Galactic Evolution of 7Li

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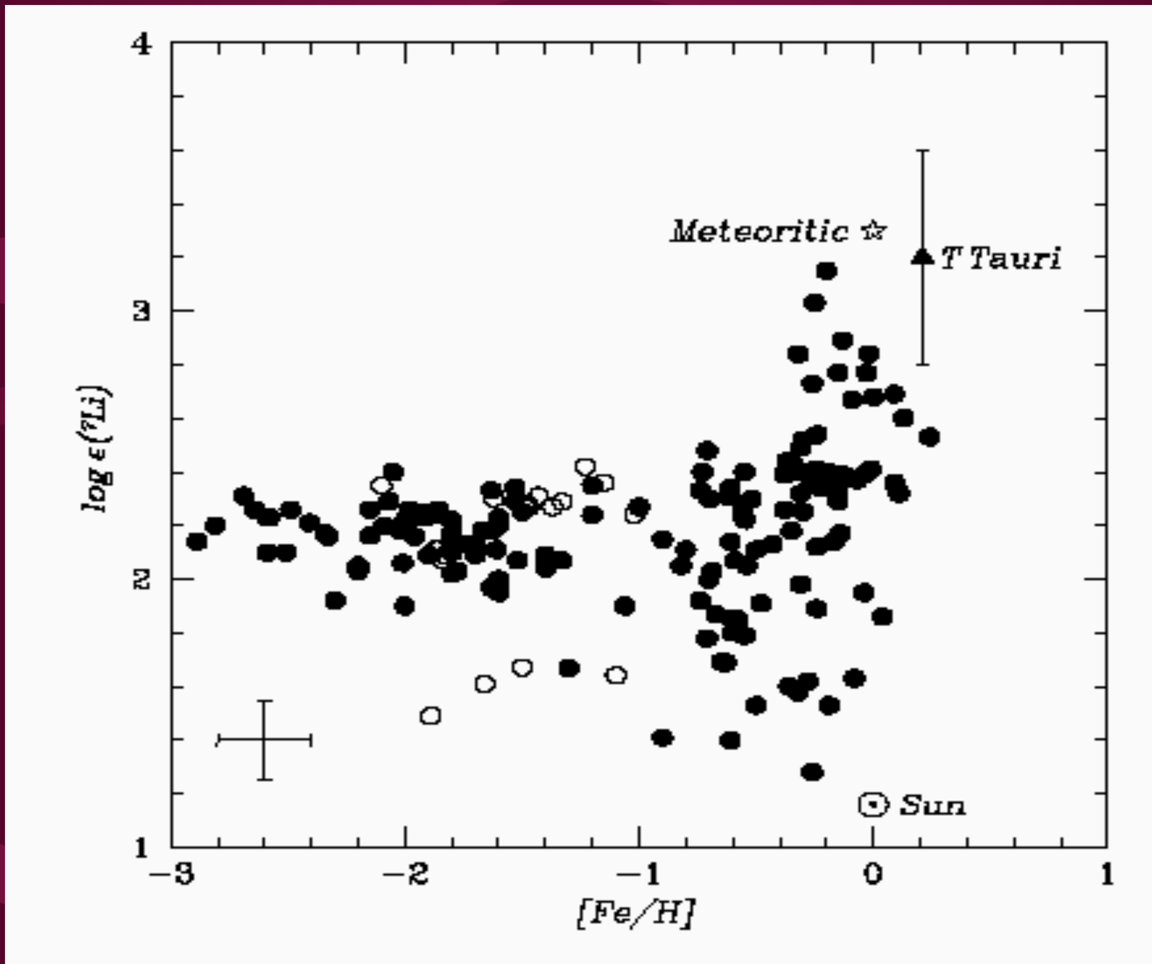
Talk Overview

- Lithium production: Big Bang, stars and cosmic rays
- Galactic chemical evolution of 7Li
- Comparison theory-observations
- What we have learned and still open problems

LogN(Li) vs. [Fe/H]



LogN(Li) vs.[Fe/H]:Spite plateau

- Most low metallicity ([Fe/H]<-1.5) field stars with 6300K>Teff> 5500K have nearly the same surface 7Li abundance (Spite & Spite 1982), the “Spite plateau”
- This led to suggest that the 7Li abundance of Pop II stars, independent of mass and metallicity, is the primordial one

Meaning of LogN(Li) vs. [Fe/H]

