The *Gaia*-ESO Survey: Calibrating the lithium-age relation with open clusters and associations

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Abstract

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**. This relation will ultimately allow us to **infer the ages of GES field stars** and identify their potential membership to young associations and stellar kinematic groups. In the present work we performed a thorough analysis of **membership and Li abundance of 20 clusters** observed in **GES (iDR4)**, ranging in age from **young clusters and associations**, to **intermediate-age and old open clusters**, to conduct a comparative study. All this allowed us to characterize the properties of the members of these clusters, as well as identify a series of **field contaminant stars, both lithium-rich giants and non-giant outliers**.

* https://www.gaia-eso.eu/

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Context

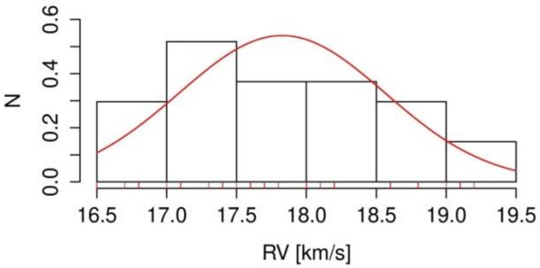
- In solar-type and lower mass stars, lithium is slowly being depleted over time. For this reason, **lithium is a very sensitive tracer of stellar evolution**, relevant in the determination of the **age of stellar clusters**.

- **Li depletion** and the lithium abundance observed in late-type stars depends not only on the **age** and the temperature but **also on metallicity, mixing mechanisms, convection structure, rotation and magnetic activity**.

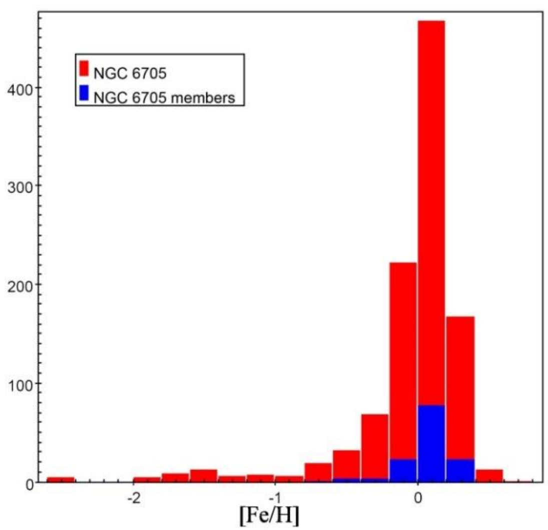
- The **Gaia-ESO Survey** (**GES** - Gilmore et al. 2012; Randich et al. 2013) is a large, public spectroscopic survey that provides an homogeneous overview of the distribution of kinematics, dynamical structure and chemical compositions in the Galaxy. GES uses the multi-object spectrograph **FLAMES** (ESO, Chile) to obtain high resolution spectra with **UVES** (*Ultraviolet and Visual Echelle Spectrograph*) and medium resolution spectra with **GIRAFFE**.

- We use lithium, among other criteria, to **constrain the cluster membership of 20 open clusters of ages ranging from 1 Myr to 5 Gyr** using the data provided by the fourth internal data release of GES (**iDR4**)

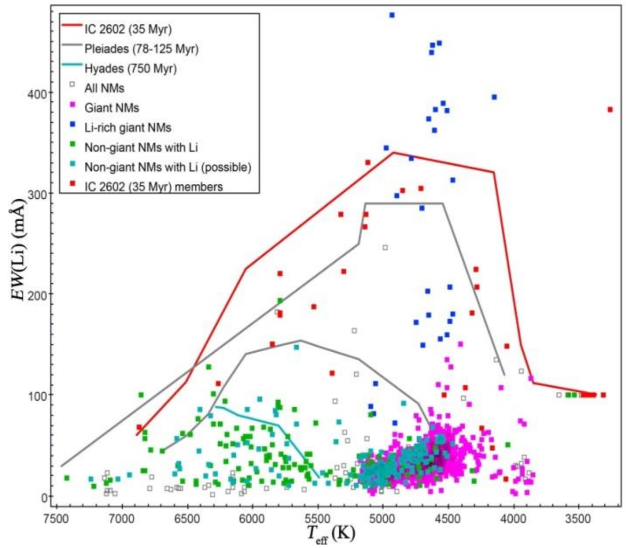
Methodology



1) Kinematic selection: We studied the RV distribution by adopting a **2σ limit** about the cluster mean yielded by the **Gaussian fit** to identify the most likely **RV members**.



