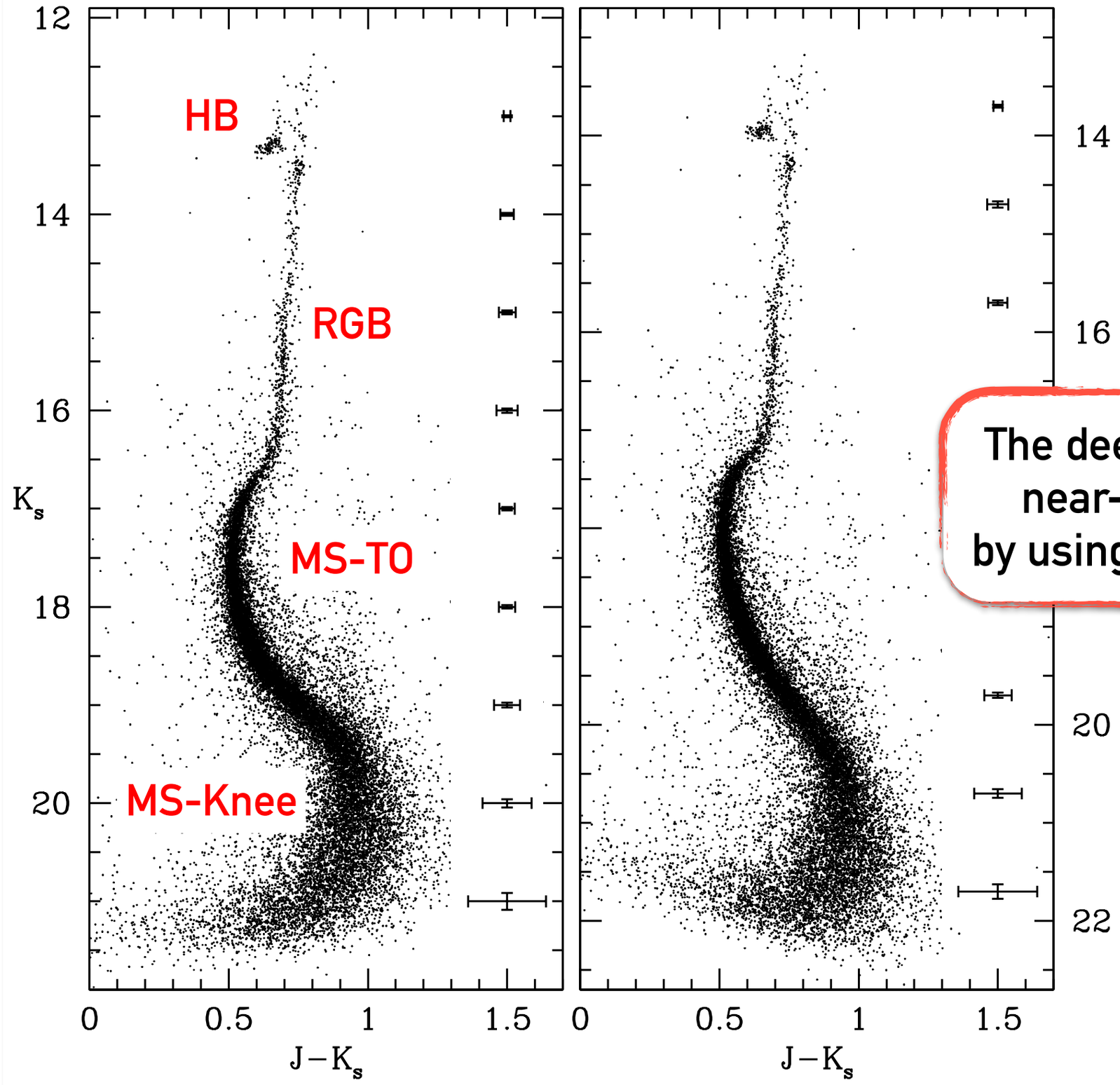
## Main properties:

