Young Open Clusters in SPA

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In collaboration with:
The SPA Team

High-Resolution optical spectra

Atmospheric parameters (T_{eff}, logg, [Fe/H])

Radial and rotation velocity (RV, vsini)

Activity indicators ($F_{H\alpha}$, F_{CaII}, $R'_{H\alpha}$, R'_{HK})

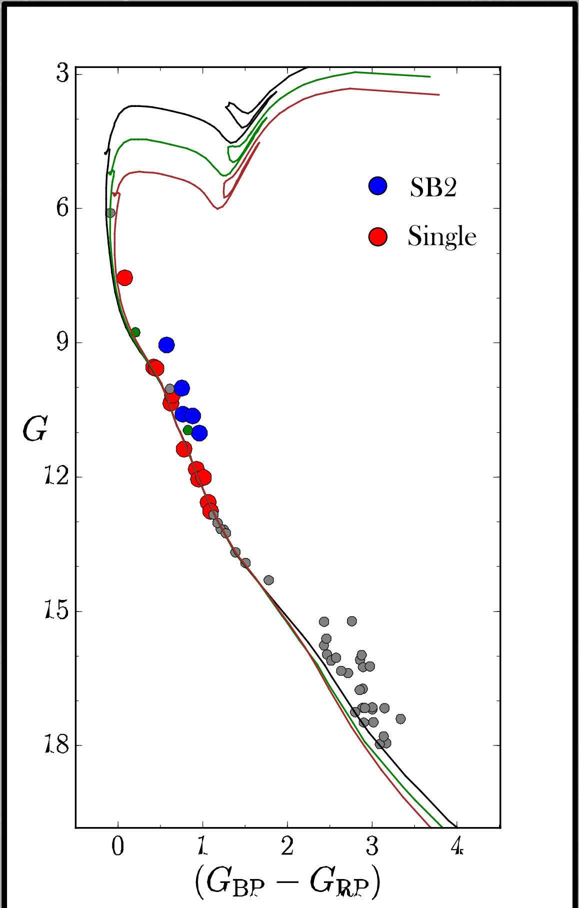
Chemical Abundances

Photometry

Rotation Periods

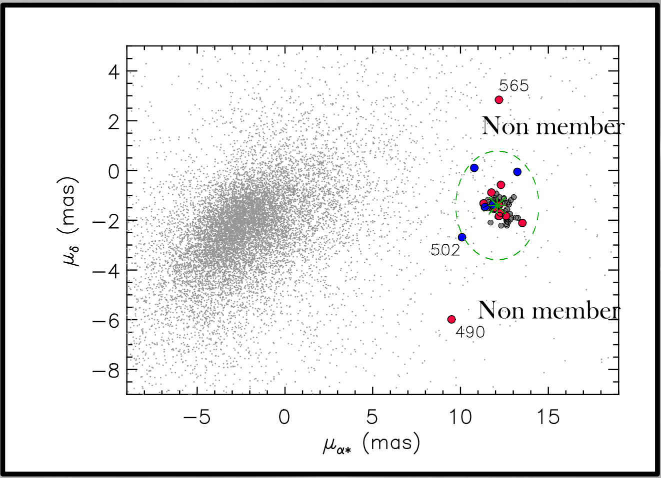
Amplitude variations

ASCC123



Gaia DR2 color-magnitude

Nearby (d= 233 pc) and very sparse **open cluster** (R ~ 1°)
discovered by Kharchenko (2005) analyzing HIPPARCOS astrometry and BV photometry from the ASCC-2.5 catalogue



Gaia DR2 proper motions

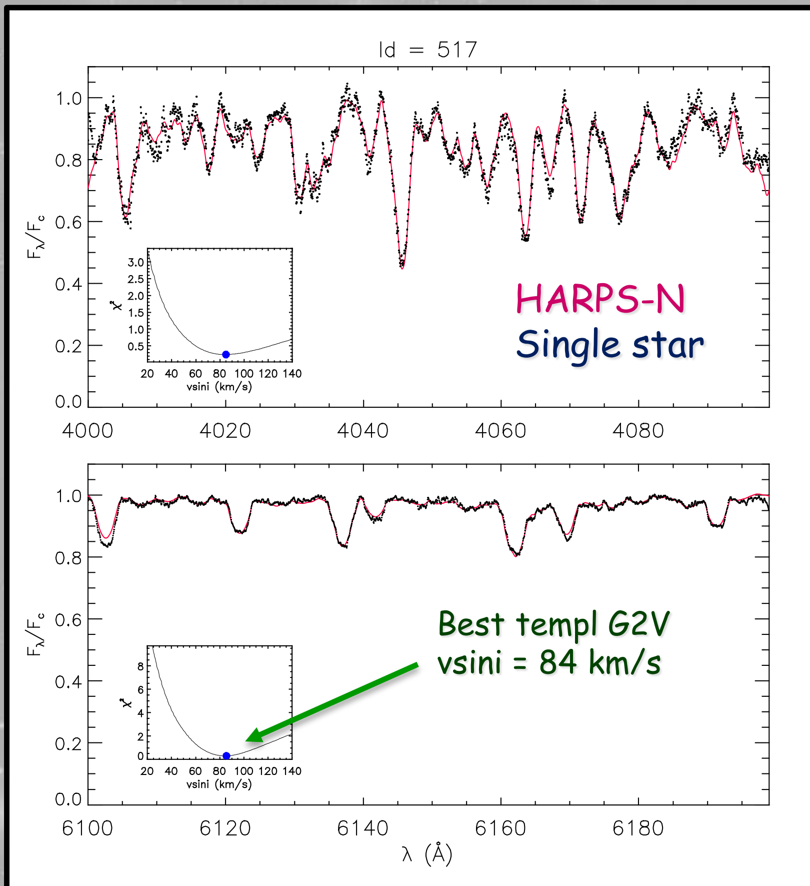
55 candidate members
(Cantat-Gaudin et al. 2018)

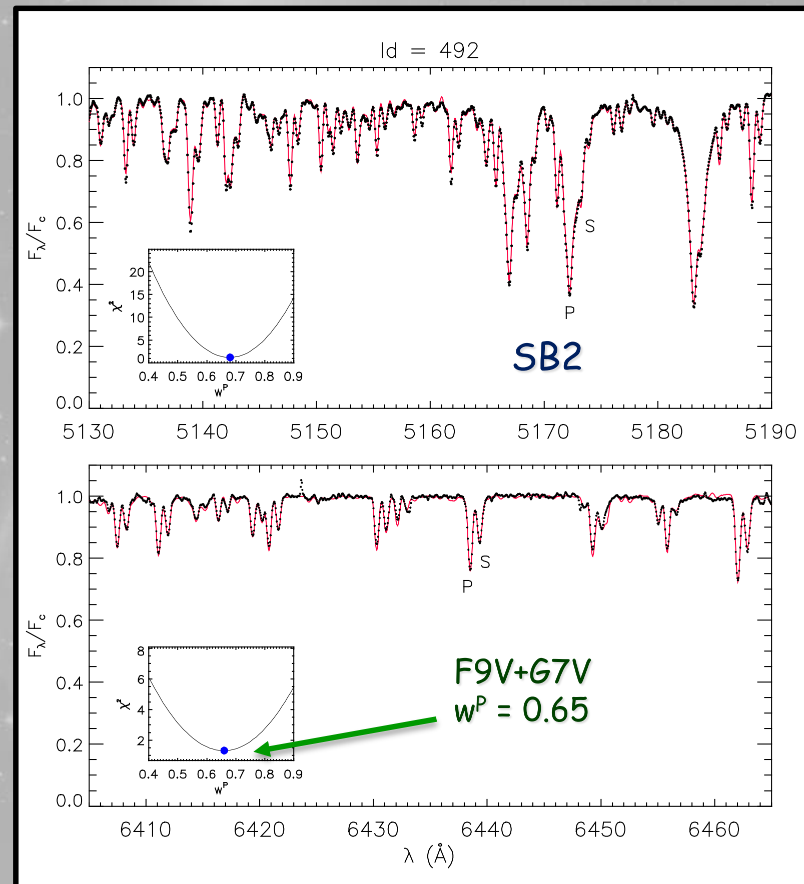
Age ~ 150 Myr, based on CMD, Lithium abundance and Chrom. Emission
14 cluster members observed with HARPS-N

(Frasca et al. 2019, A&A 632, A16)