- Since 7Li is destroyed inside stars (T>2.5 millions K), only the upper envelope of this diagram is representative of 7Li in the interstellar medium
- Pop II stars have a roughly constant logN(Li)= 2.0-2-3 (Spite plateau) ten times lower than in young stars (Pleiades) and in meteorites (logN(Li)=3.3)
- Two possible interpretations: i) Pop II stars 7Li is the primordial one and 7Li in young *s has been produced by stars and cosmic rays, ii) the 7Li in young *s is primordial and has been depleted in Pop II *s

7Li in the Big Bang

- A primordial LogN(Li)=3.3 would imply a non-standard BBN
- In this case astration of 7Li should have occurred during galactic evolution reducing the 7Li abundance to that of the Spite plateau
- Standard BBN before WMAP results was compatible with a primordial LogN(Li)=2.1-2.3 as measured in the Spite plateau (Bonifacio & al. 2002), but see Ryan & al. (1996)
- WMAP suggests LogN(Li)=2.72

7Li production in stars

- There is only one way to produce 7Li during normal stellar evolution by means of the reaction 3He(alpha,gamma)7Be
- But 7Be must be fastly transported by convection into regions of lower temperature where it decays into 7Li by k-capture (Cameron & Fowler, 1971)

7Li from spallation

- Big Bang produces 7Li, 6Li is produced by galactic cosmic rays (Reeves 1994)
- 6Li detected in low metallicity stars (Asplund & al. 04,05) thus suggesting that also some of the original 7Li in the same stars comes from GCRs
- 7Li production from GCRs has been considered in chemical evolution models

Stellar Li producers

- K giants and M supergiants are Li rich indicating that 7Li is produced by AGB stars and perhaps low mass giants
- Novae can be also 7Li producers as suggested first by Starrfield et al. (1978)
- Supernovae II can also produce 7Li by neutrino-induced nucleosynthesis (Woosley & al. 1990)

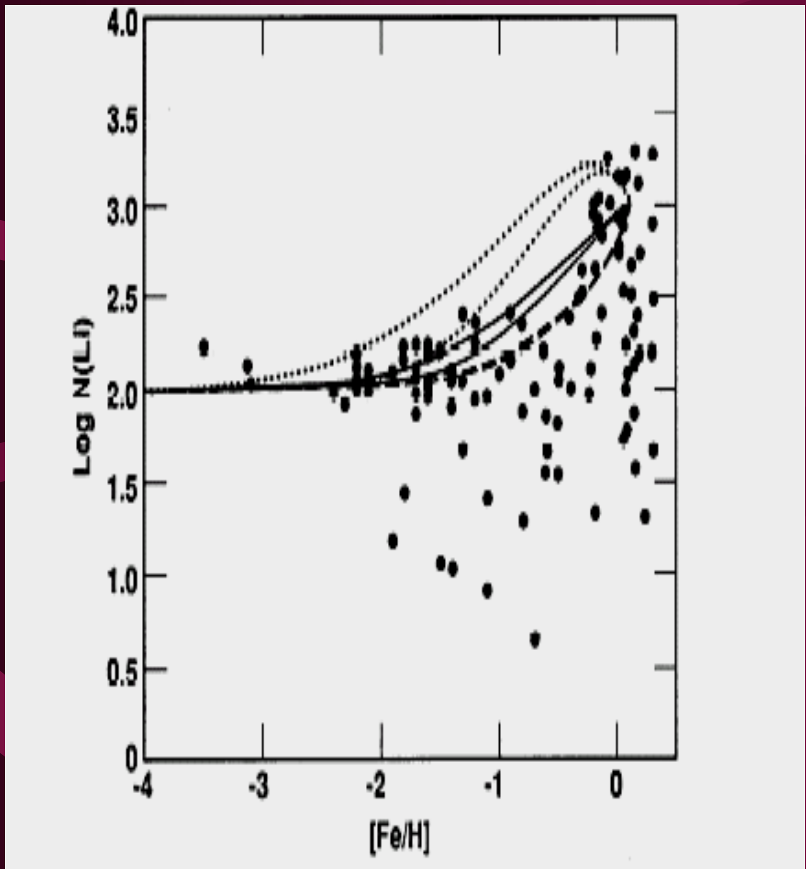
Chemical Evolution Models

- Chemical evolution models for the Milky Way aimed at reproducing the upper envelope of the LogN(Li) vs. [Fe/H] diagram were presented in the past years (Mathews & al. 91; D'Antona & FM 91; FM & al. 95; Romano & al. 99, 01,03; Ryan &al.01;Travaglio & al. 01)
- They predict the evolution of the abundances of 7Li and Fe in the ISM in the Galaxy by making specific assumptions about the SFR, IMF, stellar yields, stellar lifetimes, infall/outflow