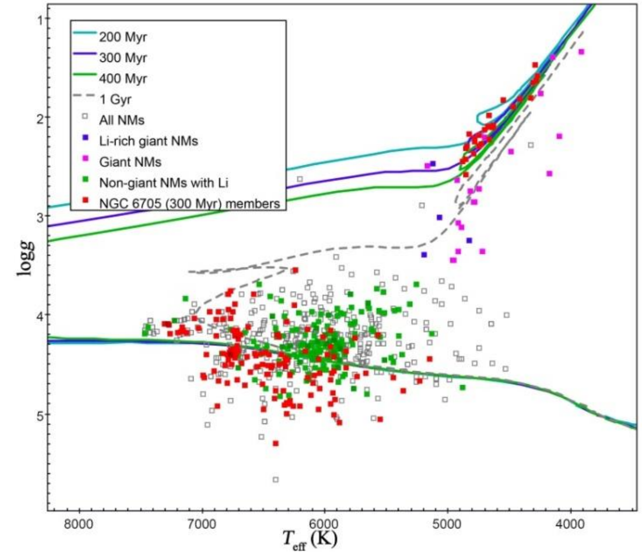
4) [Fe/H] histograms also help rule out stars with metallicities too far away from the mean for each cluster.

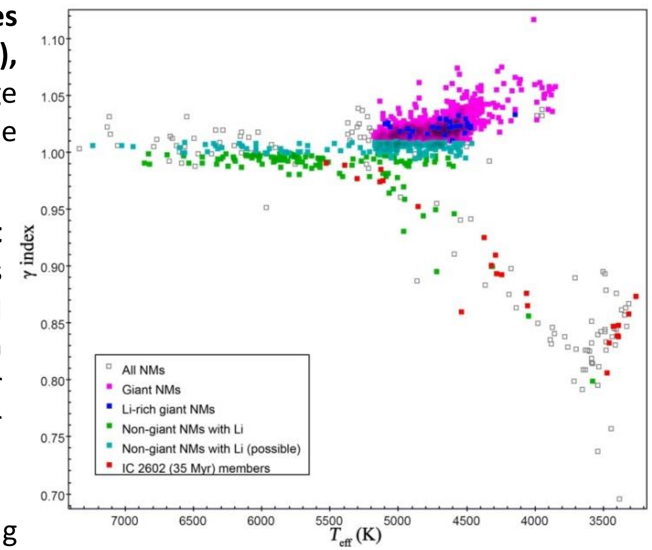


2) *EW*(Li) vs T_{eff}: By plotting the **lithium envelopes of IC 2602 (35 Myr), the Pleiades (78-125 Myr), and the Hyades (750** Myr), we can estimate age ranges and identify probable members among the kinematic candidates.

3) 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 also used the gravity indicator gamma in **Gamma index vs T_{eff}** diagrams.

5) In addition, we also used a series of studies using data from ***Gaia* DR1 and DR2** to further assess the membership of our candidate selections. These studies include Cantat-Gaudin et al 2018, Randich et al 2018 and Cánovas et al 2019.





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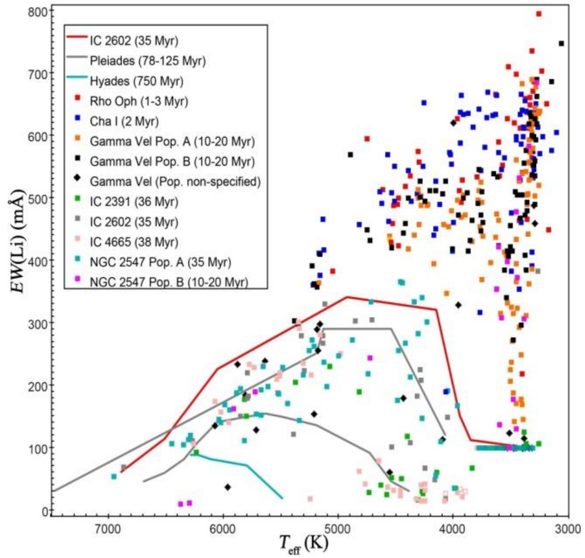
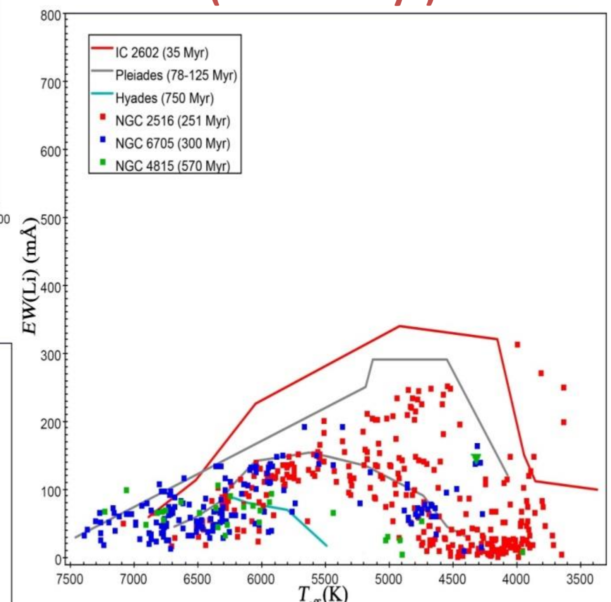
Results

