Galactic Globular Cluster Ages by observing white dwarfs with the E-ELT

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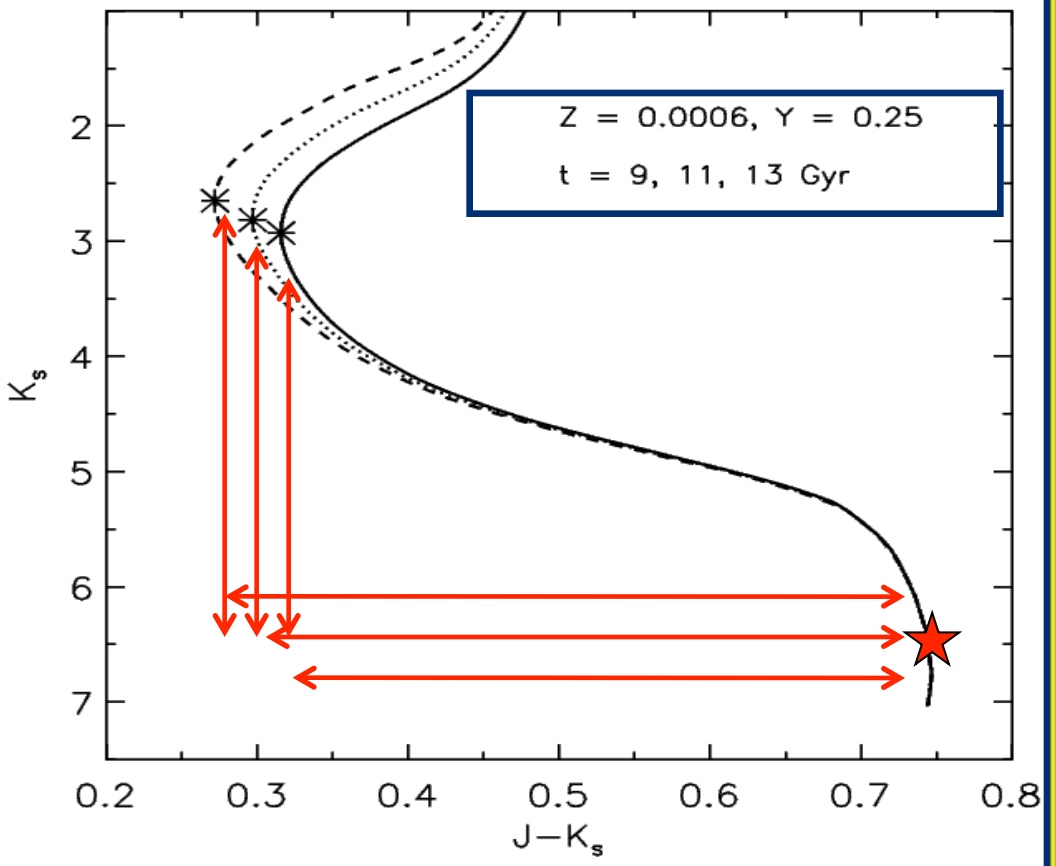
Absolute ages of globular clusters

Comparison between Theory & Observations:

NIR PROS ☺

- ✓ Minimally affected by reddening & differential reddening
- ✓ Faint MS stars are brighter (NIR vs optical)
- ✓ Intrinsic feature of the main-sequence (MS) -> MS-Knee
- ✓ Intrinsic feature of the white dwarf (WD) cooling sequence -> Blue Turn-Off

MS stars, for M ≤ 0.40-0.45 M⊙, show in NIR CMDs a well defined bend toward fainter magnitudes and fixed color



The difference in magnitude and/or color between the TO and the knee of NIR bend is a robust absolute age indicator.

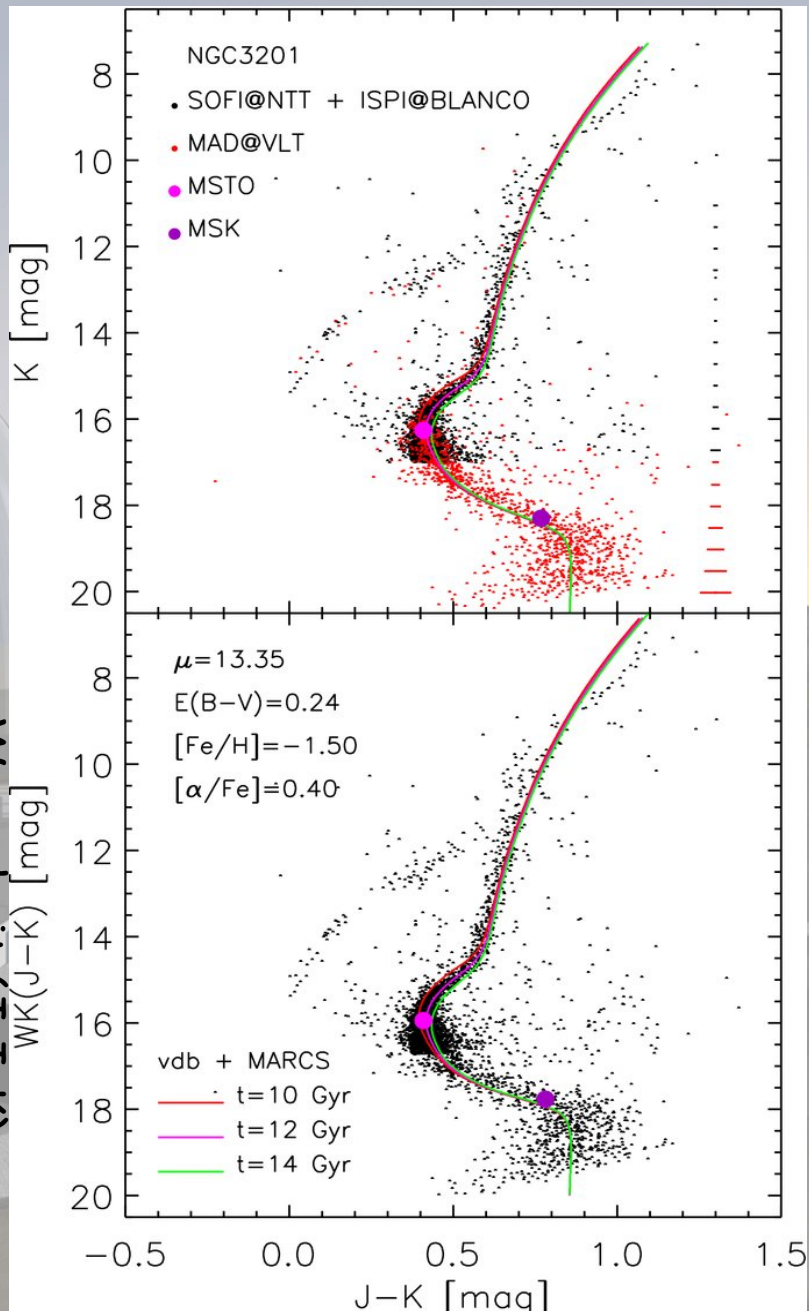
NO Distance and NO reddening dependence!

Caused by Collisional Induced Absorption of H_2 (CIA, Saumon et al. 1994)