Chemical Evolution Models:basic equations

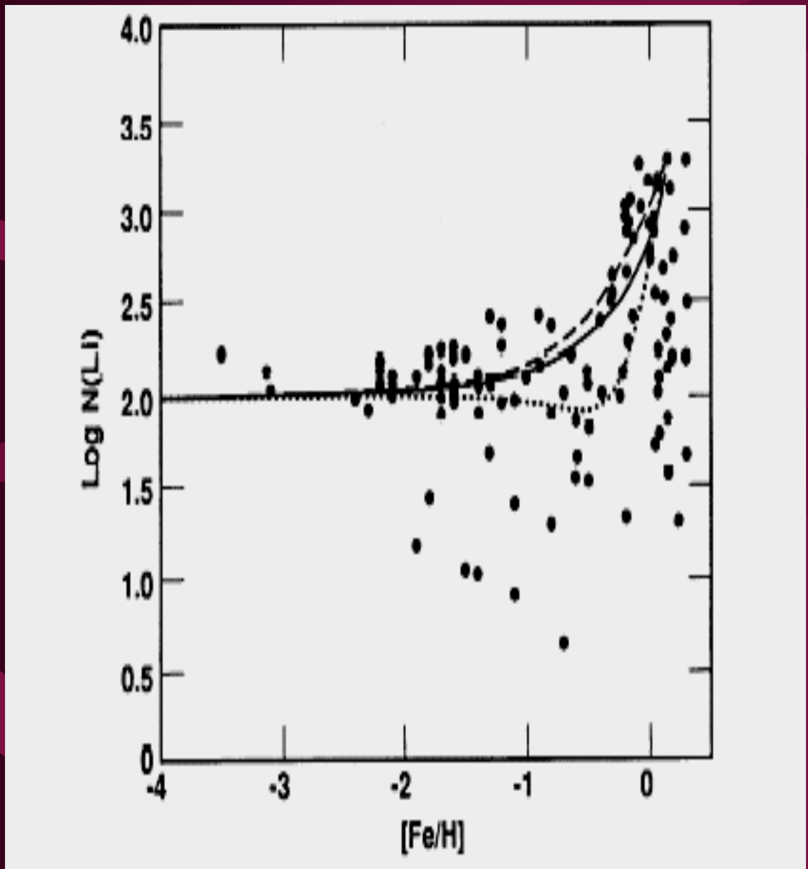
$$\dot{G}_i(t) = -\psi(t)X_i(t)$$
$$+ \int_{M_L}^{M_{Bm}} \psi(t-\tau_m)Q_{mi}(t-\tau_m)\phi(m)dm$$
$$+A \int_{M_{Bm}}^{M_{BM}} \phi(m)$$
$$\cdot[\int_{\mu_{min}}^{0.5} f(\mu)\psi(t-\tau_{m2})Q_{mi}(t-\tau_{m2})d\mu]dm$$
$$+B \int_{M_{Bm}}^{M_{BM}} \psi(t-\tau_m)Q_{mi}(t-\tau_m)\phi(m)dm$$
$$+ \int_{M_{BM}}^{M_U} \psi(t-\tau_m)Q_{mi}(t-\tau_m)\phi(m)dm$$
$$+X_{A_i}A(t) - X_iW(t)$$

Low or high primordial 7Li? (Mathews et al. 1990)



