Calibrating the lithium-age relation with open clusters observed with GES (Gaia-ESO Survey)

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M.L. Gutiérrez Albarrán[1], D. Montes[1], M. Gómez Garrido[1], H.M. Tabernero[1,2], J.I. González Hernández[3,4], & GES Survey Builders

[1]Departamento de Astrofísica, Universidad Complutense de Madrid (UCM), Spain; [2]Universidad de Alicante, DFISTS, E-03080 Alicante, Spain; [3]Instituto de Astrofísica de Canarias (IAC), Spain; [4]Universidad de La Laguna, Dept. Astrofíisica, E-38206 La Laguna, Tenerife, Spain.

Abstract

Li depletion is strongly **age-dependent** but currently available data have shown a complex pattern of Li depletion on the pre- and main-sequence stars that is not yet understood. The lithium abundance observed in late-type stars depend not only of the age and the temperature but also on metallicity, mixing mechanisms, convection structure, rotation and magnetic activity. The large number of stars observed within the Gaia-ESO survey (**GES**) for many open clusters and associations can be used to calibrate the **lithium-age relation** and its dependence with other parameters that can be derived from the UVES and GIRAFFE spectroscopic observations. We present here the preliminary results of the analysis of membership and Li abundance of the **young clusters** and associations, as well as of **the intermediate-age and old open clusters**, observed until now in GES (iDR4) in order to conduct a comparative study. All this information allowed us to characterize the properties of the members of these clusters and identify a series of field contaminant stars, both lithium-rich giants and non-giant outliers.

Lithium EW measurements

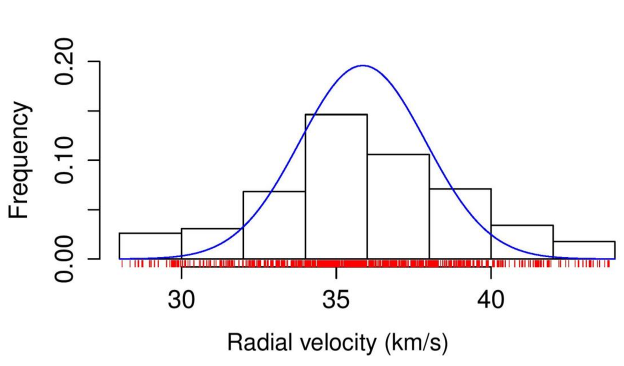
- **UVES:** We have used the spectra provided by GES (iDR4). Initial *EWs* (equivalent widths) of the Li (6707.76 Å) line and adjacent Fe (6707.43 Å) line were measured with the automatic tool *TAME* (Tool for Automatic Measurement of Equivalent Widths, Kang & Lee 2012). This tool allowed us to discard all spectra with *EW*(Li)<5 mÅ. We then did an individual analysis of each of the remaining spectra by measuring the *EW*(Li) and *EW*(Fe) manually with the *IRAF* task *splot*, using the *TAME* values for comparison purposes. With enough resolution *EW*(Li) and EW(Fe) can be measured individually, but in the case of lower resolution spectra only *EW*(Li I + Fe I) can be measured. *EWs* were corrected as *EW*(Li)=*EW*(Li I + Fe I) - *EW*(Fe I) in those cases where the Li and Fe lines could not be resolved. *EW*(Fe I) was estimated using the *ewfind* driver within MOOG code (Sneden 1973).

- **GIRAFFE**: We have also used the *EWs* (already corrected in the case of the WG12 clusters) from the spectra provided by GES (iDR4).

