Calibrating the lithium-age relation and its dependence with rotation, activity and metallicity using open clusters and associations

M.L. Gutiérrez Albarrán[1], D. Montes[1], H.M. Tabernero[1,2], J.I. González Hernández[3,4], A. Frasca[5], A.C. Lanzafame[5], R. Smiljanic[6], A.J. Korn[7], S. Randich[8], G. Gilmore[9], et al. & GES Survey Builders

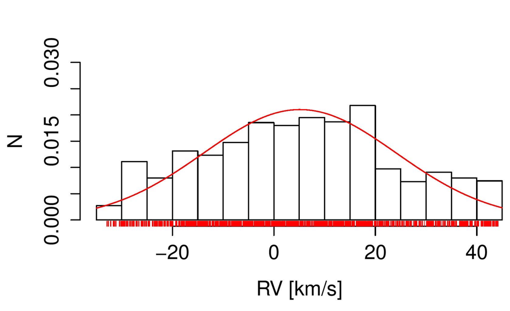
[1]Departamento de Física de la Tierra y Astrofísica and IPARCOS-UCM, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, E-28040, Madrid, Spain; [2] CAB; [3] IAC; [4] Universidad de la Laguna, Tenerife; [5] INAF Catania; [6] Nicolaus Copernicus Astronomical Center; [7] Department of Physics and Astronomy, Uppsala University; [8] INAF Arcetri; [9] Institute of Astronomy, University of Cambridge

Abstract

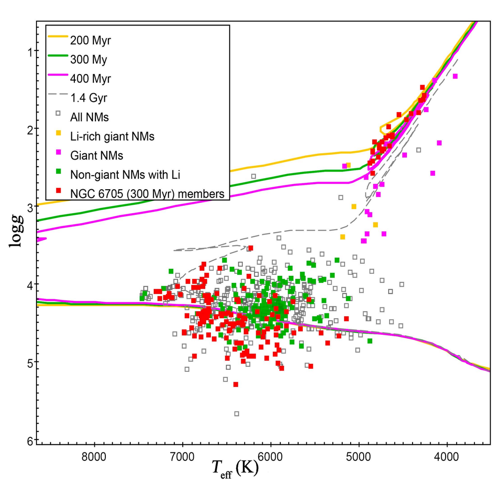
In this work we use a series of open clusters and associations observed by the **Gaia-ESO Survey (GES)** to study the use **of lithium abundances** (Li I spectral line at 6708 Å) **as an age indicator for pre- and main-sequence FGKM late-type stars**. Previous studies of open clusters have shown that lithium depletion is not only strongly age dependent, but also shows a complex pattern with several other parameters, such as rotation, chromospheric activity and metallicity. Using the available data from both **GES iDR6 and Gaia EDR3**, we performed a thorough **membership analysis** and **obtained lists of candidate members for 41 open clusters, ranging in age from 1-3 Myr to 5 Gyr.** We then conducted a comparative study that allowed us to quantify the observable lithium dispersion in each cluster and **study influence of rotation, activity and metallicity in the lithium dispersion of the selected candidates**. All this allows us to **calibrate a Li-age relation and create empirical lithium envelopes** for several clusters in our sample.

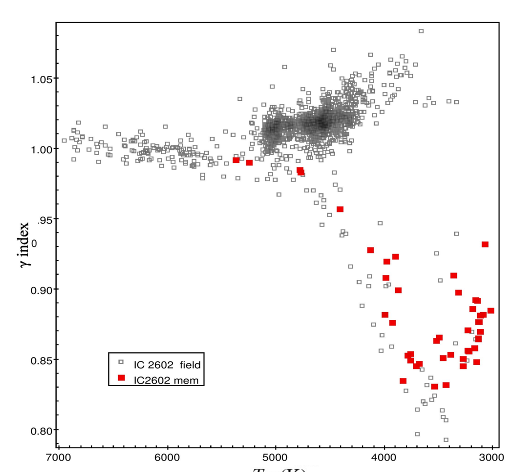
Selection criteria and cluster membership

