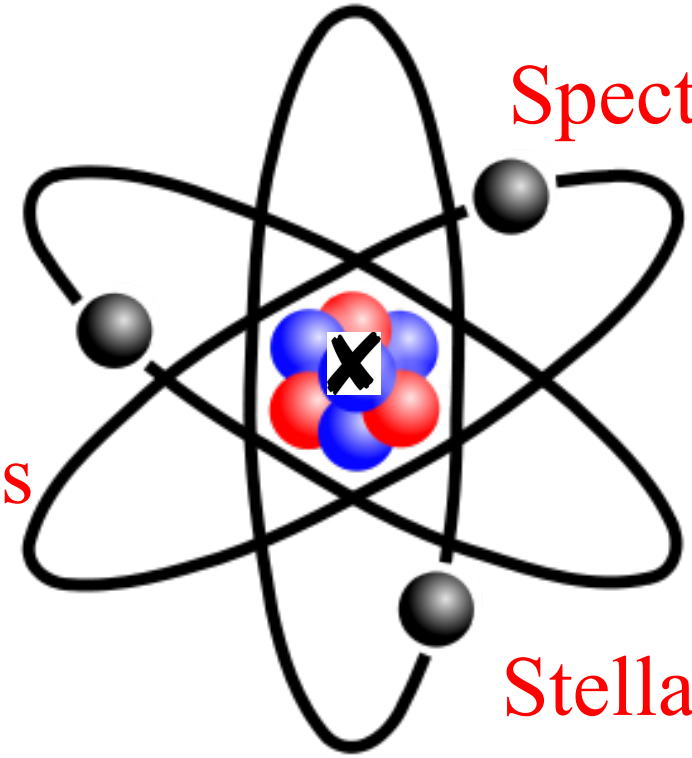
Li isotopes in halo stars

Spectral line formation

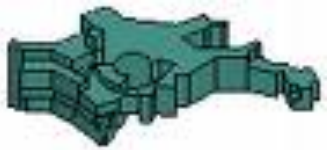


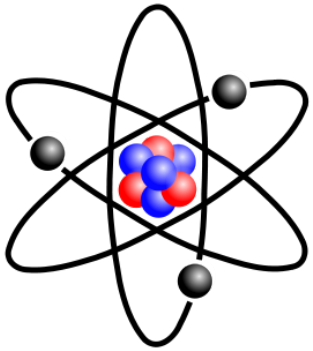
Big Bang nucleosynthesis

Stellar evolution

Karin Lind, MPA Garching

In collaboration with Martin Asplund, Corinne Charbonnel, Remo Collet, Frank Grundahl, Jorge Meléndez & Francesca Primas





Outline

- ^{7}Li surface evolution in metal-poor globular clusters
  - **Has ^{7}Li been depleted? YES MAYBE NO**

- Measuring ^{6}Li in three metal-poor halo stars
  - **Has ^{6}Li been detected? YES MAYBE NO**

Outline

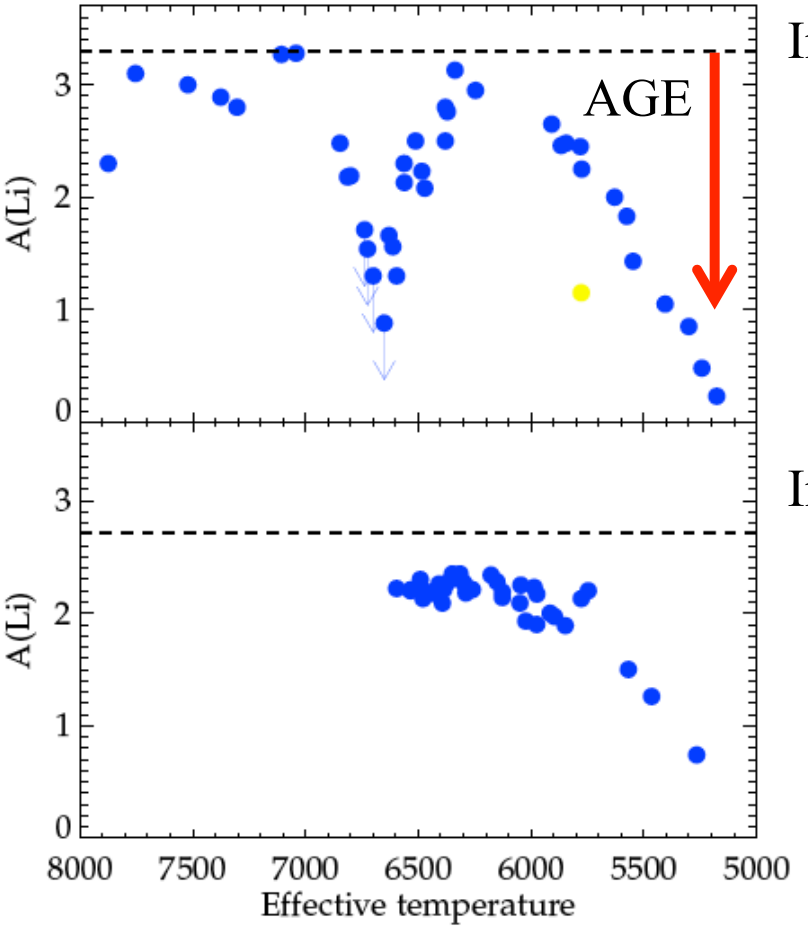
Said about the cosmological Li problems:

”There is too little of one of them and too much of the other, right?”

Li depletion in Pop I & II

Hyades
0.7Gyr
[Fe/H]~0

Halo field
13Gyr
[Fe/H]~-2



Initial A(Li)~3.3?

Initial A(Li)~2.7?

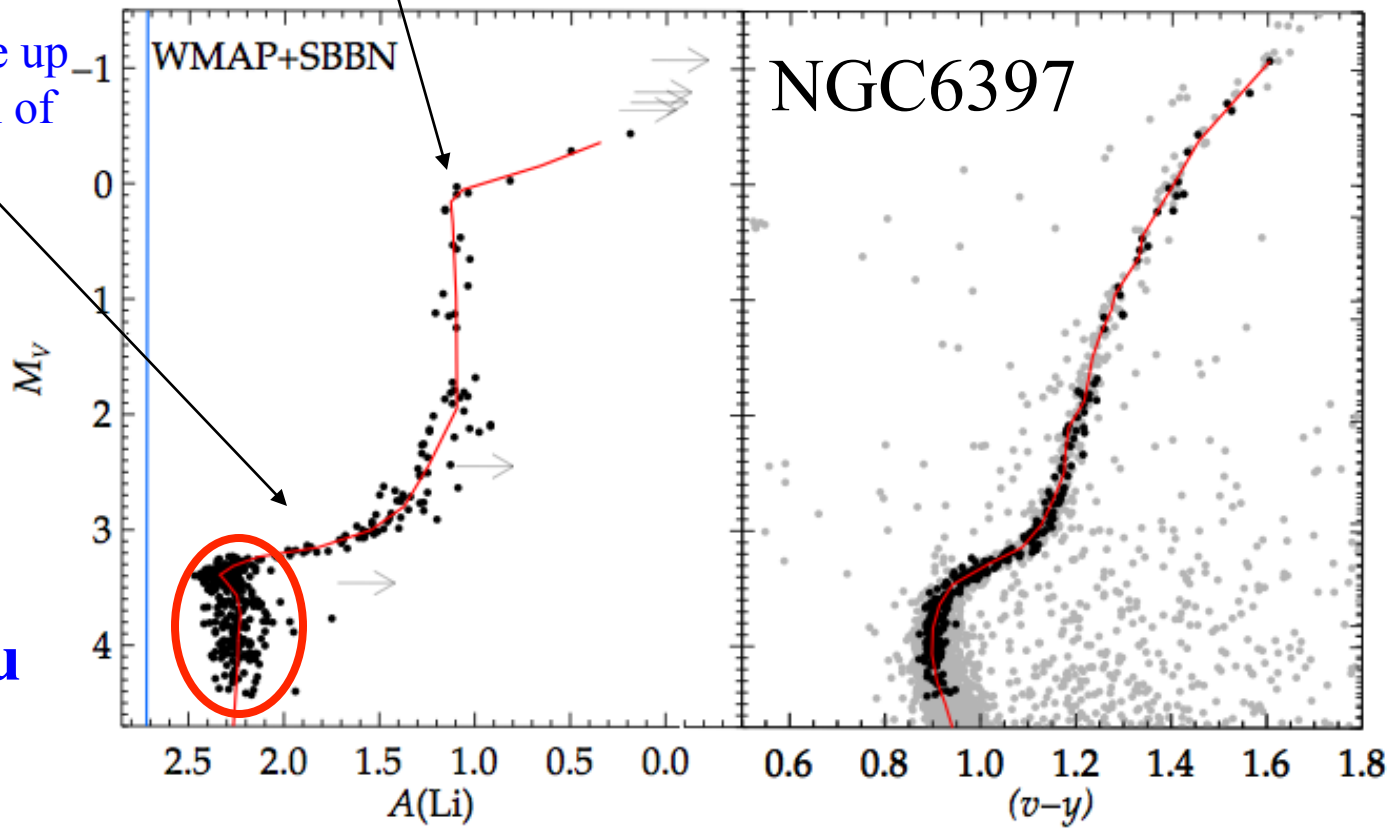
Data sources:
Boesgaard et al 1986
Cayrel et al 1984
Burkhart & Coupry 1986
Melendez et al 2010

