Extreme depletion of light elements in late F stars

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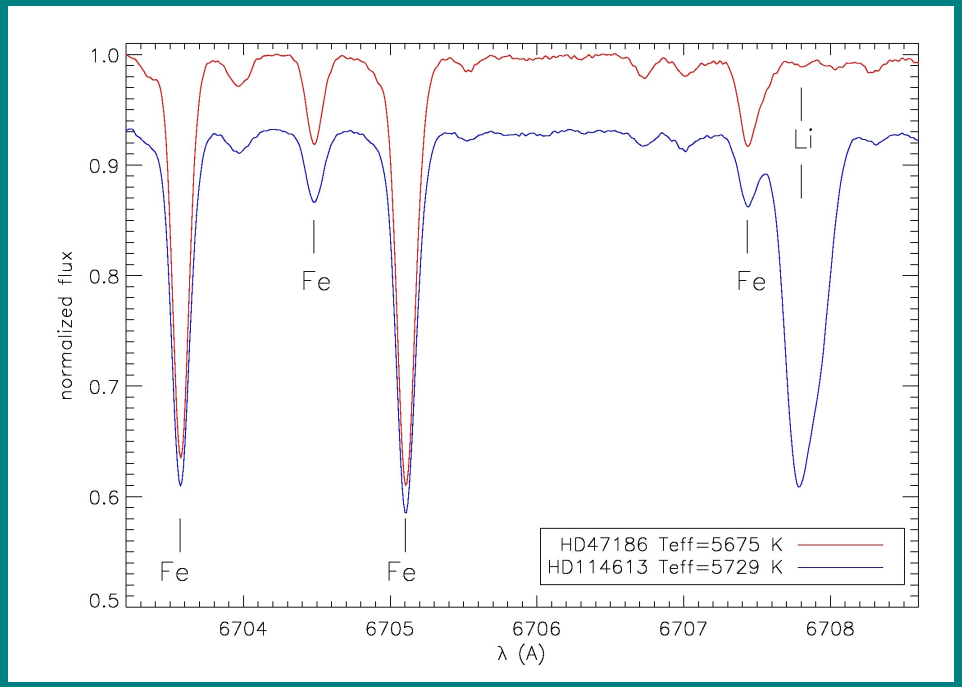
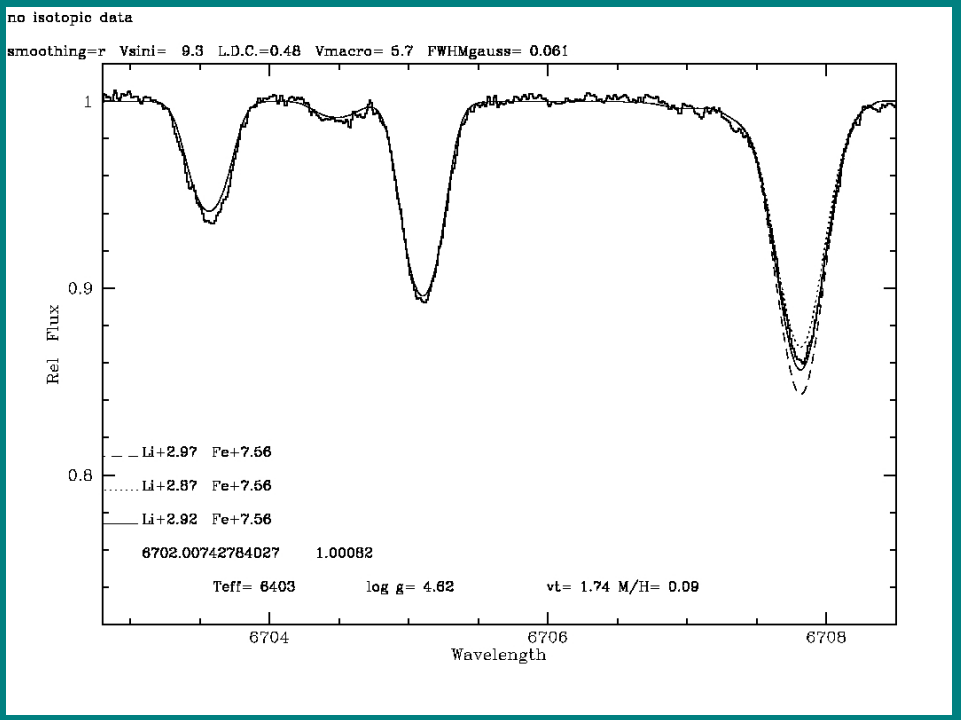
The importance of light elements

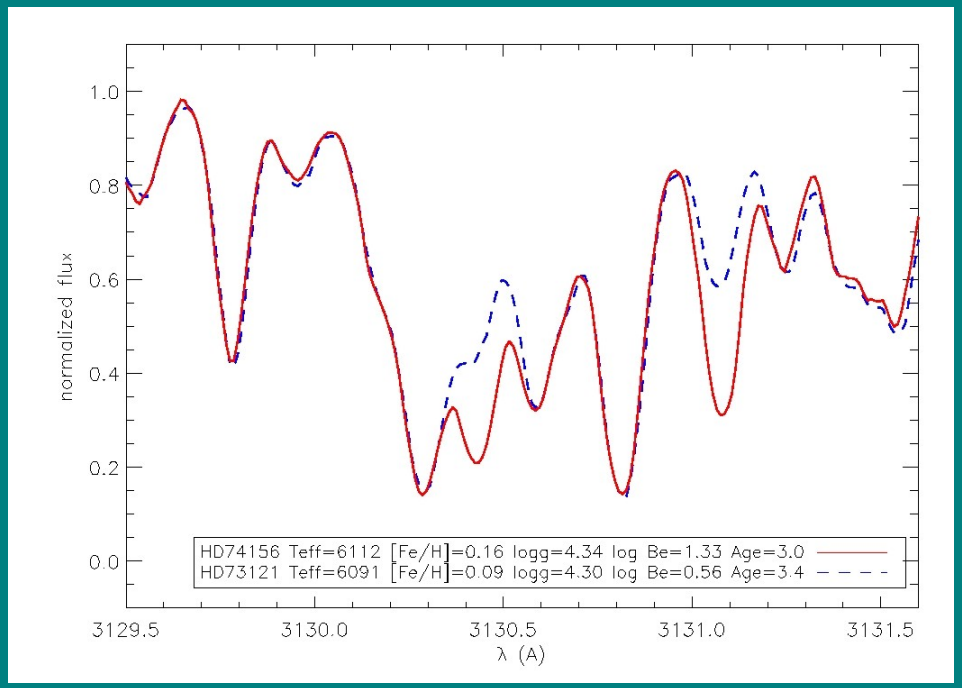
Light elements provide information regarding the distribution and mixing of matter within a star since they can be destroy by (p,α)-reactions at different temperatures:

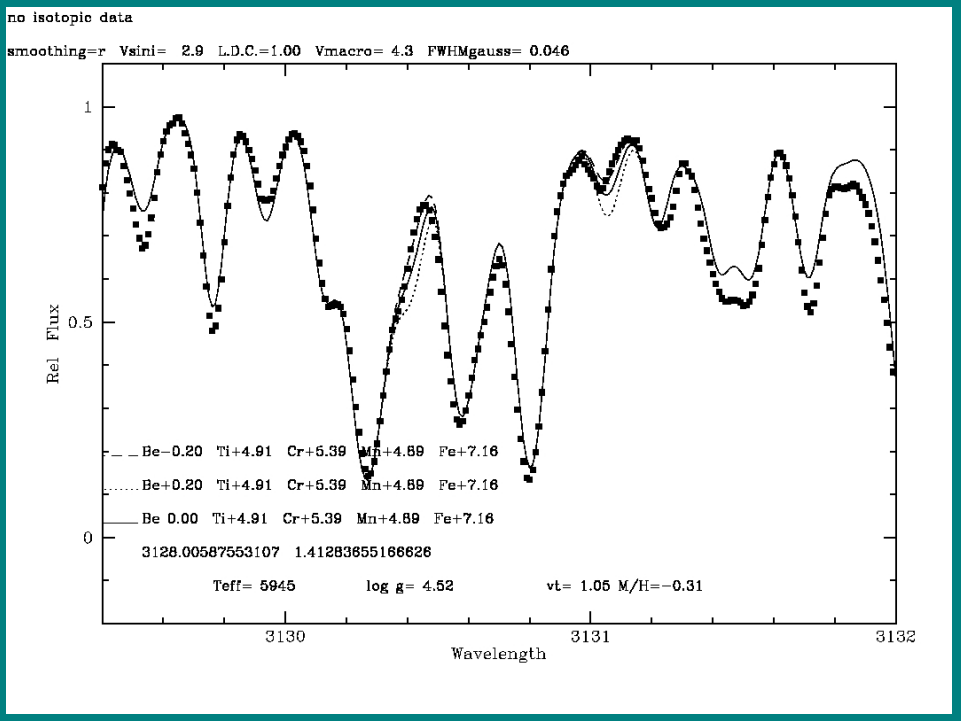
Lithium: 2.5 million K
Beryllium: 3.5 million K
Boron: 5.0 million K

This depletion takes place primarily during the early evolution but light elements can also be destroyed in stellar envelopes during the Main Sequence if any mixing process exists.


normalized flux
λ (A)
Fe
Fe
Fe
Li
HD47186 Teff=5675 K
HD114613 Teff=5729 K


no isotopic data
smoothing=r Vsini= 9.3 L.D.C.=0.48 Vmacro= 5.7 FWHMgauss= 0.061
Rel Flux
Wavelength
Li+2.97 Fe+7.56
Li+2.87 Fe+7.56
Li+2.92 Fe+7.56
6702.00742784027 1.00082
Teff= 6403 log g= 4.62 vt= 1.74 M/H= 0.09