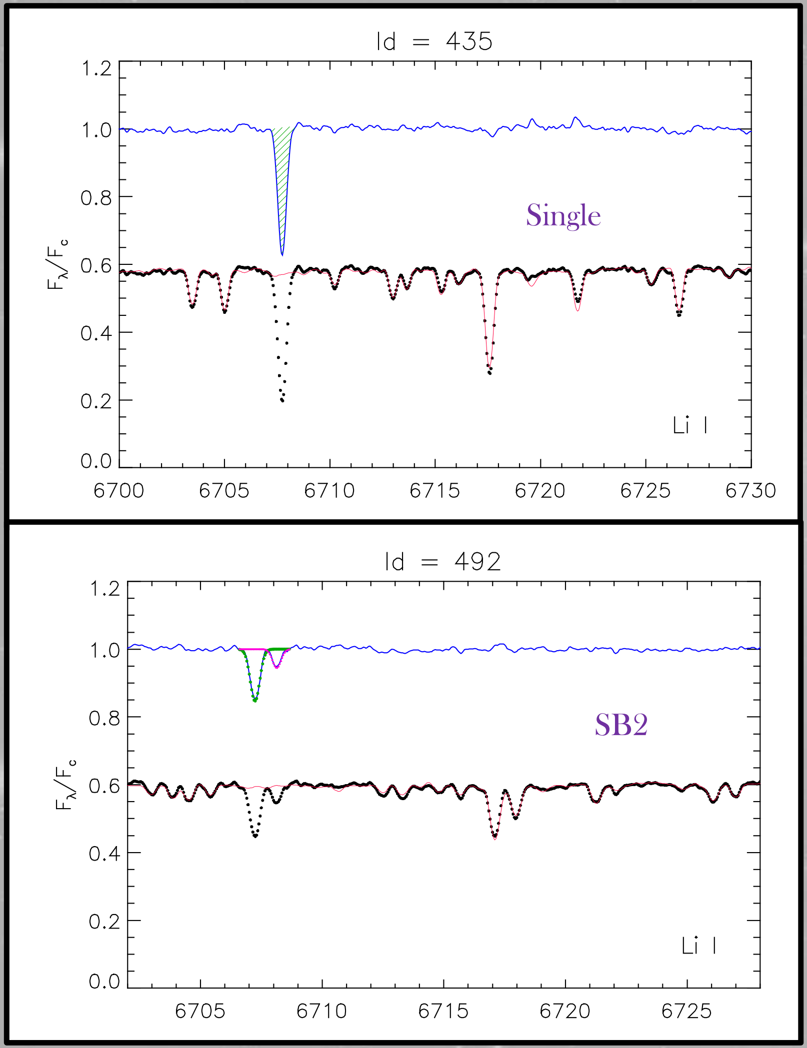
ASCC123

MK classification and Stellar parameters derived with the code ROTFIT for the single(-lined) objects and COMPO2 for the SB2 binaries (Frasca+2019)





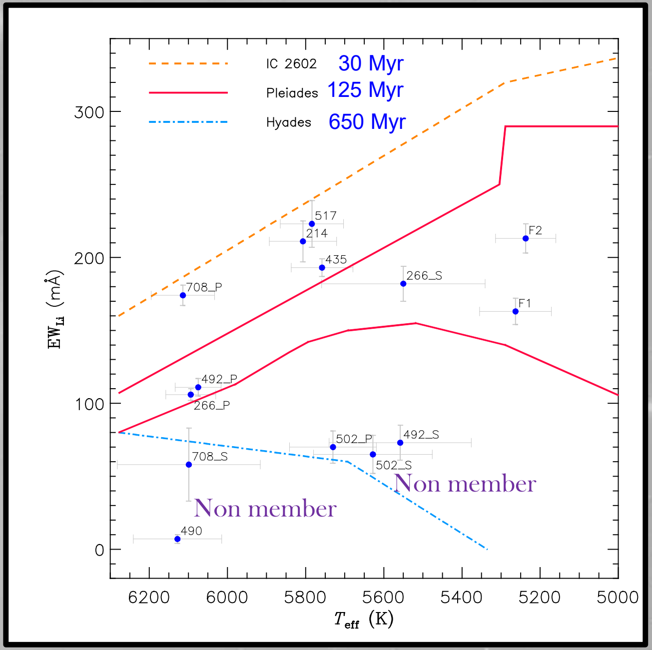
ASCC123



Lithium 6708Å line

The subtraction of the photospheric template enables measuring the Lithium EW (age indicator) for single stars and the components of binary systems

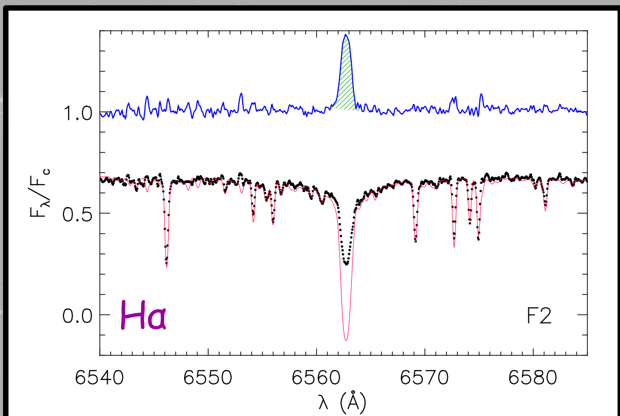
Young age similar to that of the Pleiades

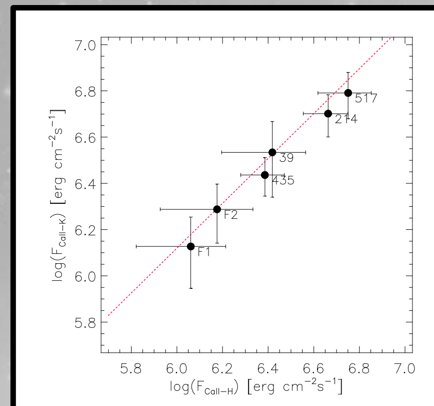


LiI6708 Equivalent width versus T_{eff}

ASCC123

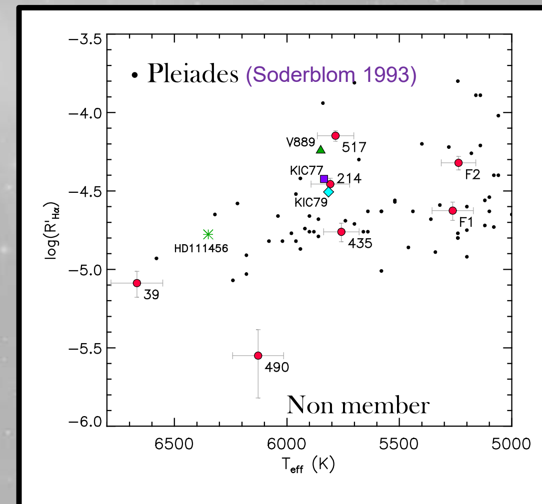
Chromospheric activity



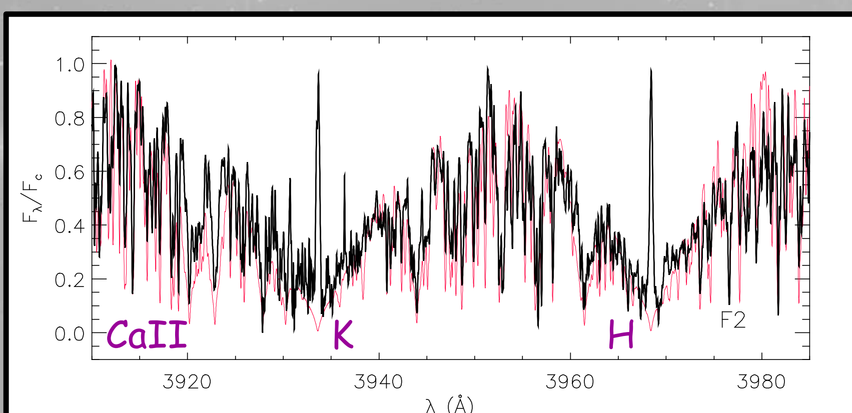


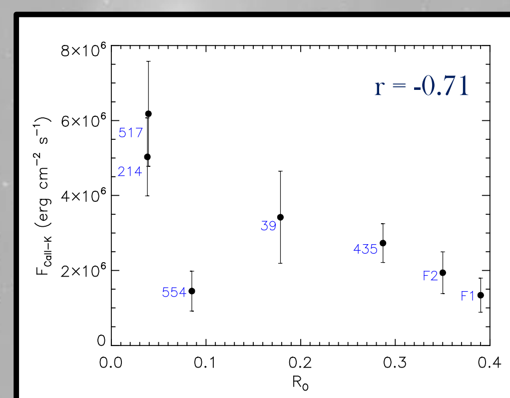
Flux-flux relations

$R'_{H\alpha} = F'_{H\alpha}/F_{bol}$ versus T_{eff}



The subtraction of the photospheric template enables measuring the emission in the cores of chromospheric lines