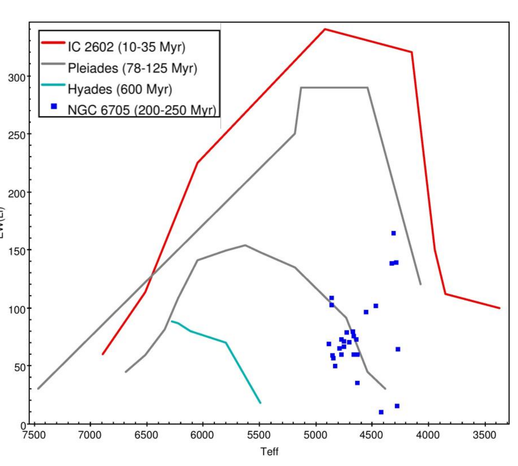
For all the following analysis, we have used the recommended parameters provided by GES (iDR4).

Cluster membership. Selection criteria

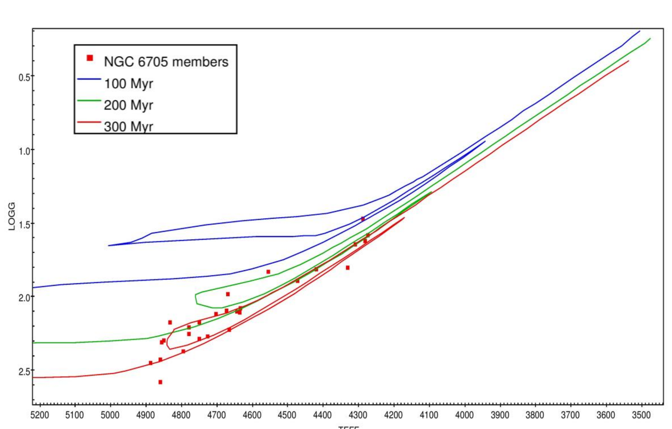
We present initial lists of candidate members for each cluster (using both the UVES and GIRAFFE spectra), based on their radial velocities (given that cluster members must have similar *RVs*), their position in the *EW*(Li) vs $T_{\rm eff}$ and HR (log*g* vs $T_{\rm eff}$) diagrams (criteria that discard additional outliers such as Lithium-rich giant stars), and their metallicity. As and example we show here the case of **NGC 6705:**



Kinematic selection: We have studied the velocity distribution of each cluster, discarding some outliers - field star contaminants at the tails of the distribution - before fitting. We have fitted the distribution by applying a sigma clipping procedure. We adopt a 2σ limit about the cluster mean velocity yielded by the Gaussian fit in order to identify the most likely kinematic members. We also rely on literature data in order to choose these intervals, especially in the case of those distributions which present two peaks (Gamma Velorum, NGC 2547).

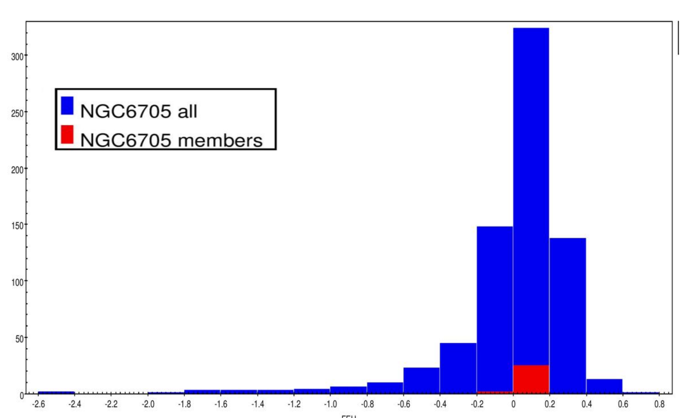


***EW*(Li) vs $T_{\rm eff}$**: By plotting the lithium envelopes of IC 2602 (10-35 Ma), the Pleiades (78-125 Myr), and the Hyades (600 Myr) in a *EW*(Li) vs $T_{\rm eff}$ figure, we can estimate age ranges for the cluster candidate stars. Given that the ages of the clusters we are studying are known, we can identify further outliers among the kinematic candidates in this way. Some of the cluster selections present greater dispersions than others.



The position of the stars in the **HR diagram** also helps in order to identify potential giant outliers (logg < 3.5) – some of them Li-rich giants (A(Li) > 1.5) – and other field contaminants. Apart from member candidates for each cluster, we have searched for Li-rich giants in this fashion, making use of the PARSEC isochrones (Bressan et al. 2012), with Z=0.019 and ages ranging from 1 Myr to 12 Gyr.