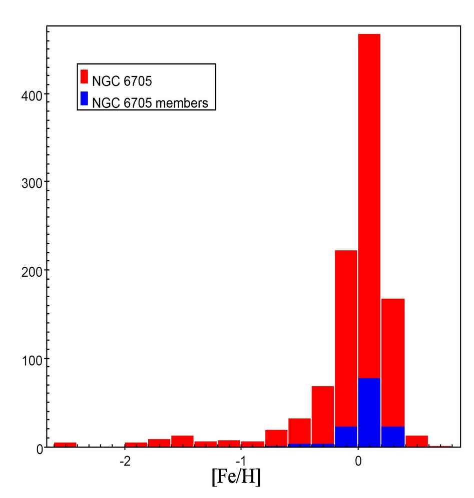
Candidate members for each cluster are selected from the **Gaia-ESO Survey (GES)** (Gilmore et al. 2012) **iDR6** data based on the following criteria: *RVs*, *Gaia* astrometry (proper motions and parallaxes), gravity indicators - Kiel (log*g* vs T_{eff}) and γ index diagrams, [Fe/H] metallicity, and the position in the *EW*(Li) vs T_{eff} diagram. As an example we show here the case of **IC 2602** (*RV, PMs, CMD, EW*(Li) vs T_{eff} and γ index) and **NGC 6705** (Kiel diagram and [Fe/H] histogram):



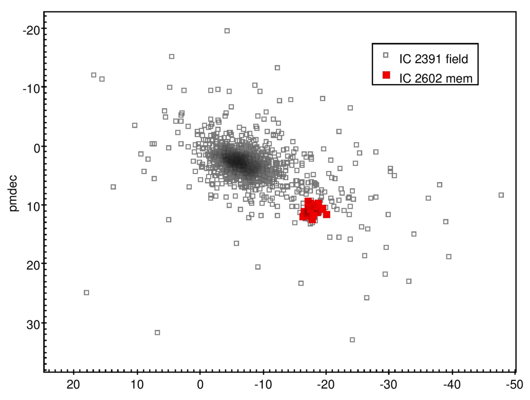
Kinematic selection: We studied the RV distribution of each cluster by applying a **2-sigma clipping procedure** and adopting a 2σ limit about the cluster mean yielded by the **Gaussian fit** to identify the most likely **RV members**.





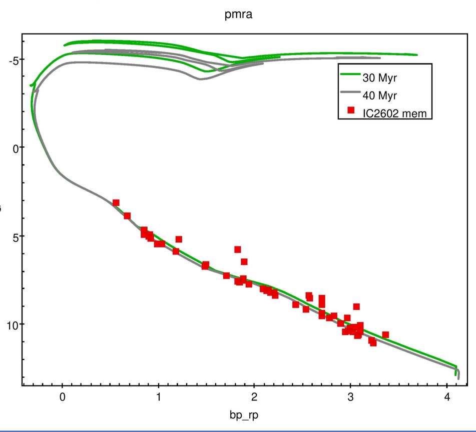


[Fe/H] histograms also help rule out stars with metallicities too far away from the mean for each cluster.



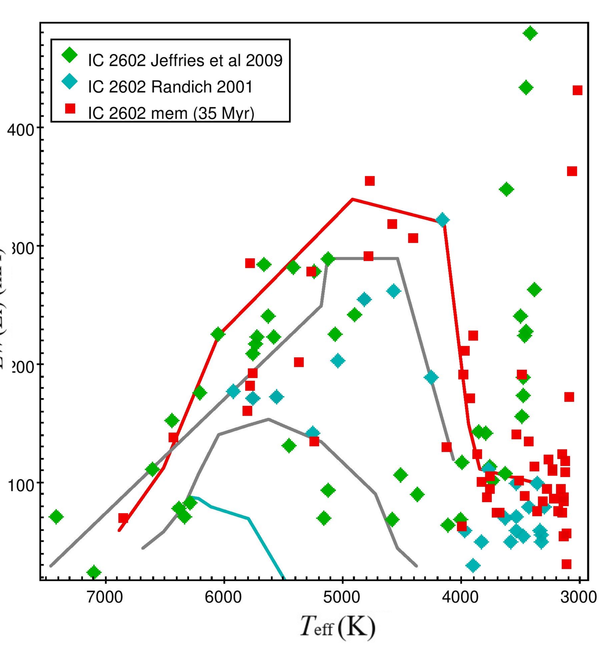
The **Kiel diagram** enables us to **discard giant outliers** (log*g* < 3.5) – some of them Li-rich giants (A(Li) > 1.5) – and other field contaminants. We used the ***PARSEC* isochrones** (Bressan et al. 2012), with *Z* = 0.019 and ages ranging from 1 Myr to 7 Gyr. For young clusters, we used the **gravity indicator gamma** (see **γ index vs T_{eff}** diagram above) to discard giant contaminants before applying any kinematic and astrometric criteria,.