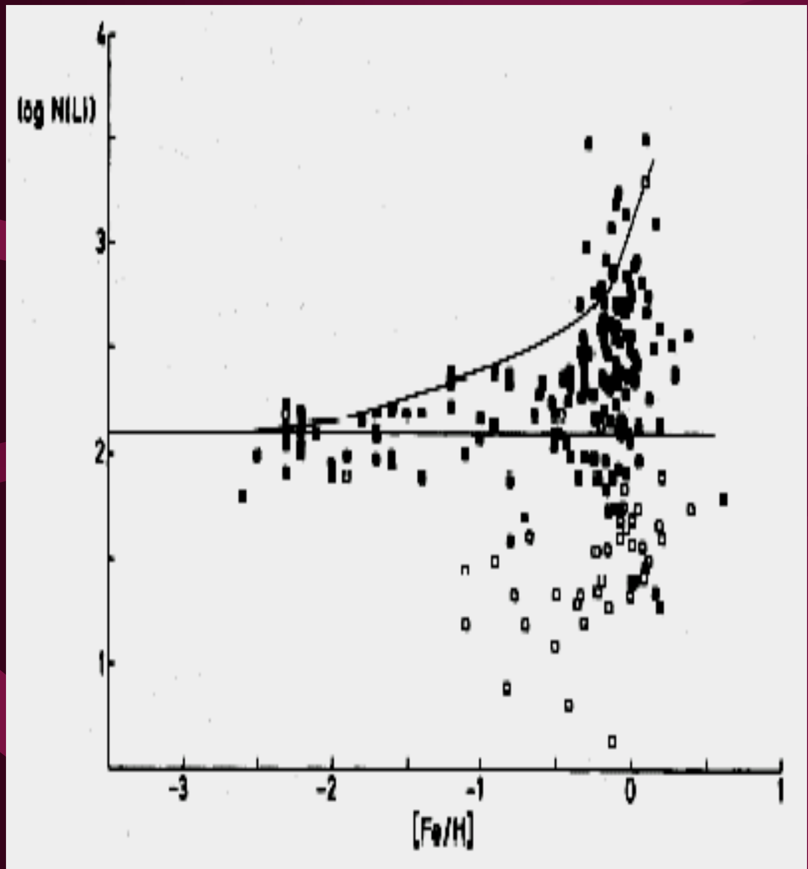
- The various curves are for different SFRs
- The models begin with a low primordial 7Li which is enhanced by supernova (upper curves) or carbon stars (lower curves)
- Data from Rebolo & al. (1988)

Low or high primordial 7Li?



- Here the models start with a high 7Li abundance and then 7Li is destroyed in main sequence
- Mathews & al. could not distinguish among the two possibilities
- Why the 7Li in the plateau is constant?

Novae and AGBs

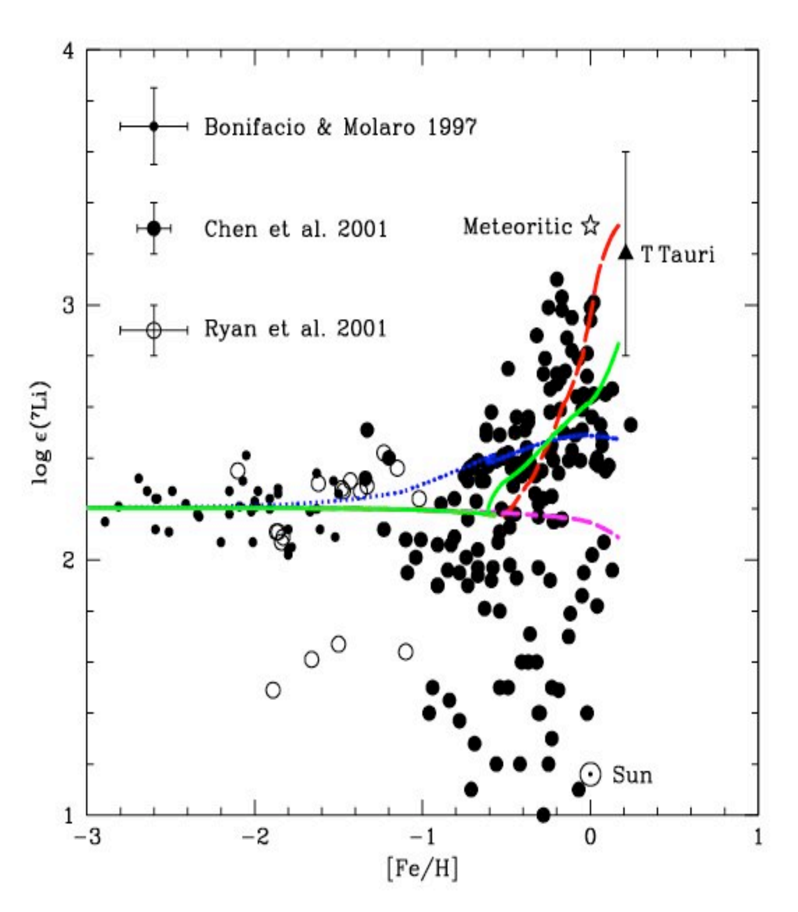


- D'Antona & Matteucci (1991) assumed that the primordial 7Li is that of Pop II *s, and that 7Li is produced in AGBs and novae
- Novae could well explain the steep rise of 7Li for [Fe/H] > -1.0, since they appear only for t>1Gyr
- Galactic model already tested on the MW