1. Located at the inner Bulge edge

2. E(B-V) = 0.3
   (Harris 1996, 2010 edition)

3. In a post core-collapse state
   (Trager et al. 1995)

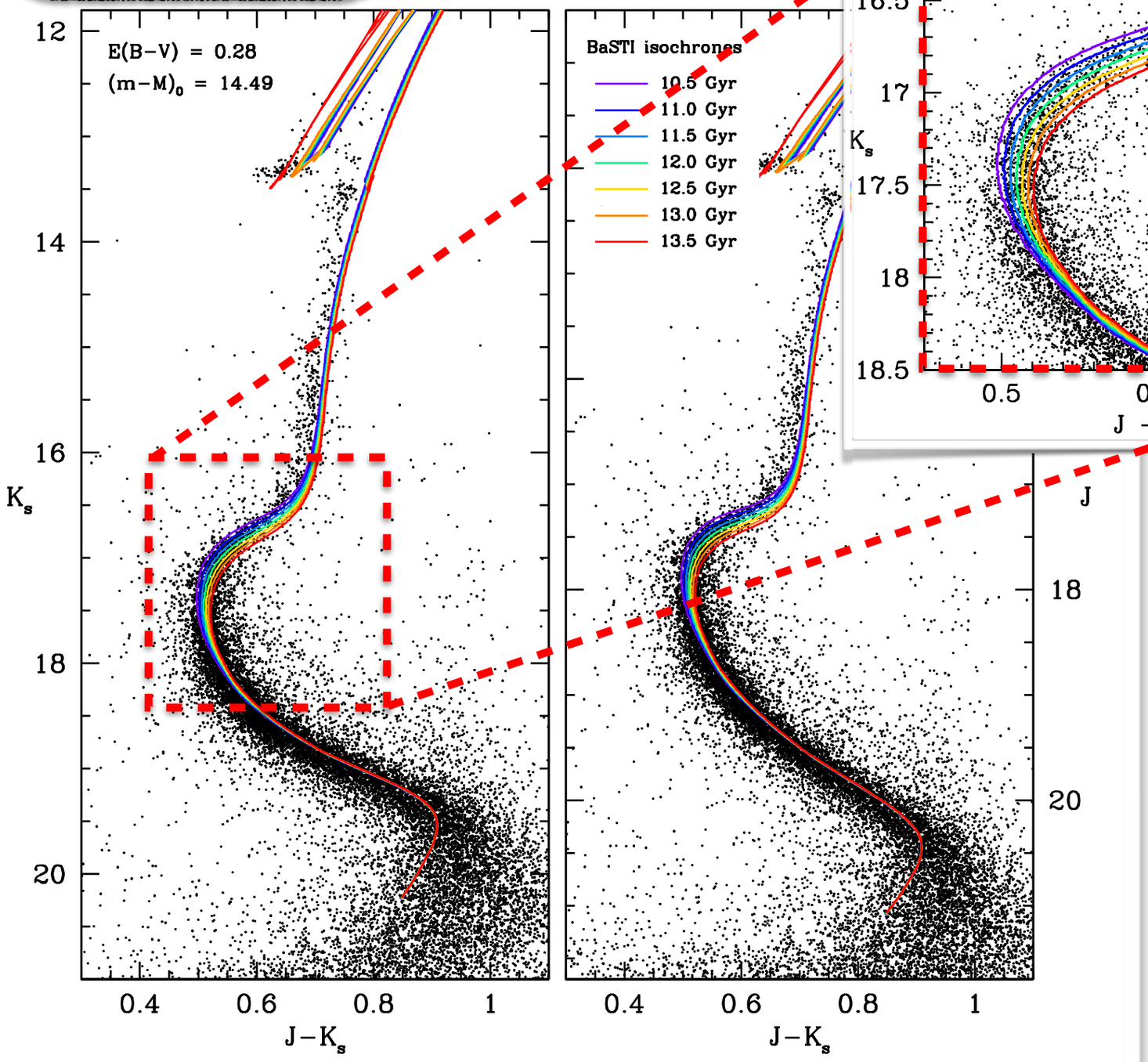
Saracino et al. 2016



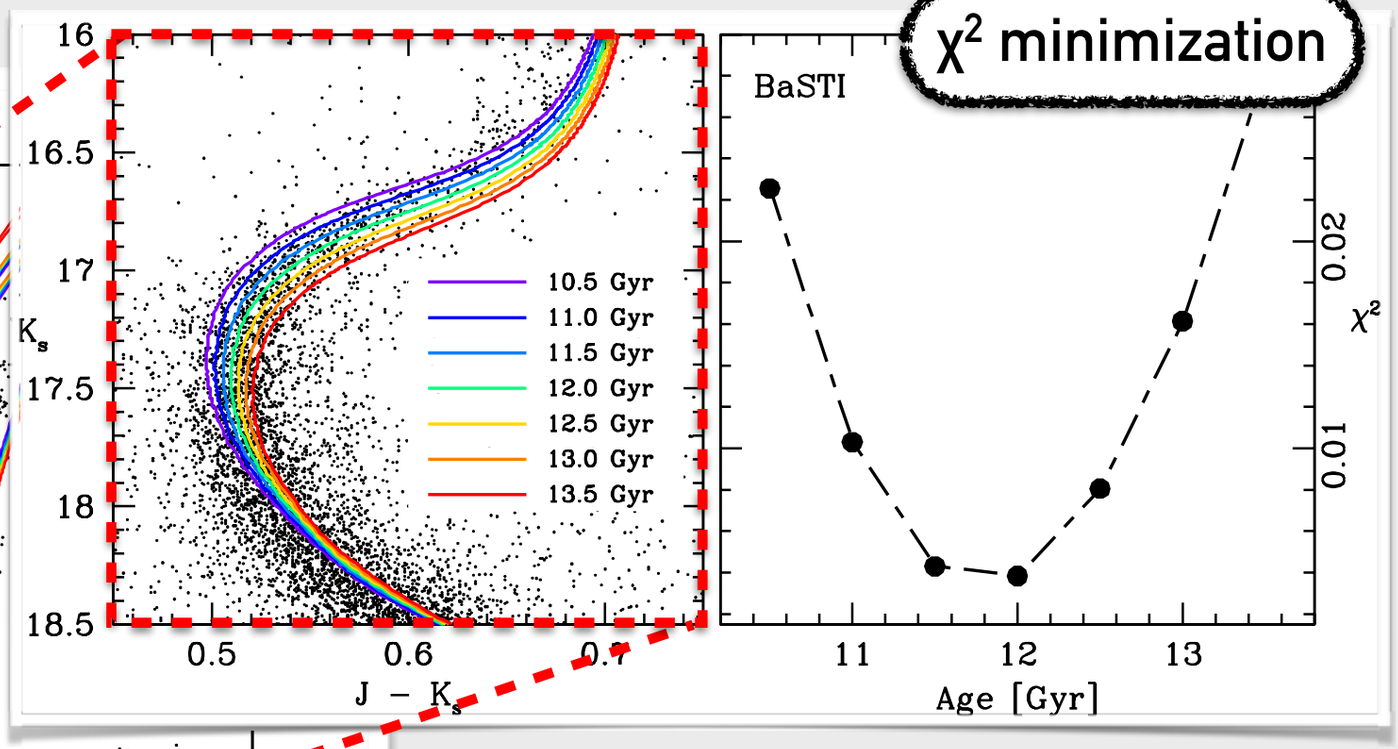

**The deepest and highest-quality near-IR photometry realized by using only ground-based data.**

Saracino et al. 2016, 2018

