No evidence for intense, cold accretion on to YSOs from measurements of Li in T-Tauri stars

Darryl J. Sergison[1] (U. Exeter), **N.J. Mayne** (U. Exeter), **Tim Naylor** (U. Exeter), **R.D. Jeffries** (U. Keele), **Cameron P.M. Bell** (U. Exeter)

Please see Tim Naylor for discussion

Abstract

Models suggest that strong depletion of lithium in T Tauri stars might be evidence for the occurrence of accretion at high rates ($dM/dt > 5 \times 10^{-4}\,M_\odot\,yr^{-1}$) during their `assembly phase' prior to the T Tauri phase. In Sergison et al. (2013; **arXiv:1306.2282**) we find no evidence for unexpected lithium depletion in veiling-corrected spectra of 168 stars in NGC 2264 and the Orion Nebula Cluster. This suggests that `cold' accretion at high rates occurs in fewer than 0.5% of $0.3 < M_\star/M_\odot < 1.9$ young-stellar objects.

Motivation

Variation in early accretion rates across a stellar population is a possible explanation for the large luminosity spreads observed in apparently co-eval pre-main-sequence clusters at ages <10 Myr. Some models (see Fig. 1) predict that depleted lithium and reduced luminosity in T Tauri stars are key signatures of `cold' high-rate accretion occurring earlier in a star's formation, e.g. Baraffe & Chabrier (2010), Hosokawa et al. (2011) and Baraffe et al. (2012). We have searched for highly lithium depleted stars in the young (<10 Myr) clusters NGC 2264 and the Orion Nebula Cluster (ONC) to look for evidence that proto-stellar objects accrete at high rates during their early `assembly phase'.

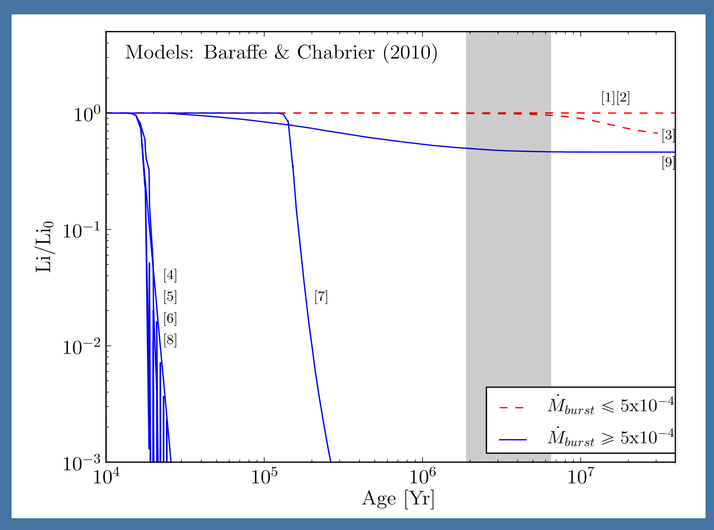

Figure 1. Accretion induced depletion of lithium from models by Baraffe and Chabrier (2010). $dM/dt > 5x10^{-4}\,M_\odot yr^{-1}$ (blue lines) is compared with those at lower rates (red dashes). The only exception (model 9) is if the initial core mass is $>0.03\,M_\odot$, which is at least an order of magnitude larger than predicted. The grey region shows the estimated age range of the clusters.

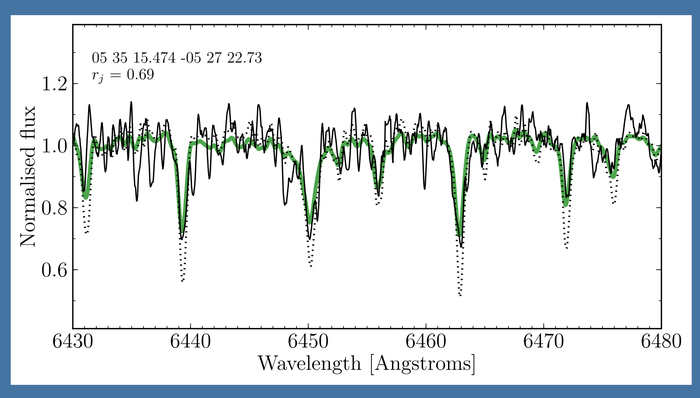

Figure 2. An example spectrum for a star in the ONC. The thin black line is the object spectrum. The dotted line is the template showing significantly deeper photospheric absorption lines. The green broad line is the appropriately broadened and veiled template that best fits the object spectrum (photospheric fraction = 59%).

Target selection and data reduction

Indicators of youth such as X-ray luminosity, Hα emission and optical variability were used in conjunction with position in colour–magnitude space to select target stars. Importantly, photometric selection did not exclude members with low luminosity. Spectra were collected using the 4.2-m WHT AF2/WYFFOS, multi object spectrograph at R~10,000, with a SNR of 20-100.

The magnitude of the accretion veiling was measured for each star using low-veiling, slowly-rotating stars from each cluster as templates. We determined the veiling using the method of Hartigan et al. (1989), assuming that the accretion spectrum is a smoothly varying continuum (see Fig. 2).

The equivalent width of the 6708 Å lithium line EW[Li] was measured with respect to a pseudo-continuum and corrected for accretion veiling using our measured values. Accurate unveiling of spectroscopic binaries is a very difficult and uncertain process, so these points have been left in their raw measured (veiled) values and are used as lower limits in EW[Li]. All data and spectra are available from the Cluster Collaboration webpages: (www.astro.ex.ac.uk/people/timn/Catalogues/)

Results

Veiling corrected lithium equivalent widths for the stars in our studied clusters are plotted in Fig. 3 as a function of $(V - I_c)_0$ colour. Model isochrones are also plotted for comparison. It is clear that no stars show lithium depletion beyond that predicted for <10 Myr clusters.