Nucleosynthesis prescriptions in DM91

- For 7Li produced by novae, DM91 assumed that the rate of nova formation is proportional to the WD formation rate and that there are roughly 10^4 nova outbursts during the life of a nova
- Time-delays for the 7Li production of several Gyr were predicted, not before [Fe/H]=-0.5
- DM91 then assumed that the mass of 7Li produced by a nova could vary from 10^(-8) to 10^(-5) Msun based on Starrfield & al. 's (1978) models, 50% of the total 7Li production

Various 7Li sources



- Magenta line are AGB
- Green line are novae
- Blue dotted line are SNeII
- Long dashed red line are low mass giants
- Again novae and low mass giants are important for the steep rise at [Fe/H] >-1.0 (Romano & al. 2001)

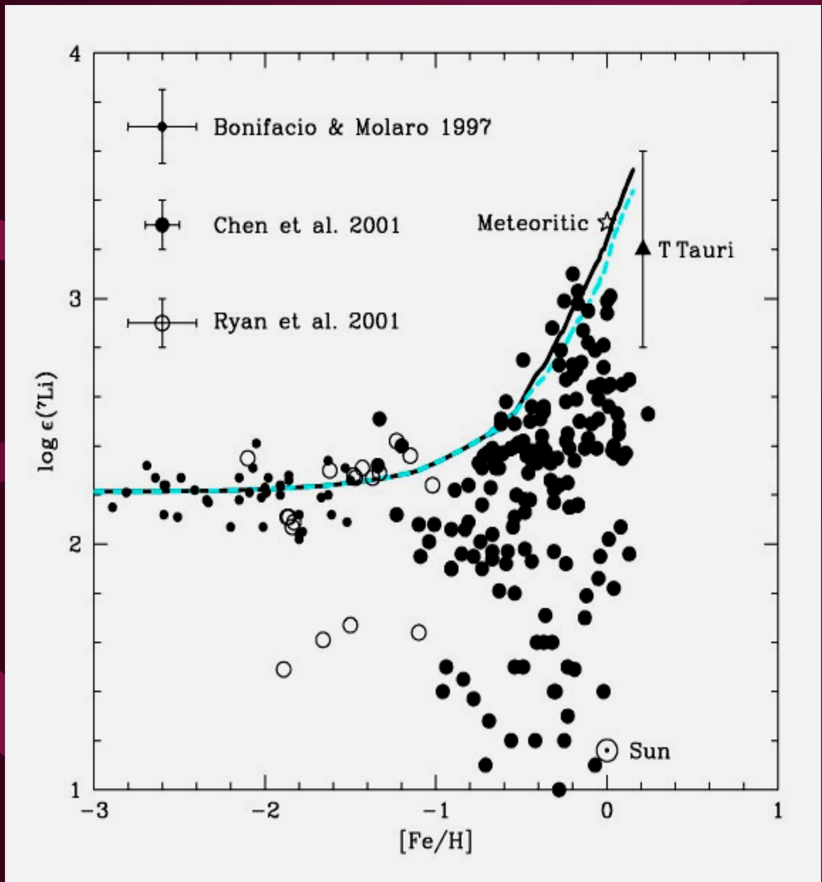
7Li prescriptions

- Low mass giants (M<2.5 Msun) are assumed to produce 7Li enrichment in the upper part of the RGB, between the first dredge-up and the tip, coupled with mass loss (de la Reza et al. 2000). Each star is assumed to produce logN(Li)=4.0!
- Classical novae yields from Jose' & Hernanz (1998) (less 7Li than in DM91)
- Supernovae II produce 7Li in the He-shell: excitation of He by mu and tau neutrinos followed by de-excitation with emission of a n or p which react with He and form 7Li (Woosley&Weaver 95)

7Li prescriptions

- 7Li from massive AGB (4-6Msun) stars has been suggested from observations and theory (Smith & Lambert, 1989,90: Sackmann & Boothroyd 1992).
- Ventura & al. (1998) computed 7Li yields from AGBs but their contribution is low
- GCRs yields from Lemoine et al. (1988)