# Isochrone fitting technique

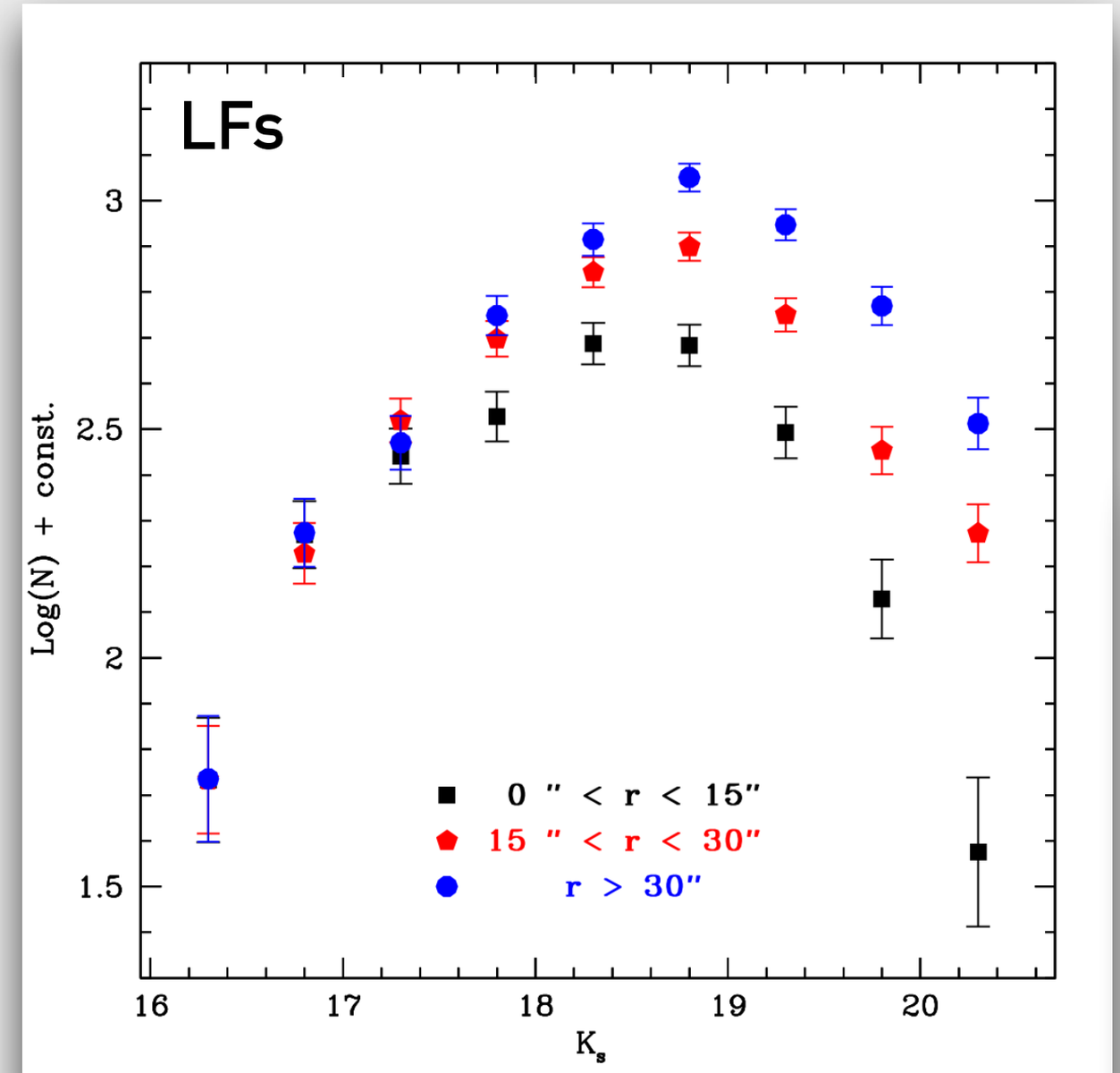



# $\chi^2$ minimization

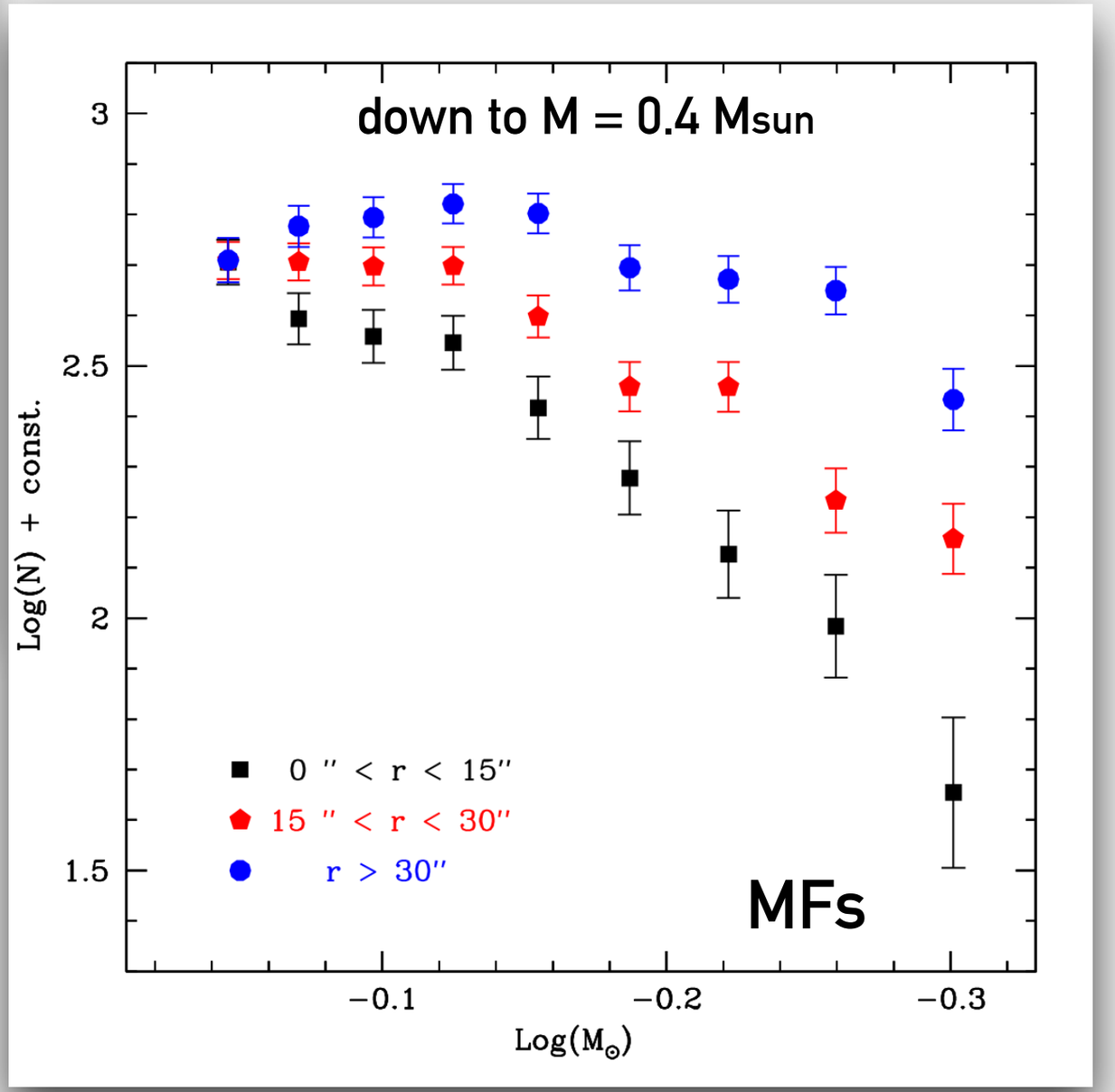



**The absolute age of NGC 6624 is of about 12 ± 0.5 Gyr**

Saracino et al. 2016



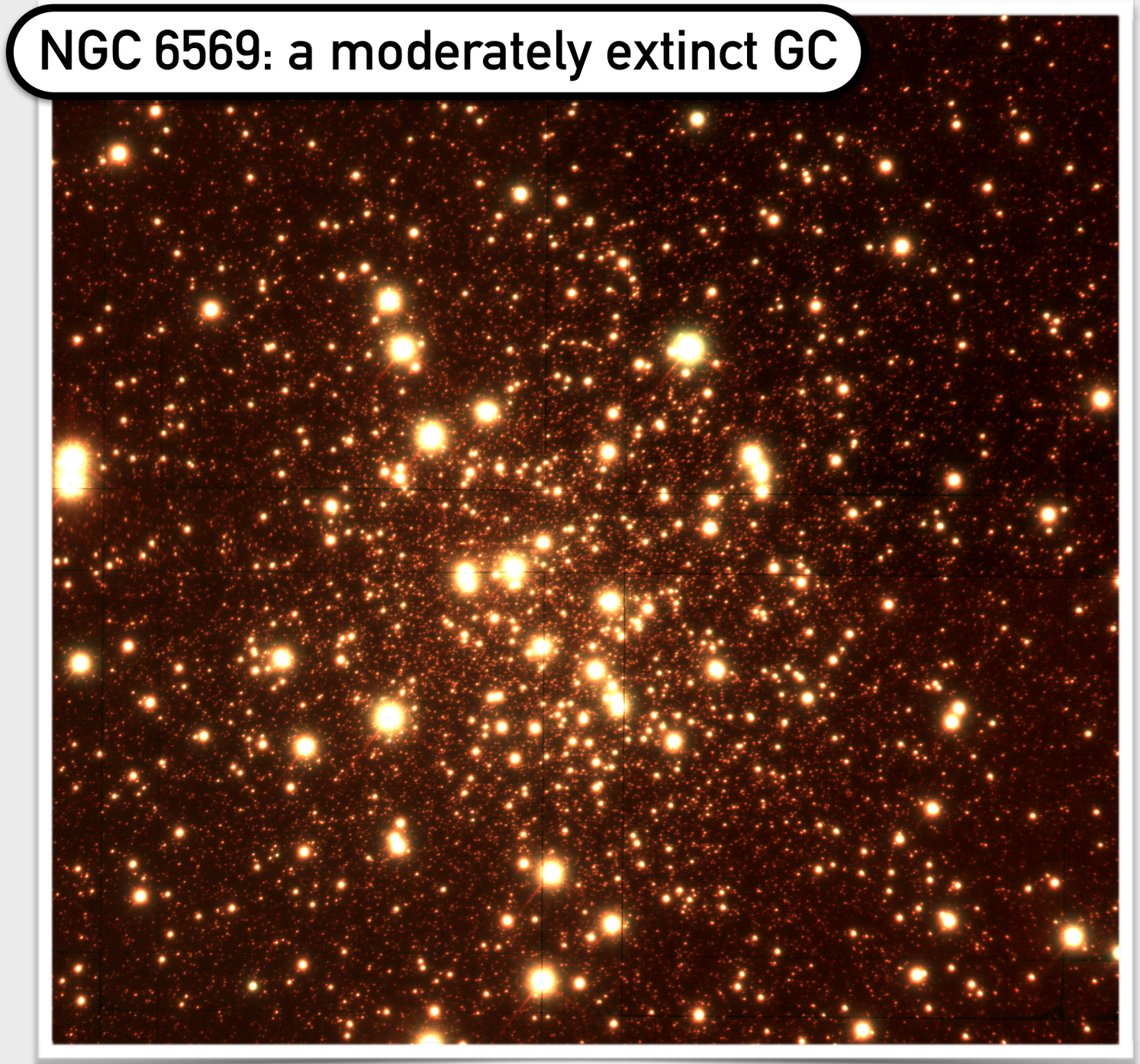

**Clear signatures of MASS SEGREGATION**




**NGC 6624 is a dynamically evolved cluster!**

Saracino et al. 2016

# NGC 6569: a moderately extinct GC



93”