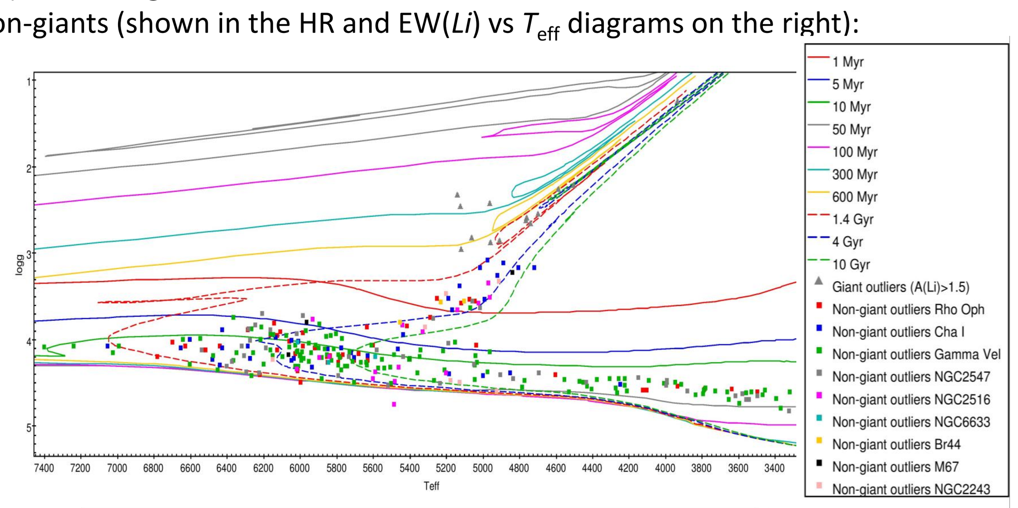
Finally, we have taken the clusters' **metallicity** into account in order to identify further non-members: **[Fe/H] histograms** help rule out stars with metallicities too far away from the mean for each cluster. Additionally, *RV* versus [Fe/H] diagrams are also useful in order to find additional outliers near the cluster velocity.