Total 7Li production (Romano & al. 2001)

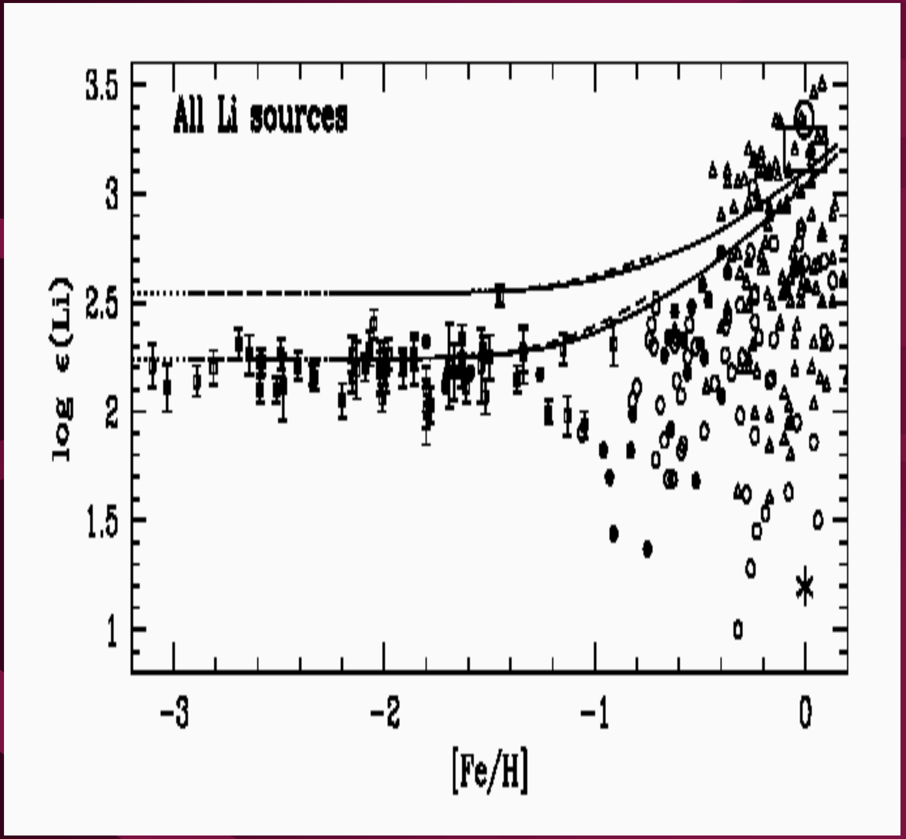


- Here we show the total 7Li production during galactic evolution, by summing the contributions of novae, C-stars, AGB and supernovae (dashed line)
- The contribution of cosmic rays to 7Li (no more than 25%) is shown (black continuous line)

Conclusions of Romano & al. (2001)

- AGB stars are not important contributors to 7Li galactic enrichment (0.5%)
- Novae contribute 18%
- Type II SNe contribute 9%
- Low mass giants contribute 41%
- GCRs contribute 25%
- One or more sources contributing with time delay are necessary to explain the steep rise