Li evolution in low-mass stars

Extra mixing

1st dredge up
Extension of CZ

Spite plateau



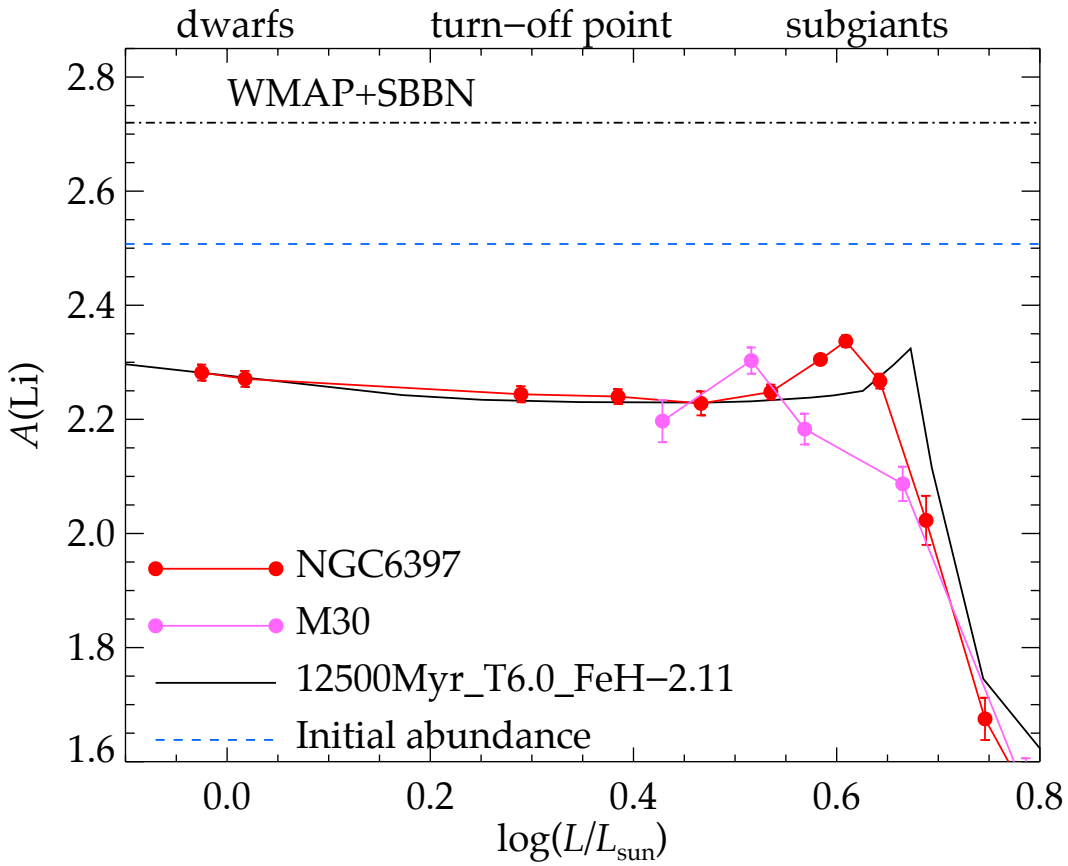
Lind+ 2009

How much ^{7}Li is destroyed on the Spite Plateau?

Models by Richard +

"Low" turbulence: ~0.2dex depletion

"High" turbulence: ~0.4dex depletion



New Li data for M30 [Fe/H]=-2.4

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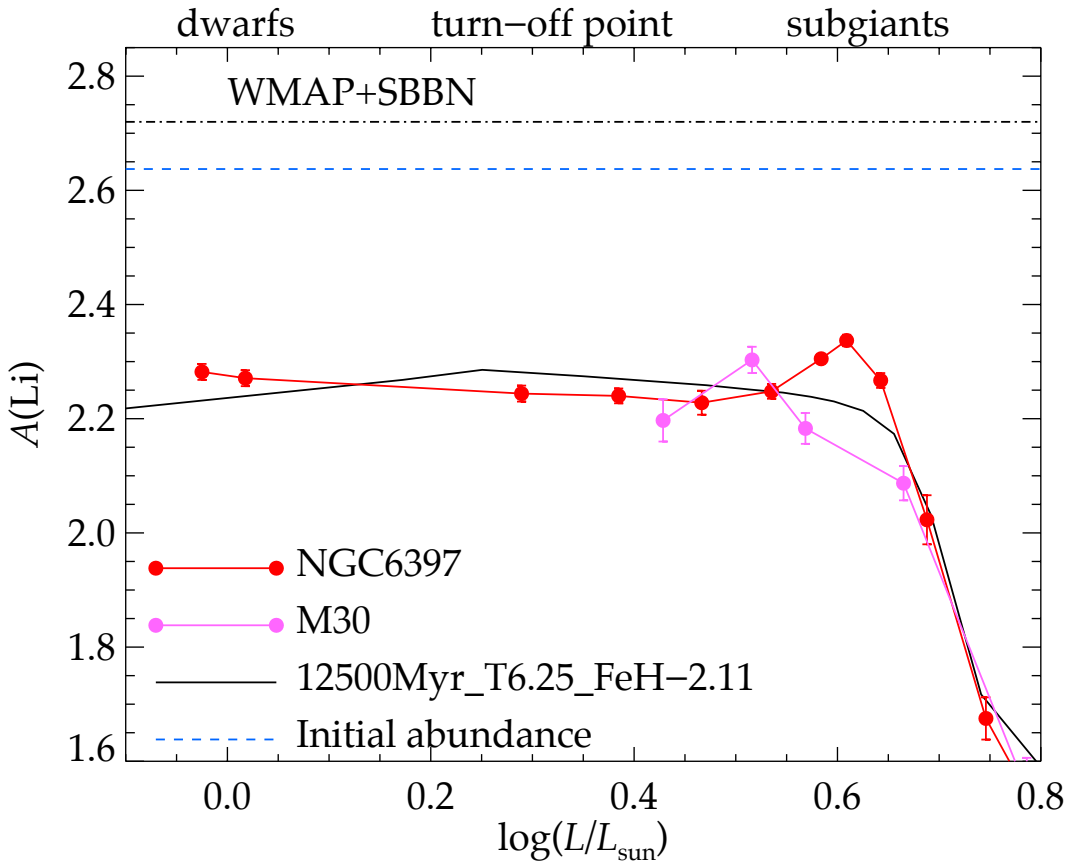