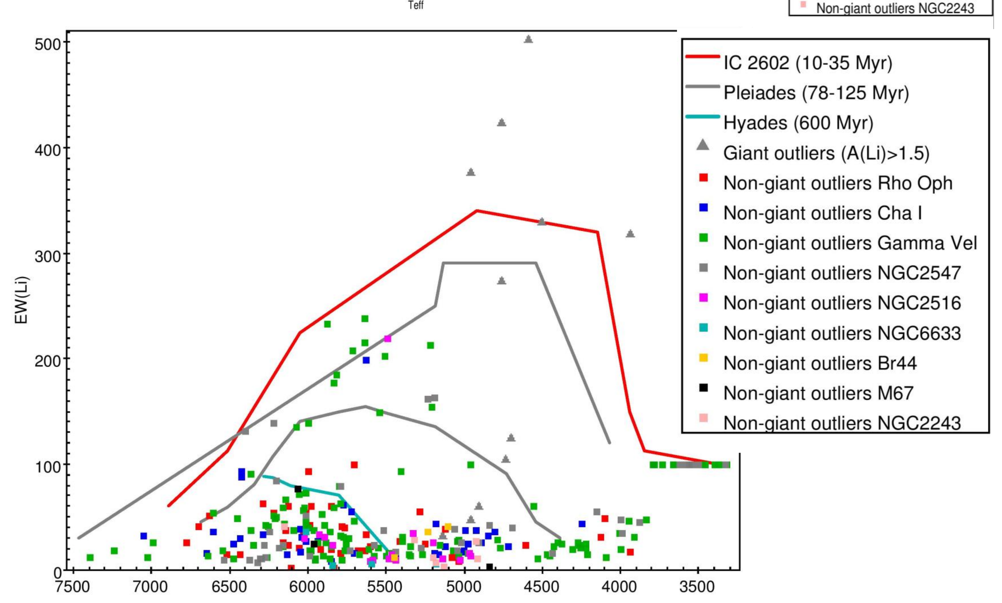


Open clusters analysed

The table below shows the 20 open clusters analysed (covering a range of age from a few Myr to 4 Gyr), indicating the number of stars with Li detected in UVES and GIRAFFE, the number of stars selected as possible members, and the number of potential outliers, both giants and non-giants (shown in the HR and EW(*Li*) vs $T_{\rm eff}$ diagrams on the right):

Name	Age	[Fe/H]	RV (km/s)	Nº* UVES con Li	Nº* GIRAFFE con Li	Nº * selected as members	Non-giant outliers	Giant outliers (A(Li)>1.5)
ρ Ophiuchi	1-3 Myr	-0.140 to -0.090	-7.03	23	191	47	44	0
Chamaeleon I	2 Myr	-0.080	14.60	40	438	85	36	2
γ Velorum	10-20 Myr	-0.057 to -0.040	15.45	31	884	142	124	3
IC 2391	20-50 Myr	-0.055	14.70	23	366	22	-	4
IC 2602	30-67 Myr	-0.022	17.90	118	1536	25	-	9
IC 4665	35-43 Myr	-0.044	-13.60	33	426	27	-	2
NGC 2547	35-36 Myr	-0.030	14.78	18	278	95	40	1
NGC 2516	112-150 Myr	0.160	23.60	32	0	15	16	0
NGC 6705	220-250 Myr	0.300	34.90	29	0	27	0	1
NGC 4815	500-630 Myr	-0.030	-29.60	10	0	4	0	0
NGC 6633	600-660 Myr	-0.050	-28.80	39	0	35	4	2
NGC 6802	0.74-1 Gyr	0.100	11.90	13	0	8	0	2
Br 81	0.75-1 Gyr	0.210	48.30	9	0	12	0	1
Trumpler 20	1.2-1.7 Gyr	0.100	-40.20	38	0	41	0	0
Trumpler 23	1 Gyr	0.140	-61.30	13	0	10	0	1
Pismis 18	1.2 Gyr	0.11	-27.50	8	0	6	0	0
NGC 6005	1.2 Gyr	0.16	-24.10	14	0	12	0	1
Br 44	1-3 Gyr	0.17	-8.70	6	0	4	3	0
M67	2.57-5 Gyr	0.06	33.64	18	0	17	3	0
NGC 2243	4.5 Gyr	-0.54	61.90	21	0	15	7	0





Work in progress

We are working on a detailed analysis of the dependence of the **lithium-age relation** on other **stellar parameters** that can be derived from the UVES and GIRAFFE spectroscopic observations such as the level of chromospheric activity (Hα), accretion indicators, rotation (*v*sin*i*), metallicity ([Fe/H]), and well as **other parameters** (photometric rotational period, etc.) from the literature. In addition, the **age** of each cluster will be revised using all this information, the lithium depletion boundary when it is possible or other methods.

For each cluster observed within GES, we plan on including all the *EW*(Li) provided by other authors (see poster in this meeting about IC 2391, IC 2602 and IC 4665 by Gómez Garrido, Montes, et al.). In addition, we will include in our analysis other well known open clusters studied in the literature which will not be observed by GES, in order to have a larger **age coverage.** We are also studying in more detail some unknown non-member contaminants in the field of these clusters, both non-giant outliers and Li-rich stars which could be **possible new young field stars** or **Li-rich giants.**

We plan to use the lithium-age relation derived during this project to search or confirm the membership of GES field stars to young associations and stellar kinematic groups of different ages.