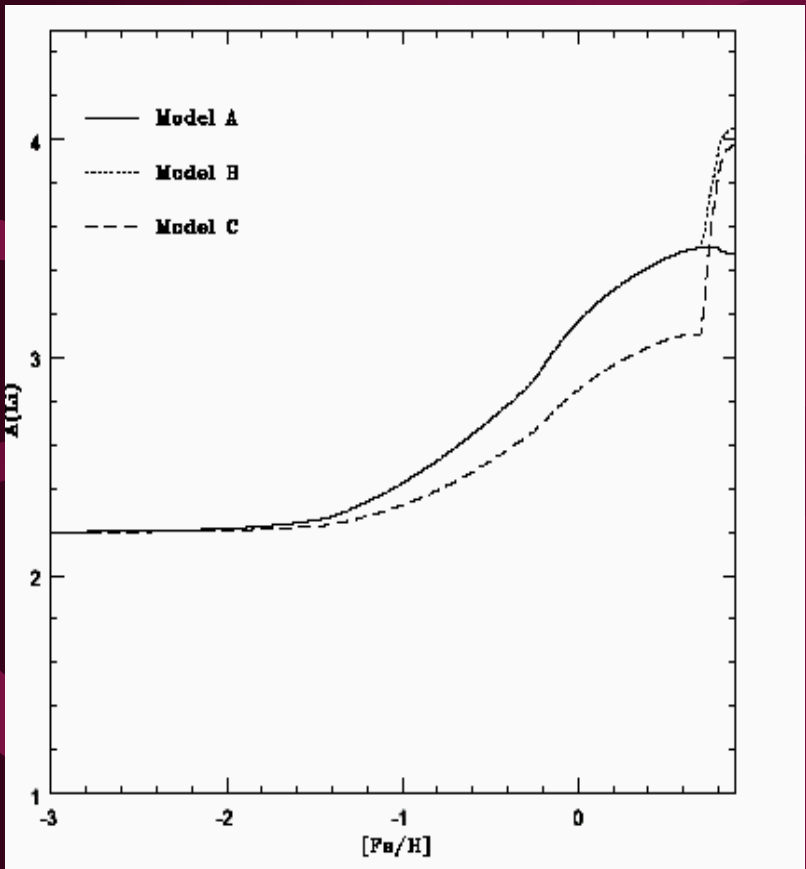
Higher 7Li yields from AGB (Travaglio & al. 2001)



- The most important contribution to 7Li enrichment here is from superwind phase in AGB

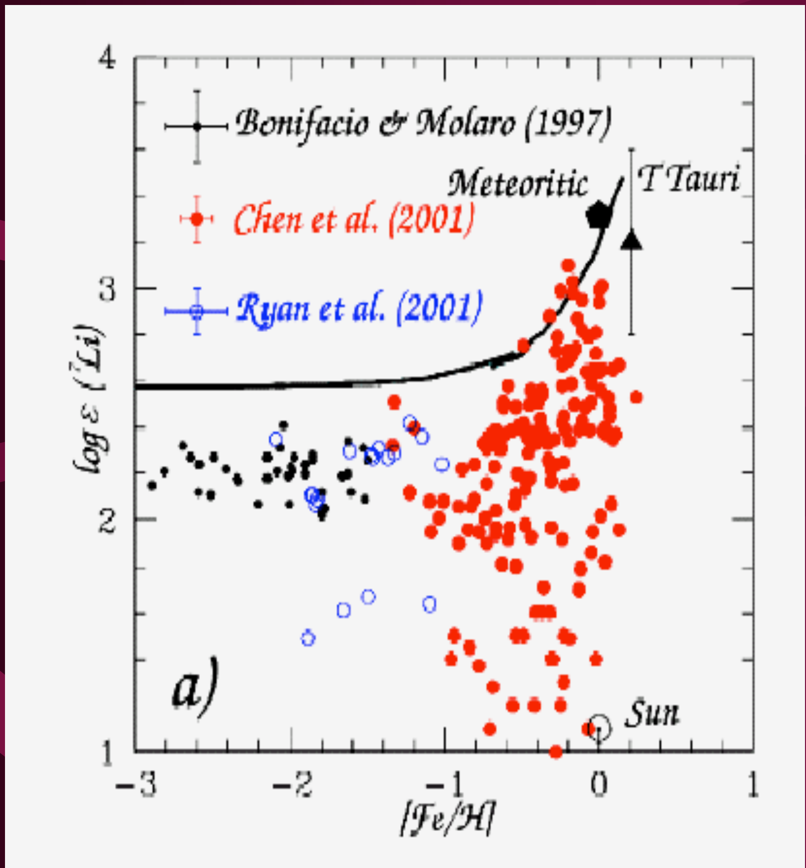
- Small contributions from novae, SNe and low mass giants are also present

Predicted 7Li in the Bulge



- Romano & al. (1999) applied a model with 7Li production from AGB, novae, C stars, SNeII to the galactic Bulge
- Different models: model C has no C-stars and less Li from SNeII. Model A does not have novae
- Predicted 7Li in the Bulge (4.0) is higher than in the S.V. due to the higher SFR