WFC3@HST images

## Main properties:

1. E(B-V) = 0.5
   (Ortolani 2001, Valenti 2005)

2. Metallicity [Fe/H]=-0.8/-0.9
   (Jonhnson et al. 2018, Valenti et al. 2011)

3. A sizable population of variable stars
   (Kunder et al. 2015, Hazen-Liller et al. 1984,1985)

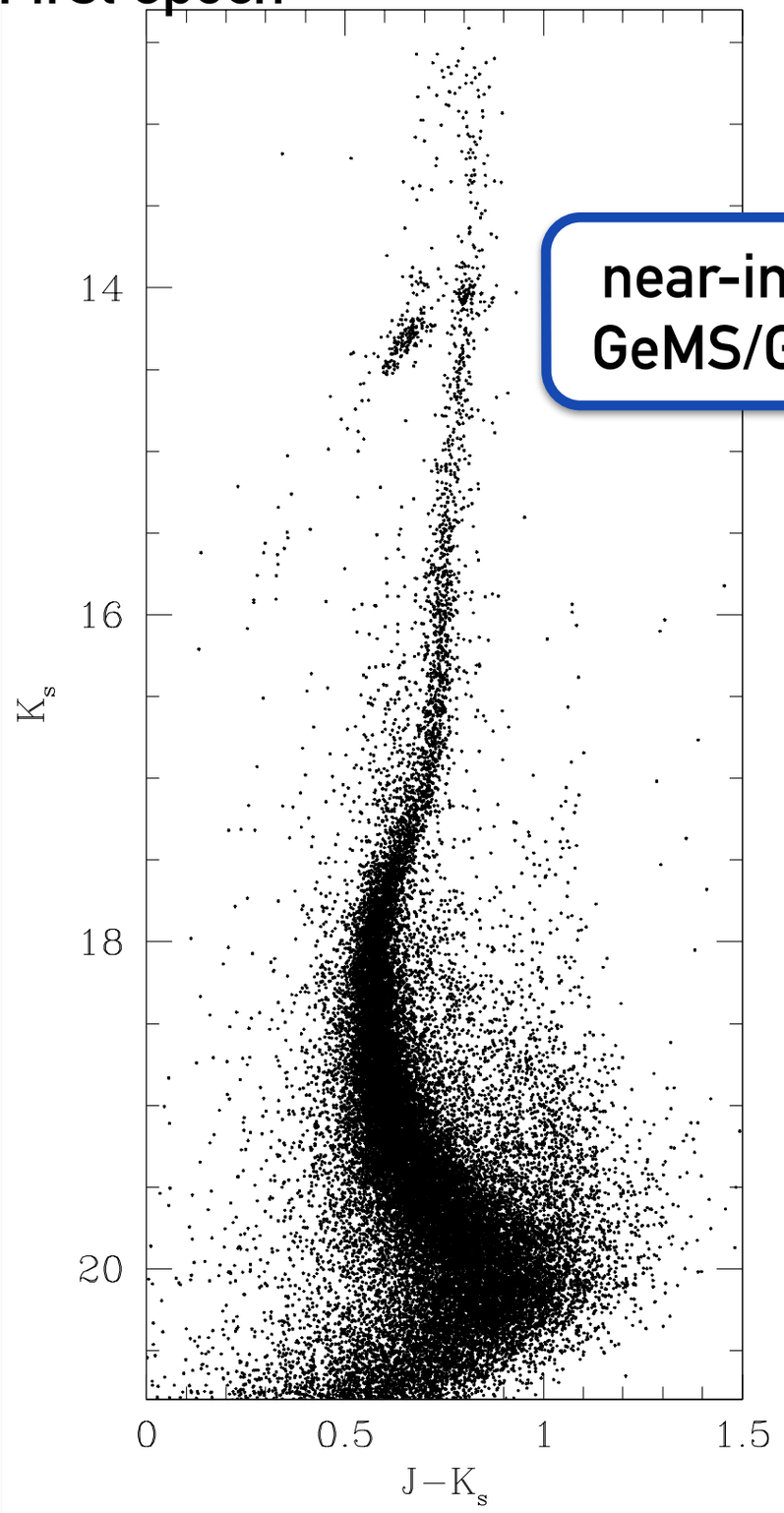
Saracino et al. 2018, to be submitted



# PMs: A multi-wavelength/instrument approach

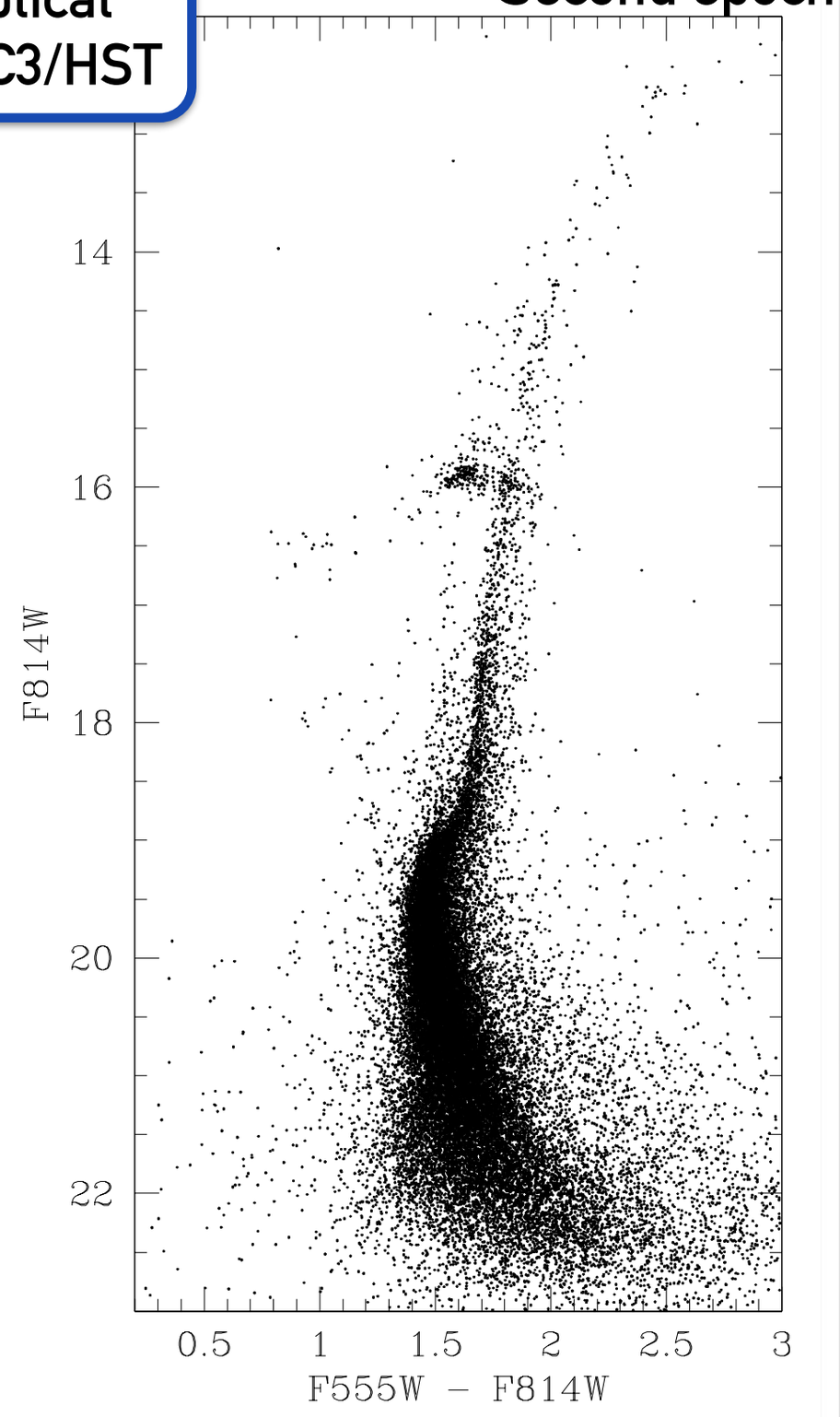
First epoch

near-infrared
GeMS/GEMINI



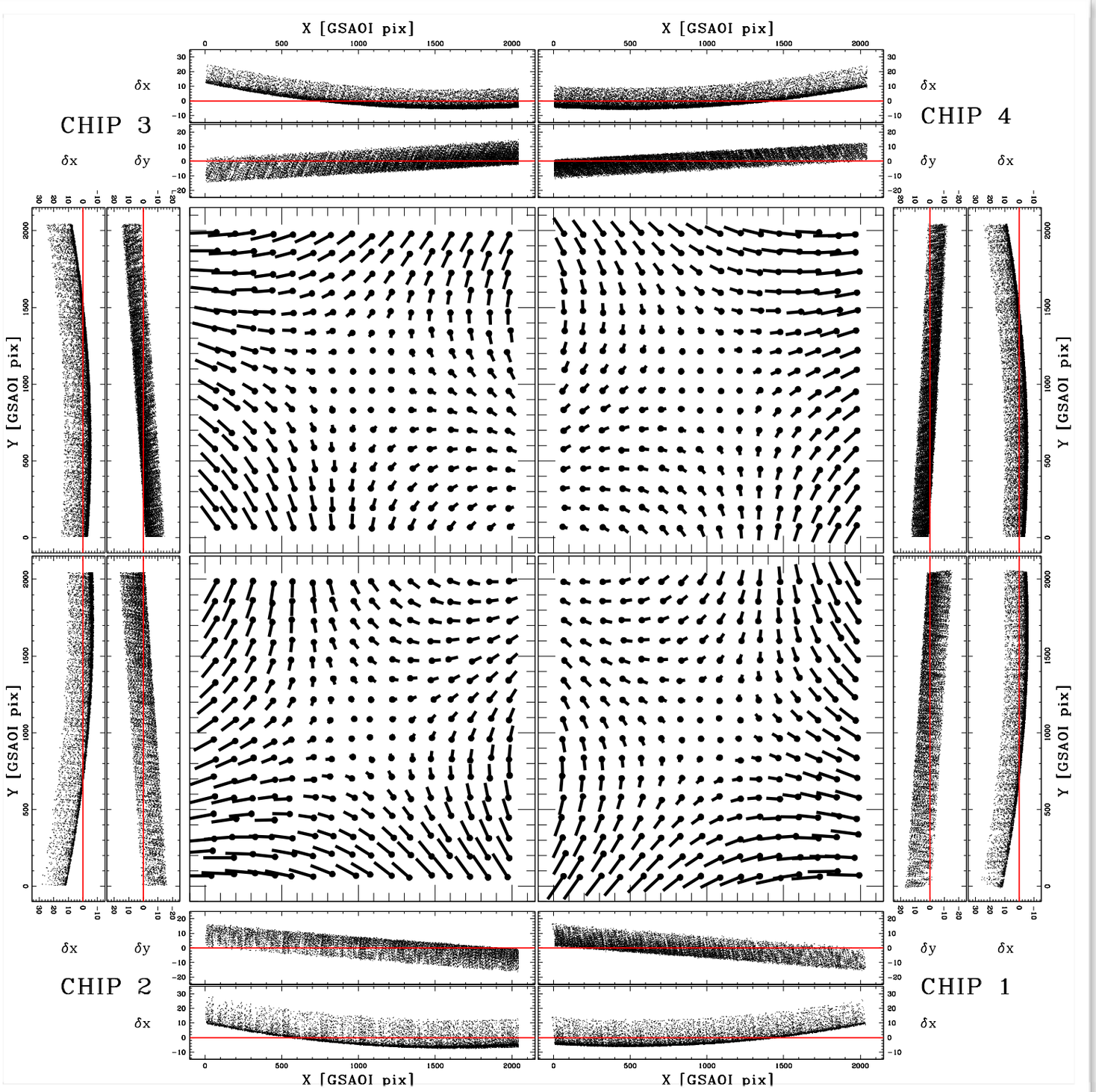

optical
WFC3/HST

Second epoch



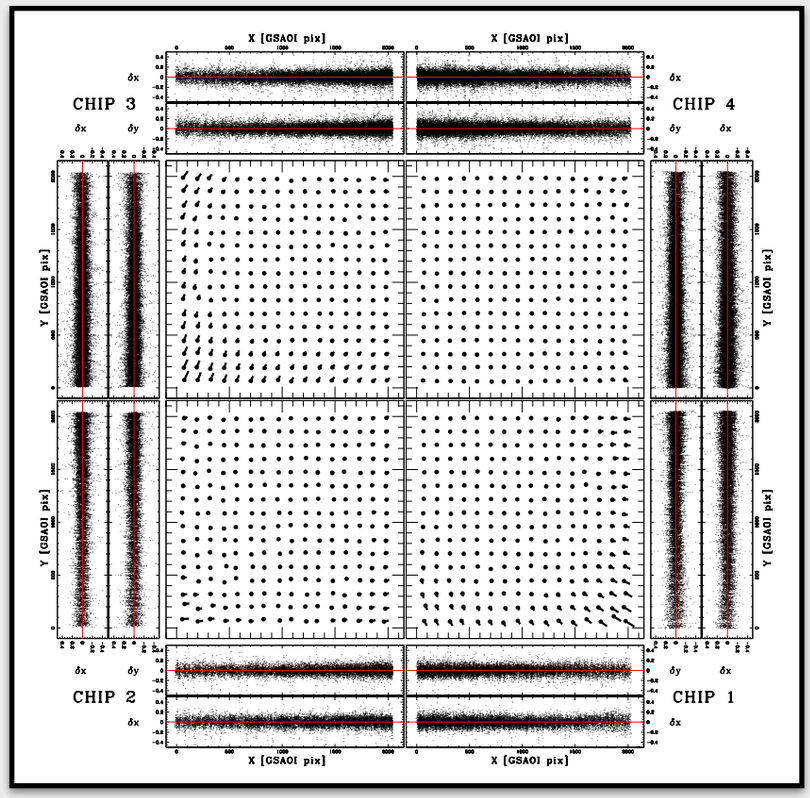
# Astrometry with GSAOI: Geometric Distortions