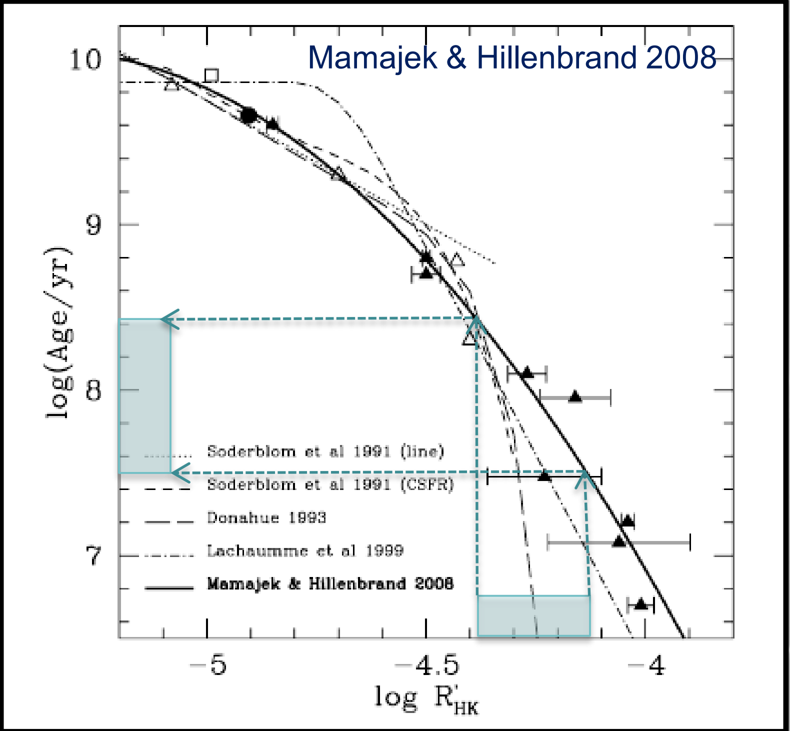


Correlation of the CaII flux with the Rossby number $R_0 = P_{rot}/\tau_c$

Frasca et al. (2023, MNRAS 522, 4894)

ASCC123

Chromospheric activity



$$\log \tau = -38.053 - 17.912 \log R'_{HK} - 1.6675 \log(R'_{HK})^2$$

For Sun-like stars

Age-activity correlation

The CaII-HK index $R'_{HK} = F'_{HK}/\sigma T^4$ is also an age indicator

A broad age range (30-250 Myr) for the range of R'_{HK} measured for the solar-type stars in ASCC123.

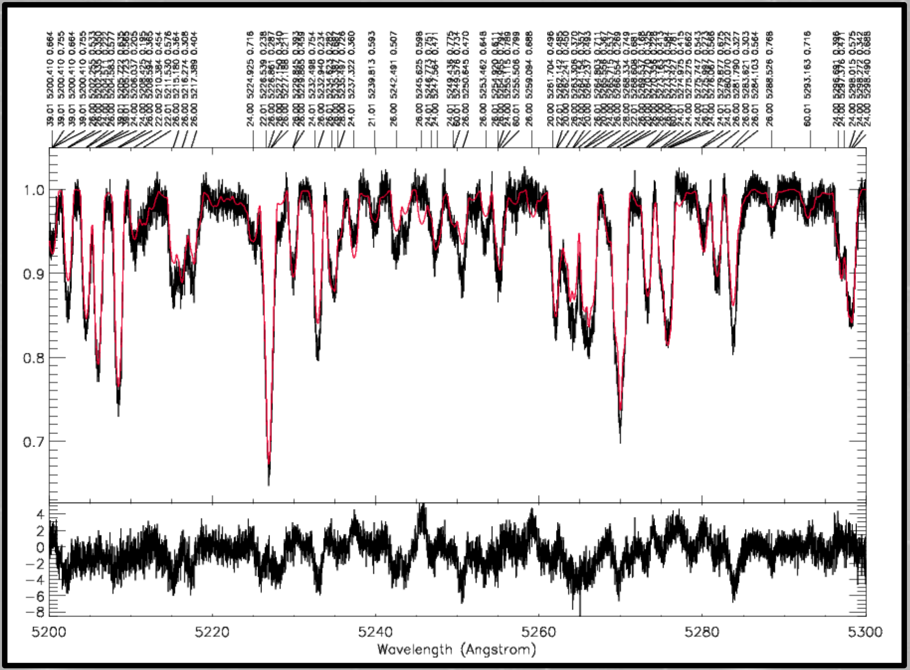
It is more effective for older clusters.

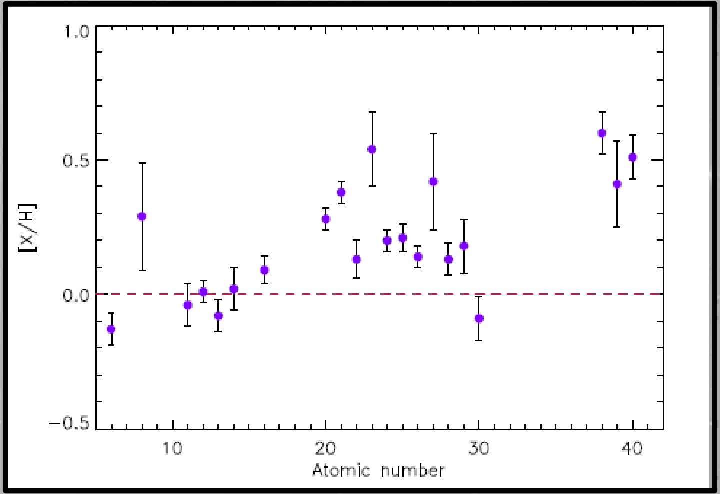
ASCC123

Chemical abundances

Most targets are rotating too fast to apply the COG method. **Spectral synthesis** (Catanzaro et al. 2013) of 39 segments (50 Å each) based on LTE ATLAS9 atmospheric models (Kurucz 1993) and SYNTHE (Kurucz & Avrett 1981).

Element	ASCC 123	Sun [(a)]
C	8.41 ± 0.06	8.54 ± 0.04
O	9.09 ± 0.20	8.80 ± 0.01
Na	6.13 ± 0.08	6.17 ± 0.14
Mg	7.71 ± 0.04	7.70 ± 0.10
Al	6.47 ± 0.06	6.55 ± 0.15
Si	7.52 ± 0.08	7.50 ± 0.08
S	7.42 ± 0.05	7.33 ± 0.10
Ca	6.60 ± 0.04	6.32 ± 0.09
Sc	3.52 ± 0.04	3.14 ± 0.13
Ti	4.99 ± 0.07	4.86 ± 0.12
V	4.50 ± 0.14	3.96 ± 0.10
Cr	5.77 ± 0.04	5.57 ± 0.15
Mn	5.56 ± 0.05	5.35 ± 0.15
Fe	7.59 ± 0.04	7.45 ± 0.08
Co	5.35 ± 0.18	4.93 ± 0.05
Ni	6.29 ± 0.06	6.16 ± 0.10
Cu	4.44 ± 0.10	4.26 ± 0.10
Zn	4.44 ± 0.08	4.53 ± 0.09
Sr	3.55 ± 0.08	2.95 ± 0.15
Y	2.66 ± 0.16	2.25 ± 0.04
Zr	3.16 ± 0.08	2.65 ± 0.14