The WMAP results



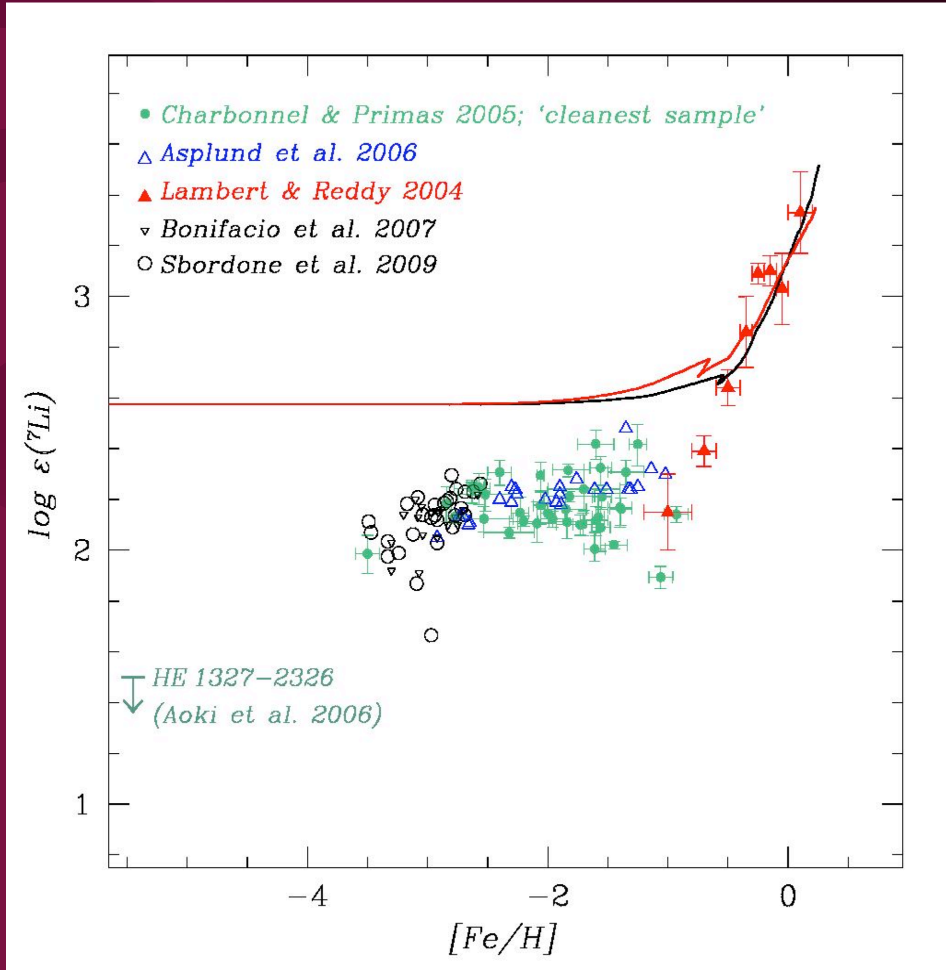
- The primordial 7Li suggested by WMAP is LogN(Li)=2.6 (Spergel & al. 03), more recent value 2.72, higher than the Spite plateau (2.1-2.3) but not as high as the PopI 7Li
- A significant 7Li depletion is necessary in Pop II stars
- Model Romano & al. (2001)

7Li astration in Pop II stars

- WMAP results imply a reduction of the 7Li surface abundance by a large factor during the evolution of *s with [Fe/H] < -1.5. This depletion is measured in GCs (Korn & al. 2006)
- The 7Li abundance of Pop II *s can be reproduced by assuming gravitational settling in the presence of weak turbulence (Richard & al. 2005, see also Melendez & al. this conference). But conflict with 6Li detection in PopII *s

Newer data and model

- Models starting from the WMAP primordial 7Li value (red line new model, black line model of Romano et al. 01)
- 7Li sources are novae, SNeII, and super-AGB*s (7-9 Msun) producing Li only after [Fe/H] >-1.0 (Ventura & D'Antona, in preparation)
- Li variation in the Spite plateau (Spite, this conf.)



What have we learned about 7Li

- The 7Li yields available in the literature contain still uncertainties but we have learned that a delayed 7Li source is necessary to reproduce the steep rise from the Spite plateau

- Novae, low mass giants or massive AGB*s, these latter acting only for high metallicities, can be a solution

Still open problems

- 7Li yields in low & intermediate mass stars and novae need further study. Possible detection of 7Li in novae only from Della Valle & al. (2002). No detection in SNe
- Is 7Li astration in Pop II *s the real solution to the WMAP primordial Li?
- A measure of 7Li in the ISM of SMC lower than WMAP value (Howk & al.'s poster) supports a low primordial Li