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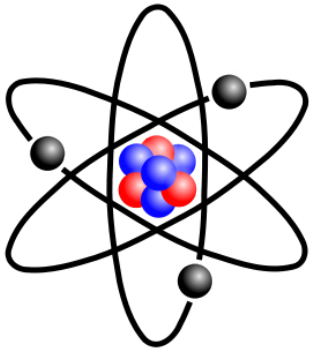


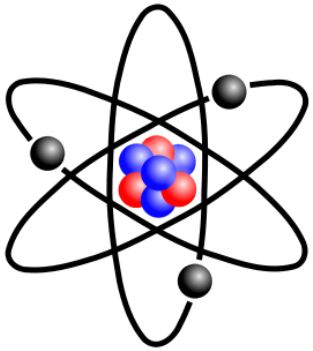
Another aspect of the problem

- **"High turbulence" (T6.25)** — **cf. Meléndez+, Gonzalez-Hernandez+**
  - Explains ~0.4dex of ^{7}Li depletion
  - Cannot explain why subgiants appear more Li rich than turn-off stars

  Predicts >1.6dex depletion of ^{6}Li

- **"Low turbulence" (T6.00)** — **cf. Korn+, Nordlander poster**
  - Explains ~0.2dex of ^{7}Li depletion - not enough
  - Reproduces qualitatively a dredge up of settled ^{7}Li in subgiants

  Predicts similar depletion of ^{6}Li



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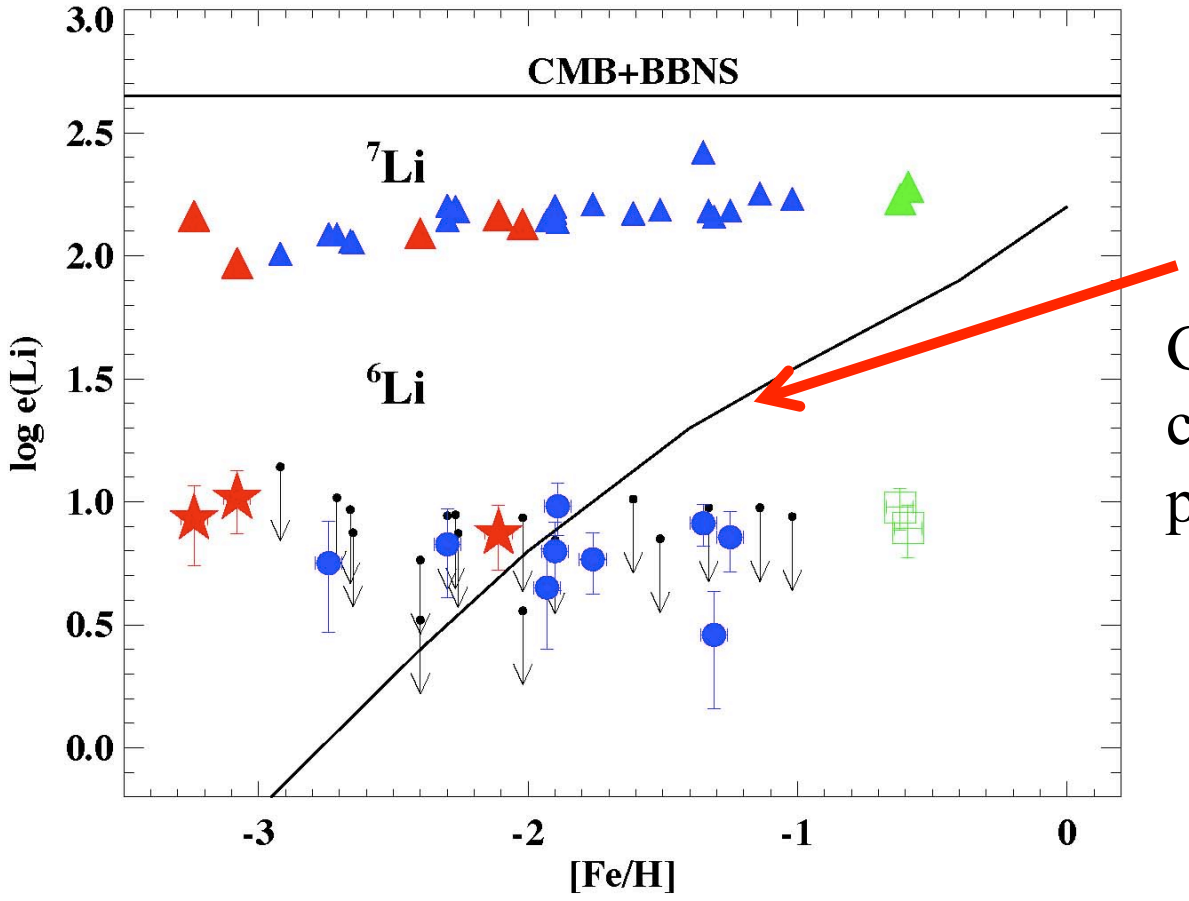
Origin of ^{6}Li?

^{6}Li depletion?



Galactic cosmic ray production

Asplund +

A brief history of HD84937 ([Fe/H]=-2.1)

- **Hobbs et al. 1993/1997**
  - 8 ± 4% 1D LTE
- **Smith et al. 1993/1998**
  - 6 ± 3% 1D LTE
- **Asplund et al 2009:**
  - 5 ± 1 % 3D NLTE
- **Steffen et al 2009:**
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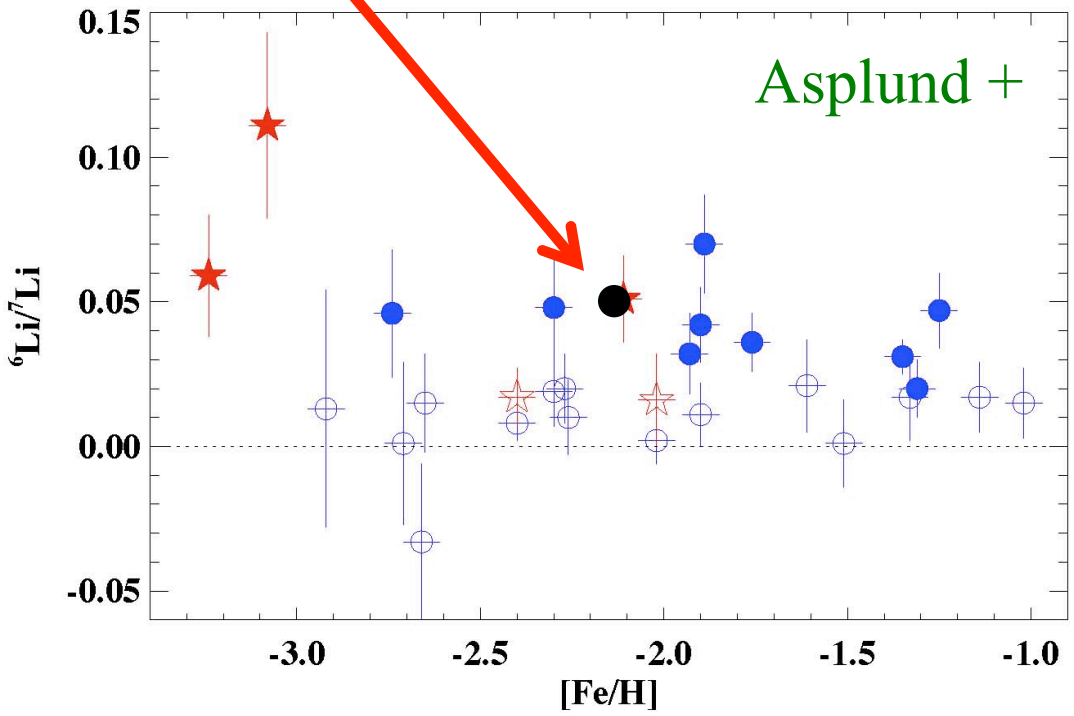