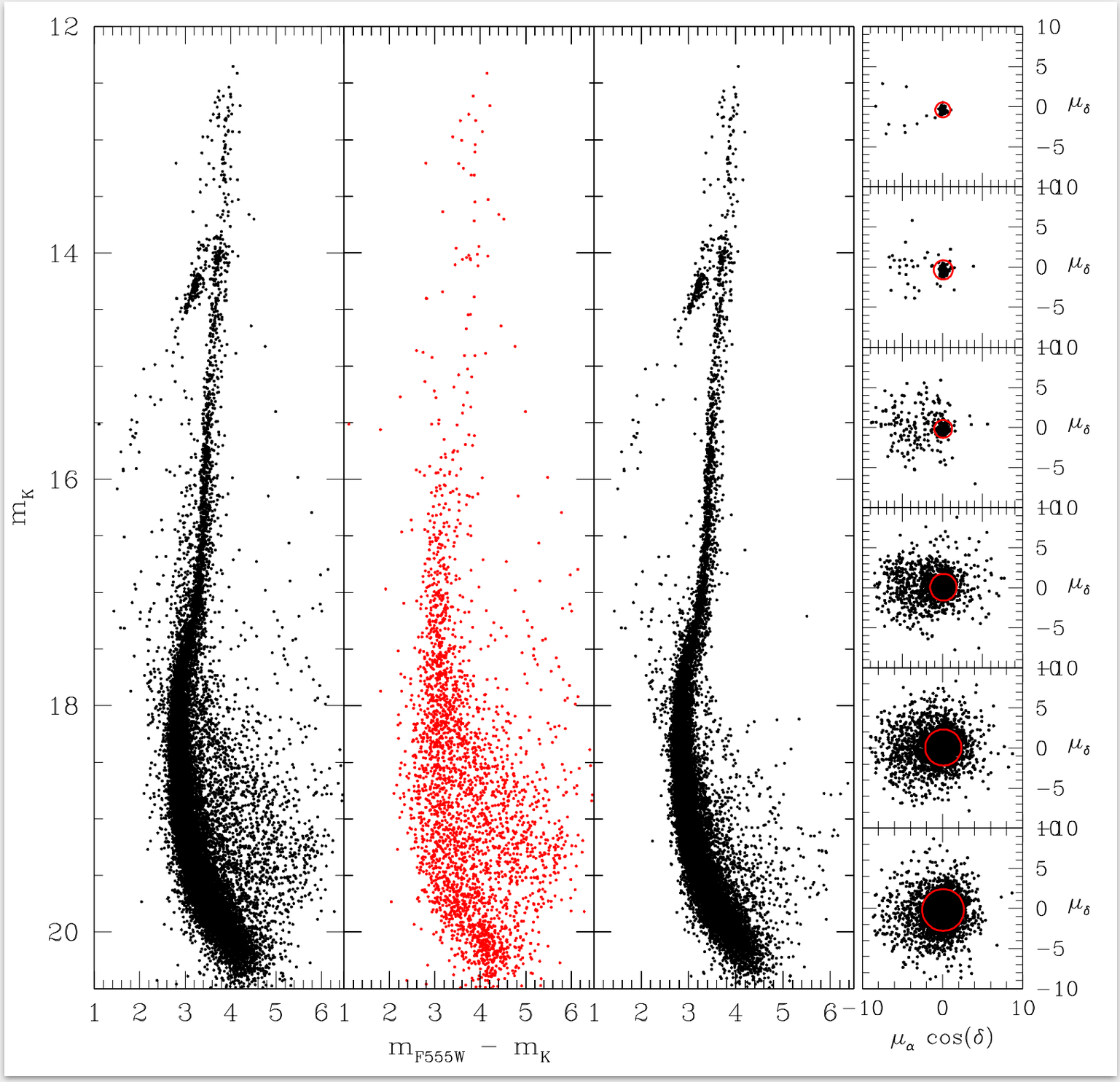

**The GSAOI camera is strongly distorted!**

up to 40 pixels in both axes (about 0.8")




accuracy = 1 mas!

Dalessandro, Saracino et al. 2016



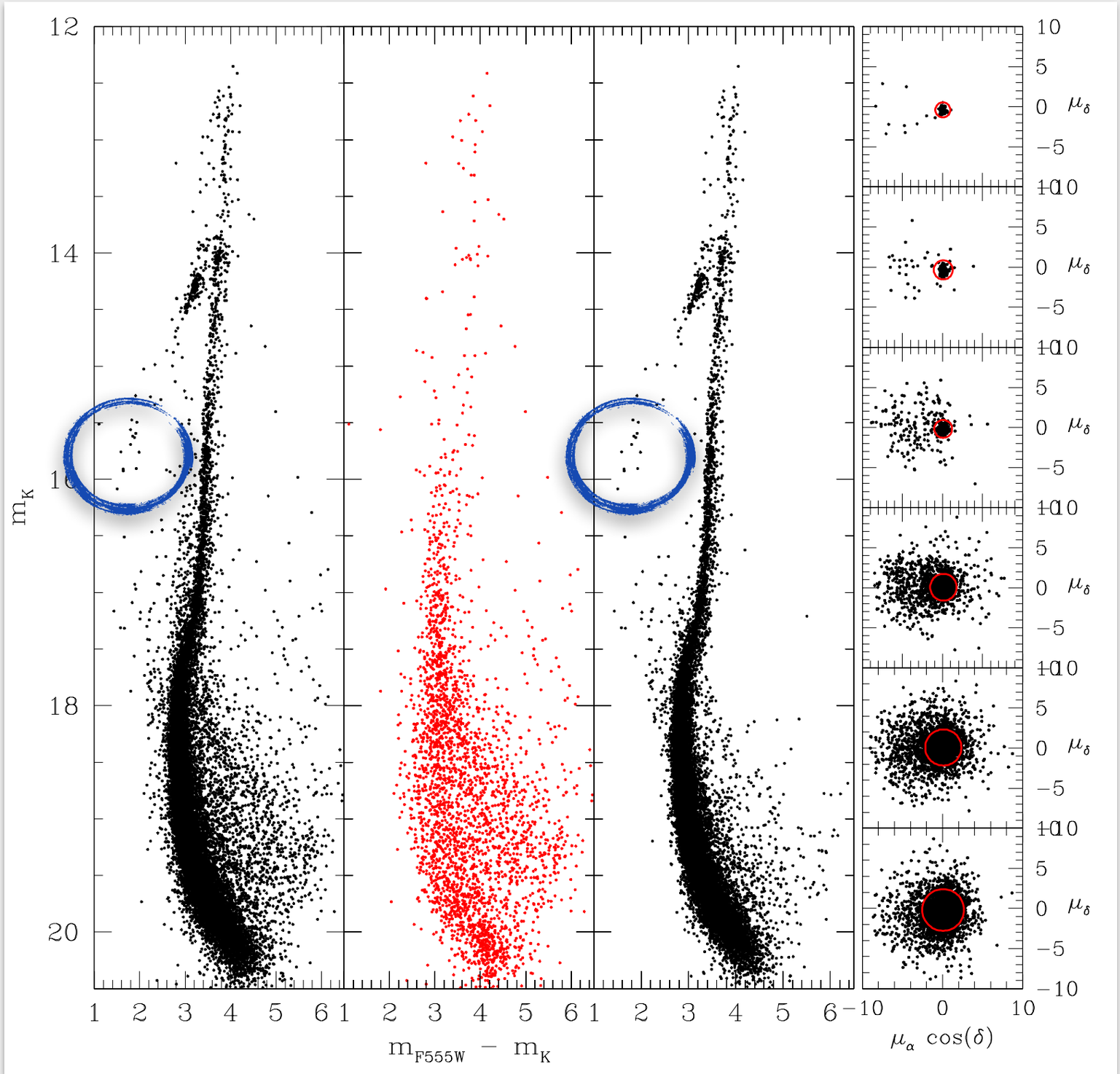

Relative PROPER MOTION of NGC 6569

GEMINI: first epoch
HST : second epoch

Temporal baseline
5 years!

Without any information
about cluster membership!

Saracino et al. 2018, to be submitted



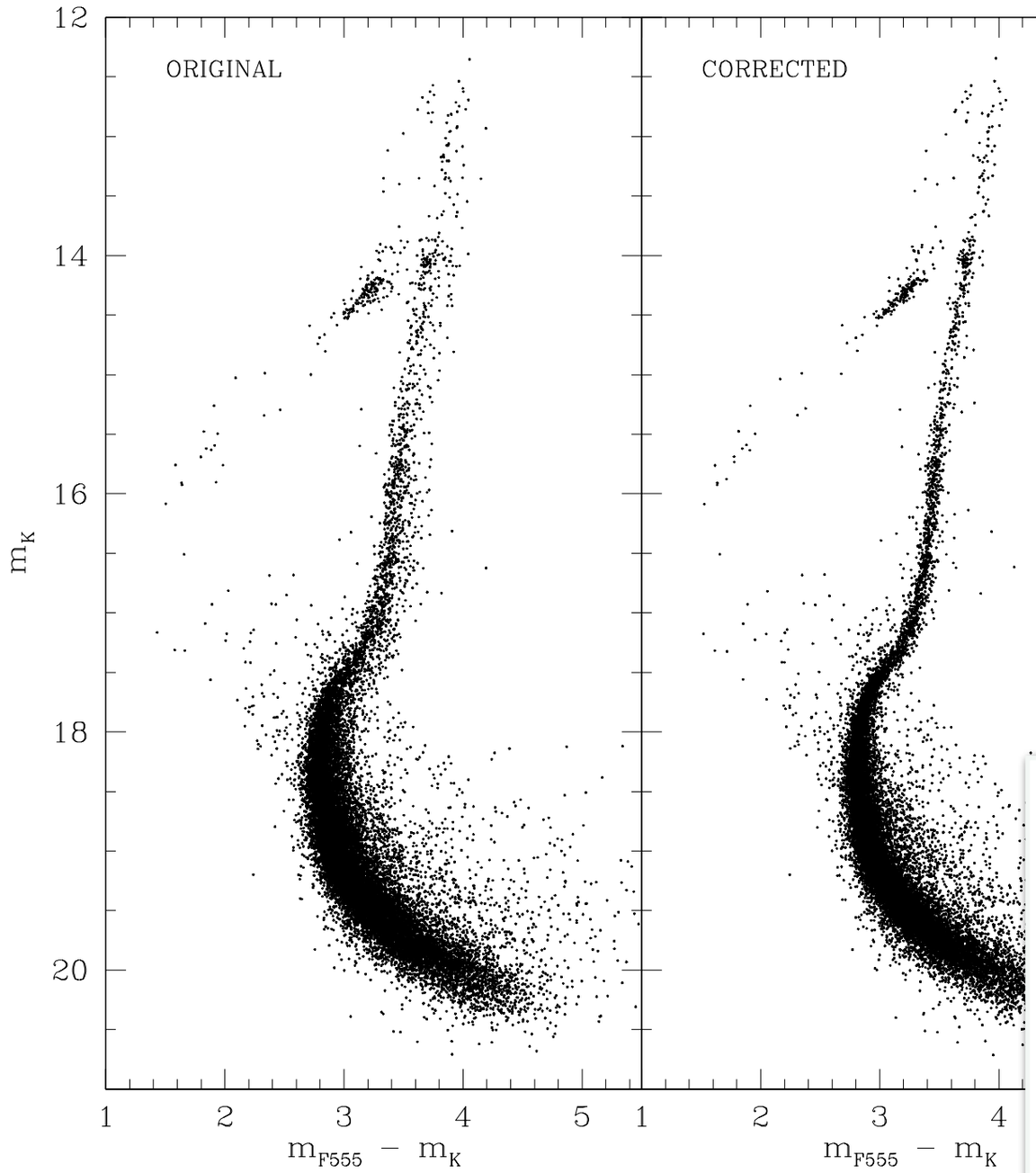

GEMINI: first epoch
HST : second epoch

Without any information about cluster membership!