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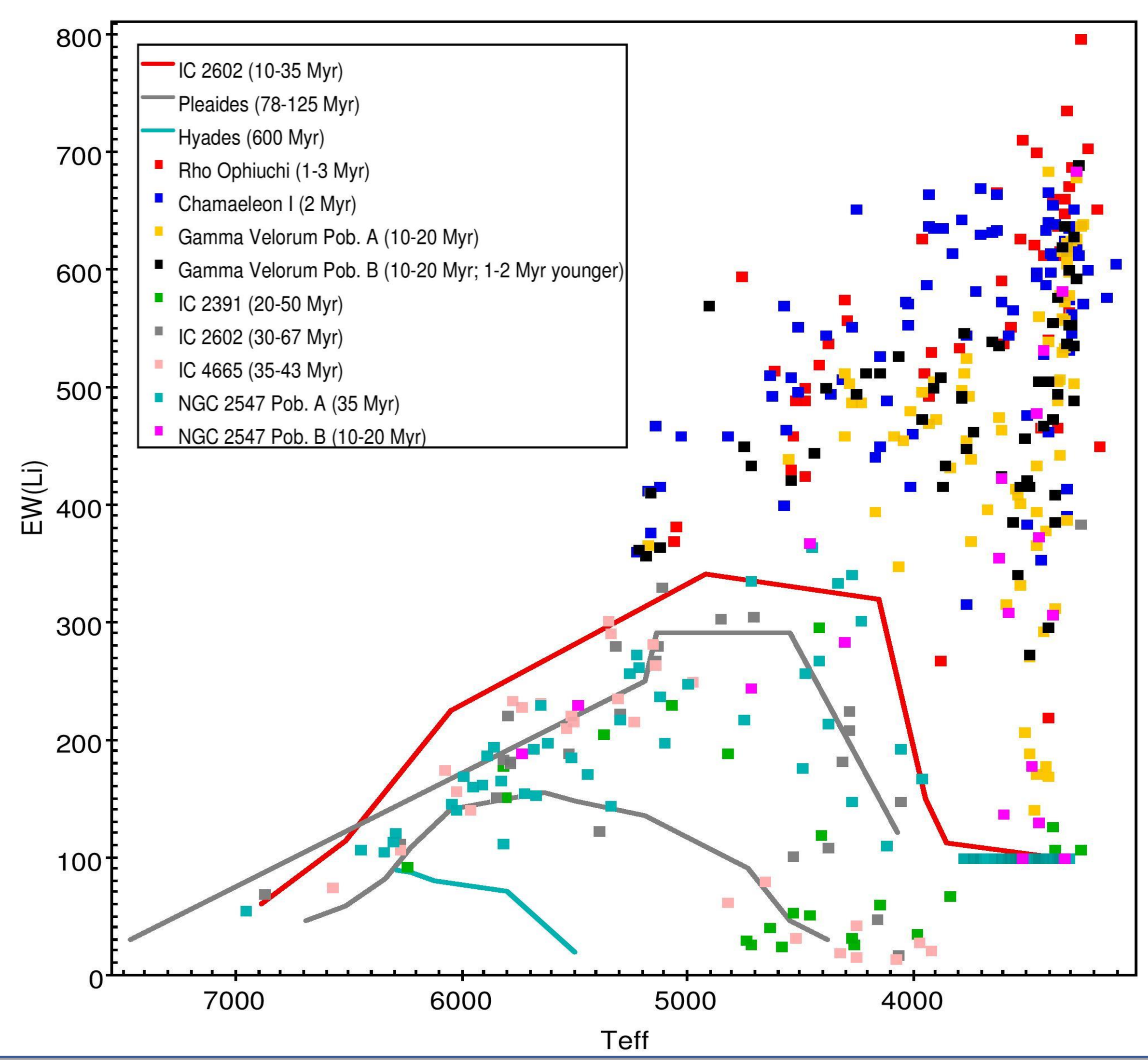
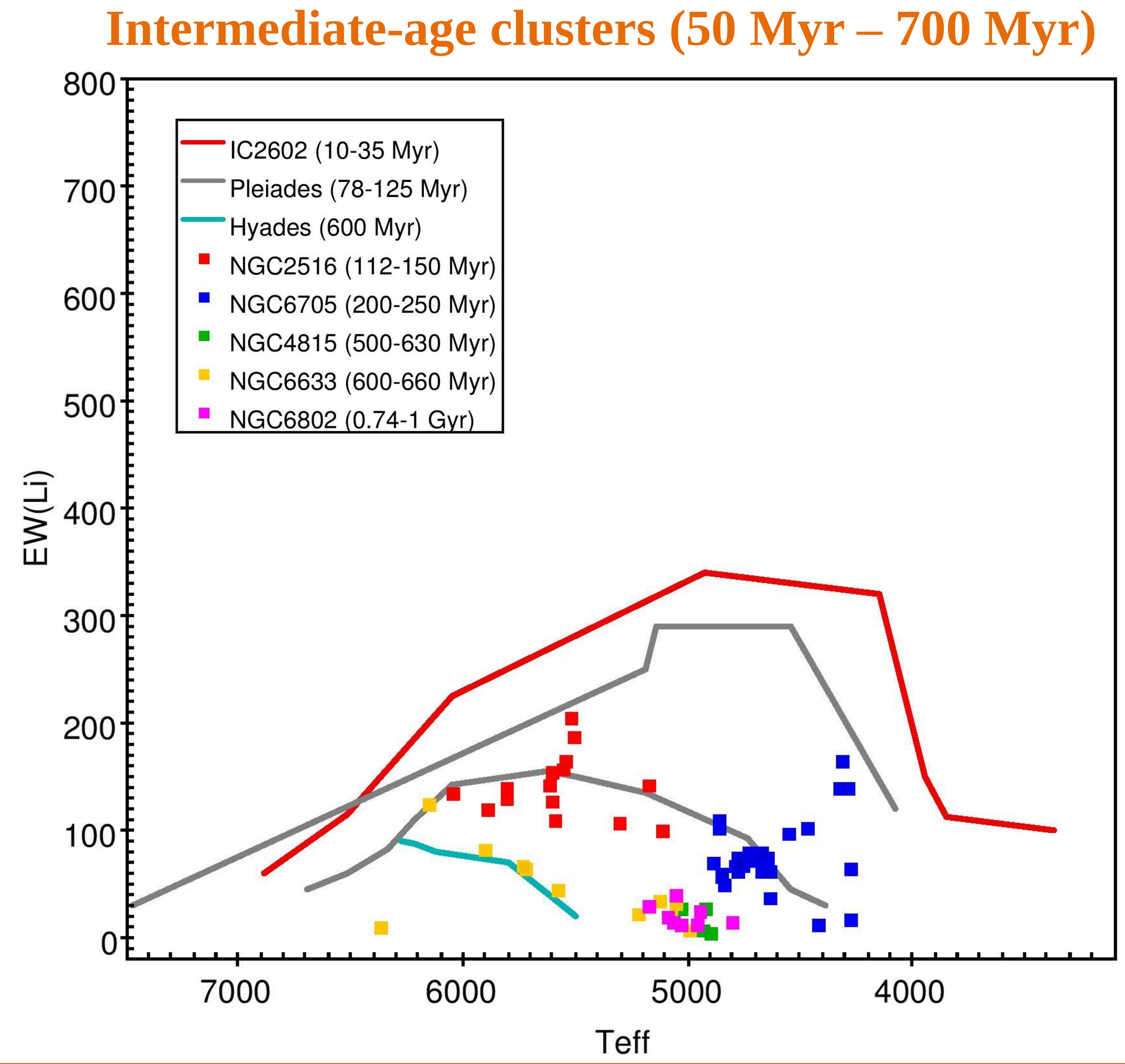