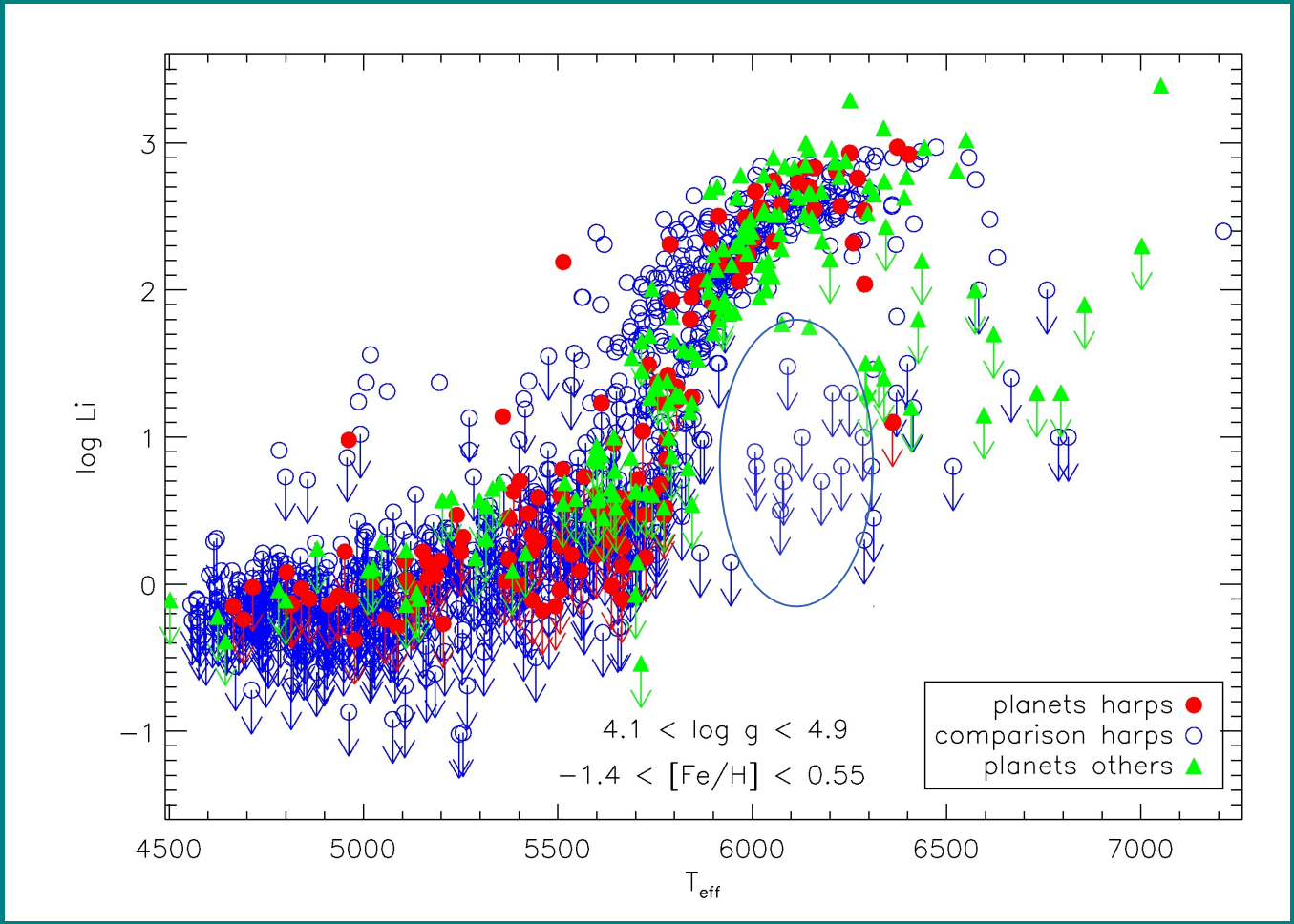

normalized flux
λ (A)
HD74156 Teff=6112 [Fe/H]=0.16 logg=4.34 log Be=1.33 Age=3.0
HD73121 Teff=6091 [Fe/H]=0.09 logg=4.30 log Be=0.56 Age=3.4


no isotopic data
smoothing=r Vsini= 2.9 L.D.C.=1.00 Vmacro= 4.3 FWHMgauss= 0.046
Rel Flux
Wavelength
Be-0.20 Ti+4.91 Cr+5.39 Mn+4.89 Fe+7.16
Be+0.20 Ti+4.91 Cr+5.39 Mn+4.89 Fe+7.16
Be 0.00 Ti+4.91 Cr+5.39 Mn+4.89 Fe+7.16
3128.00587553107 1.41283655166626
Teff= 5945 log g= 4.52 vt= 1.05 M/H=-0.31

HARPS GTO sample:

Homogeneous stellar parameters (Sousa et al. 2008, 2011ab; Santos et al 2005, Mortier et al. 2013)

134 stars with planets
993 comparison stars
135 extra planet hosts



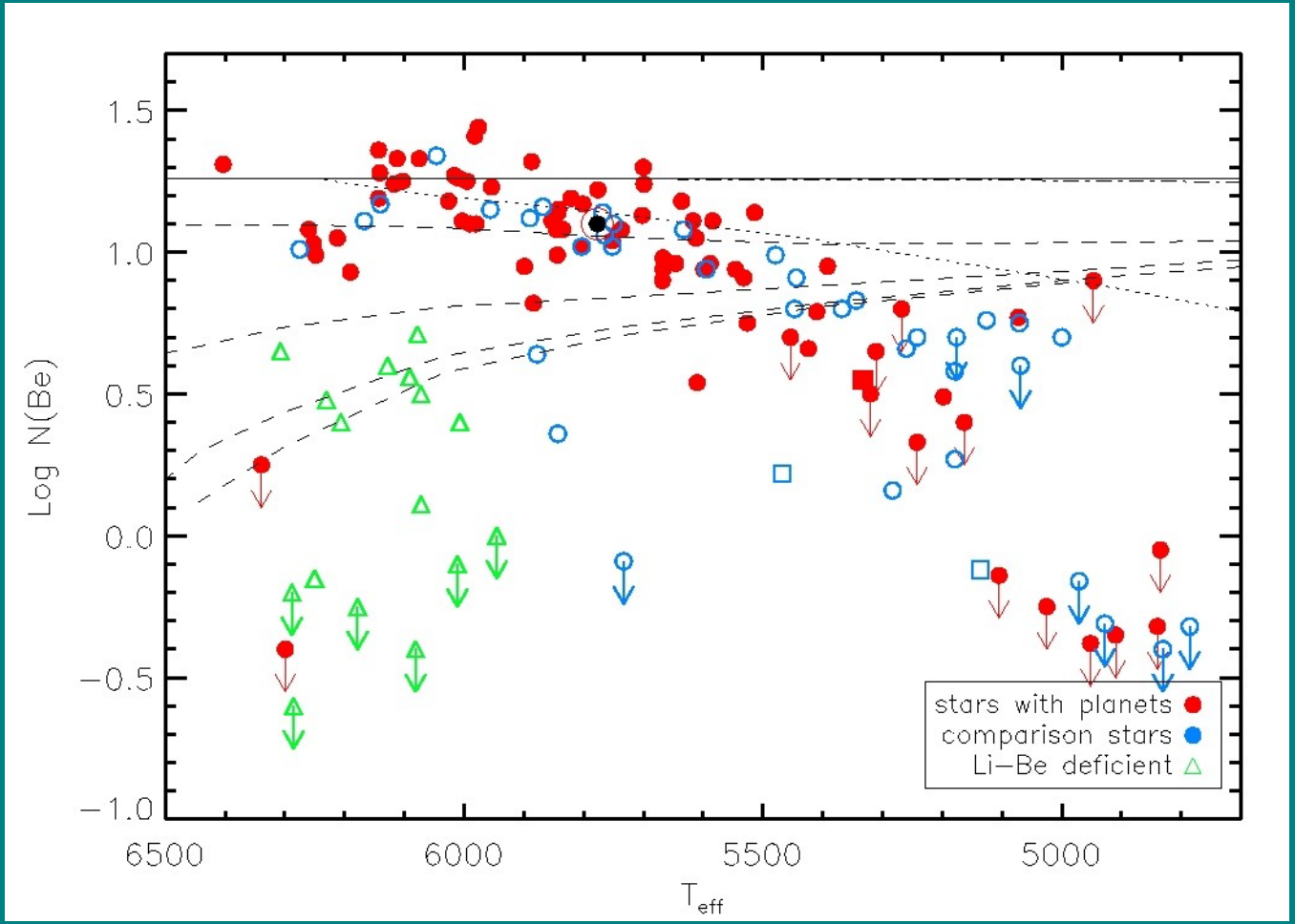
~7% of stars in 5900-6300K with Li upper limits