Name	Age (Myr)	Nº* UVES w/ Li	Nº* GIRAFFE w/Li	Nº * Final mem	NG outliers	G outliers	Li-rich giant outliers (A(Li)>1.5)
ρ Oph	1-3	23	231	45	48(75)	90	2
Cha I	2	39	473	85	44(76)	247	9
γ Vel	10-20	60	855	210	13(14)	506	14
NGC 2547	35-45	25	278	107	-	122	3
IC 2391	36	23	360	27	18(67)	253	10
IC 2602	35	115	1465	32	138(244)	1212	28
IC 4665	38	32	534	37(40)	168(244)	133	2
NGC 2516	251	33	429	298	59	70	0
NGC 6705	300	31	309	163	166	19	6
NGC 4815	570	11	46	29	23	5	0
NGC 6633	773	42	354	101 (118)	186	590	13
Tr 23	800	15	17	17	11	4	1
Br 81	860	14	77	28	60	0	0
NGC 6005	973	19	89	38	62	17	1
NGC 6802	1000	13	29	22	14	2	3
Pismis 18	1200	10	30	15	23	1	0
Tr 20	1500	41	214	124	122	15	-
Br 44	1600	7	43	22	28	4	0
M67	4000-4500	20	0	18(19)	1	0	0
NGC 2243	4000	26	108	36	90	7	7

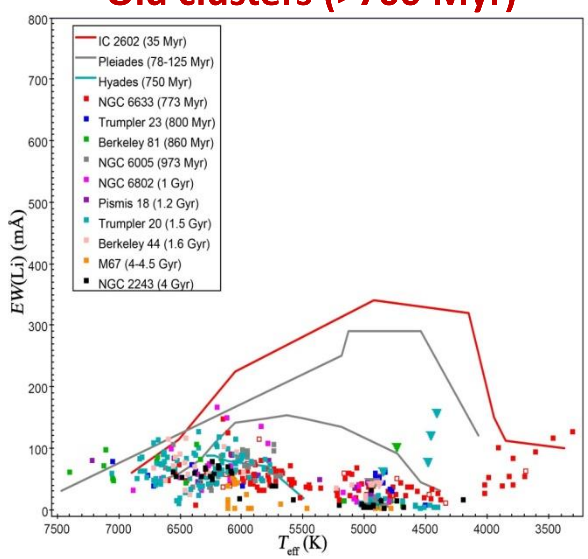
Young clusters (1-50 Myr)



Intermediate–age clusters (50-700 Myr)



Old clusters (>700 Myr)



Impact and prospects for the future

In this work we used the data provided by the iDR4 release of GES to conduct an analysis of the membership and Li abundance of the selected 20 young, intermediate and old clusters. This first publication is available on ArXiv: **The *Gaia-ESO* Survey: Calibrating the lithium-age relation with open clusters and associations. I. Cluster age range and initial membership selections (Gutiérrez Albarrán et al. 2020. A&A, accepted) (https://arxiv.org/abs/2009.00610)**

- We aim to update all the selections of cluster members and contaminants presented in this study using both the **GES iDR6 data release**, and data from **Gaia DR3**. This will also allow us to add **new clusters** to our calibration and contribute to better constrain the lithium-age relation.

- We are working on a detailed analysis of the **dependence of the lithium-age relation on other stellar parameters** derived from the GES spectroscopic observations, such as the level of chromospheric activity (Hα), accretion indicators, and rotation (*v*sin*i*), and other parameters available from the literature.

- The calibration of cluster ages is of great importance to study the **lithium-age relation**, which will allow us to derive the **ages of GES field stars**, as well as search or confirm the membership of these field stars to **young associations and stellar kinematic groups of different ages**.

- We also plan to study the unknown **Li-rich stars, and giant and non-giant outliers with Li** in the field of these clusters, which could be possible new young field stars or Li-rich giants.