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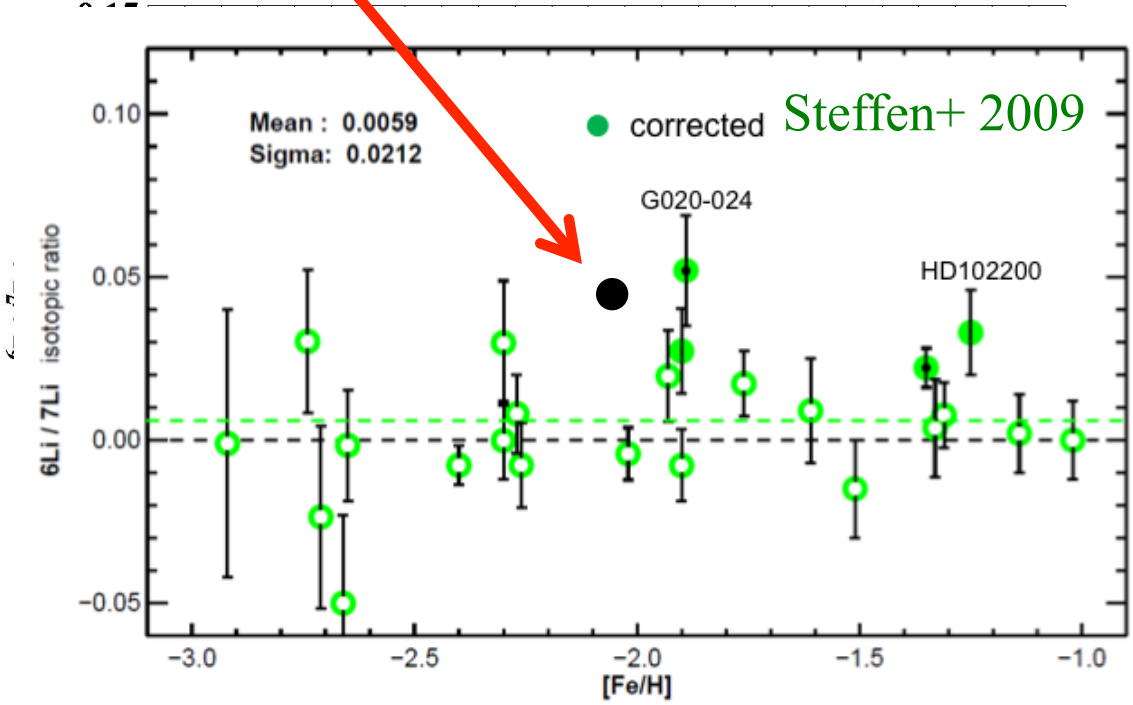
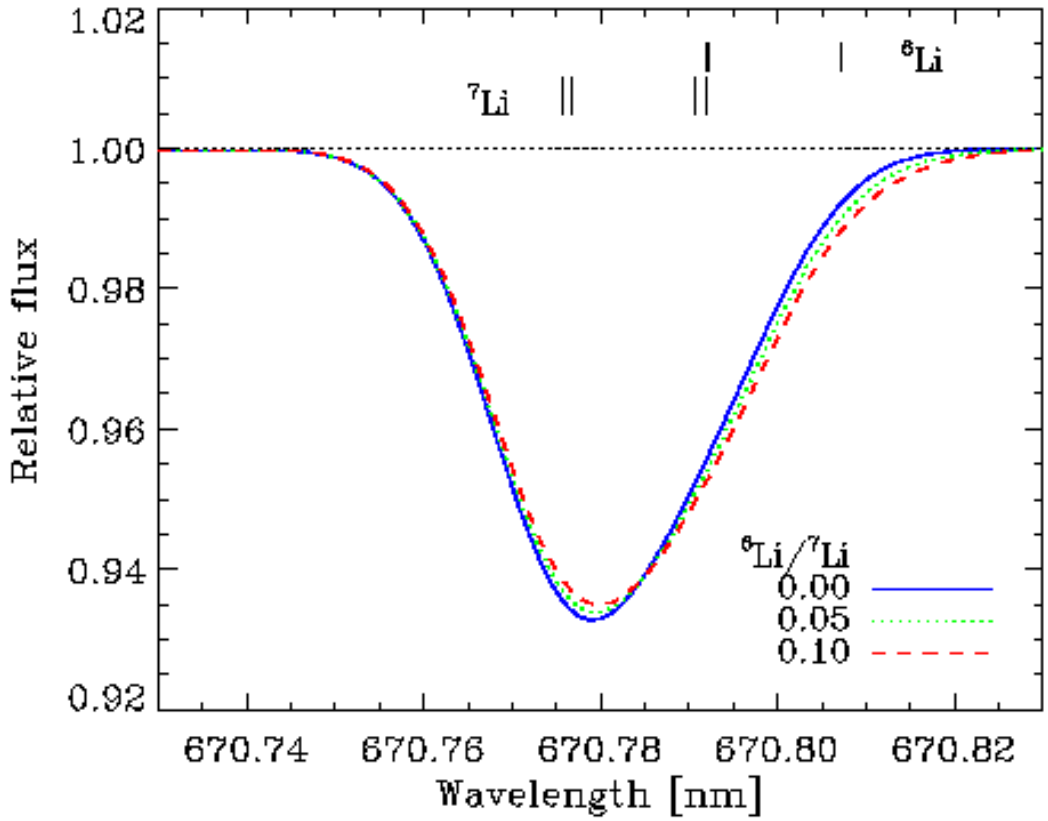


Convective asymmetry mistaken for ^{6}Li?



Line strength:

^{7}Li abundance

1D/3D

LTE/NLTE

Line profile:

^{6}Li/^{7}Li

1D/3D

LTE/NLTE

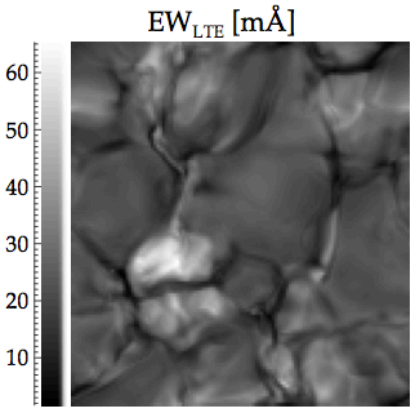
Broadening

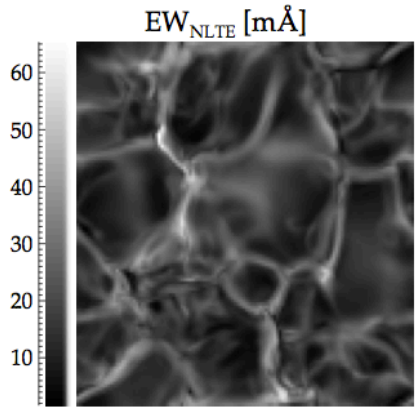
3D+NLTE spectrum synthesis

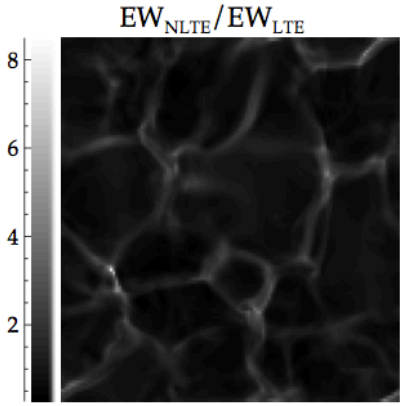
STAGGER (R. Collet) simulations of 3 metal-poor halo stars on Spite plateau