The absolute age of NGC3201: NIR

A new method to estimate the absolute age of stellar systems

Difference in magnitude and/or in color between the TO and the NIR MS knee



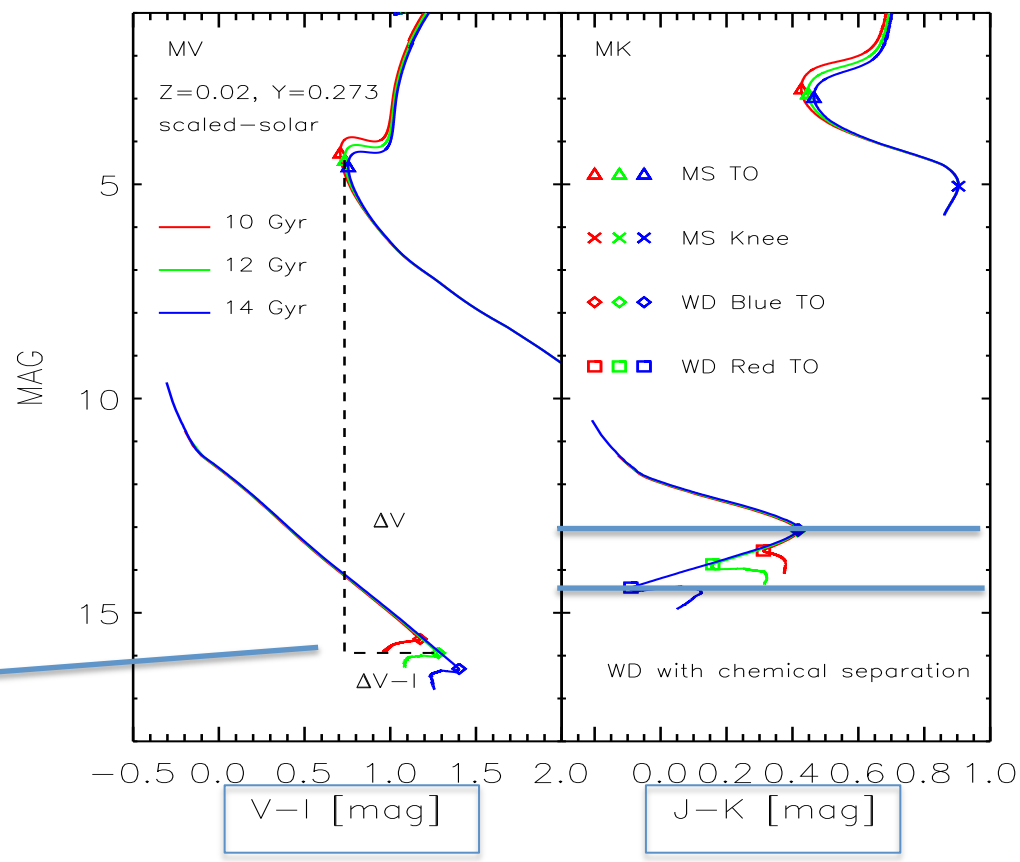
Calamida et al. (2009), Bono et al. (2010)

Theory of WD cooling sequences

Validation for different physics between MS & WDs

Perfect lab. x NGS! local AGB/RGB

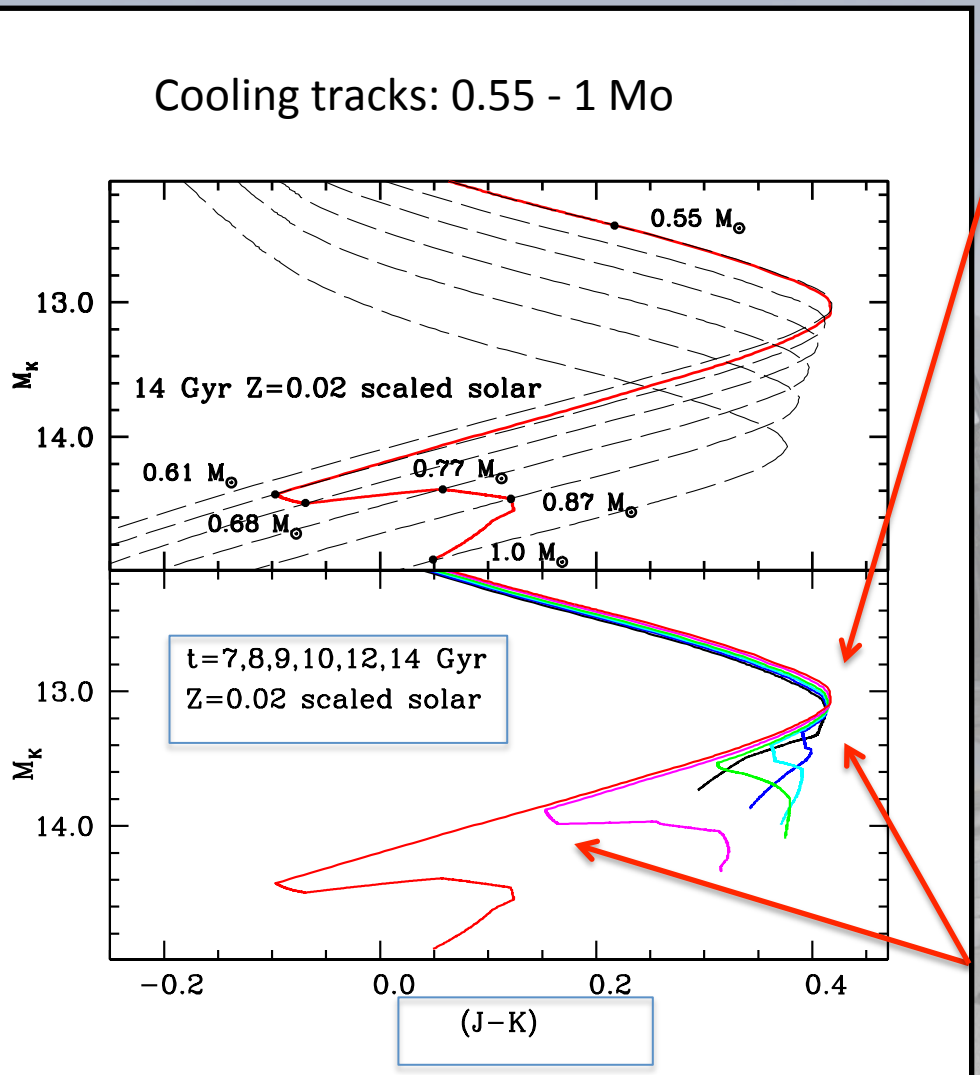
Observed in the optical bands in the closest GGCs, such as M4 with HST (Bedin et al. 2010)



Bono et al. (2013)

DA WDs

Theory of WD cooling sequences



DA WDs

Bono et al. (2013)

Blue TO caused by CIA

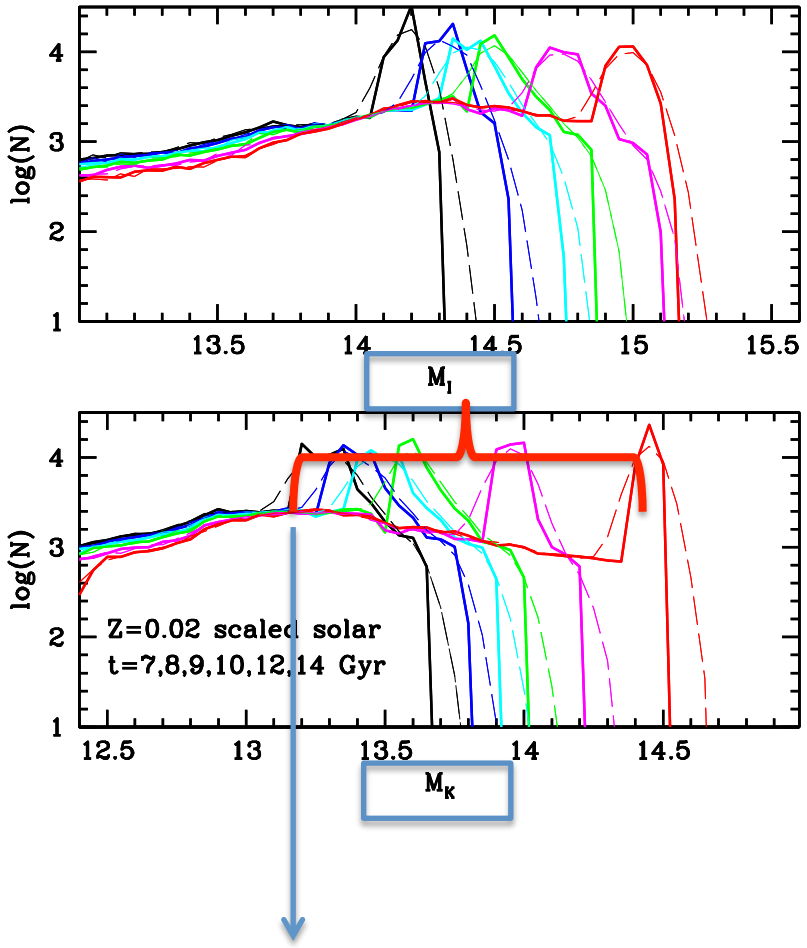
Independent of age

Independent of metallcity

Distance Indicator

Red TO caused by the pile up of WDs in mass

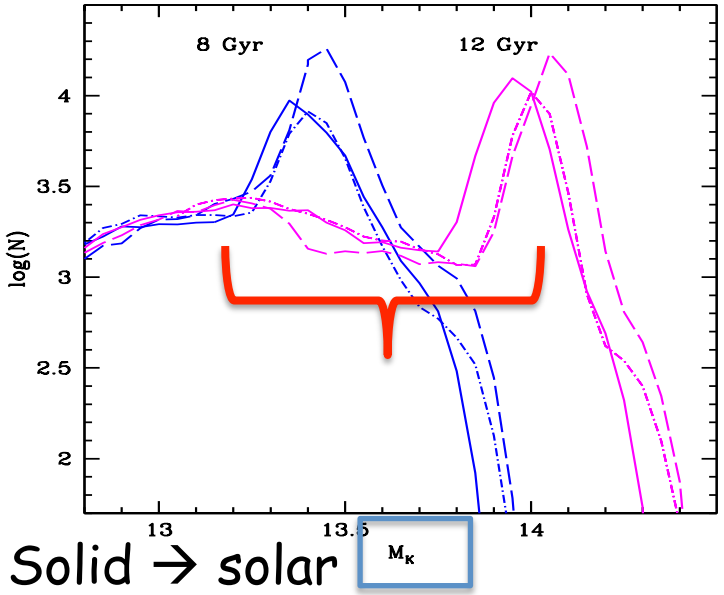
Theory of WD cooling sequences



Secondary maximum; age independent!