A few blue HB stars are cluster members!

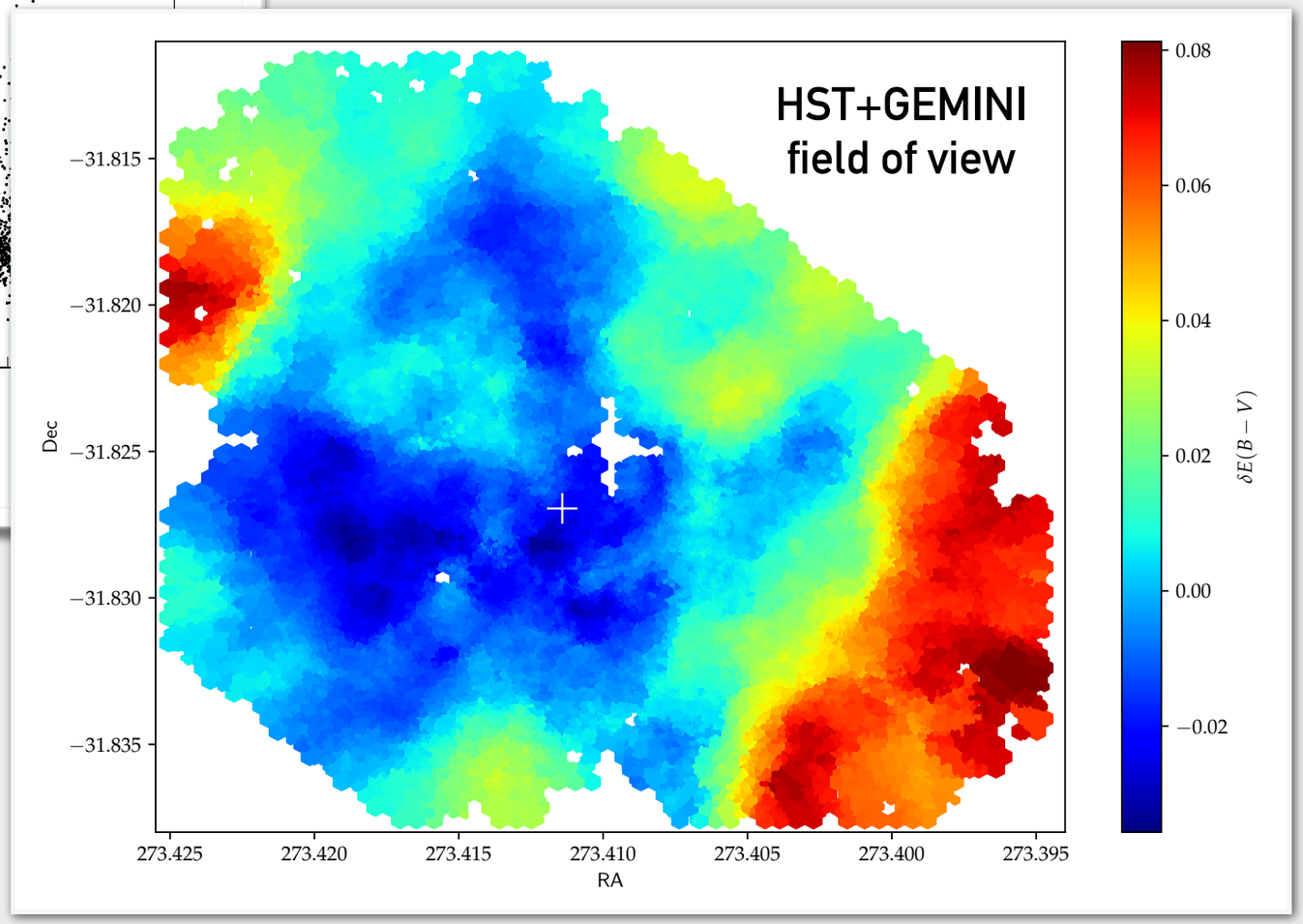
(confirmed by Cohen et al. 2018)