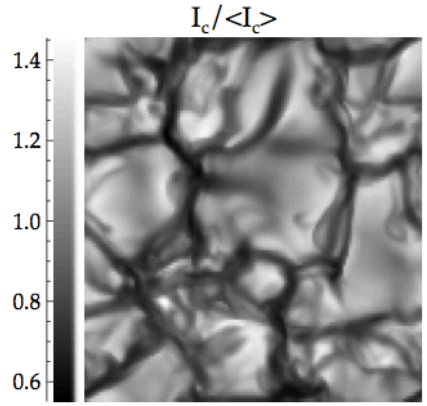
LTE profiles computed with **SCATE** (W. Hayek) from 20 snapshots

NLTE/LTE ratio of LiI and CaI lines obtained with **MULTI3D** (J. Leenaarts+) from 4 snapshots









3D+NLTE spectrum

I.e. this analysis uses:

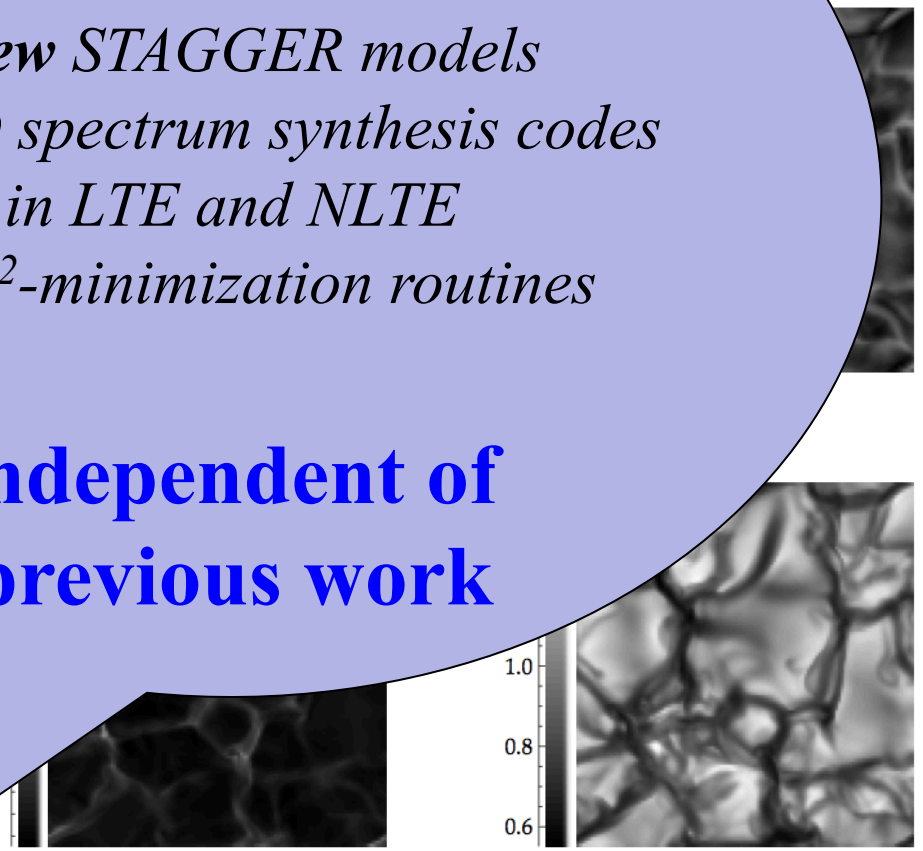
***New** STAGGER models*
***New** 3D spectrum synthesis codes in LTE and NLTE*
***New** χ^2-minimization routines*

Independent of previous work

STAGGE
simulation
halo stars

LTE profil
with **SCAT**
from 20 snap

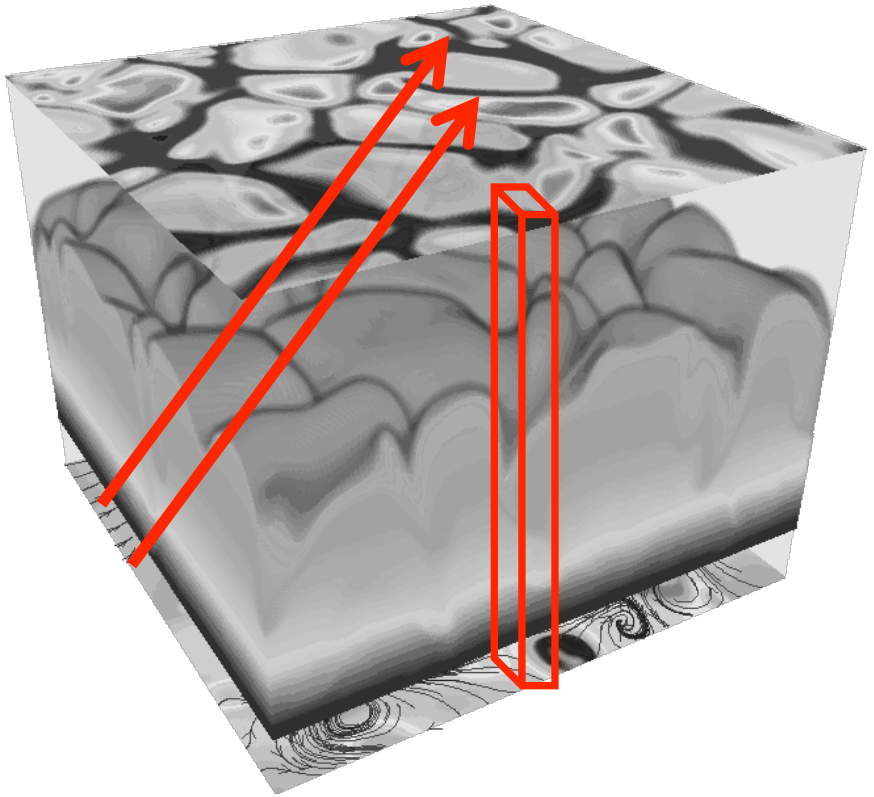
NLTE/LTE ratio of
CaI lines obtained with
MULTI3D (J. Leenaarts+
from 4 snapshots



3D+NLTE spectrum synthesis

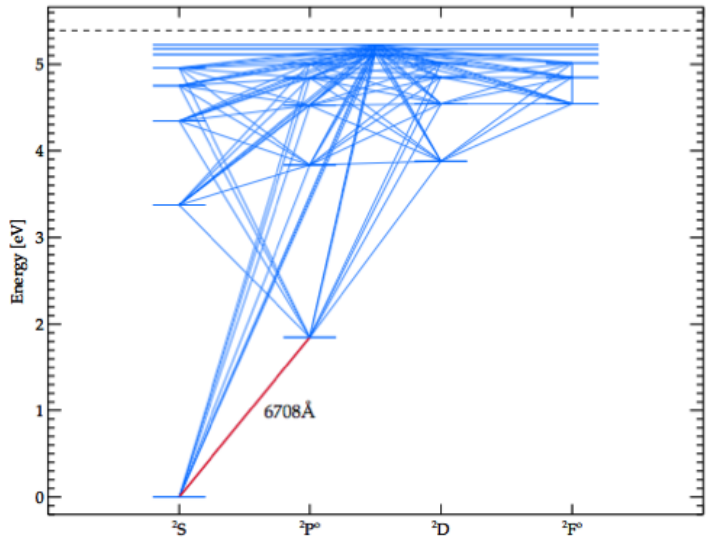
NLTE level populations computed column-by-column for efficiency