***Gaia* astrometry**: Alongside the RVs measured by GES. We use the **proper motions and parallaxes provided by Gaia EDR3** (Gaia Collaboration et al. 2021A&A...649A...1G) to obtain lists of probable astrometric members.



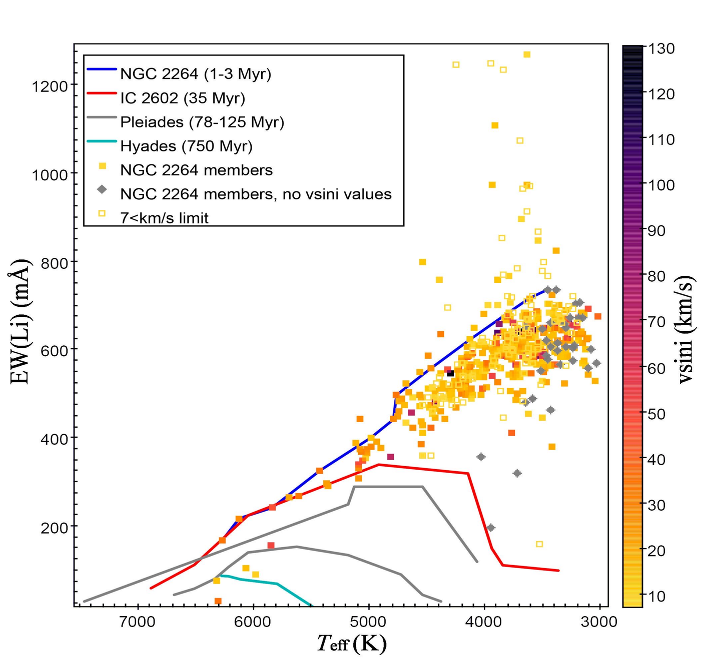
CMDs: We also make use of **Gaia EDR3 photometry** to analyse the membership of our candidates and discard contaminants in ***G* vs G_{BP}-G_{RP} colour-magnitude diagrams.**

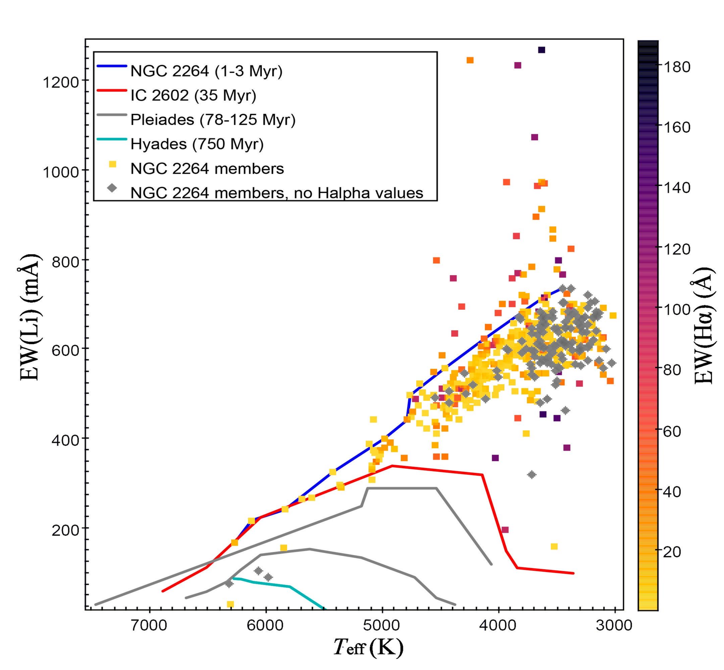
***EW*(Li) vs T_{eff}**: Plotting the **lithium envelopes of IC 2602 (35 Myr), the Pleiades (78-125 Myr), and the Hyades (750 Myr)** in an *EW*(Li) vs T_{eff} figure, we can estimate age ranges and verify probable members (see Montes et al. 2001).

