A Lithium Depletion Boundary age of 40-50 Myr in NGC2232:

Implications for tests of pre-main sequence stellar evolution

A. S. Binks, R. D. Jeffries & R. J. Jackson (2021, submitted to MNRAS)

Keele University

Alex Binks
a.s.binks1@keele.ac.uk
alexbinks.github.io/astro/
Young Stars Near the Sun

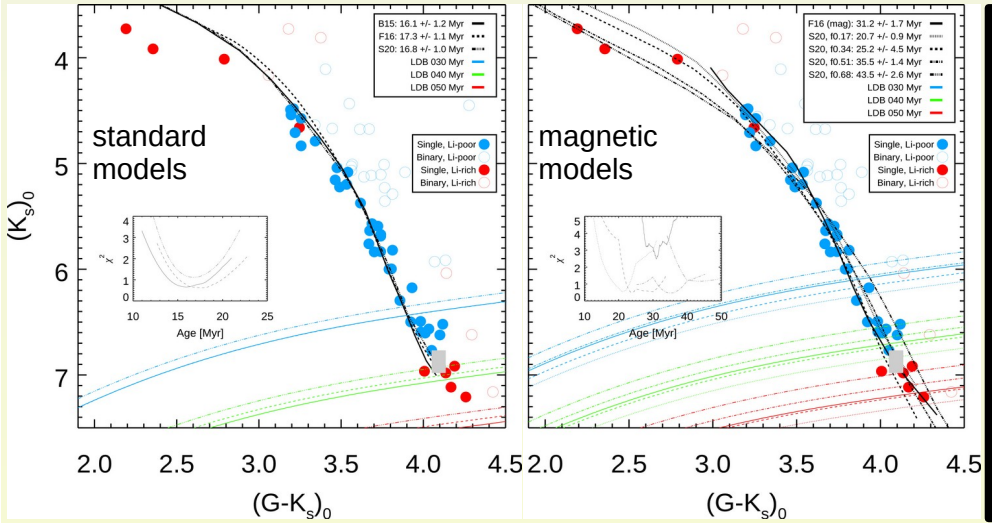
ABSTRACT: We identify a lithium depletion boundary (LDB) in the open cluster NGC2232, using spectroscopy obtained for high-probability cluster members observed in the Gaia ESO Survey[a]. Using 2 "flavours" of evolutionary models: ones that adopt standard stellar physics (SMs)[bcd] and models that incorporate some form of radius inflation either using starspots[d] or large surface magnetic fields[e] (MMs), we find that:

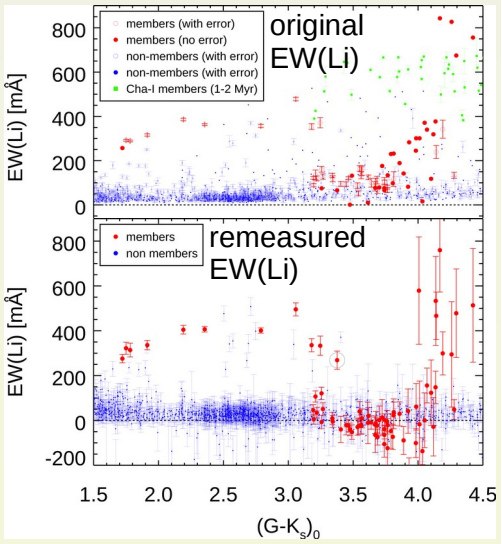
(1) LDB ages from SMs strongly agree (38±2 Myr), and those from MMs are 10-20% older, where spot-covering fraction (f_{sp}) scales with age.
(2) The isochronal ages are 2-3 times younger using the SMs, and get closer to a 1:1 agreement for heavily-spotted models.

These results show that ages determined from CMD fits are highly sensitive to the choice of model inputs[fg], radius inflation plays a key role for young low-mass stars[h], and that additional "ingredients" for models are vital to provide a full, quantitative predictive theory of pre-MS evolution.

CONTEXT: The LDB provides a potentially very accurate, highly model-insensitive way to determine the ages of young clusters[ij]. LDB ages can be used as benchmarks to calibrate ages from model-dependent methods (e.g., isochronal fits to the CMD) and empirically-derived ages (e.g., rotation, activity), allowing us to test PMS evolution[k].

LITHIUM: Li is rapidly destroyed in low-mass stars at 2.5MK. The Li equivalent width at 6708Å is used to infer how much is left. The EW(Li)/colour plot clearly shows some Li-rich low mass stars - marking the LDB, but there is an offset, likely caused from continuum placement. We remeasure EW(Li) using GES field stars to trace the continua and fit Li profiles calibrated with vsini. This "*empirical*" method fixes the offset, gives realistic errors and cleans the LDB - more Li-rich stars!





LDB ages: The LDB location is a box in the CMD between Li-rich/Li-poor stars (> or < 250mÅ). Ages are found by interpolating the luminosity at which the models predict 99% Li-depletion.
CMD ages: We fit isochrones to single stars for each model, calculating CMD ages by minimising the χ^2 fit. We find:

- MM LDB ages are 10-20% older.
- MM CMD ages are 2-3x older!
- "strong" MM CMD/LDB age → 1

Model/age	LDB	CMD
SMs	38±2	17±1
F16, magnetic	43.1±2.5	31.2±1.7
f_{sp}=17%	40.7±2.0	20.7±0.9
f_{sp}=34%	42.7±2.1	27.2±1.5
f_{sp}=51%	44.8±2.3	35.5±1.4
f_{sp}=68%	47.3±2.5	43.5±2.6

References: (a) Jackson et al. 2020, MNRAS, 496, 4701; (b) Dotter et al. 2008, ApJS, 178, 89; (c) Baraffe et al. 2015, A&A, 577, A42; (d) Somers, Cao & Pinsonneault 2020, ApJ, 891, 29; (e) Feiden 2016, A&A, 593, A99; (f); Jeffries et al. 2017, MNRAS, 464, 1456; (g) Binks et al. 2021 (*in prep.*); (h) Somers & Pinsonneault 2015, MNRAS, 449, 4131; (i) Burke, Pinsonneault & Sills 2004, ApJ, 604, 272; (j) Tognelli, Prada Moroni & Degl'Innocenti 2015, MNRAS, 449, 3741; (k) Soderblom et al. 2014, prpl.conf, 219