Bono et al. (2013)

The WD Luminosity function in K-band is a solid age indicator independent of distance, reddening & metallicity



Solid → solar

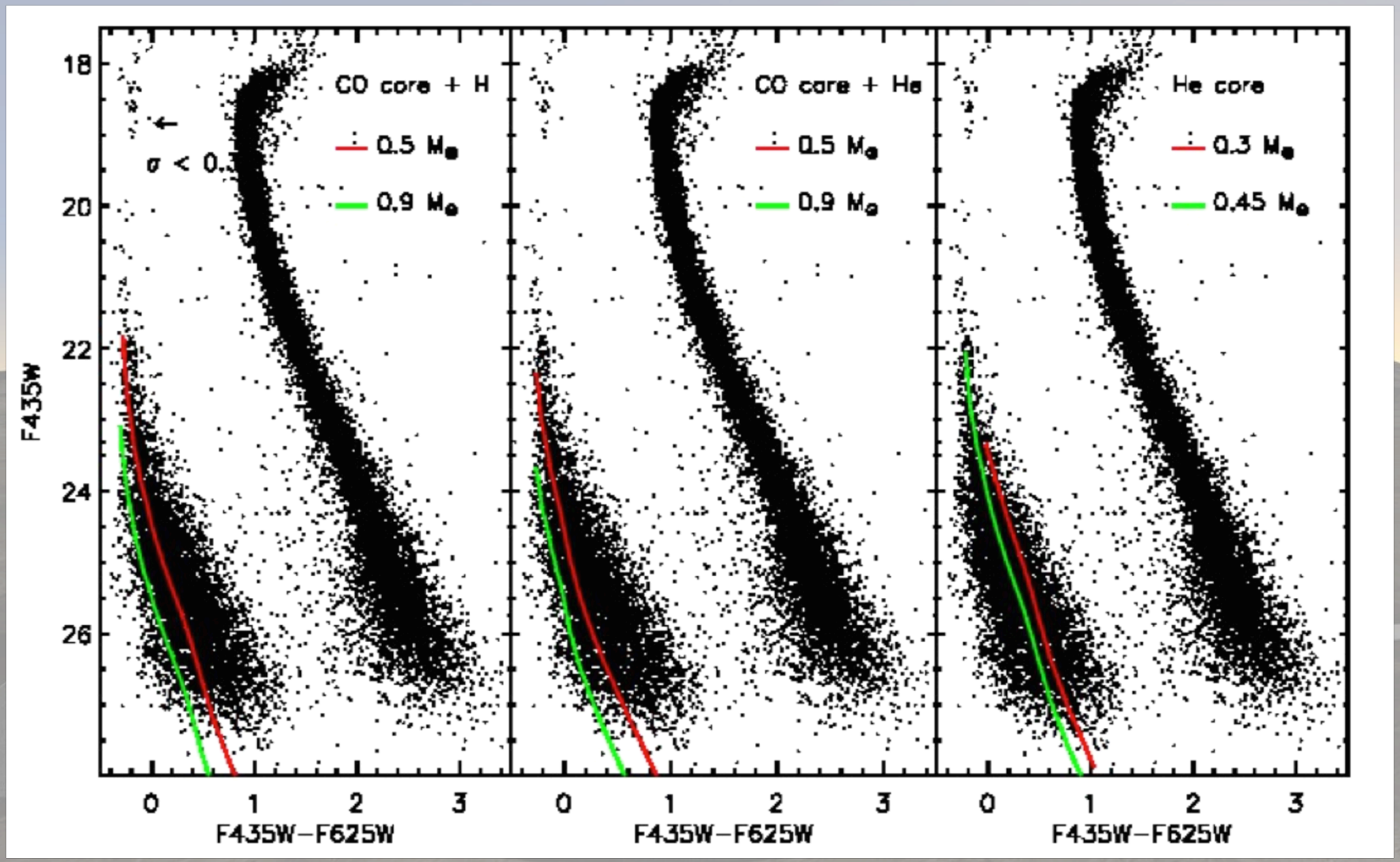
Dashed-dotted → [Fe/H] =-0.7

Dashed→ [Fe/H] = -2.1

Photometry of WD cooling sequences

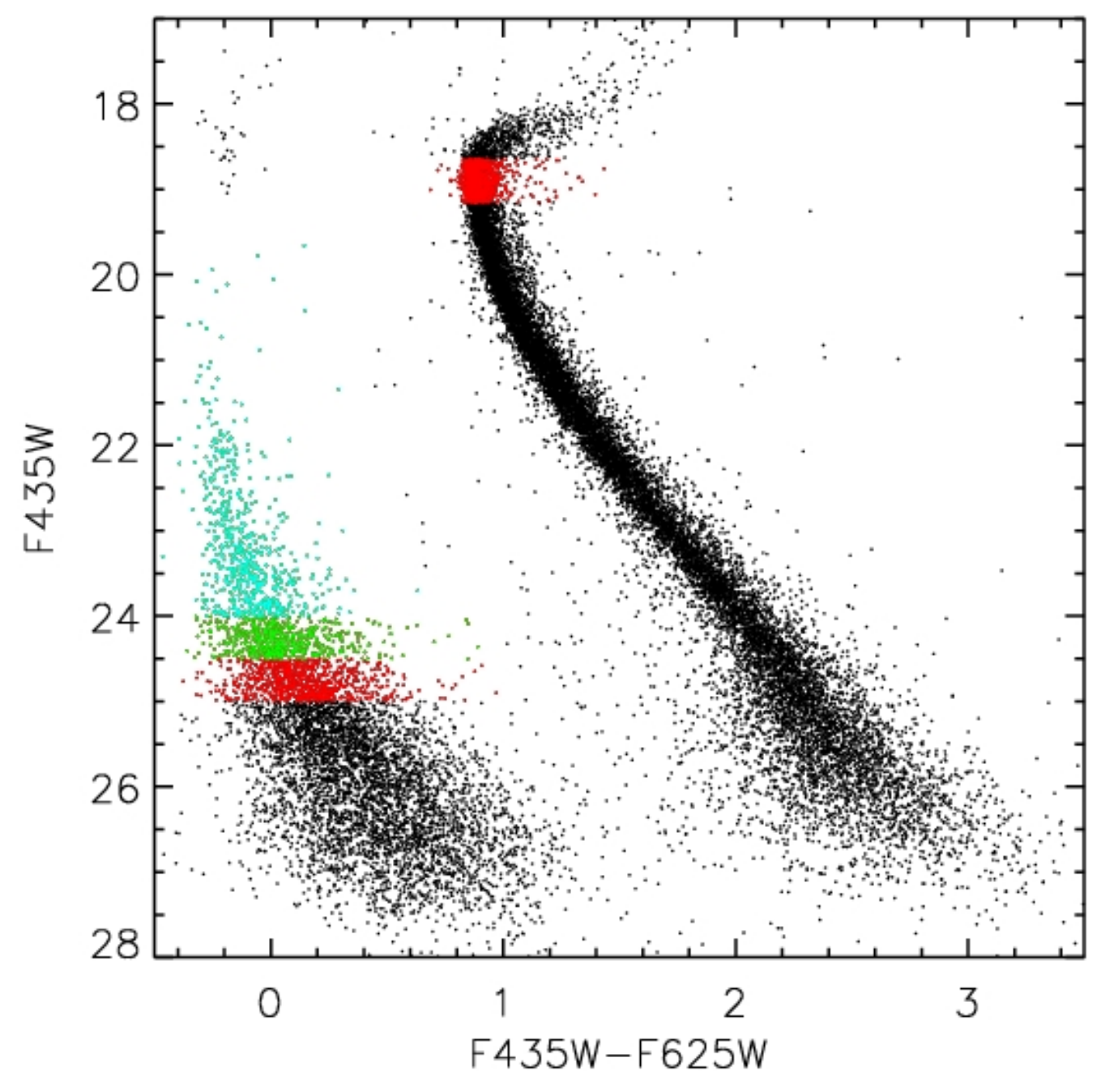
ACS/HST

ω Cen: 6500 WDs!