Possible contamination of evolved stars from the Li dip

Be observations in period 93

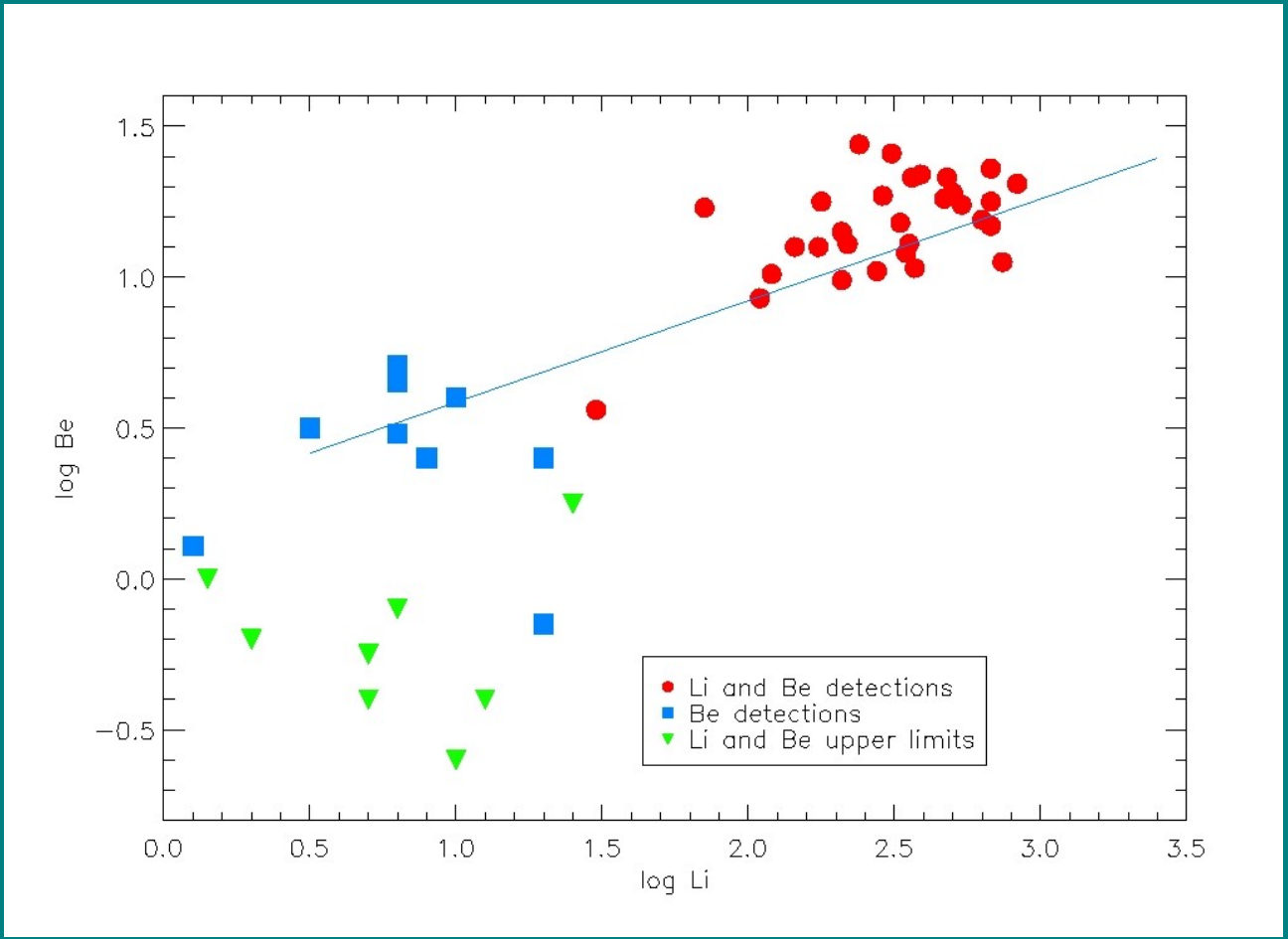
Previous measurements from Santos et al. 2002,2004; Galvez-Ortiz et al. 2011, Delgado Mena et al. 2011, 2012

Models of Be depletion from Pinsonneault 1990



Li/Be depletion relation for the range 5900-6400K

- 30 stars with Be and Li detections
- 9 stars with detections of Be and limits of Li
- 8 stars with Li and Be limits