Saracino et al. 2018, to be submitted

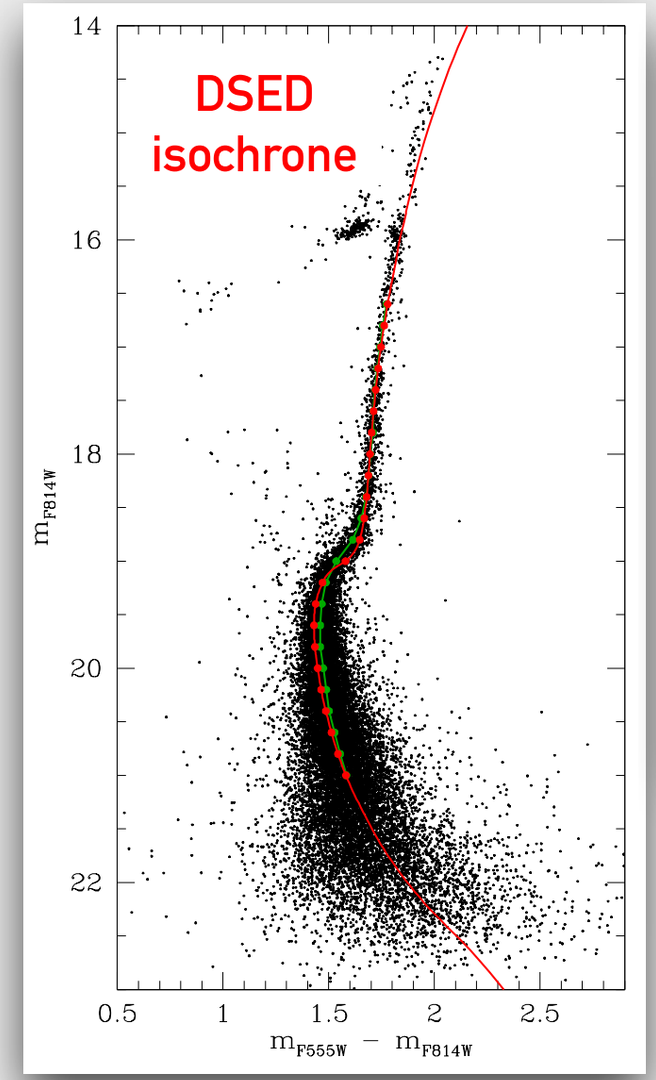


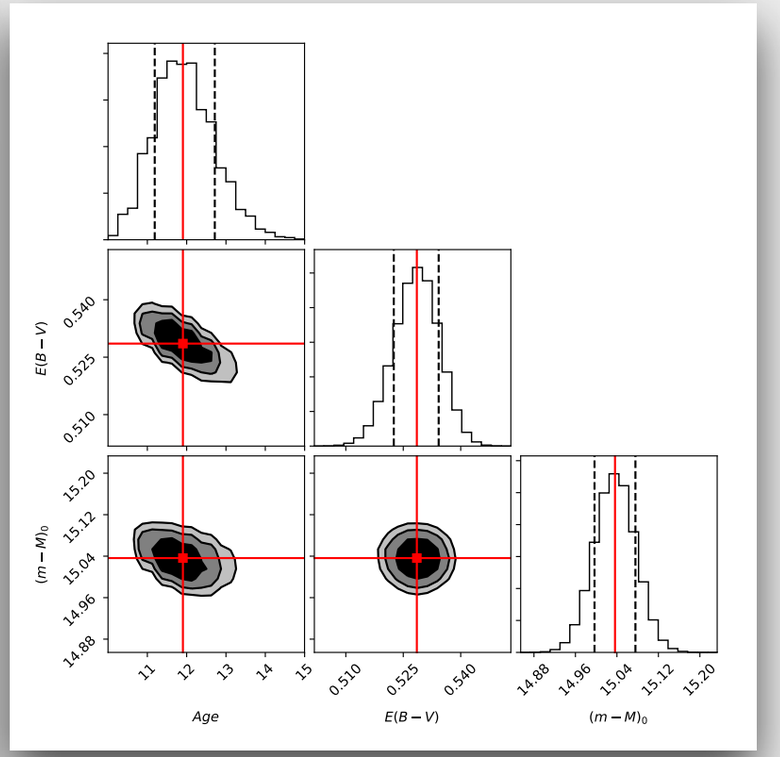

# Differential Reddening correction

$\Delta E(B-V) = 0.12$ mag




Saracino et al. 2018, to be submitted



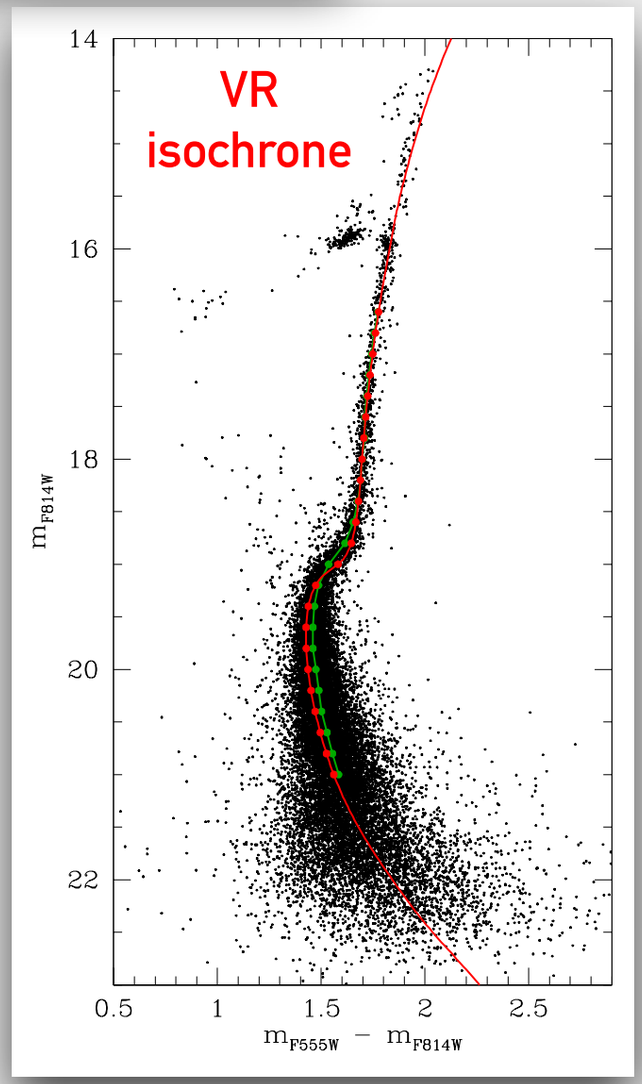

**The absolute age of NGC 6569 derived for the first time!**

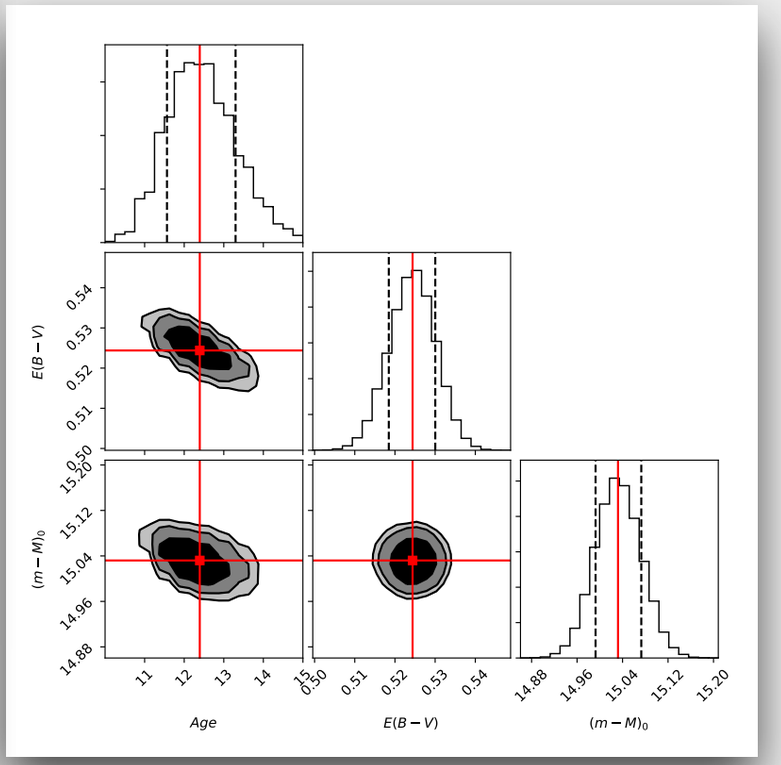
**T = 11.9 - 12.4 Gyr**

**with an uncertainty of 1 Gyr!**

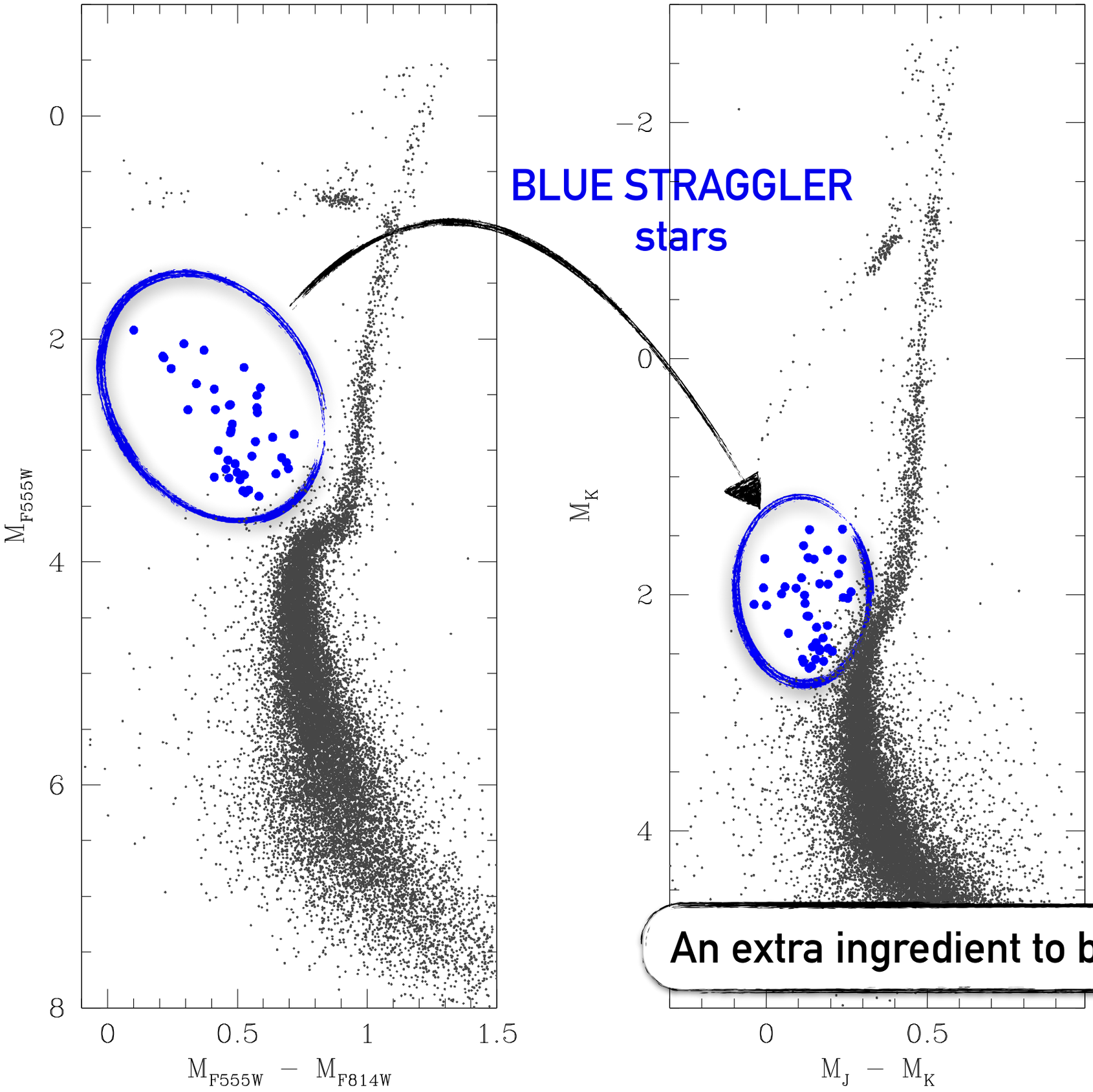
1. Isochrone fitting technique
2. Three stellar models (BaSTI, VR and DSED)
3. $\chi^2$ statistics