Monelli et al. (2005), Calamida et al. (2008)

FoV: less than 9'x9'!

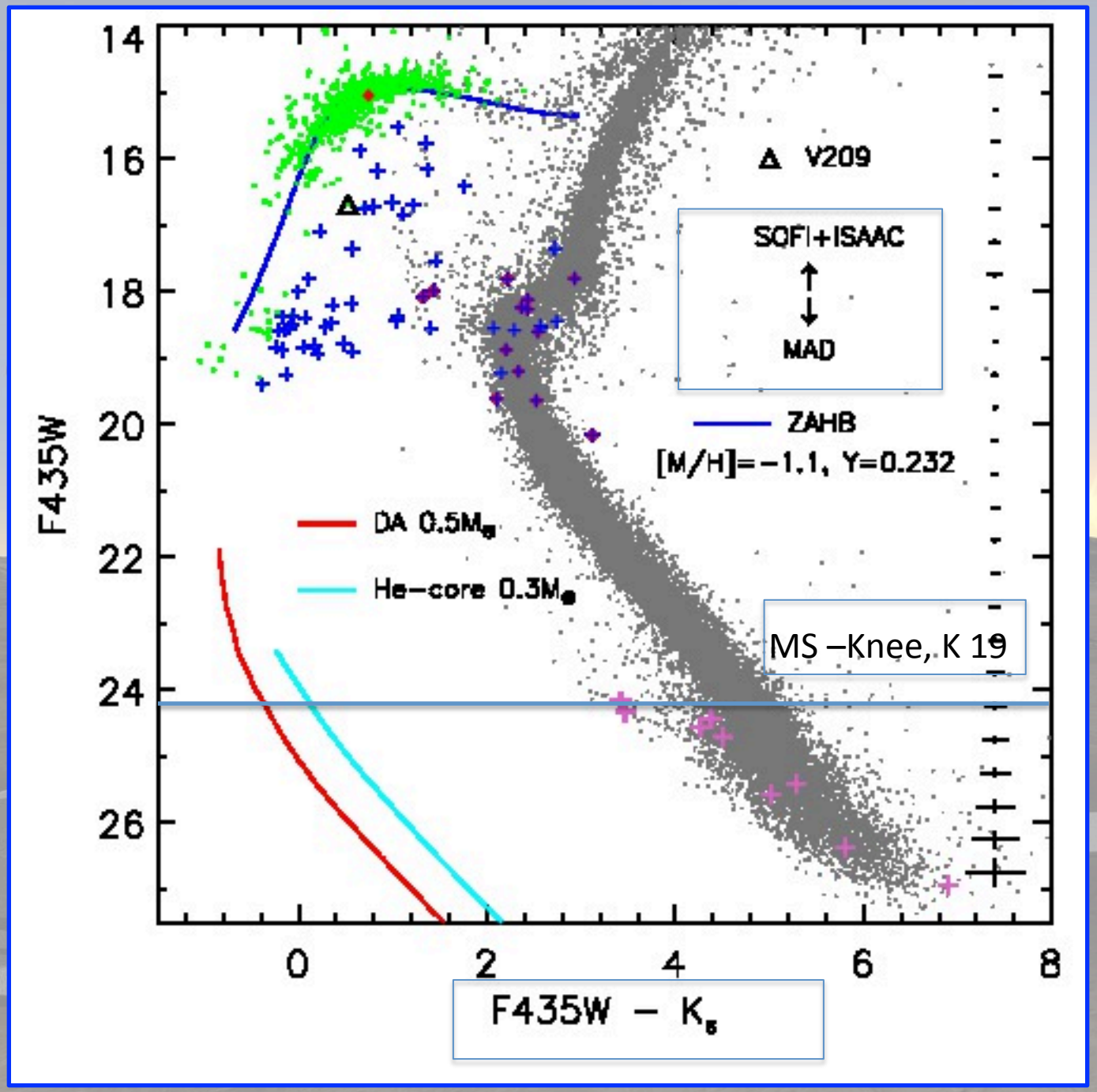


Are He-core WDs popular?

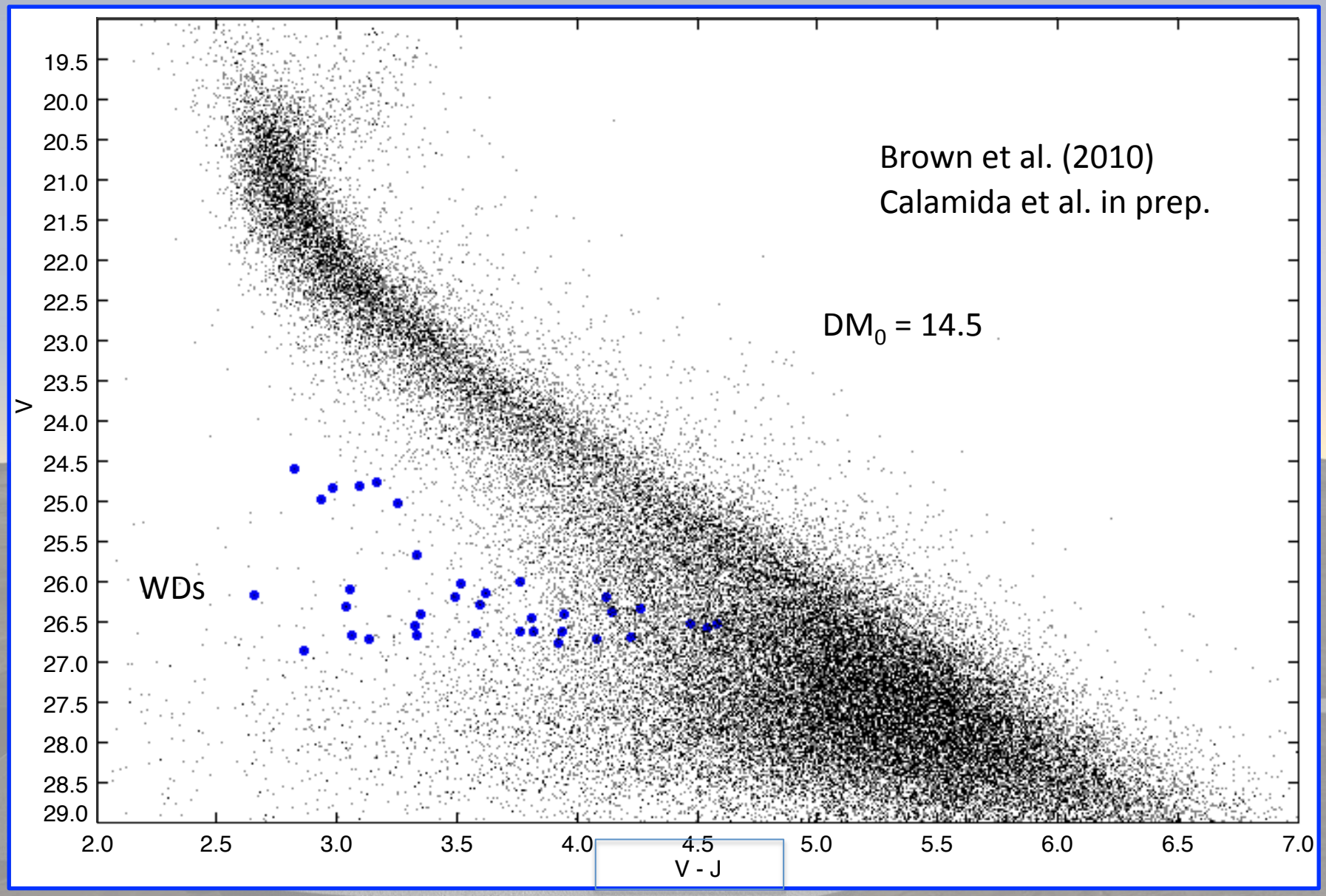
Are they produced mainly in *GCs*?

Do they have a different radial distribution compared to MS stars?