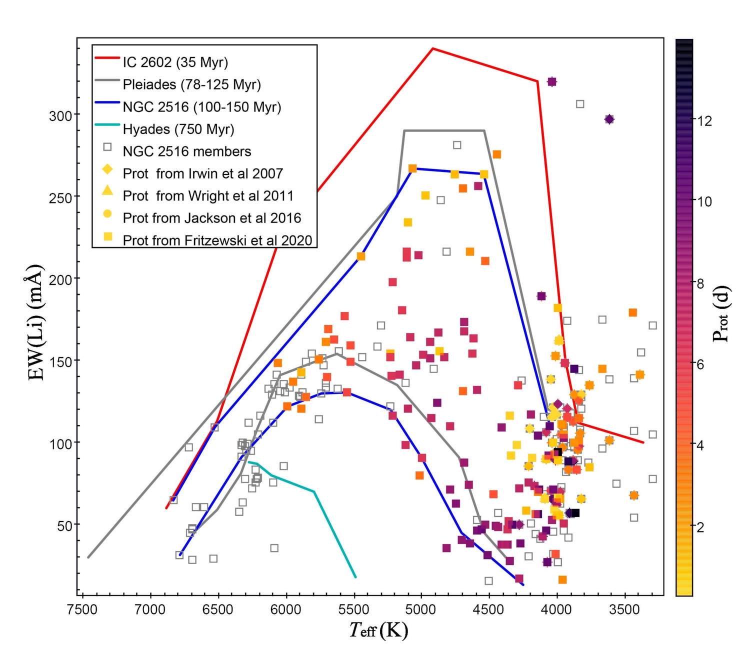


For more details see: Gutiérrez Albarrán, et al. 2020A&A...643A..71G

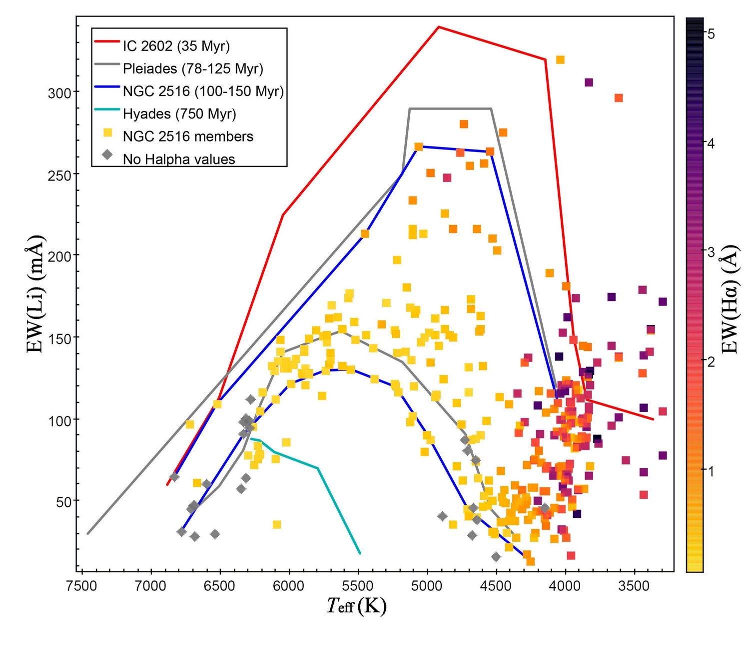
Preliminary results: dependence with rotation, activity and metallicity. Li-age relation