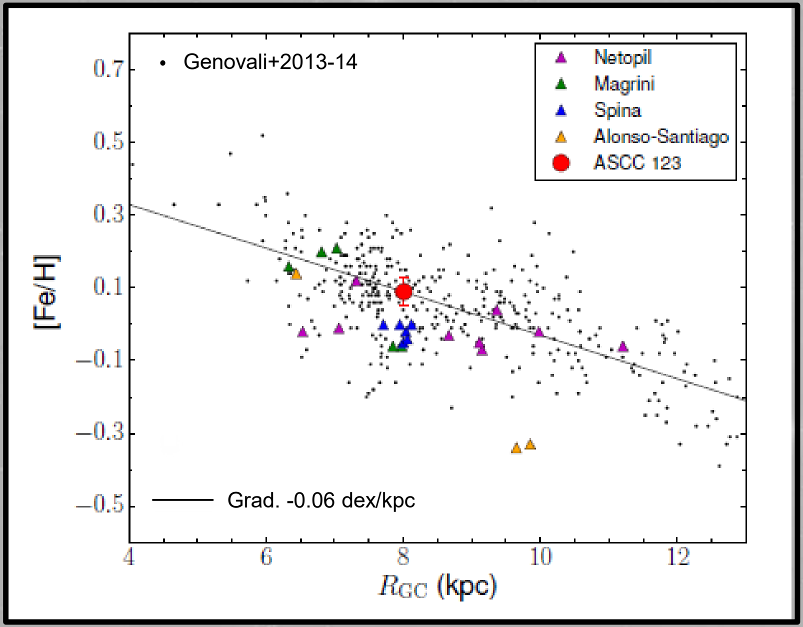


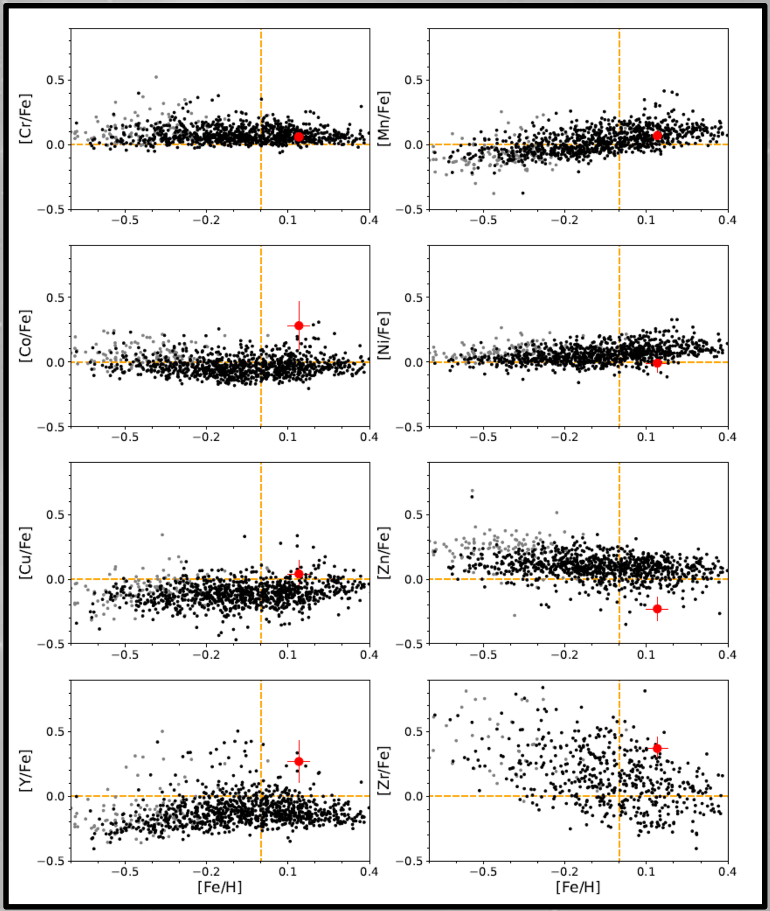


ASCC123

Chemical abundances

ASCC123 follows the metallicity trend vs the Galactocentric distance as traced by Cepheids (e.g. Genovali+2013) and OCs

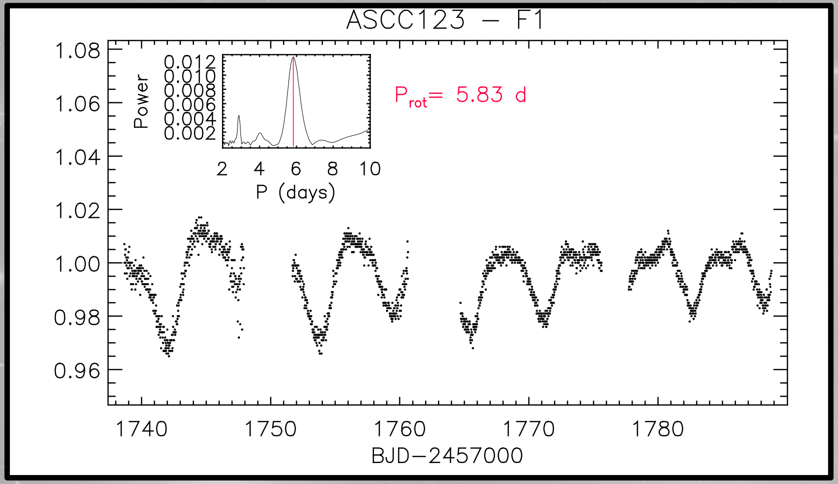


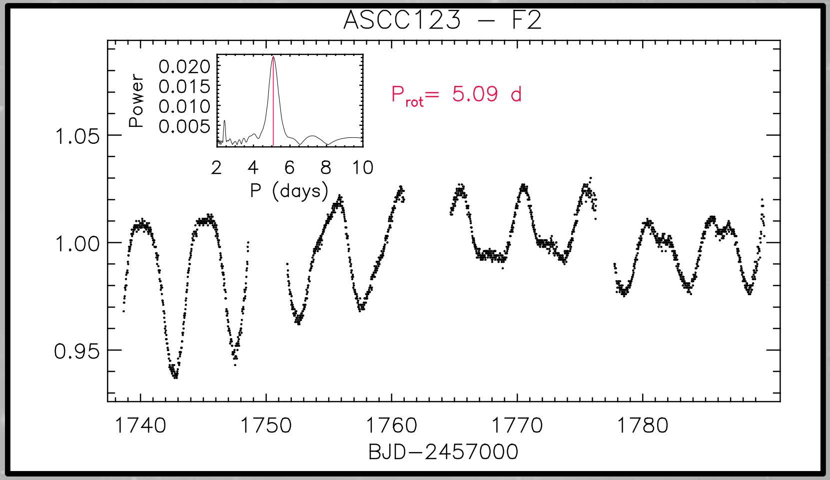


Abundance ratios [X/Fe] vs [Fe/H] in line with Galactic trends in the solar neighborhood for thin and thick disk (GES) with few exceptions (Zn under- and Y over-abundant).

ASCC123

TESS light curves for some of the cluster members





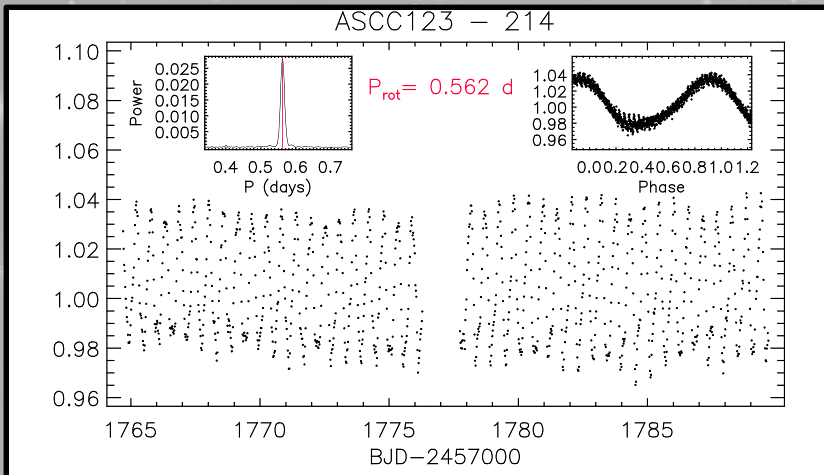
SAP or PDCSAP flux in the QLP data (Huang+2020) for the bright sources, PATHOS data (Nardiello+2019) for the faint targets, both retrieved from the MAST archive

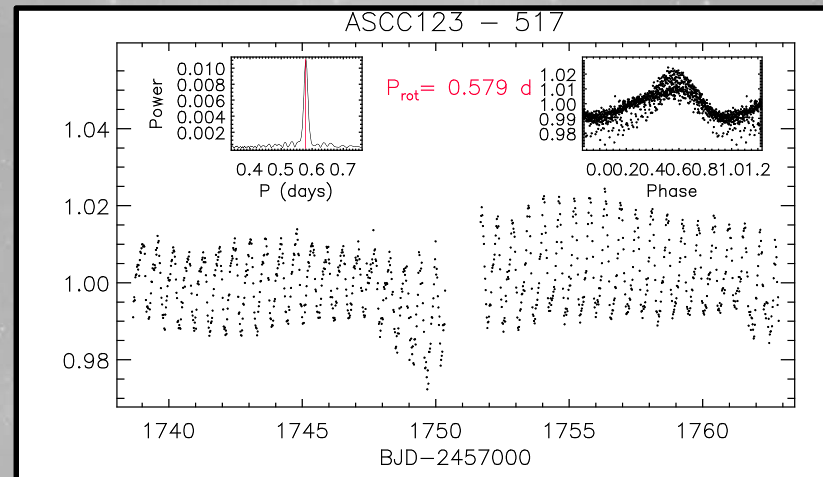
Cleaned power spectra to measure the rotation period