Calamida et al. (2008)


14
16
18
20
22
24
26
F435W
0
2
4
6
8
F435W − K_s
Δ V209
SOFI+ISAAC
MAD
ZAHB
[M/H]=−1.1, Y=0.232
DA 0.5M_⊙
He−core 0.3M_⊙
MS –Knee, K 19

Bulge, Sweeps low-reddening window, WFC3/HST photometry



We need E-ELT!

Simulations: E-ELT!

Synthetic population with:

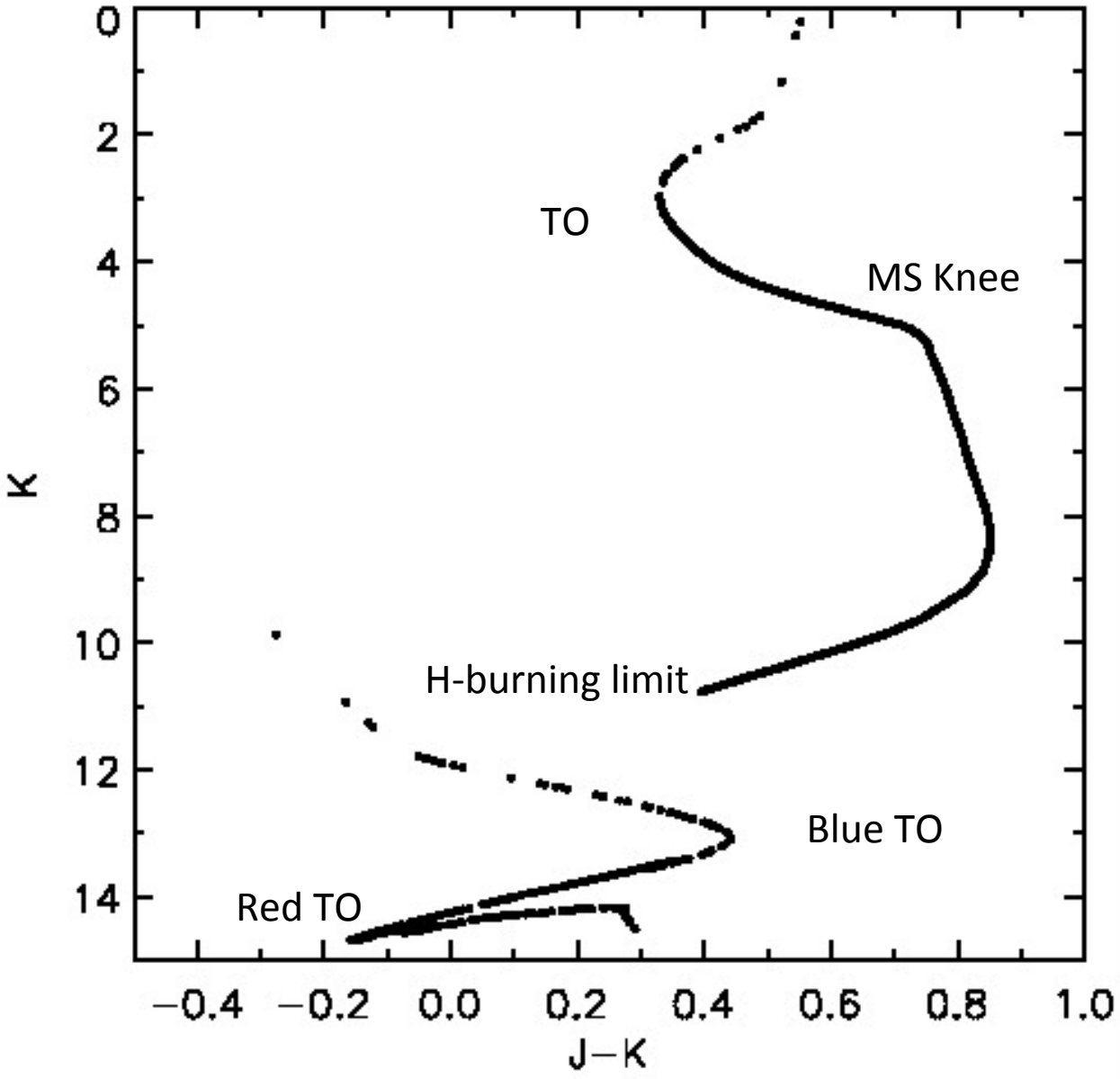
t = 13 Gyr

[Fe/H] = -1.3

Y = 0.248

[alpha/Fe] = 0.4

Initial-to-Final Mass relationship from Salaris et al. (2009)



Simulations

ω Cen like population

DMo = 13.7

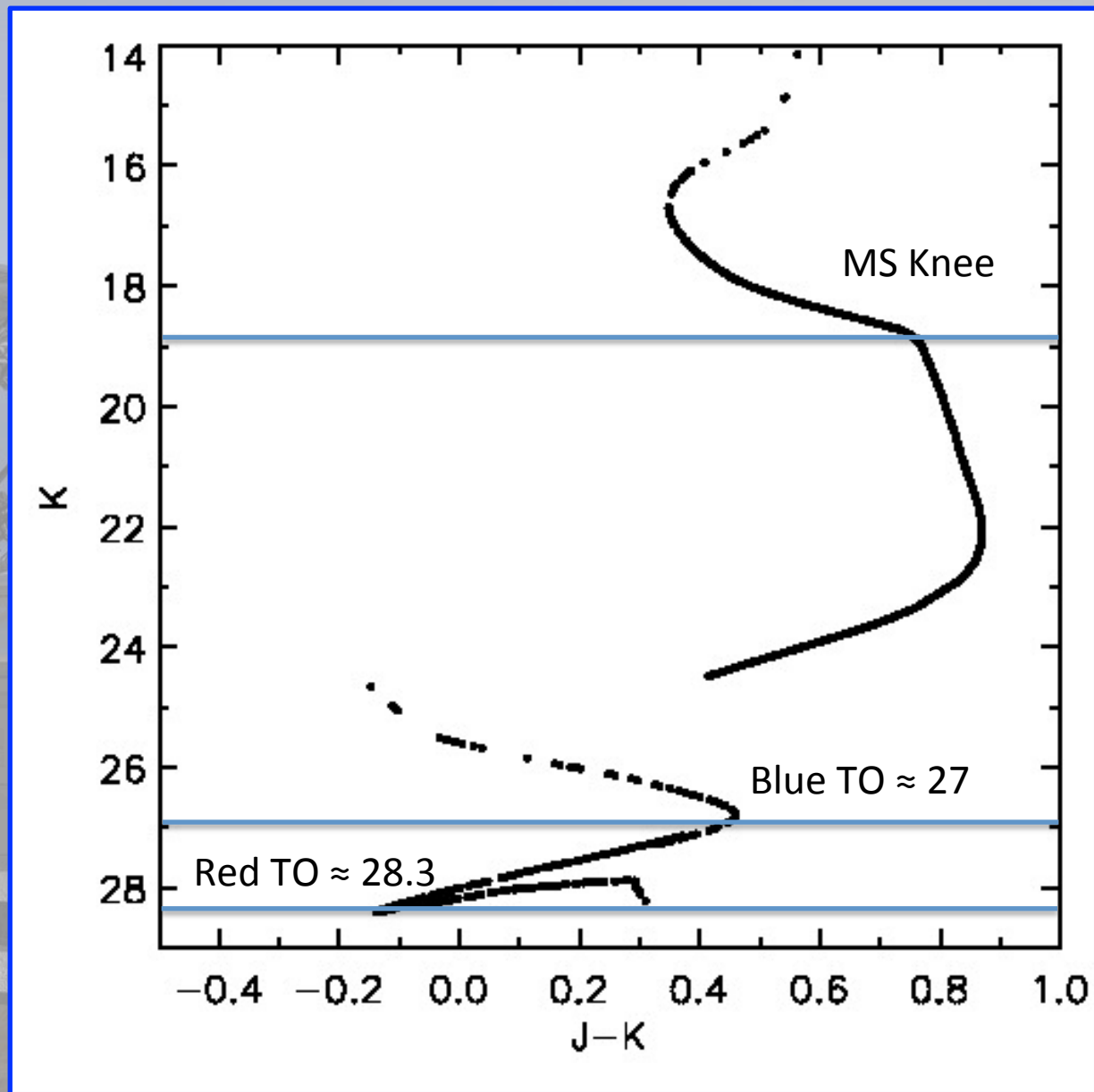
A_v = 0.34

A_k = 0.11*Av

King profile:

ρ_o = 4.77 $L_\odot/pc^3$

r_c = 2.37 arcmin



Some details on the simulations...