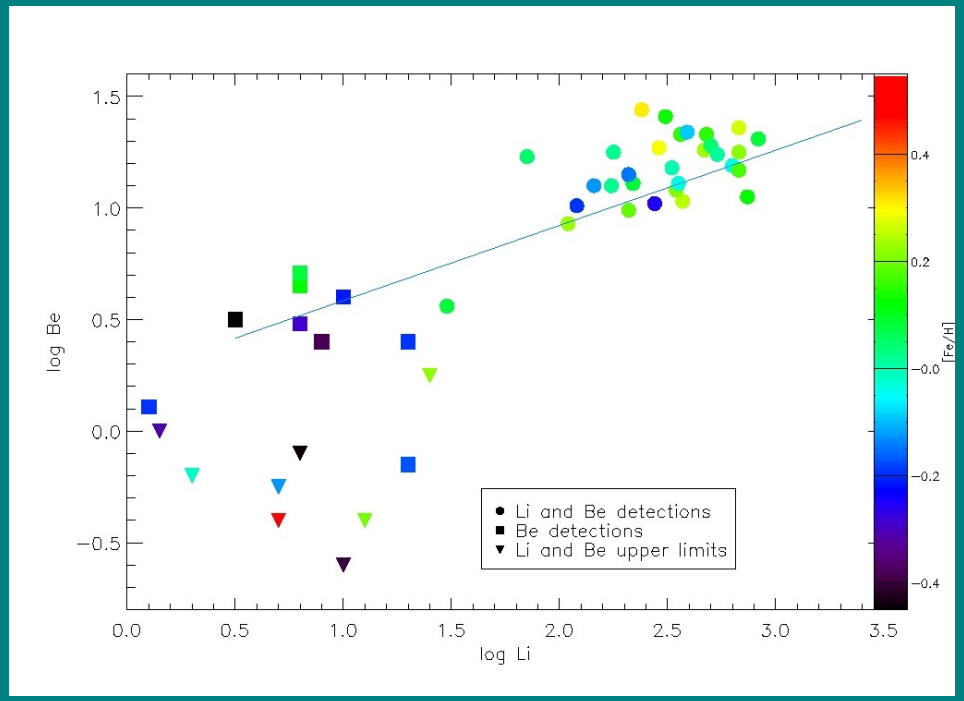
Some mechanisms to explain the Li dip (extension to lower temperatues)

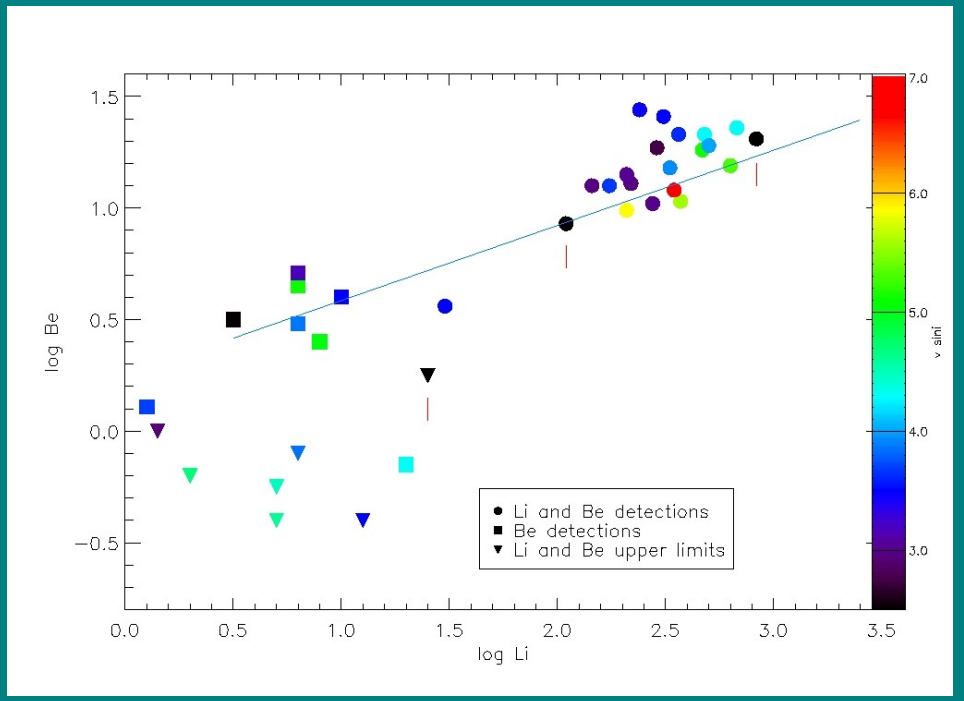
- Mass loss: reduction of the Li preservation region BUT all Li should be destroyes before Be depletion takes place

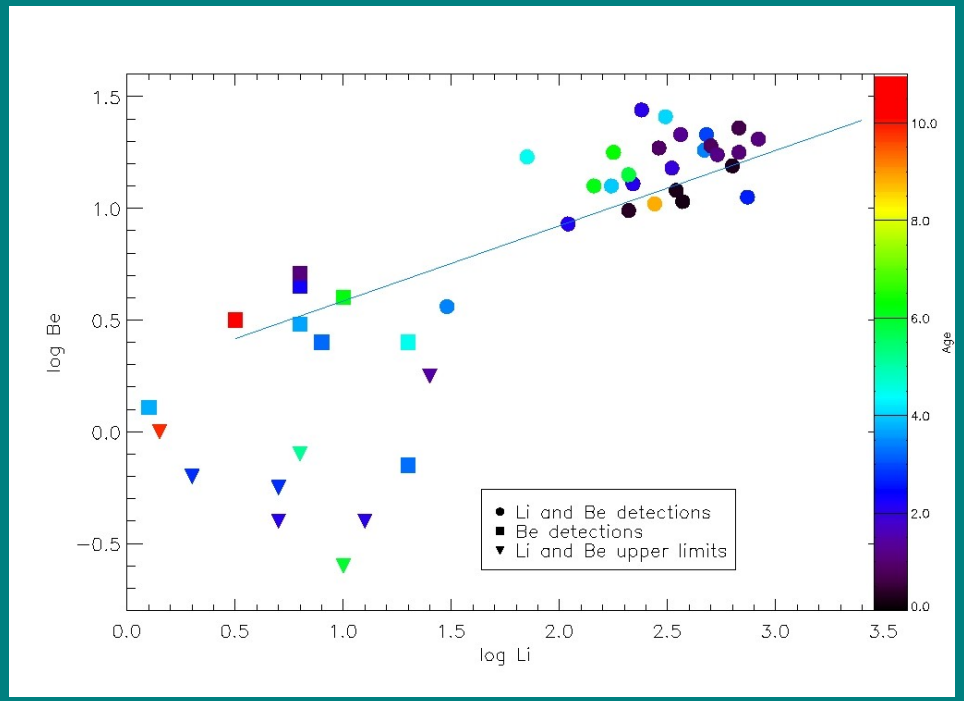
- Difussion: sink of fully ionized species by thermal difussion and gravitational settling BUT Li and Be should deplete at the same rate for $T_{eff} < 6600K$

- Rotationally induced mixing: matches the pattern of Li/Be depletion but doesn't predict as much depletion as observed

Combination of several mechanisms...