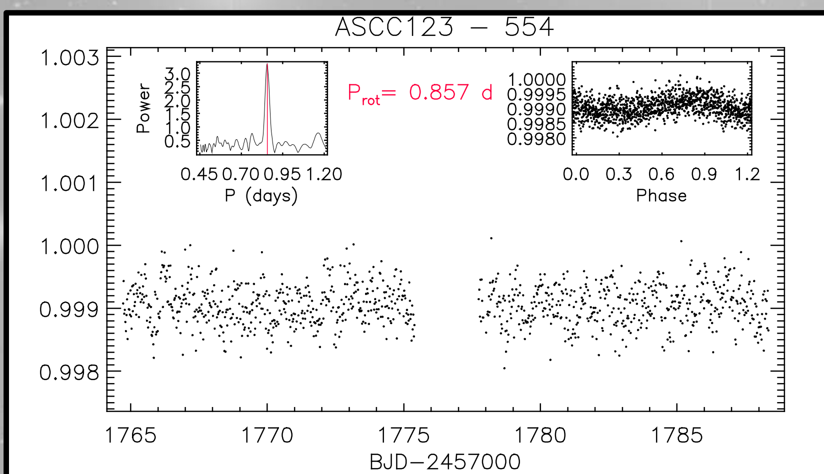
P_{rot} detected for 29/55 cluster members (G<16.5 mag)
Frasca et al. 2023, MNRAS 522, 4894

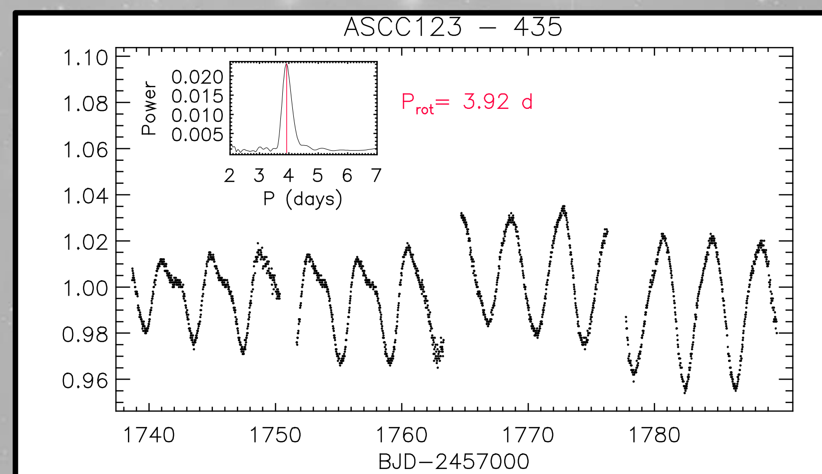
ASCC123

TESS light curves for some of the cluster members



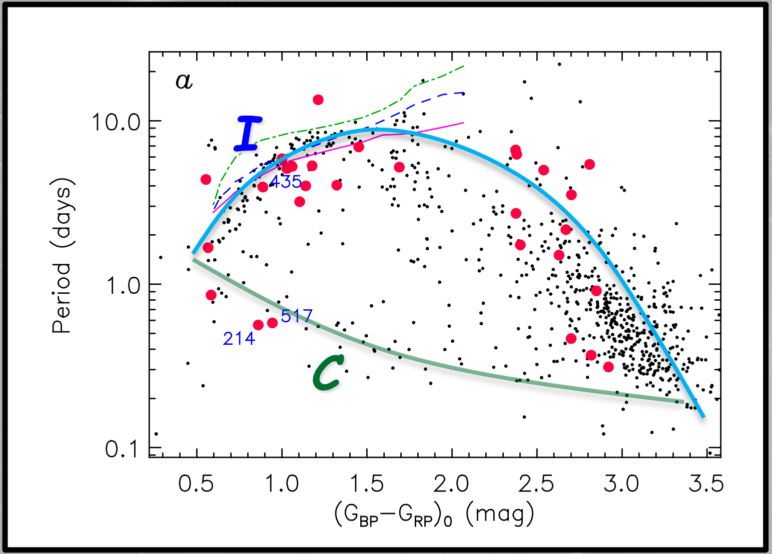




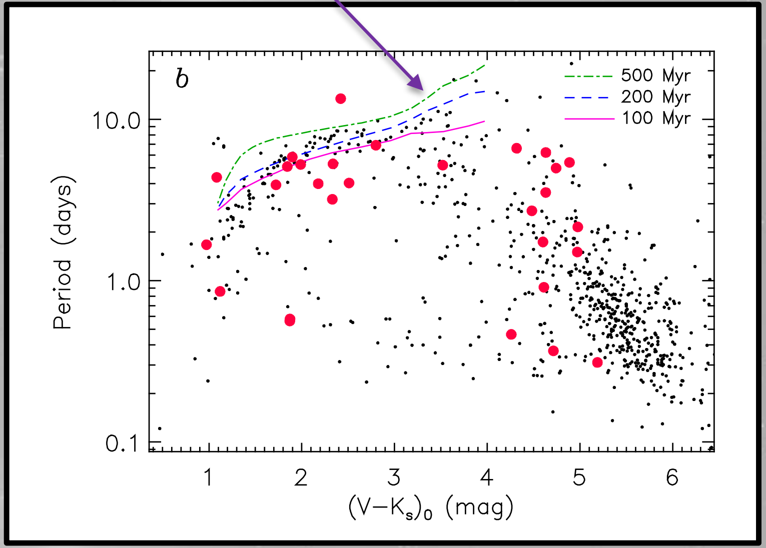


ASCC123

Rotation period vs color index → *Gyrochronogical age*



Rotational isochrones from Spada & Lanzafame (2020)

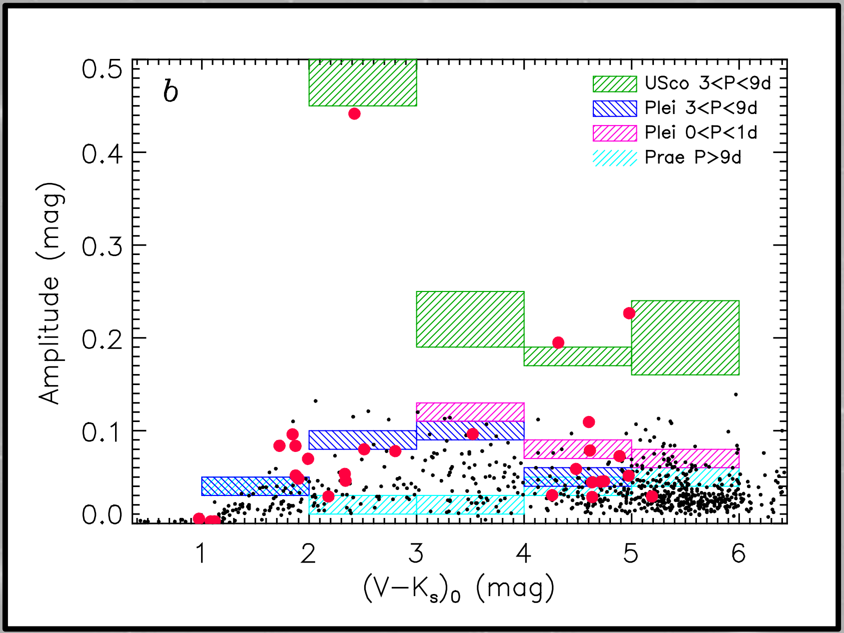


Frasca et al. 2023, MNRAS 522, 4894

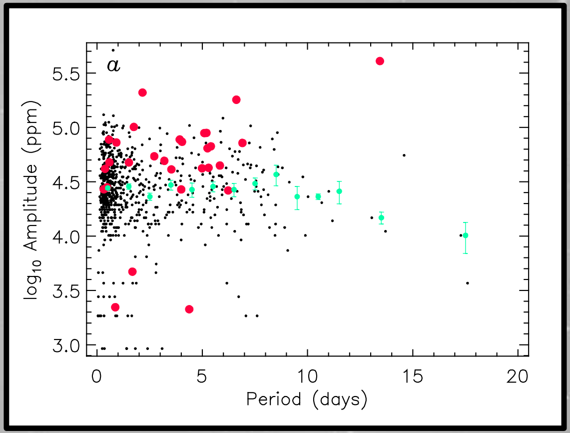
The rotation period versus G_{BP}-G_{RP} or *V-K* color indices for the members of ASCC123 (red circles) indicates an age similar to the Pleiades (small black dots, Rebull+ 2016) as also suggested by the rotational isochrones for the ***I*** sequence (slow rotators) and the presence of G-type UFRs in the ***C*** sequence which are not found in clusters with age ≥ 200-300 Myr (Barnes 2003, Fritzewski et al. 2021)

ASCC123

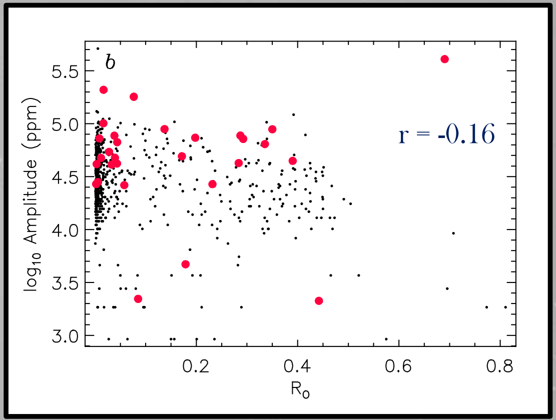
The distribution of **modulation amplitudes** is also indicative of a young age.