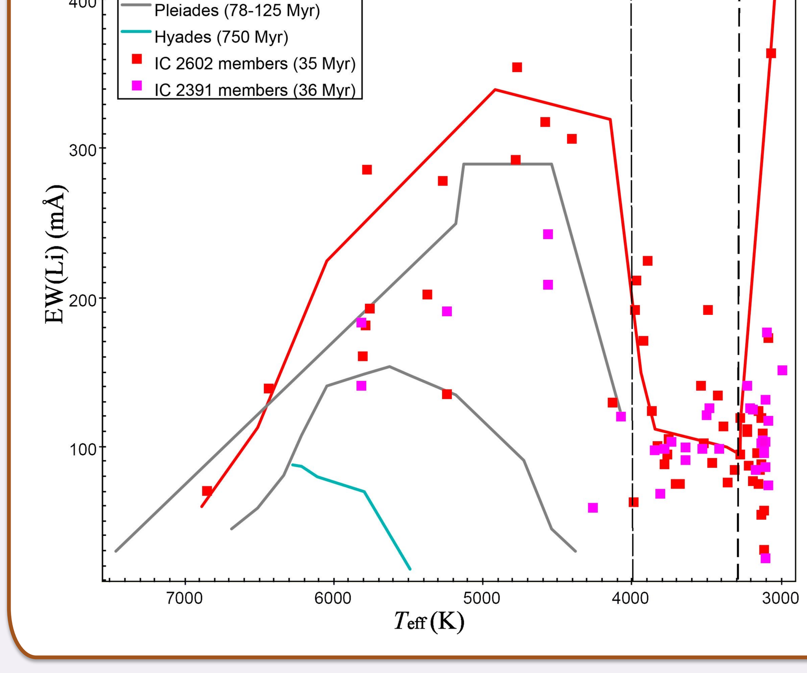






We use the **rotational velocities (*v*sin*i*), chromospheric activity indicators (*EW*(Hα)) and [Fe/H] metallicities** provided by **GES**, as well as additional **rotational periods (P_{rot})** from the literature, including ***Kepler*, *K2* and *TESS*** measurements. We confirm the findings of former publications and observe that **members with higher values of *EW*(Li) tend to be faster rotators and have higher levels of activity** (see the examples of NGC 2264, 1-3 Myr, and NGC 2516, 100-150 Myr). We have additionally observed slight **effects of [Fe/H] metallicity in the Li depletion of coeval clusters** for those which are metal-rich or metal-poor.



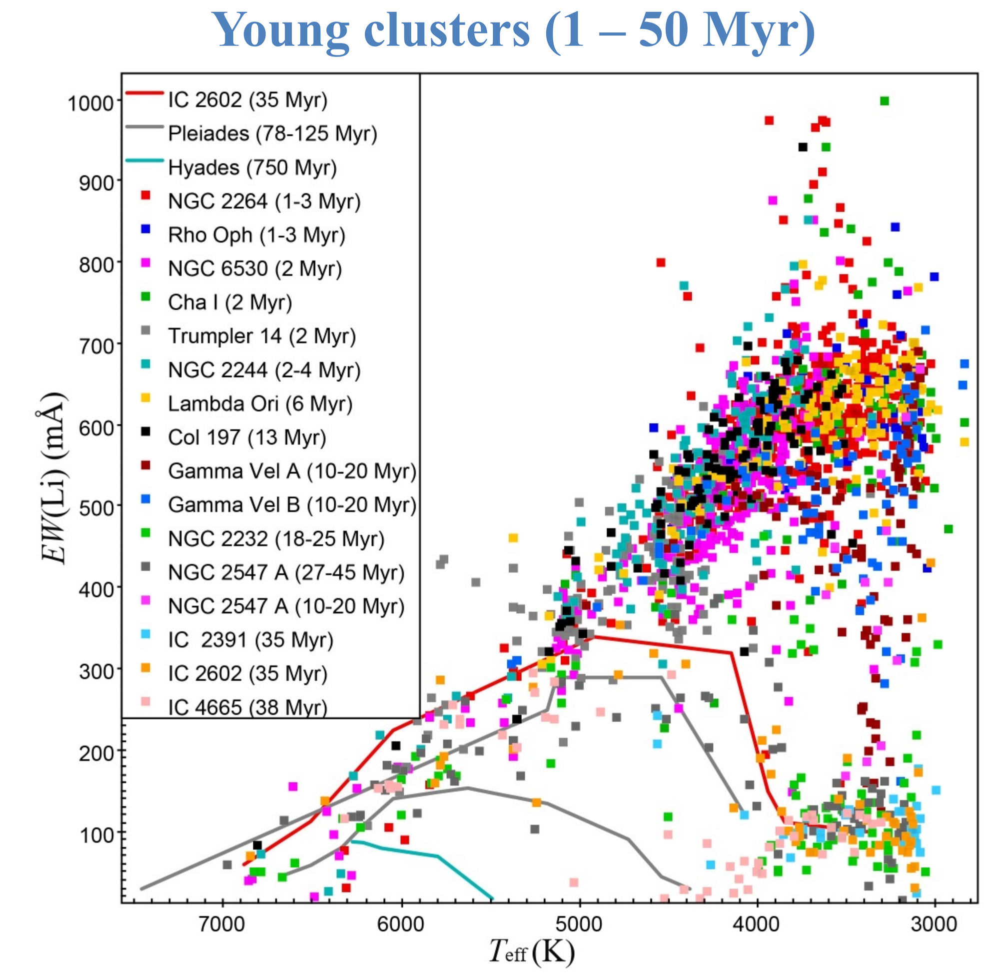


Taking all these effects into account, we are calibrating a **Li-age relation** and creating **empirical lithium envelopes** for several key age ranges in our cluster sample. This Li-age calibration will allow us to **estimate age ranges for GES field stars**. We show here as some examples the empirical envelopes for **NGC 2264 (1-3 Myr)**, **IC 2602 (35 Myr), and NGC 2516 (100-150 Myr)**. As part of this calibration we are also studying **the lithium depletion boundary (LDB)** for clusters in the 15-500 Myr range with the aid of models such as Baraffe et al. 2015 (see vertical dashed lines in the IC 2602 diagram, left).