Saracino et al. 2018, to be submitted



# Once E(B-V) and $(m-M)_0$ have been derived..



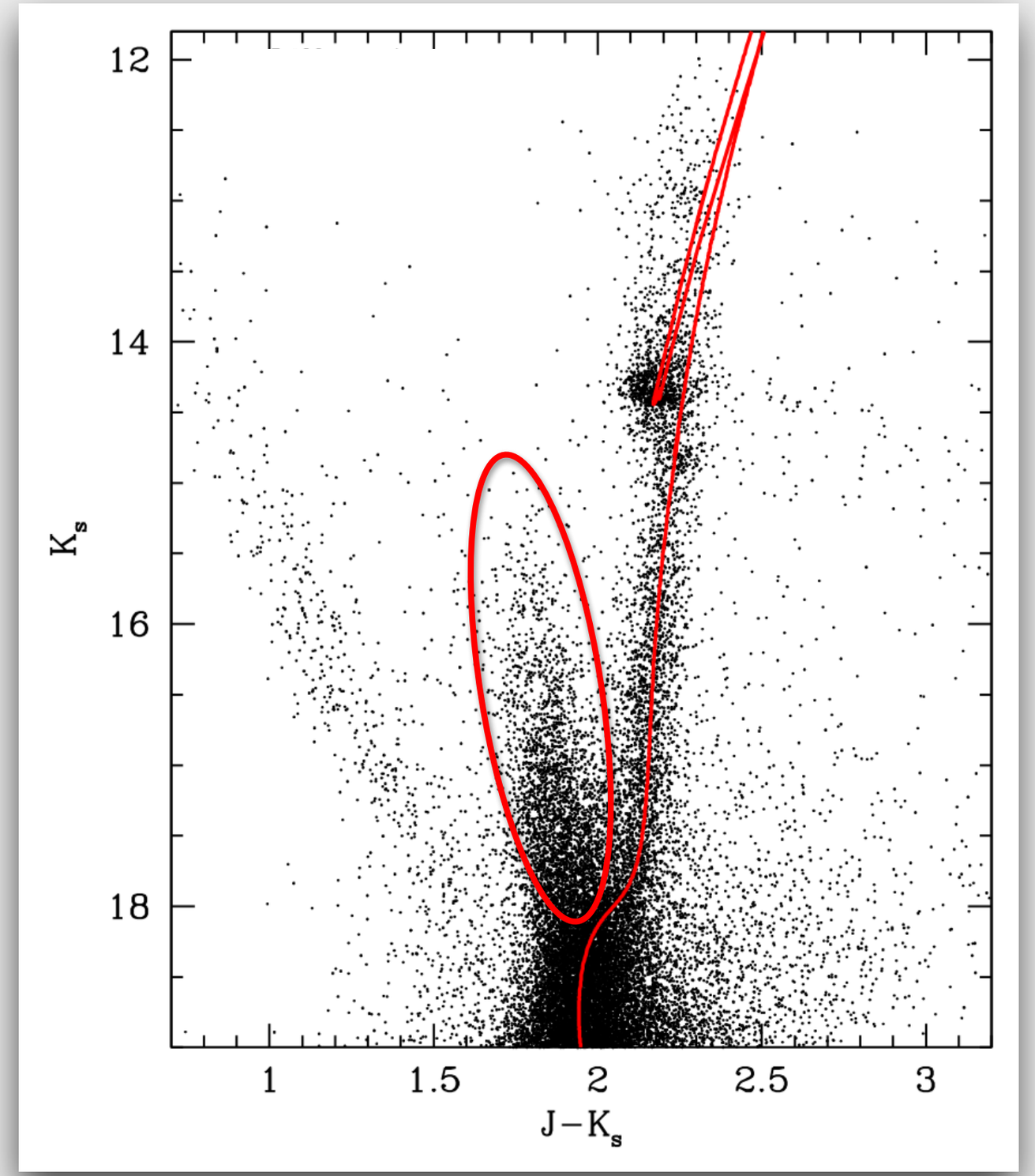

Selected in the
OPTICAL

Identified in the
NEAR INFRARED

An extra ingredient to be added in synthetic CMDs!

Valenti's talk

Thank you for your attention!

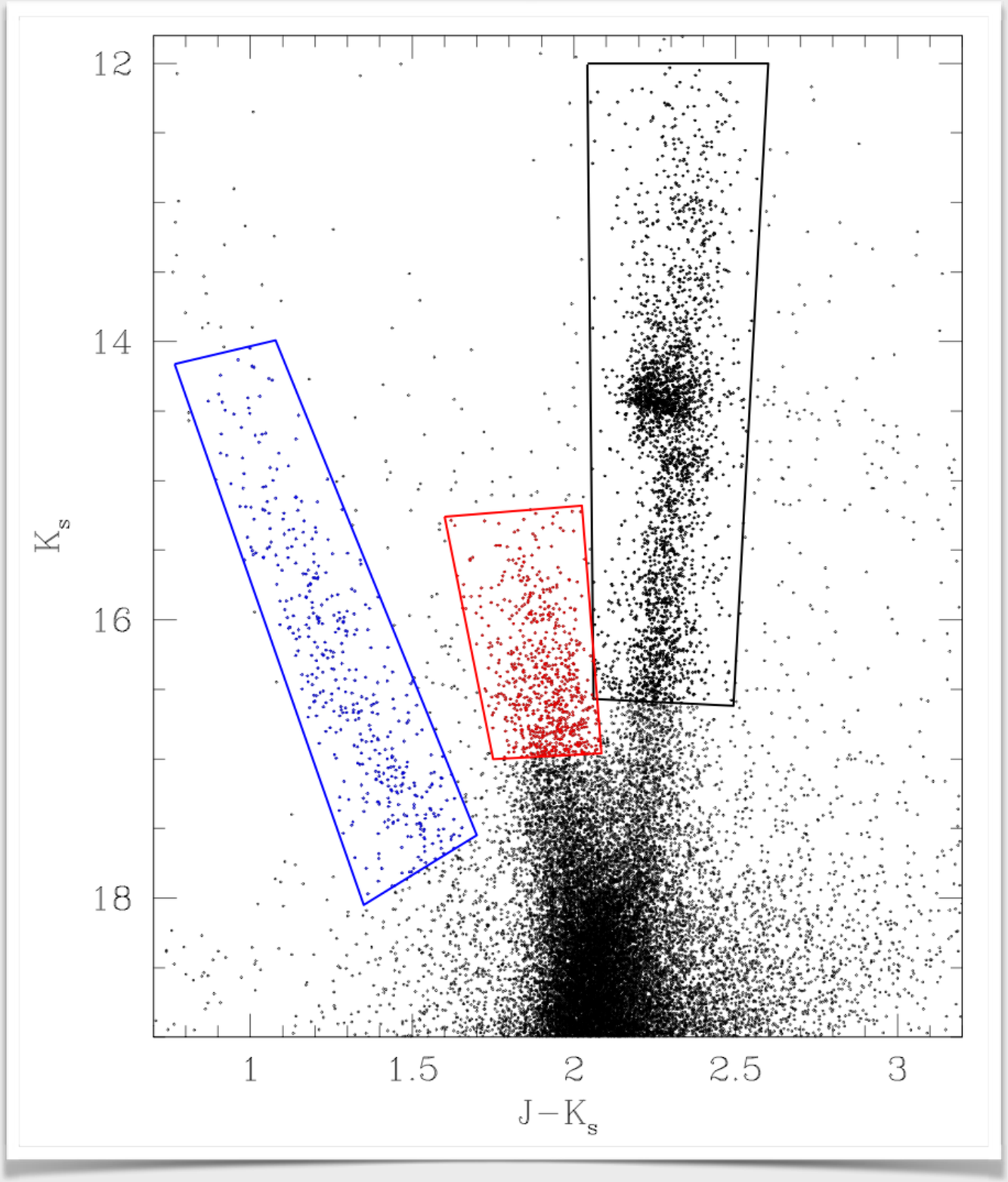


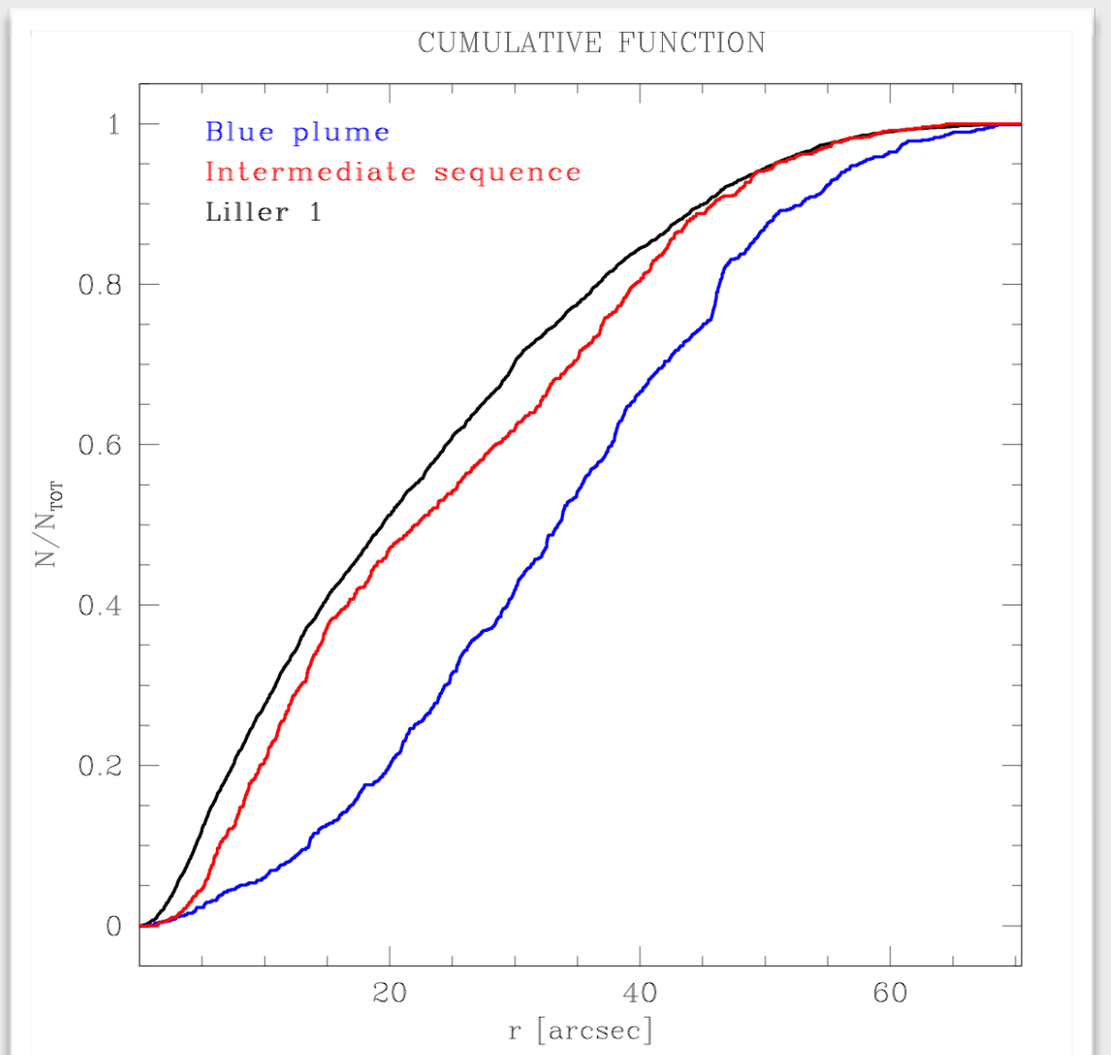

Despite the uncertainties
are pretty large,
Liller 1 is an old cluster,
with an age of about 12 Gyr.

However…

a complexity comes out!

# Which stars populate the sequence?




**Red stars are centrally concentrated as cluster members!**

**..younger stars?**