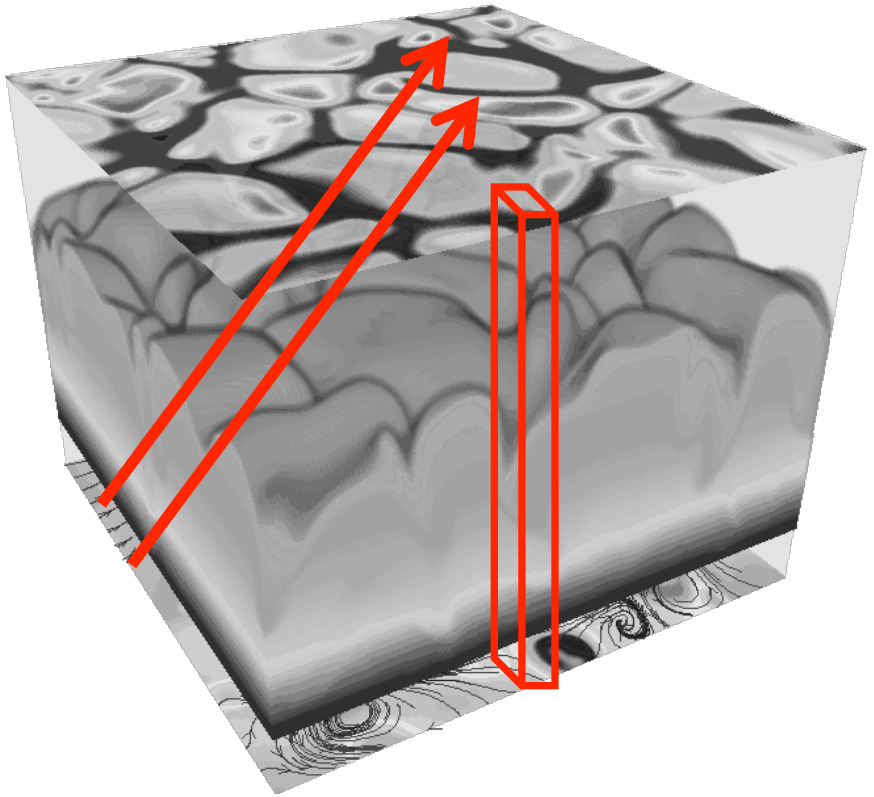
LC rays cast into tilted cube at different angles→ 3D, NLTE flux profile



LiI & CaI treated in NLTE

3D+NLTE spectrum synthesis





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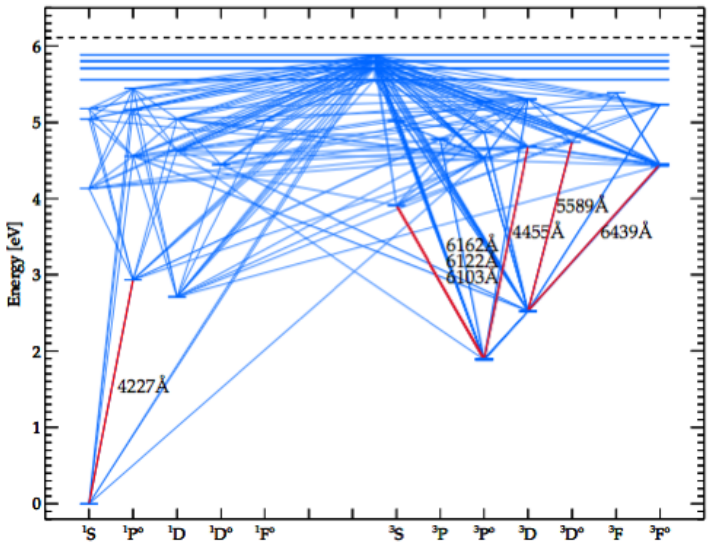
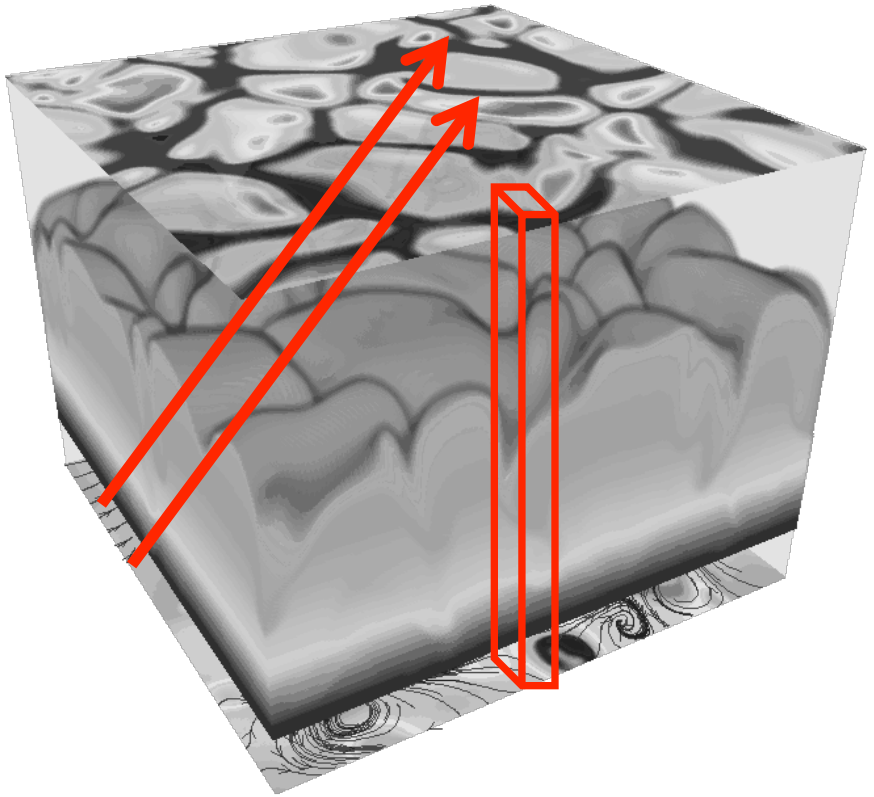