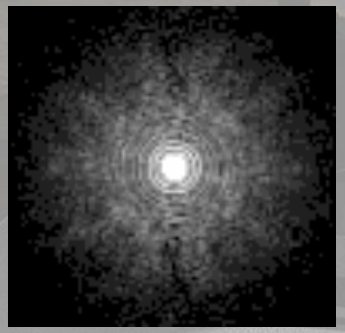
Technical data

- **J, K-band Laser Tomography AO (LTAO) simulated PSFs** (DRM technical database):

D = 42m, 6 LGS, seeing = 0.8" , **Pixel scale: 2 (J), 3.5 (K) mas**

- **Fov = 20" × 20"**

✓ **The PSF does not vary in the FoV**



✓ No contamination by field stars and galaxies

- ✓ IRAF mkobjects
- ✓ LBCImSim (Grazian et al. 2004)
- ✓ DAOPHOT/ALLSTAR/ ALLFRAME (Stetson 1987,1994)

K-band images

Texp (tot) ≈ 6 h + overh.

Very crowded!!

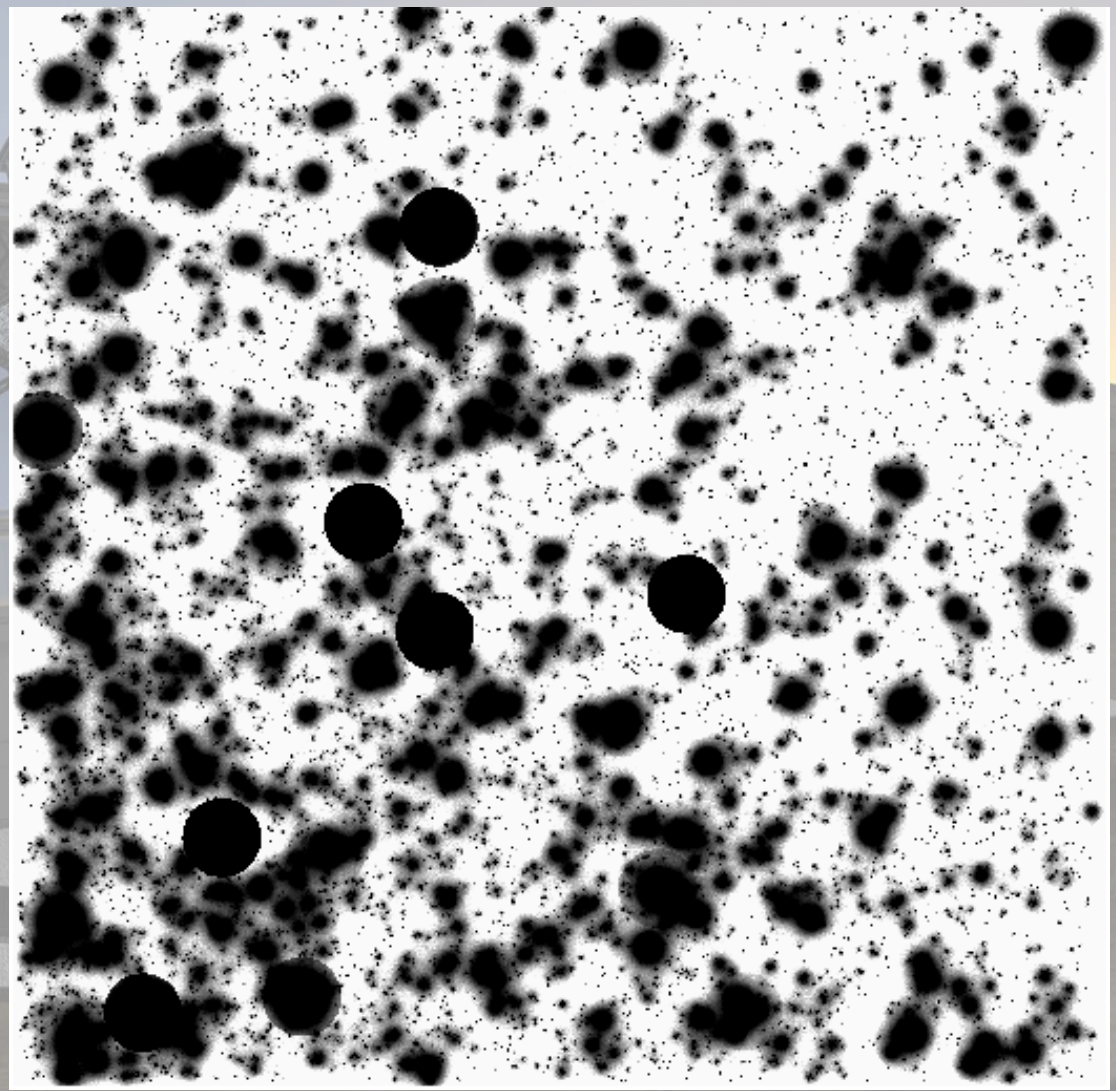
23 stars/arcsec^2

Coexistence of very faint and very bright stars!

Pointing close to the cluster center

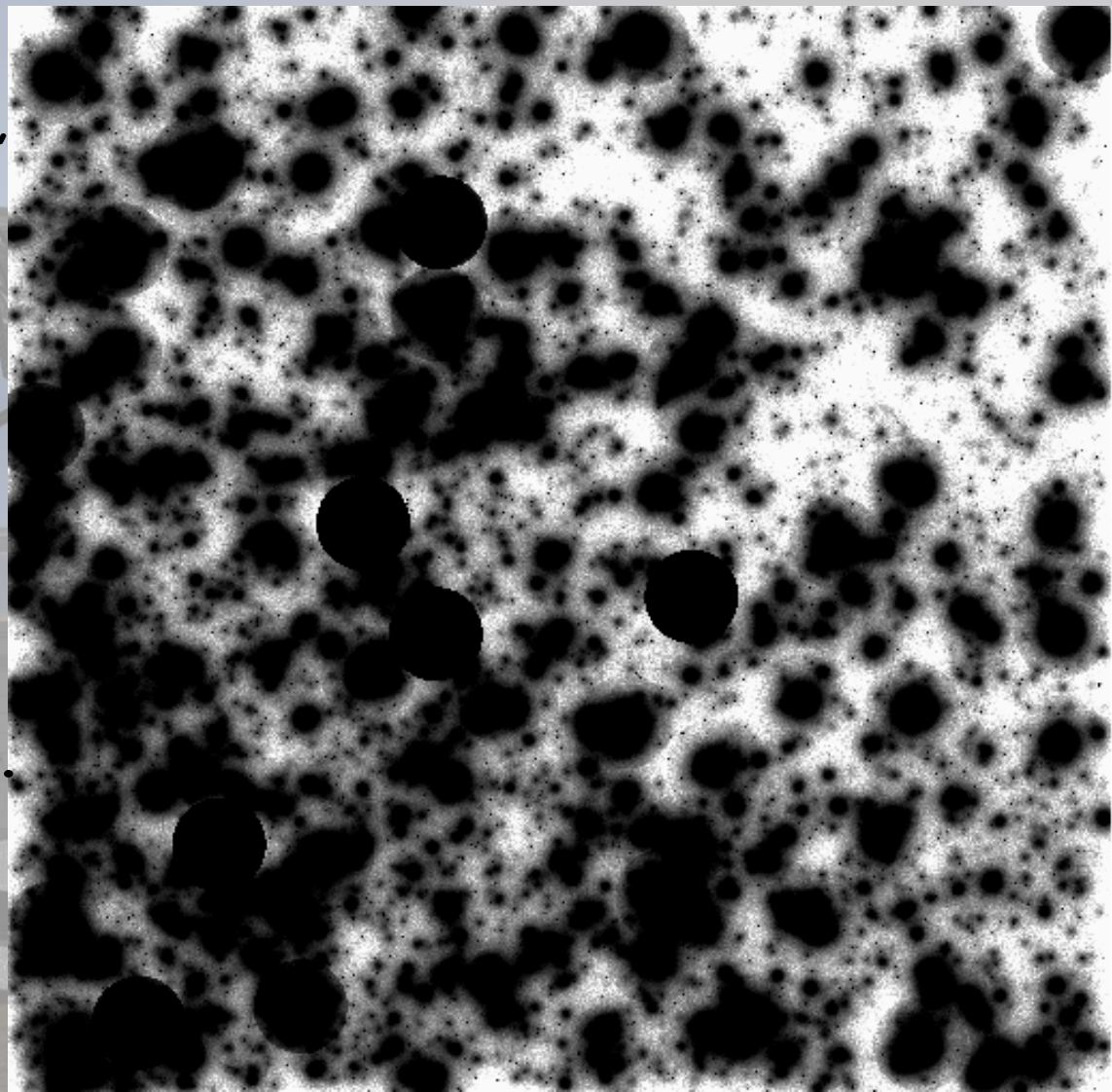
20”