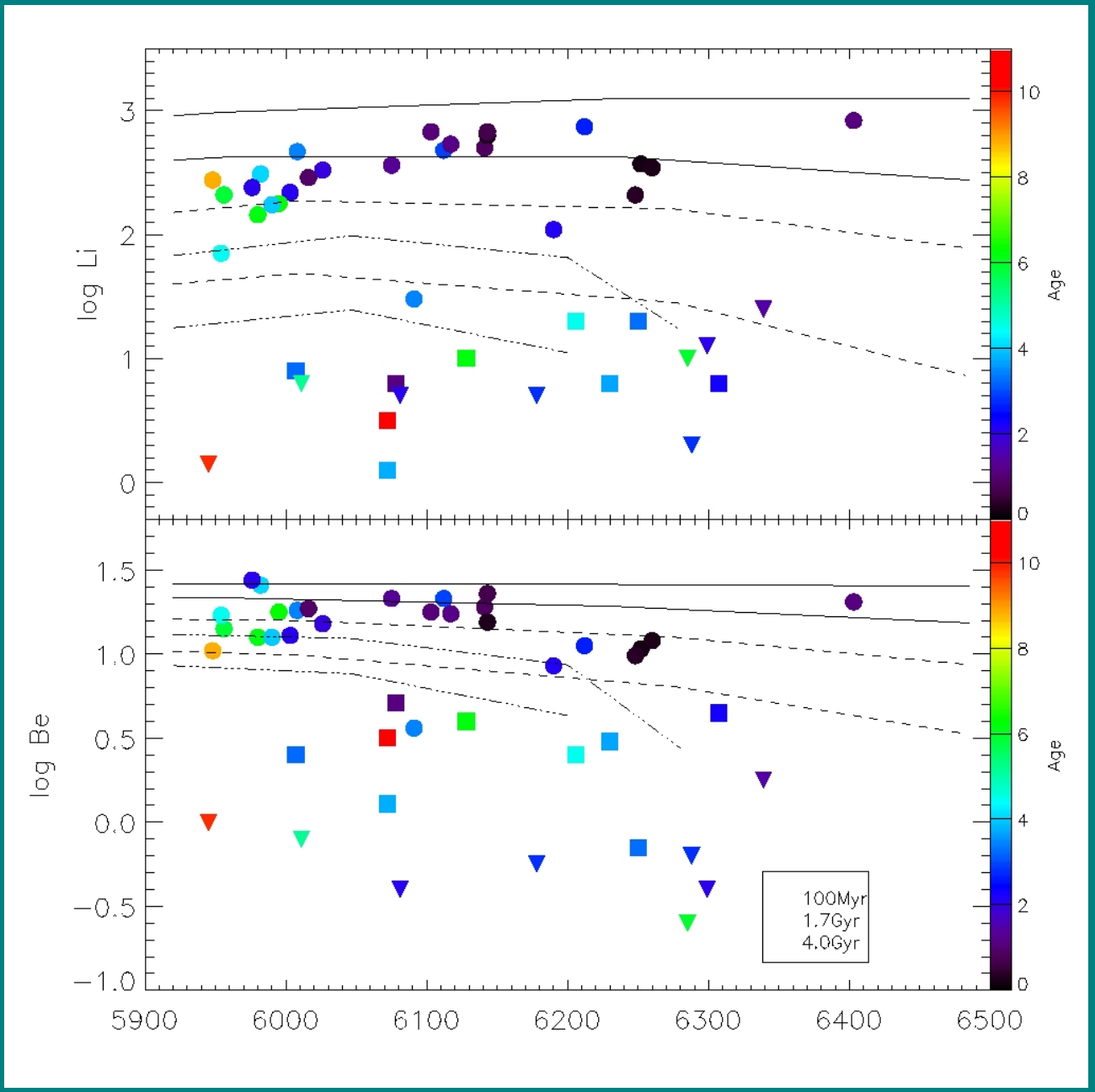






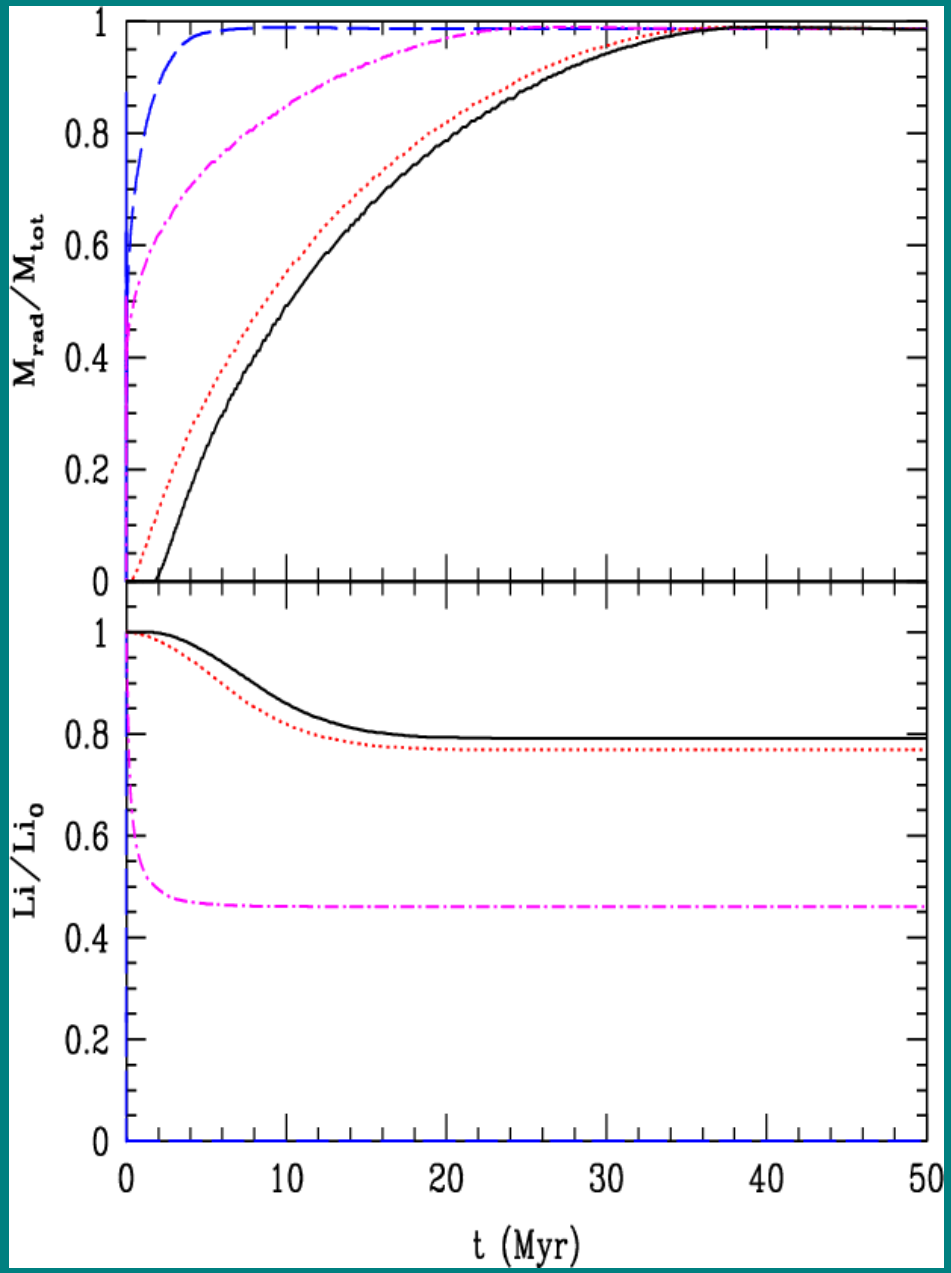
Be-Li detections <vsini>=4.5
Be detections <vsini>=3.9
Li-Be limits <vsini>=5.5

HD120136: vsini=14.2 km/s
HD142: vsini=9.3 km/s
HD19994: vsini=8.2 km/s



Models of Li and Be depletion from Deliyannis & Pinsonneault 1997 for initial rotation of 10 and 30 km/s

Accretion effects



Models of Baraffe & Chabrier 2010