LiI & CaI treated in NLTE

Rotational broadening

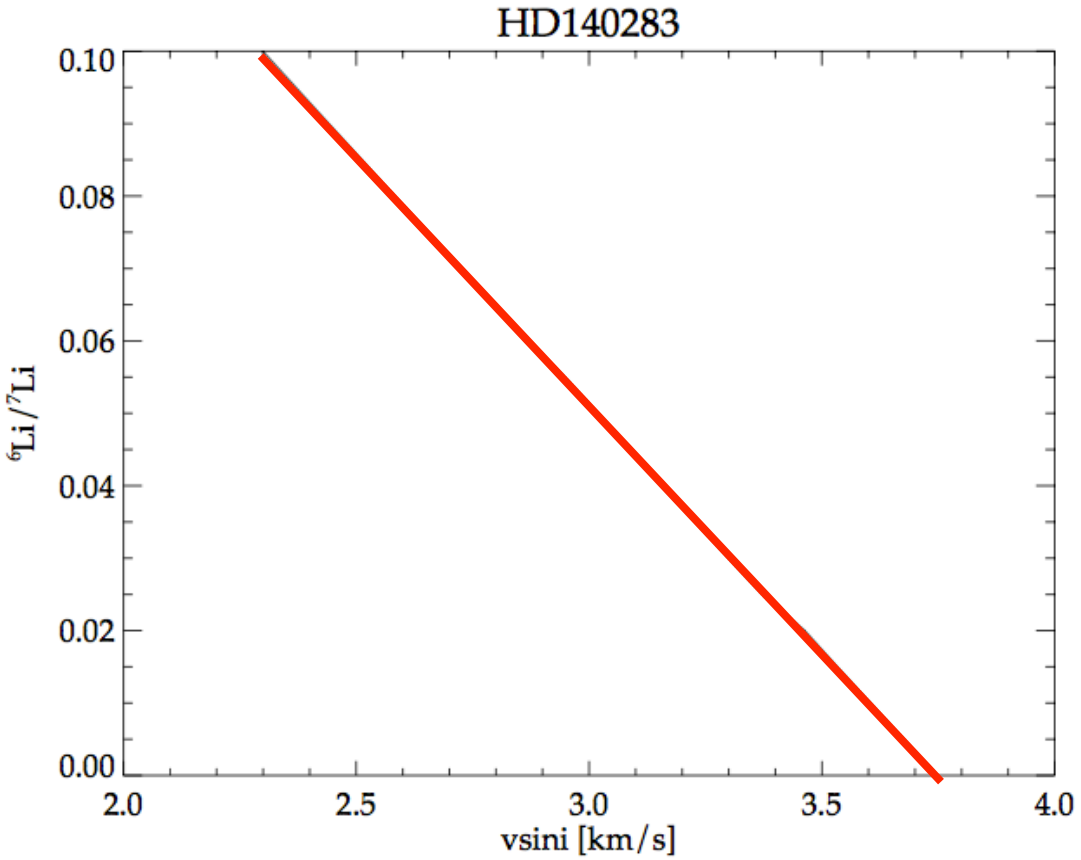
Δvsini :1km/s

→

$\Delta^6Li/^7Li$: ~7%

Need **independent constraints** on broadening for credible results

Remember that **micro-&macroturbulence** are obsolete in 3D

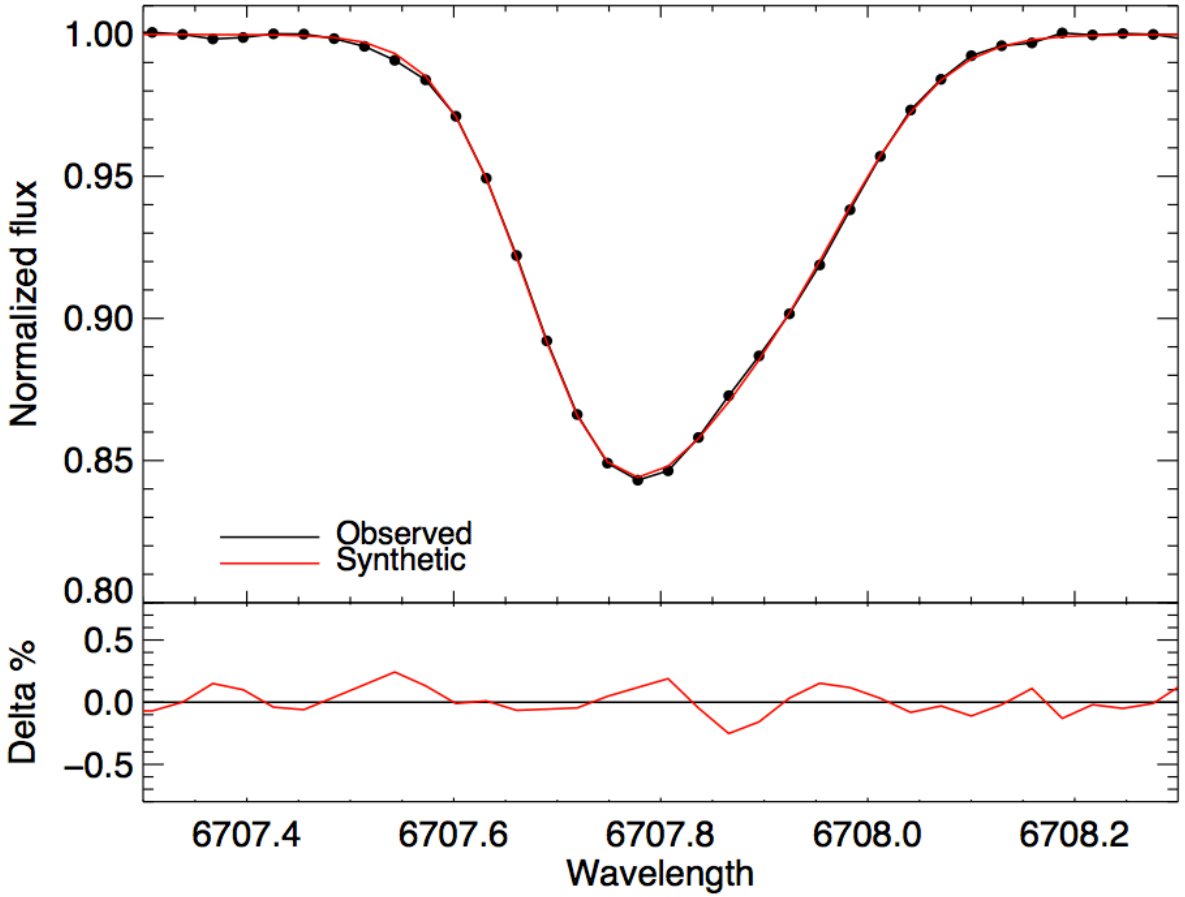


Observational data

Extremely challenging measurement.