K-band



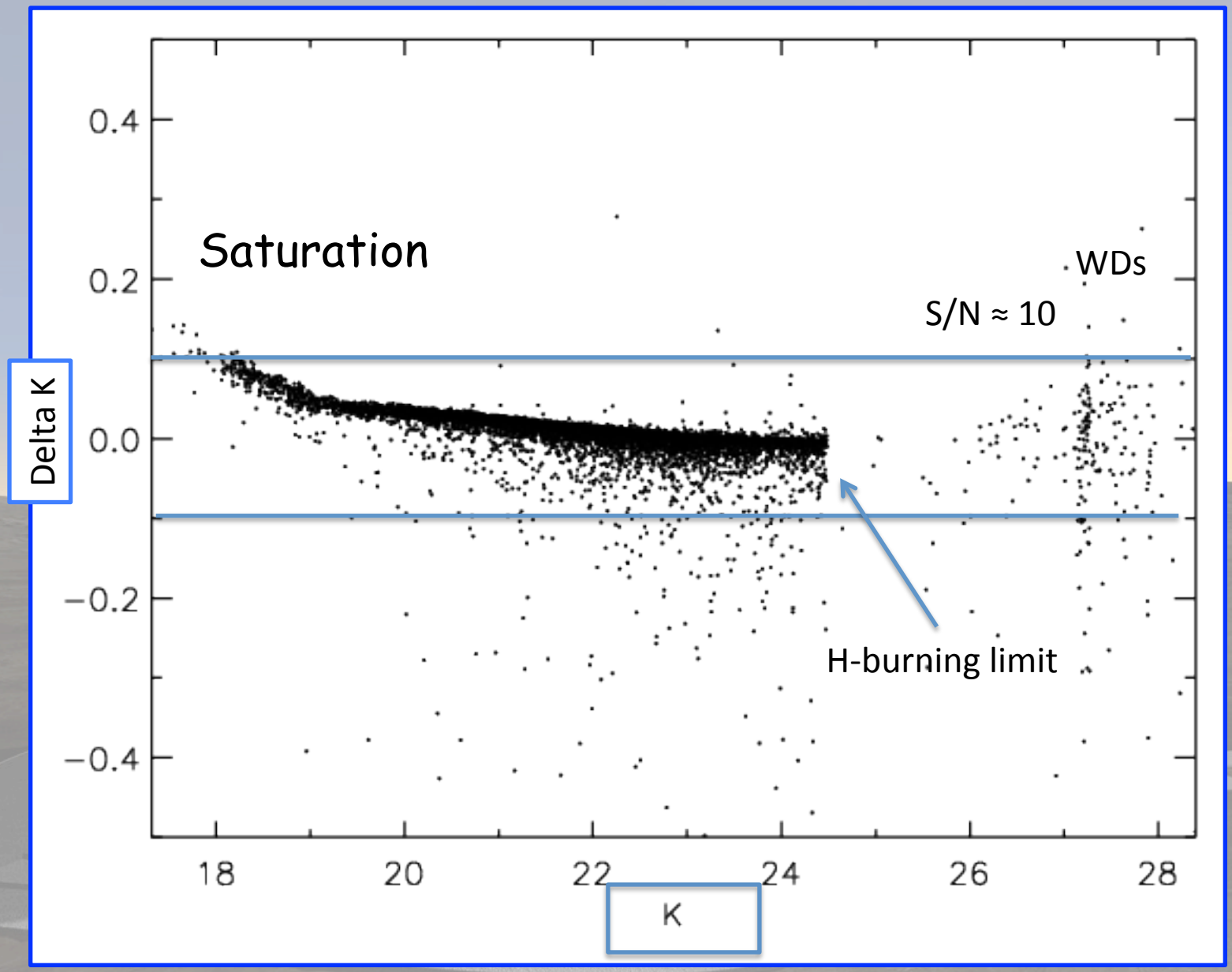
- ✓ IRAF mkobjects
- ✓ LBCImSim (Grazian et al. 2004)
- ✓ DAOPHOT/ALLSTAR/ ALLFRAME (Stetson 1987,