The hatched rectangles represent the amplitudes at the 80th percentile for the clusters and the period ranges indicated in the legend according to Messina (2021).



Marginal correlation with the period, better with the Rossby number $R_O = P_{rot}/\tau_c$



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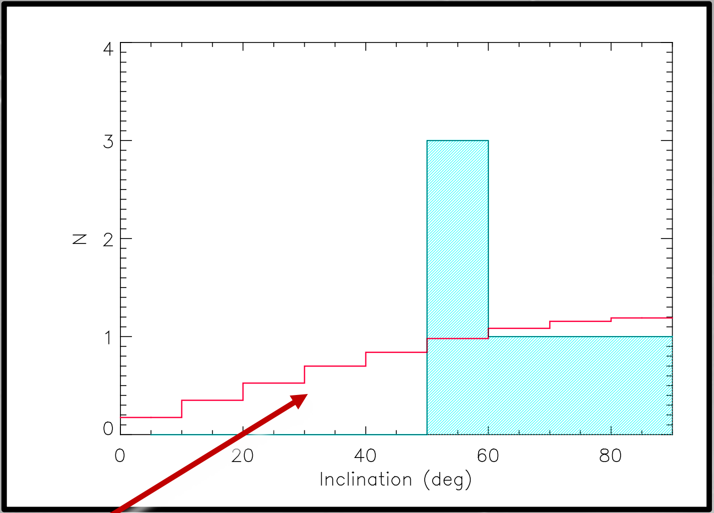
ASCC123



Expected distribution for a 3D uniform orientation of the spin vectors

From vsin*i*, P_{rot}, and the stellar radius *R*, we can infer the inclination of the rotation axis as

$$\sin i = v\sin i * P_{rot}/(2\pi R)$$

Compatible with a uniform 3D distribution

as found in a few young OCs (Healy+ 2021, 2023) but NOT for NGC6791 and NGC6819 (Corsaro+ 2017)

Too small statistical sample. Need for high- or mid-res spectroscopy for all the cluster members. Large spectroscopic surveys (WEAVE, 4MOST, …) Mid-resolution spectra !

Table 1. Stellar parameters of the late-type members of ASCC 123 from Frasca et al. (2019) and from the present work.

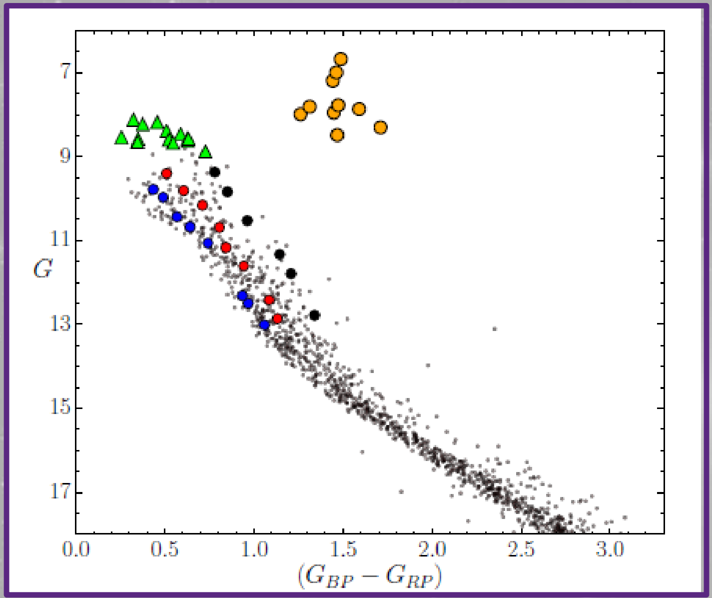
ID	TIC	RA (J2000)	DEC (J2000)	T_{eff} (K)	err	SpT	$v\sin i$ (km s^{-1})	err	M_* ($M_\odot$)	R_* ($R_\odot$)	P_{rot} (days)	err	i (°)
39	64837857	22 35 13.26	+54 46 24.8	6667	115	F4V	49.1	1.9	1.38	1.36	1.67:	. . .	~ 90
214	249784843	22 38 34.03	+53 35 08.7	5804	87	G1.5V	100.9	3.0	1.09	1.16	0.562	0.002	75^{+11}_{6}
435	388696341	22 42 00.19	+55 00 58.5	5758	79	G2.5V	11.6	0.7	1.07	0.96	3.92	0.02	69^{+15}_{10}
517	428274538	22 43 26.53	+54 11 58.4	5784	81	G2V	83.6	1.9	1.08	1.13	0.579	0.002	58^{+2}_{3}
554	361944360	22 44 00.20	+54 08 38.1	6871	152	F4V	81.8	3.3	1.46	1.40	0.857	0.007	81^{+9}_{10}
F1	66539637	22 45 28.25	+53 47 06.1	5263	92	K0V	6.6	0.6	0.94	0.92	5.83	0.05	56^{+9}_{8}
F2	64077901	22 31 17.98	+55 02 40.7	5237	77	K1V	7.5	0.6	0.93	0.88	5.09	0.05	59^{+10}_{8}

From Frasca+2022

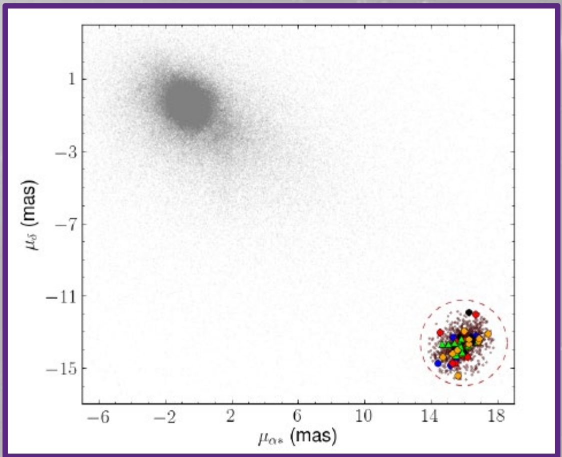
Stock2

A little-studied open cluster with an eMSTO

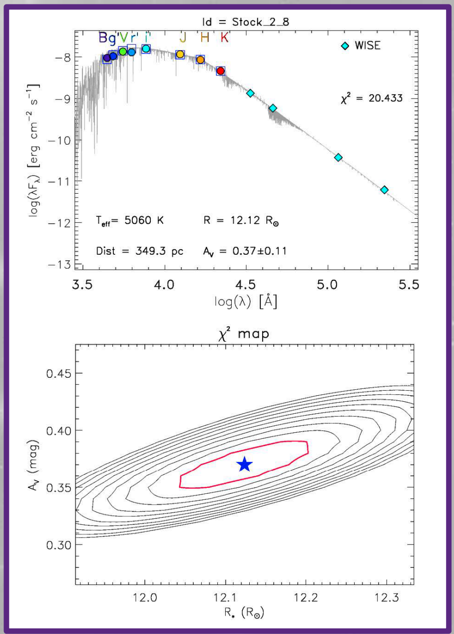
(Alonso-Santiago et al. 2021)



HARPS-N spectra complemented with CAOS@SLN (R=40,000) spectra for 14 of the brightest MS-TO stars



Proper motion membership very effective



MS stars in three sequences (*b*=blue, *r*=red,*u*=black) observed with HARPS-N plus 10 Giants (orange dots).