We also find that the dispersion in the strength of the 6708 Å lithium line might imply an age spread that is similar in magnitude to the apparent age spread implied by the luminosity dispersion seen in colour–magnitude diagrams. We are unable to determine whether age spreads or accretion at rates less than $5\times10^{-4}\,M_\odot yr^{-1}$ might be responsible for this dispersion.

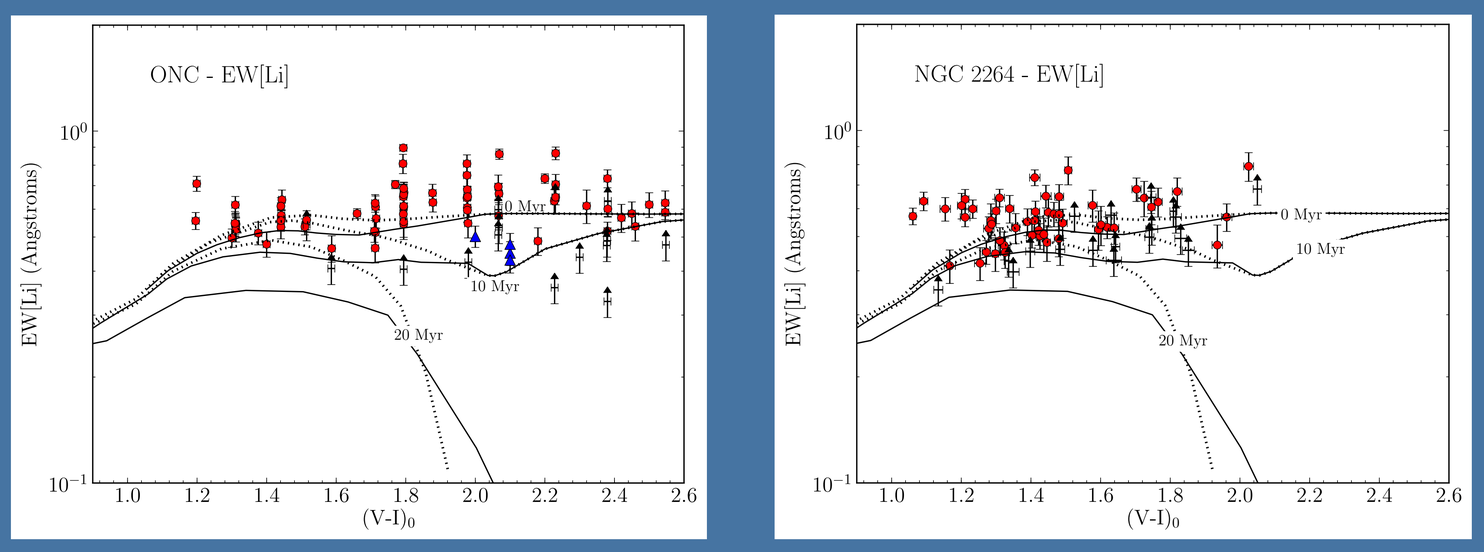

Figure 3. A comparison of EW[Li] as a function of intrinsic $(V - I_c)_0$. The red points are unveiled single star measurements, black triangles are lower limits for spectroscopic binaries which are left as veiled (raw) measurements. Blue triangles are the most depleted stars found by Palla et al (2005). Isochrones are based on Interior models by Baraffe et al. (2002), T_{eff} to $(V - I_c)_0$ from Kenyon & Hartmann (1995) and curves of growth from Jeffries et al. (2003). Solid lines indicate models that use a convective mixing length parameter (α) of 1.9. The dotted lines indicate α = 1.0.

Conclusions

- **No evidence** is found in 168 stars for lithium depletion beyond that expected from non-accreting models.
- Cold accretion with burst rates of $dM/dt \geq 5\times10^{-4}\,M_\odot yr^{-1}$ is **unlikely** to have occurred in >99.5% of $0.3 \leq M_\star/M_\odot \leq 1.9\,M_\odot$ stars.

Acknowledgements and Contact

DJS is funded by a UK Science and Technology Facilities Council (STFC) studentship. The authors wish to thank Isabelle Baraffe for providing cold accretion models and useful discussions. Spectra were processed using the AF2 pipeline developed by Richard Jackson.

1 - darryl@astro.ex.ac.uk **Darryl J Sergison,** School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK.

References

Baraffe I., Chabrier G., Allard F., Hauschildt P. H., 2002, A&A, 382, 563
Baraffe I., Chabrier G., 2010, A&A, 521, A44
Baraffe I., Vorobyov E., Chabrier G., 2012, ApJ, 756, 118
Hartigan P., Hartmann L., Kenyon S., Hewett R., Stauffer J., 1989, ApJS, 70, 899
Hosokawa T., Offner S. S. R., Krumholz M. R., 2011, ApJ, 738, 140
Jeffries R. D., Oliveira J. M., Barrado y Navascue´s D., Stauffer J. R., 2003, MNRAS, 343, 1271
Kenyon S. J., Hartmann L., 1995, ApJS, 101, 117
Palla F., Randich S., Flaccomio E., Pallavicini R., 2005, ApJ, 626, L49
Sergison Darryl J., Mayne N. J., Naylor Tim, Jeffries R. D., Bell Cameron P.M., MNRAS accepted, 2013arXiv1306.2282S.