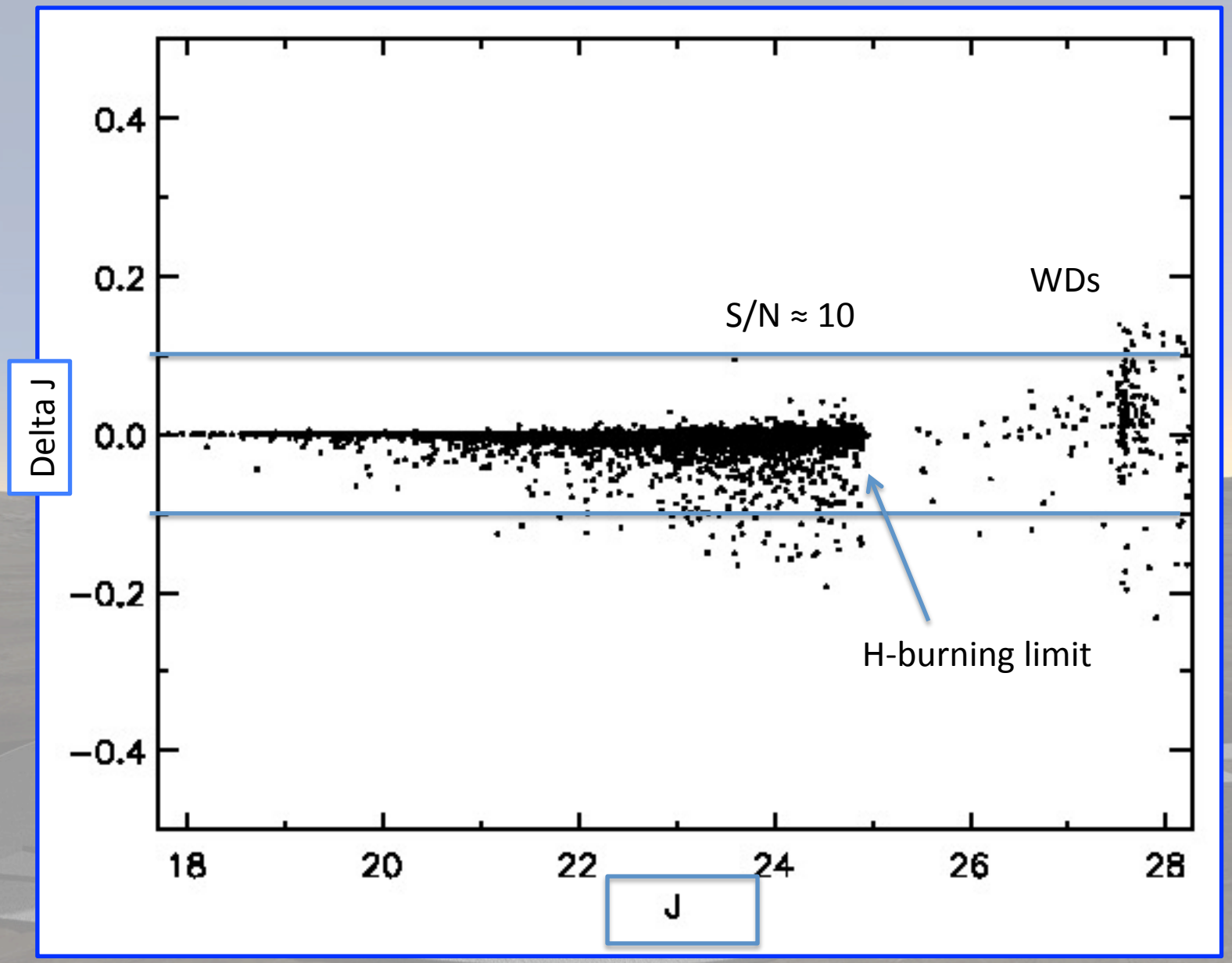
20″ J-band



J-band images

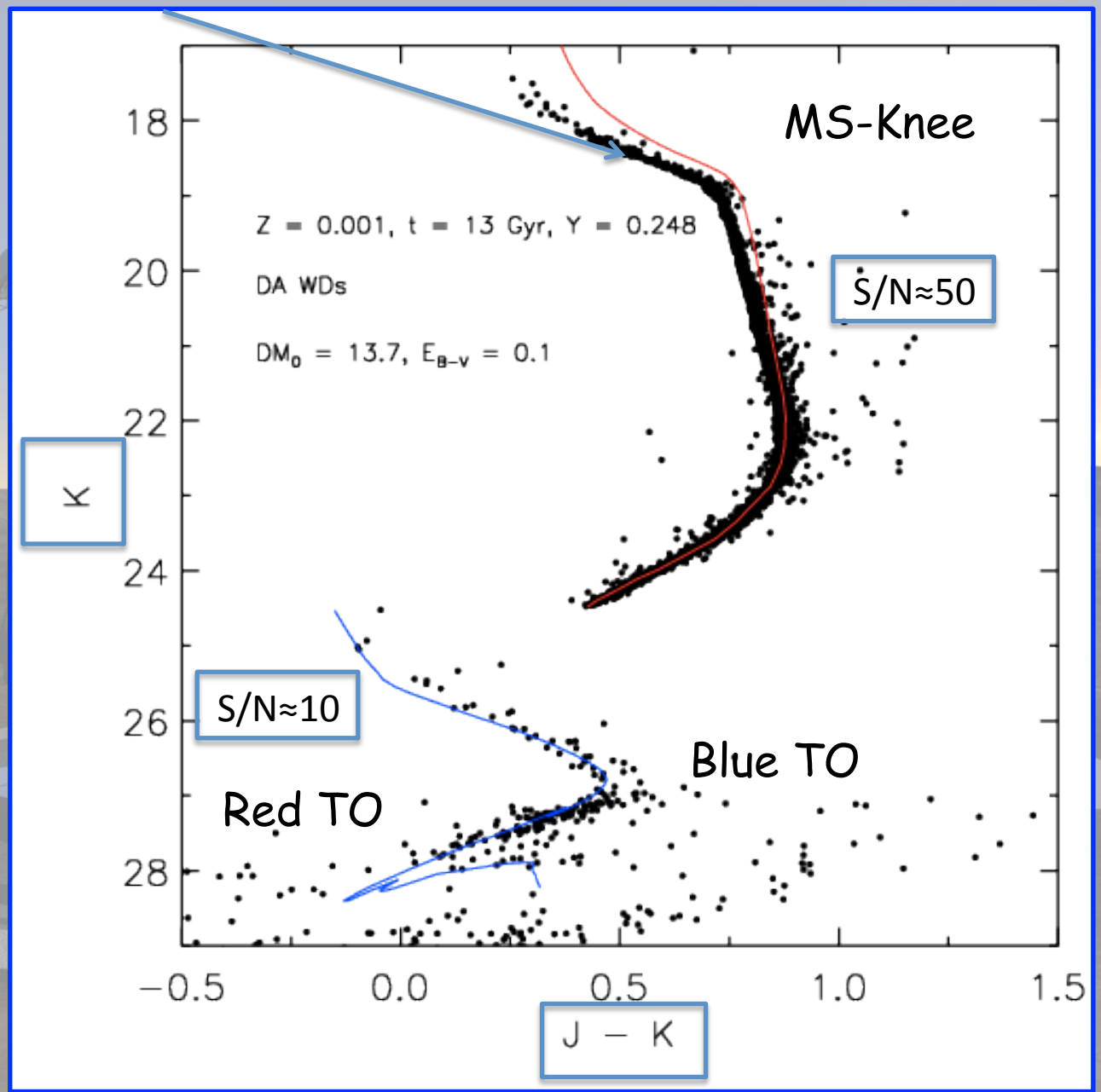
Texp (tot) ≈ 5 h + overh.


Saturation
WDs
S/N ≈ 10
H-burning limit
Delta K
K
0.4
0.2
0.0
−0.2
−0.4
18
20
22
24
26
28


0.4
0.2
0.0
−0.2
−0.4
Delta J
18
20
22
24
26
28
J
S/N ≈ 10
WDs
H-burning limit

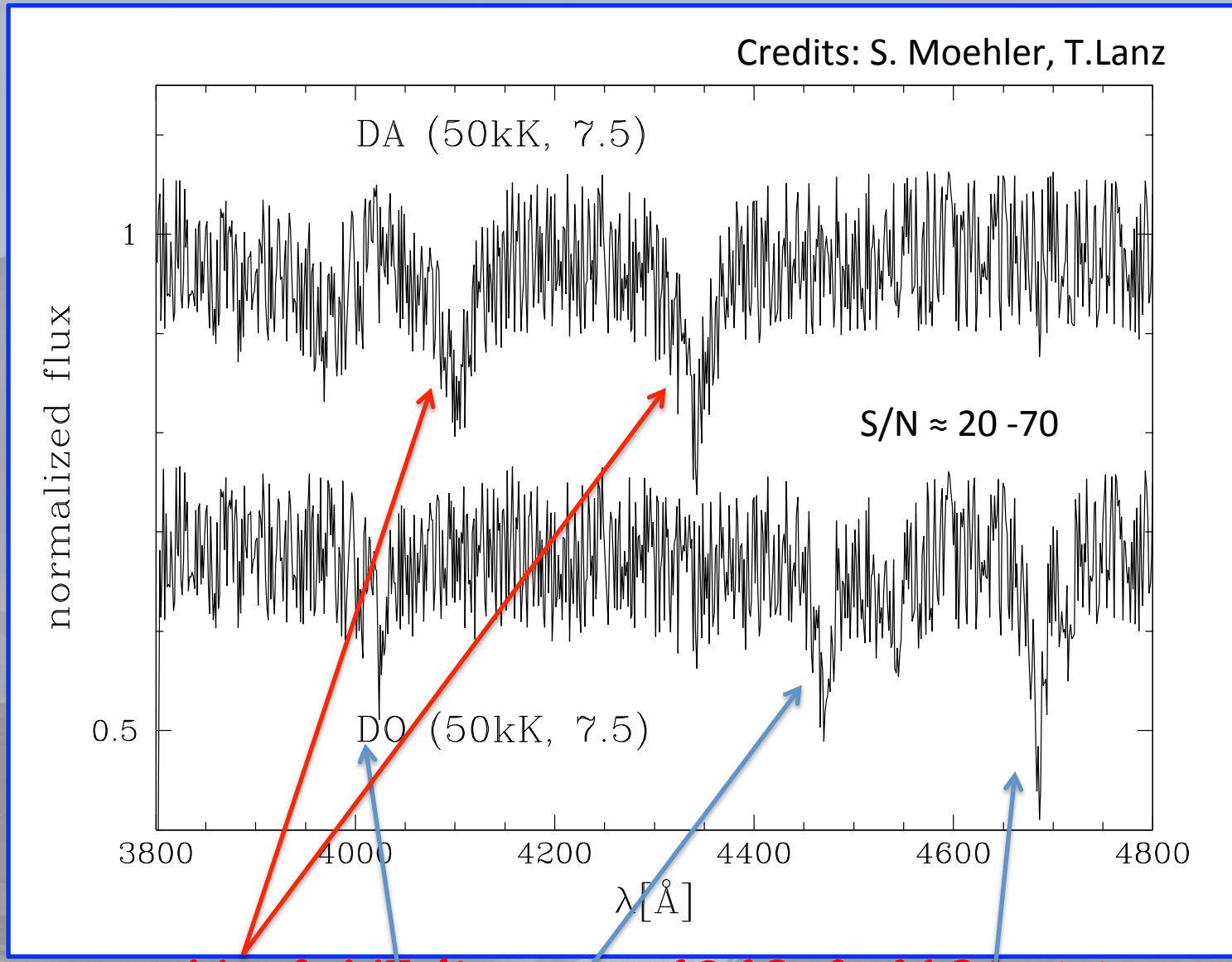
Recovered CMD

Saturation



Spectroscopy

log (g) -> Mass -> He-core or CO-core WDs



DA WDs: strong Hγ & Hδ lines at 4340 & 4101 AA

DO WDs strong HeI (4026, 4471) & HeII (4686) lines

Conclusions

WD Blue TO identified with S/N > 10 -> can be adopted to constrain the distance and the age of the cluster

With E-ELT we will be able to estimate accurate absolute ages and distances of about 20% of GGC **(DM_V < 15)** by adopting different diagnostics such as MS-Knee, WD Blue and Red TO -> constrain on systematics, input physics (E-ELT-CAM)

Spectroscopy of WDs to assess spectral type: DA/non-DA, CO-core/He-core (E-ELT-MOS)