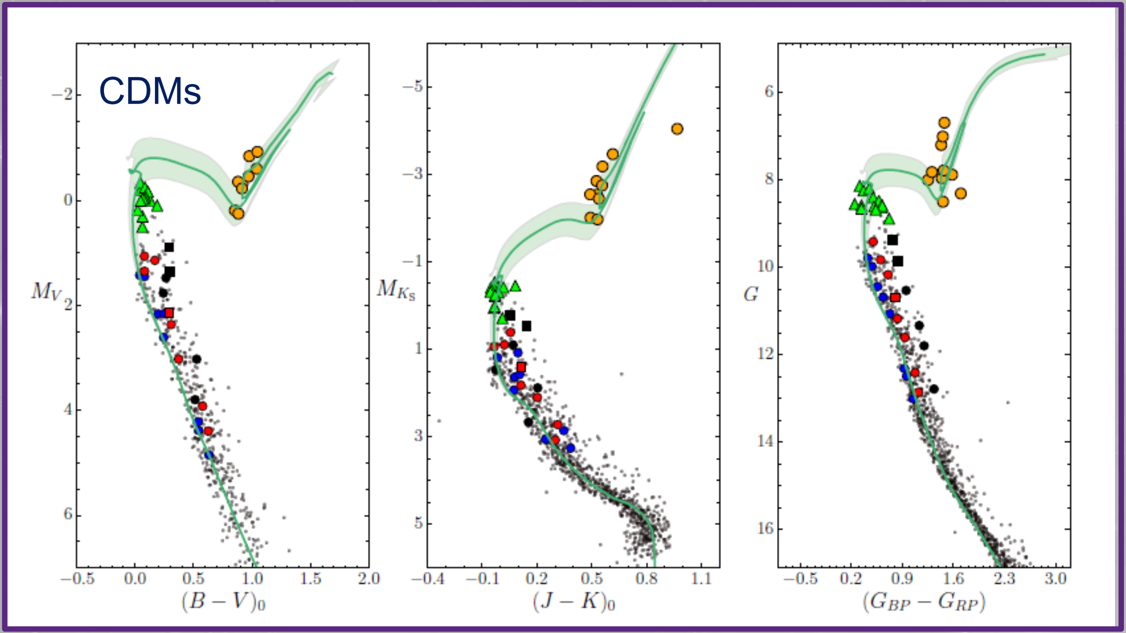
Two SB2s in the *u* sequence, 1 in the *r*

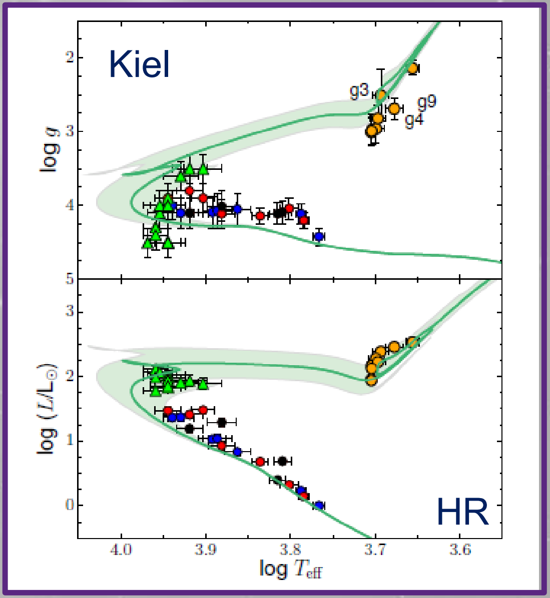
Atmospheric parameters and *vsini* with ROTFIT

Reddening and Radii from the SEDs

Stock2

A little-studied open cluster with an eMSTO

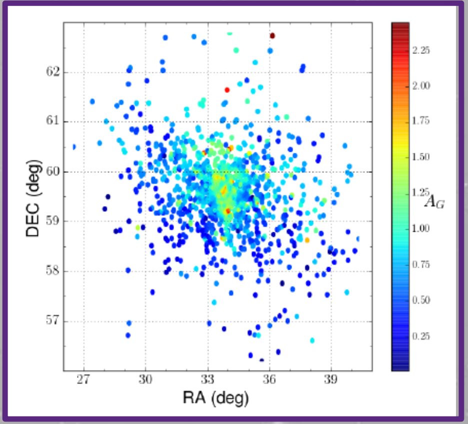




Age 450 ±150 Myr

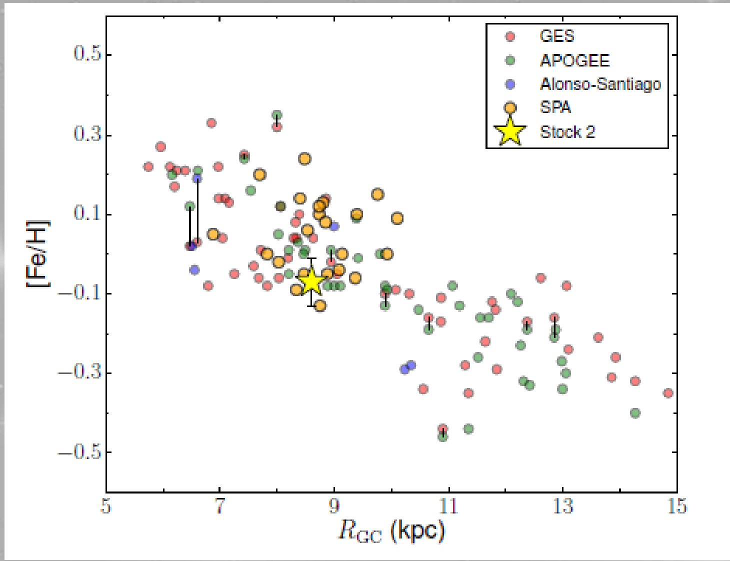
About half of the MS stars are fast rotators (*v*sin*i* >100 km/s). The distribution of slow and fast rotators along the *b, r*, and *u* sequences is random. This discards the rotational velocity as the cause of the observed eMSTO.

MS sequence (N)	$v \sin i$ ($\mathrm{km\,s^{-1}}$)	A_V (mag)
bMS (8)	103 ± 106	0.59 ± 0.15
rMS (7)	100 ± 98	0.91 ± 0.23
uMS (4)	57 ± 22	1.49 ± 0.32



Most likely explanation → variable extinction across the field

Stock2



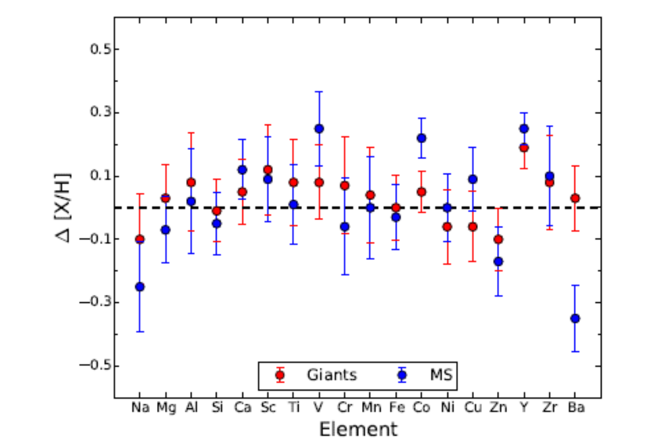
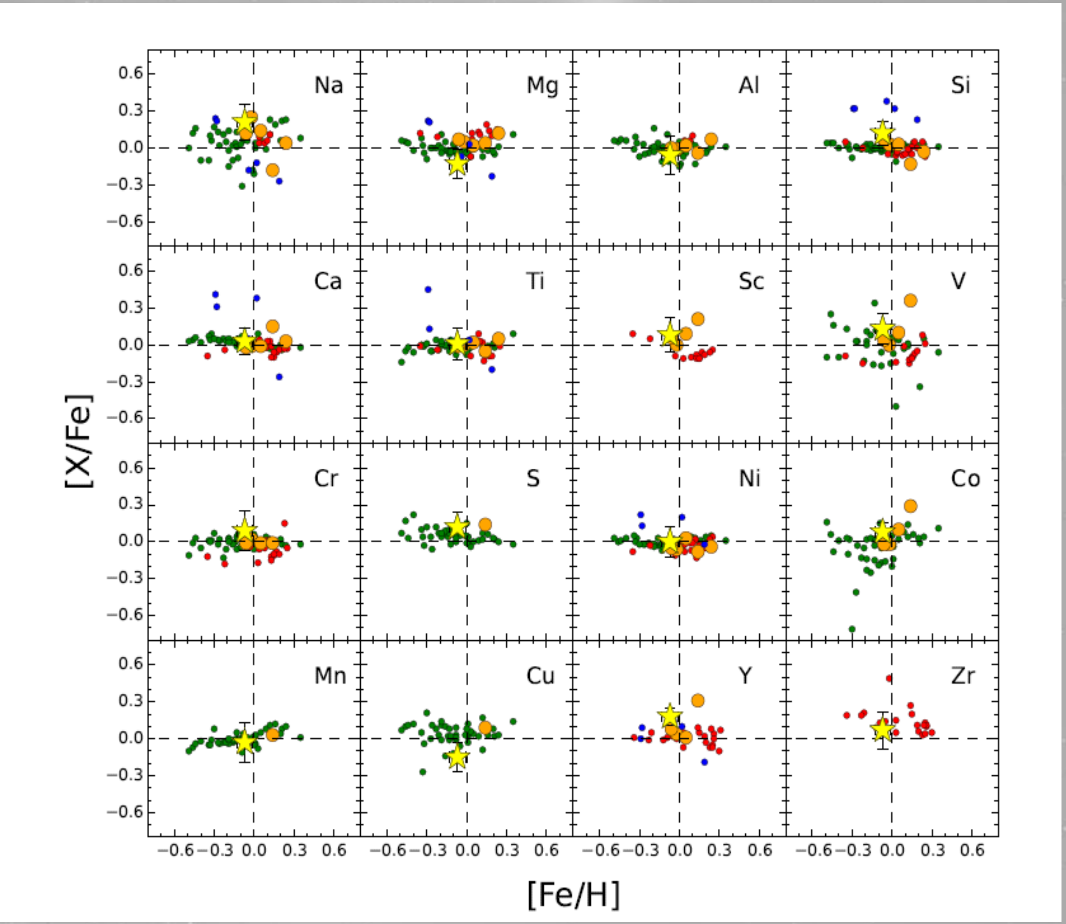