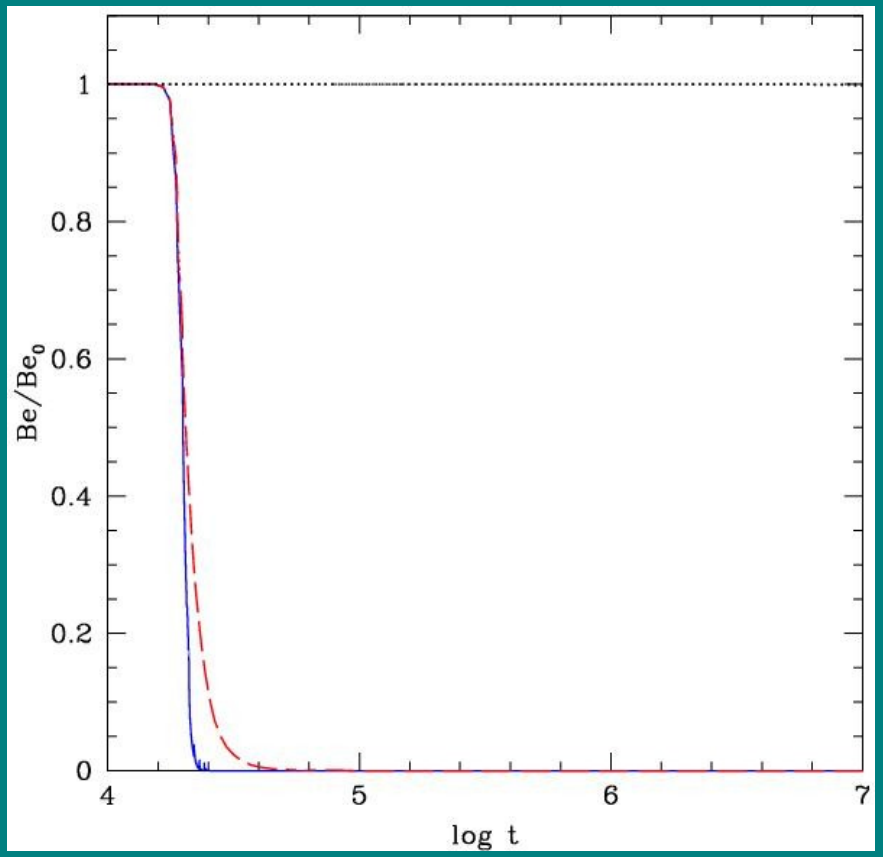
Long-dash blue: Li is entirely depleted in the model with M_{init}=10M_{Jup} in less than 1 Myr (Nburst=20)

dash-dot (magenta): M_{init}= 30M_{Jup}, N burst=20

dot (red): Minit= 0.1M_sun, Nburst=18
All calculations are done with accretion rates of 5X10^{-4} M_{sun}/yr, Δt_{burst}=100 yr and a Δt_{quiet}=1000 yr.

The solid line (black) corresponds to the evolution of a non accreting 1 M_{sun} star.