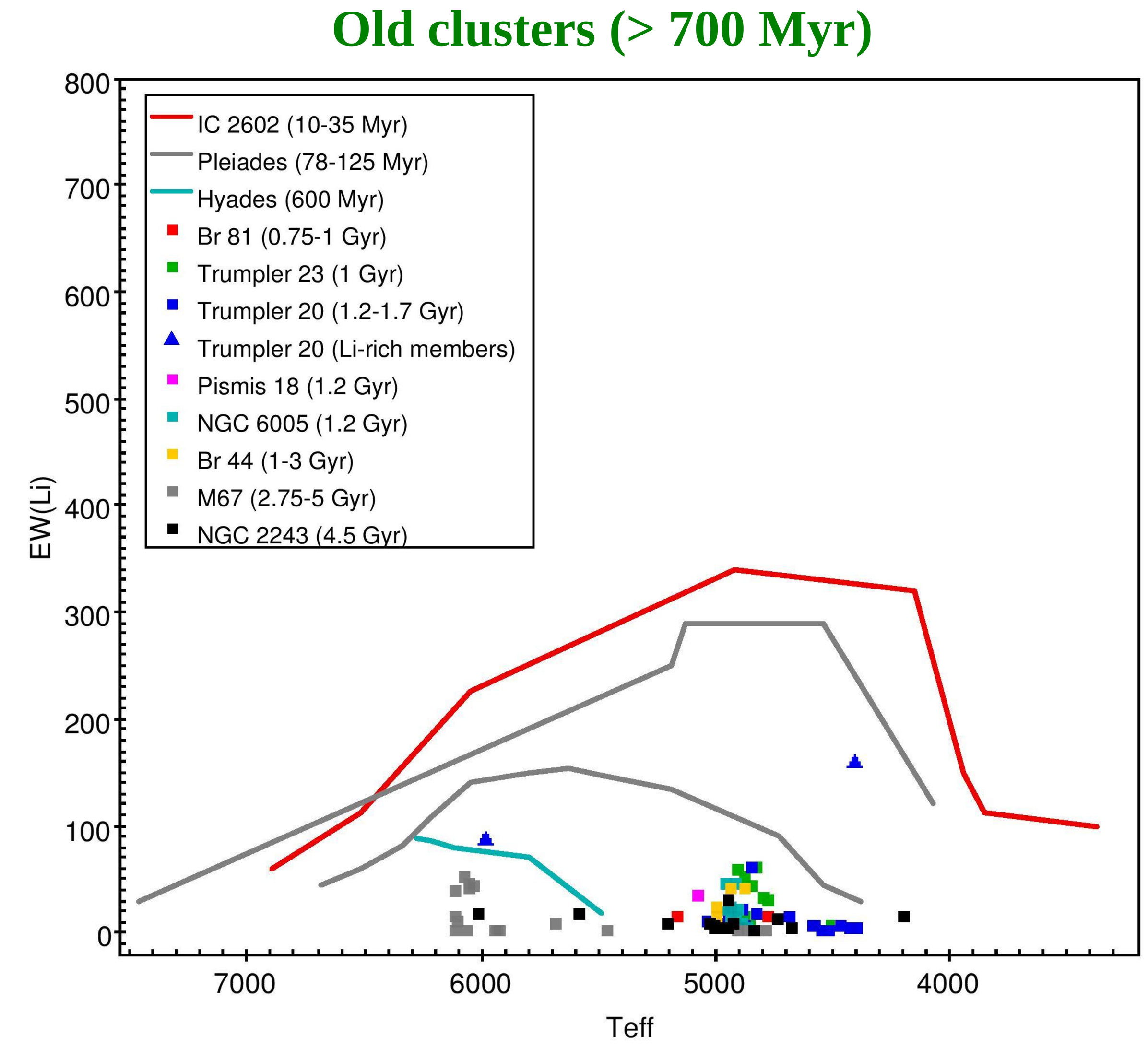
Young clusters (1 Myr – 50 Myr)

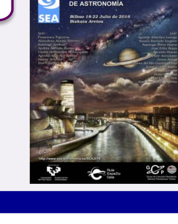


Intermediate-age clusters (50 Myr – 700 Myr)



Old clusters (> 700 Myr)





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