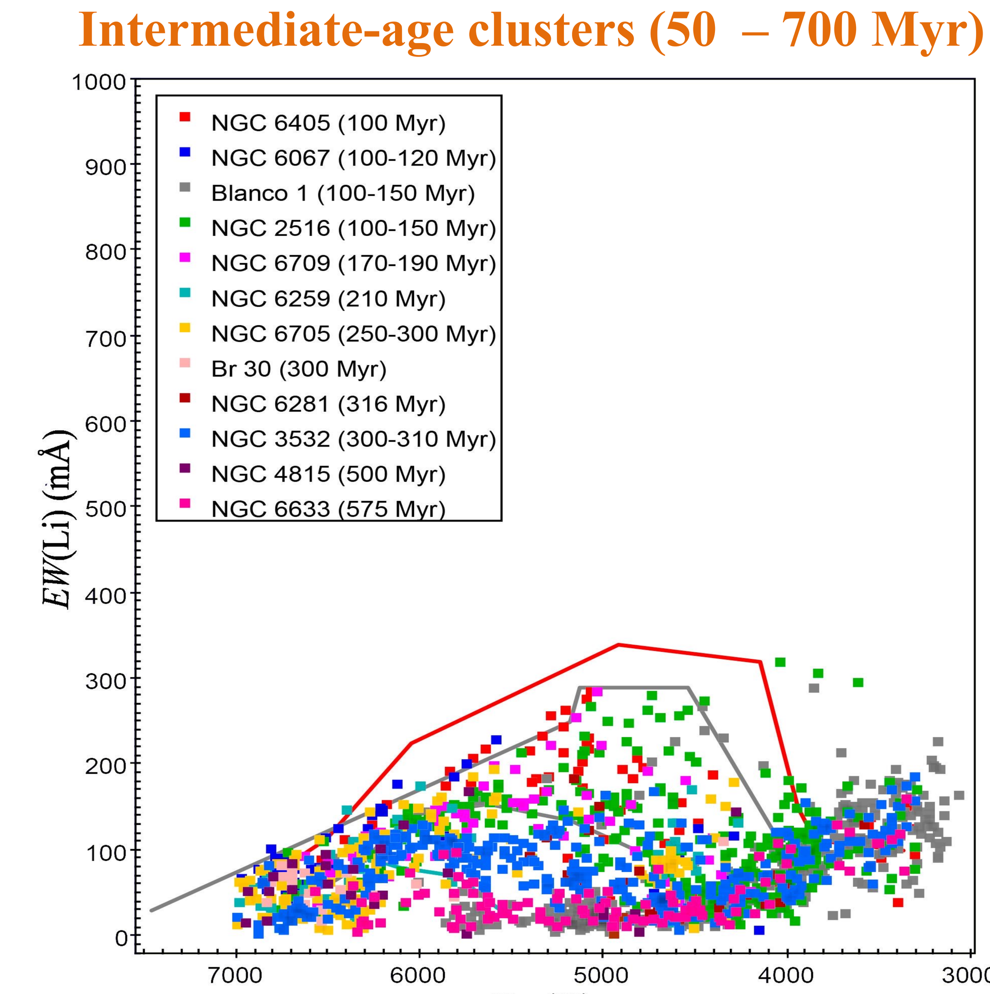
EW(Li) vs T_{eff}

***EW*(Li) vs T_{eff}**: for the 41 open clusters analysed with data from GES iDR6 (covering a range of **age from a few Myr to 5 Gyr**).