Accretion effects



Models of Viallet & Baraffe 2012

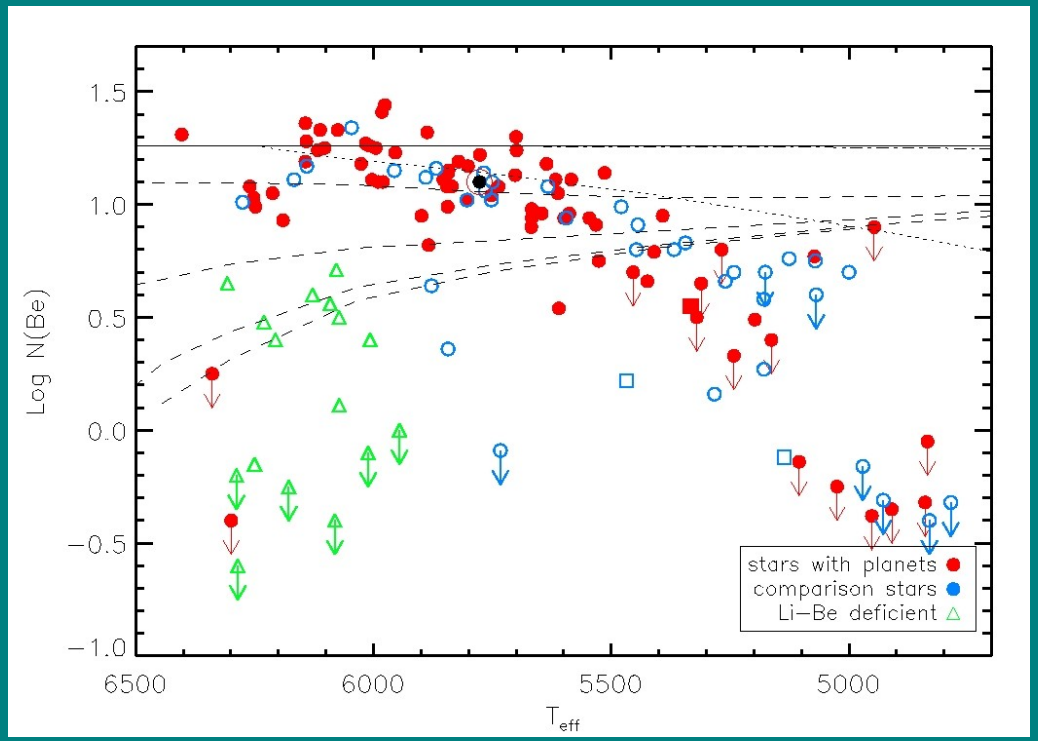
$M_{init}=10_{MJup}$, $5X10^{-4}$ M_{sun}/yr, Δt_{burst}=100 yr and a Δt_{quiet}=1000 yr

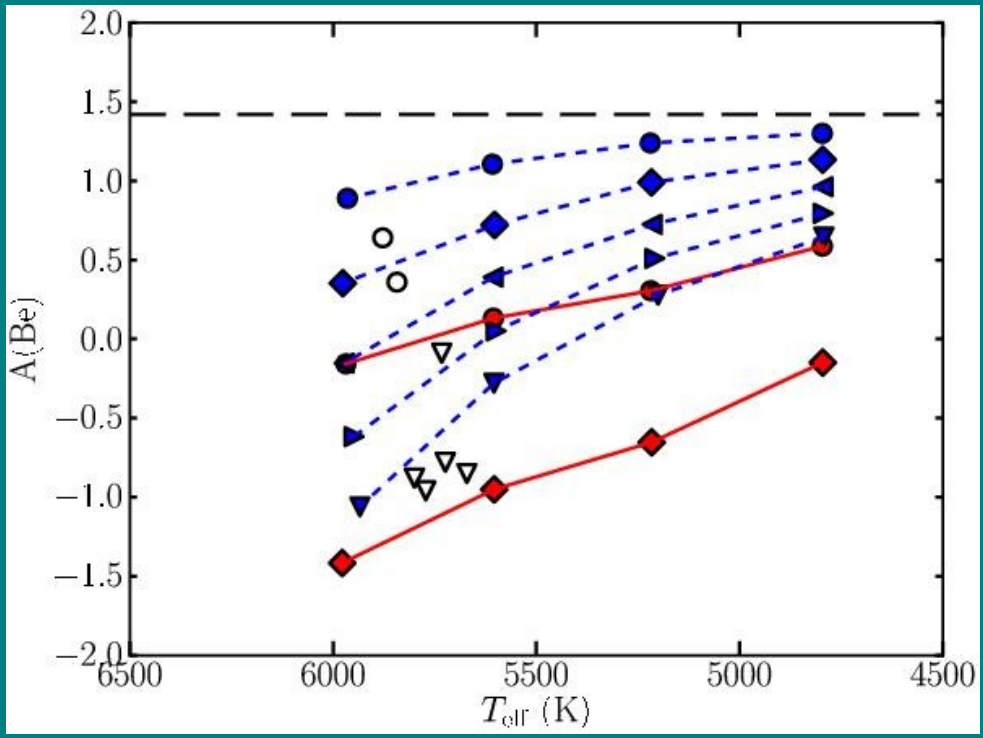
blue: Nburst=20, final mass $1M_{sun}$

red: Nburst=16, final mass 0.8 M_{sun}

The solid line (black) corresponds to the evolution of both non accreting 1 M_{sun} and 0.8 M_{sun} stars.

Rotationally induced mixing





Models of Be depletion from Viallet & Baraffe 2012
1.7 Gyr, initial period 1.2 days, and disk lifetimes of 1 Myr (red) and 5 Myr (blue)
Short disk lifetimes--> lower probability to form planets

Different effects of rotation

- Slower rotators at the ZAMS produce more Li depletion (differential rotation due to star-disk coupling, Bouvier 2008)

- Faster rotators in the Pleiades have higher Li abundances (Soderblom 1993)

- Faster rotation in the MS produces more rotationally induced mixing (Pinsonneault 1997) and thus Li depletion

CAUTION: different effect of rotation on Li abundances during the PMS and MS (Somers & Pinsonneault 2014, effect of radius inflation) and between stars less and more massive than the Sun--> rotational history of the star

Future prospects within GES

- Study of Li and vsini in field stars and clusters of different ages

- Search for Li and Be deficient stars at early stages of evolution
--> probe of extreme depletion (revise membership analysis?)