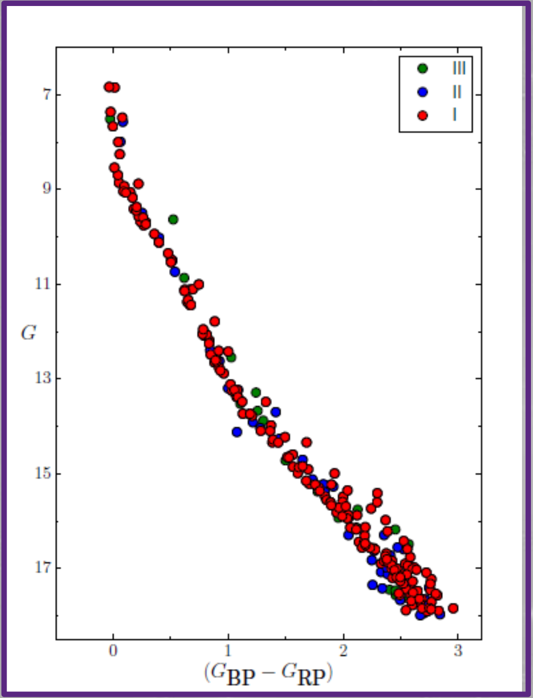
Fig. 11. Differences between our mean abundances for giants and MS stars and those by Reddy & Lambert (2019). The error bars are the quadratic sum of the uncertainties reported in the two studies for each element.



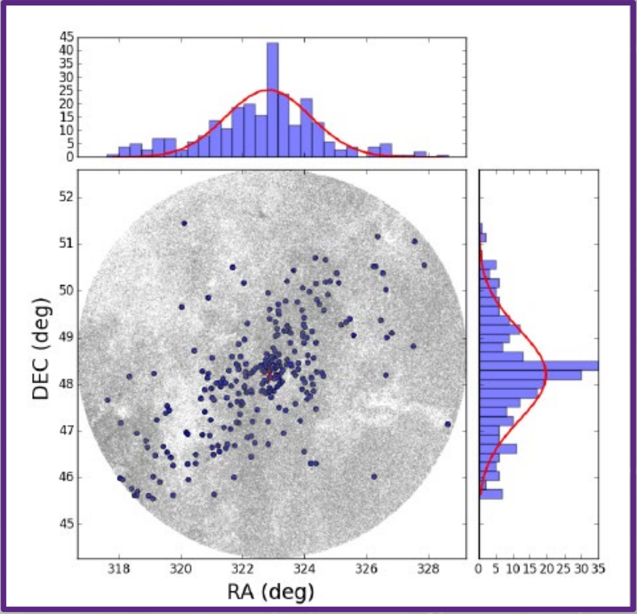
M39 (NGC7092)

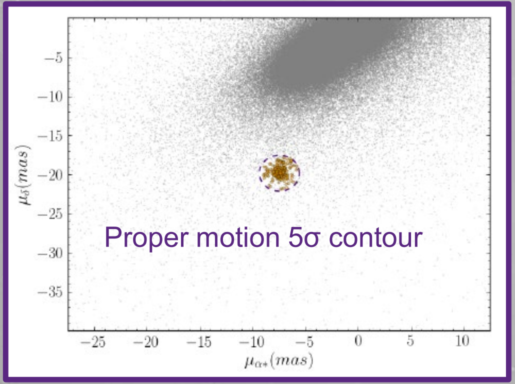
A nearby open cluster with no giant star

(Alonso-Santiago et al. 2024) Pre-SPA data



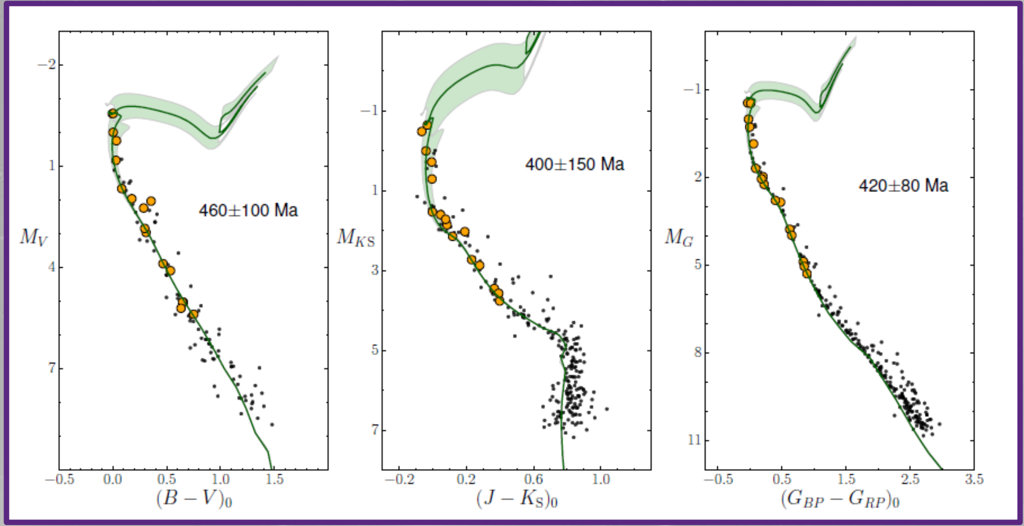
Initial selection of 198 members in Cantat+2018 (based on DR2).
Search in the Gaia DR3 for new members in a radius of 250′ from the center. In total we found 260 members, 195 of which (I=red dots) have a high priority (1σ).
No giant stars found





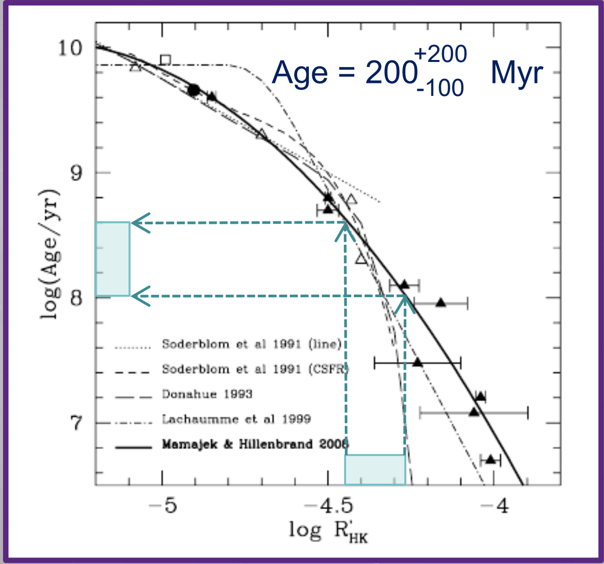
Different "tools" needed for the age determination

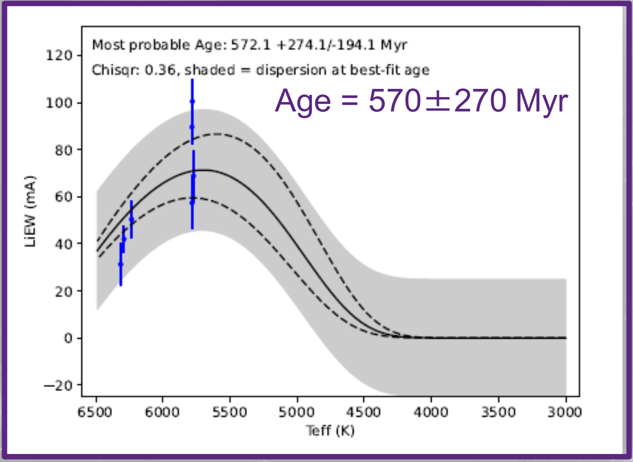
M39 (NGC7092)



From CMD
Age =430±110 Myr

From CaII H&K emission





Discrepant ages but still in agreement within the uncertainties

Fit to the Lithium depletion pattern with EAGLES

Thanks for your attention