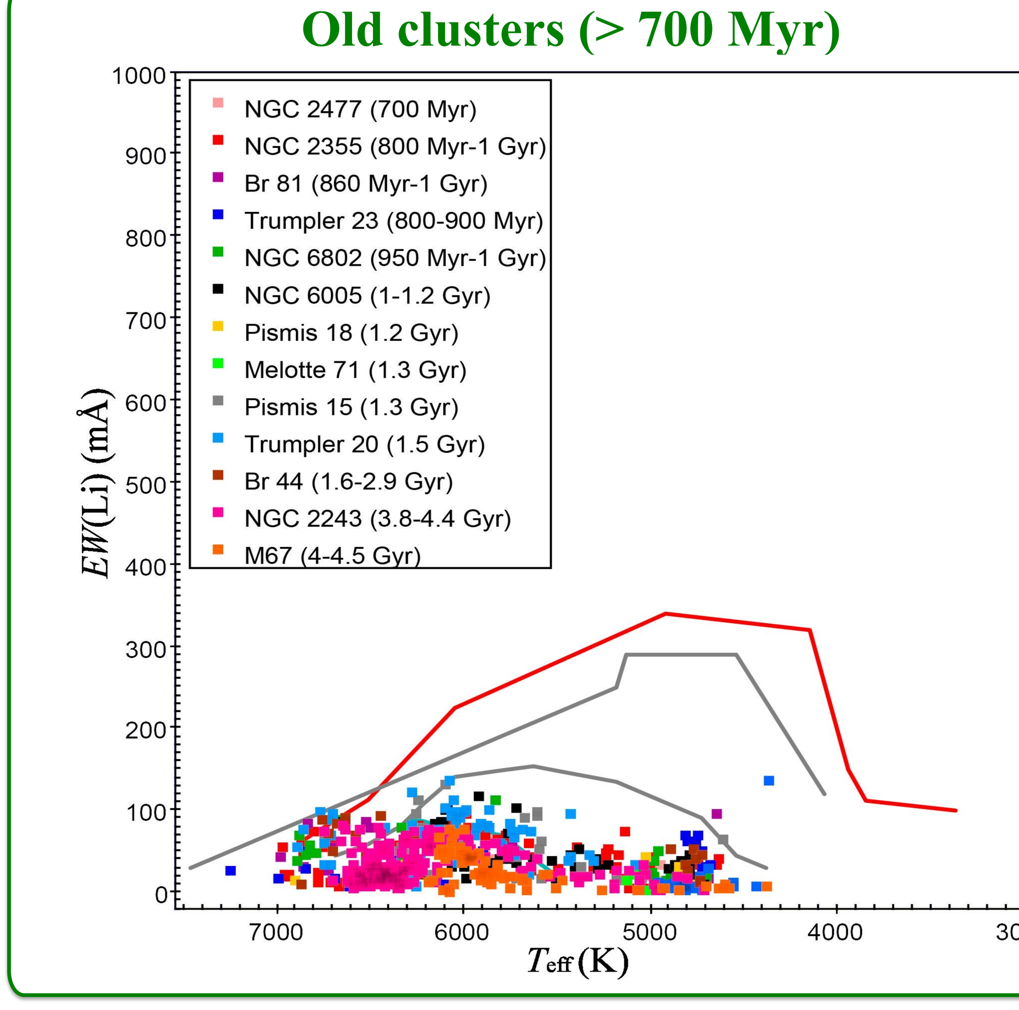
Young clusters (1 – 50 Myr)



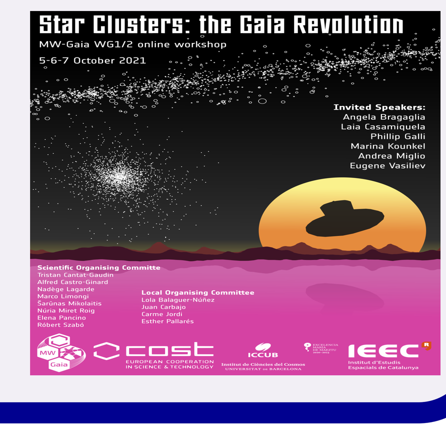
Intermediate-age clusters (50 – 700 Myr)



Old clusters (> 700 Myr)



Star Clusters: The Gaia Revolution
MW Gaia WG 1/2 online workshop
5-7 October 2021



Acknowledgments: Based on data products from observations made with ESO Telescopes at the La Silla Paranal Observatory under programme focus ID 188.B-3002. These data have been obtained from the GES Data Archive. This work has made use of data from the European Space Agency (ESA) mission Gaia. We acknowledge financial support from the Universidad Complutense de Madrid (UCM) and by the Spanish Ministerio de Ciencia, Innovación y Universidades, Ministerio de Economía y Competitividad, from project AYA2016-79425-C3-1-P and PID2019-109522GB-C5[4]/AEI/10.13039/501100011033.