Keck spectra:
HD84937
G64-12
HD140283

***S/N* = 800 – 1200**
***R*=~100 000**



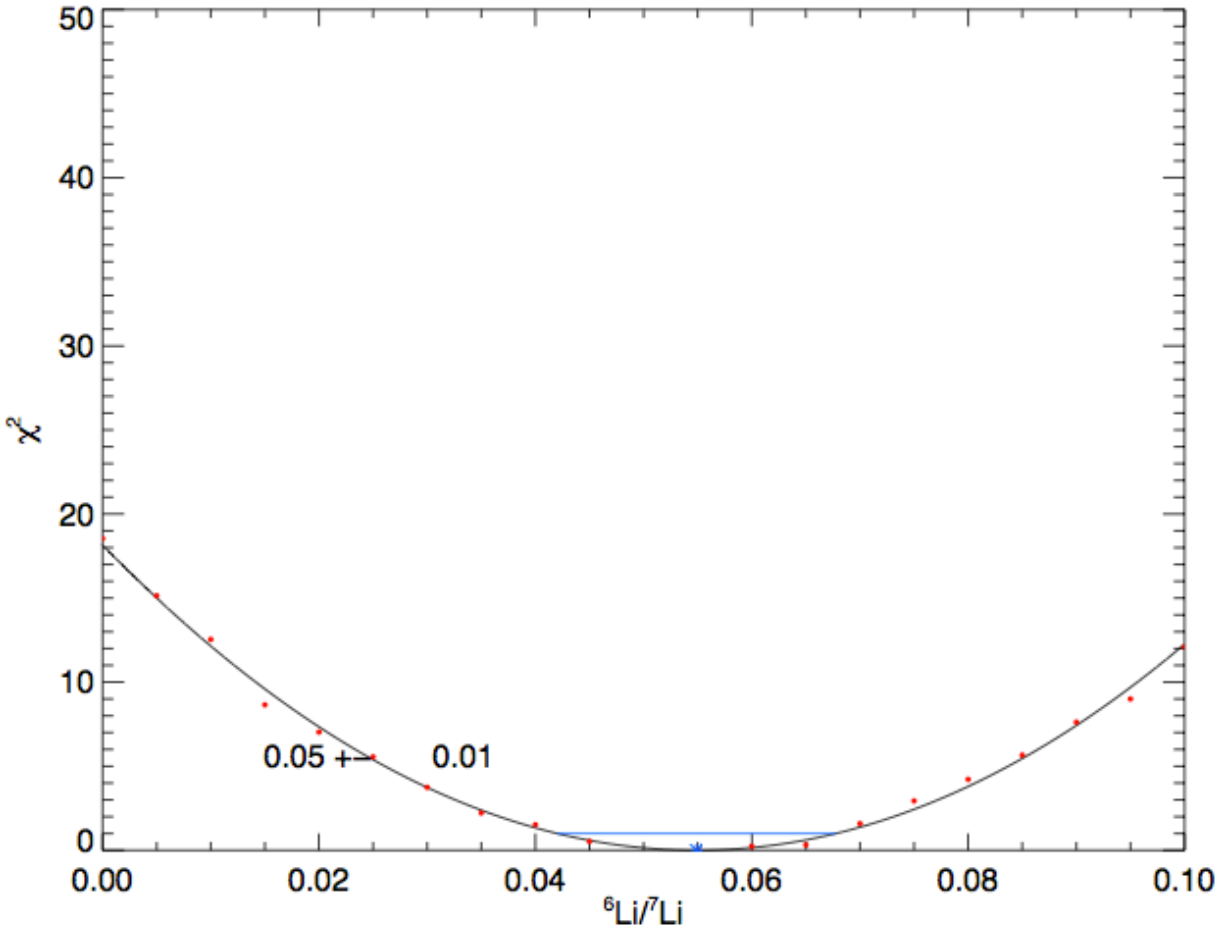
χ^2-minimization

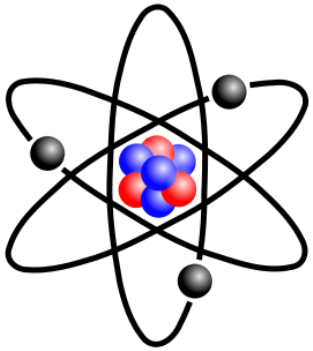
1) Determine RV and re-normalize

2) Determine abundance

3) Determine rotational broadening

4) Determine Isotopic ratio





Preliminary

Results: G64-12

[Fe/H]=-3.0
T_{eff}=6400K
log(g)=4.2

Method (3D)	vsini	7Li	6Li/7Li
Only Li LTE	3.67±0.27	2.128	Anything between 1-5%..
Only Li NLTE	1.69±0.61	2.222	
Sel. LTE (18)	2.80±0.02	2.115	
Sel. NLTE (13)	1.93±0.07	2.223	

vsini from NaI, MgI, CaI, FeI in LTE

vsini from CaI in NLTE + ScII, TiII, FeII in LTE

Results: G64-12

[Fe/H]=-3.0
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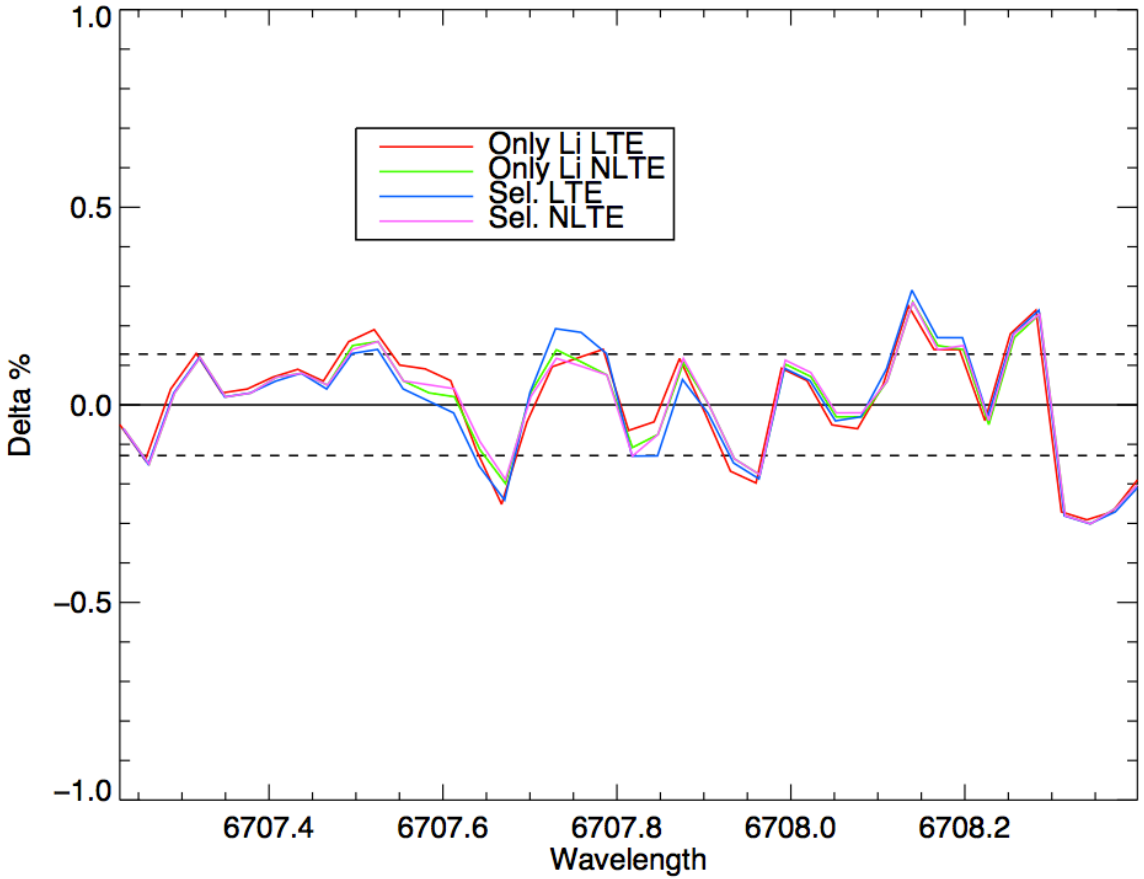
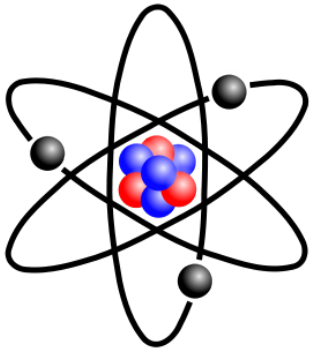
log(g)=4.2



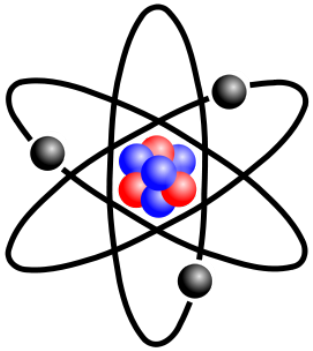


Preliminary

Results: HD140283

[Fe/H]=-2.5
T_{eff}=5750K
log(g)=3.7

Method (3D)	vsini	7Li	6Li/7Li
Only Li LTE	3.53±0.09	1.843	Anything between 0-5%..
Only Li NLTE	1.71±0.19	2.126	
Sel. LTE (16)	2.31±0.02	1.824	
Sel. NLTE (4)	2.14±0.03	2.127	



Preliminary

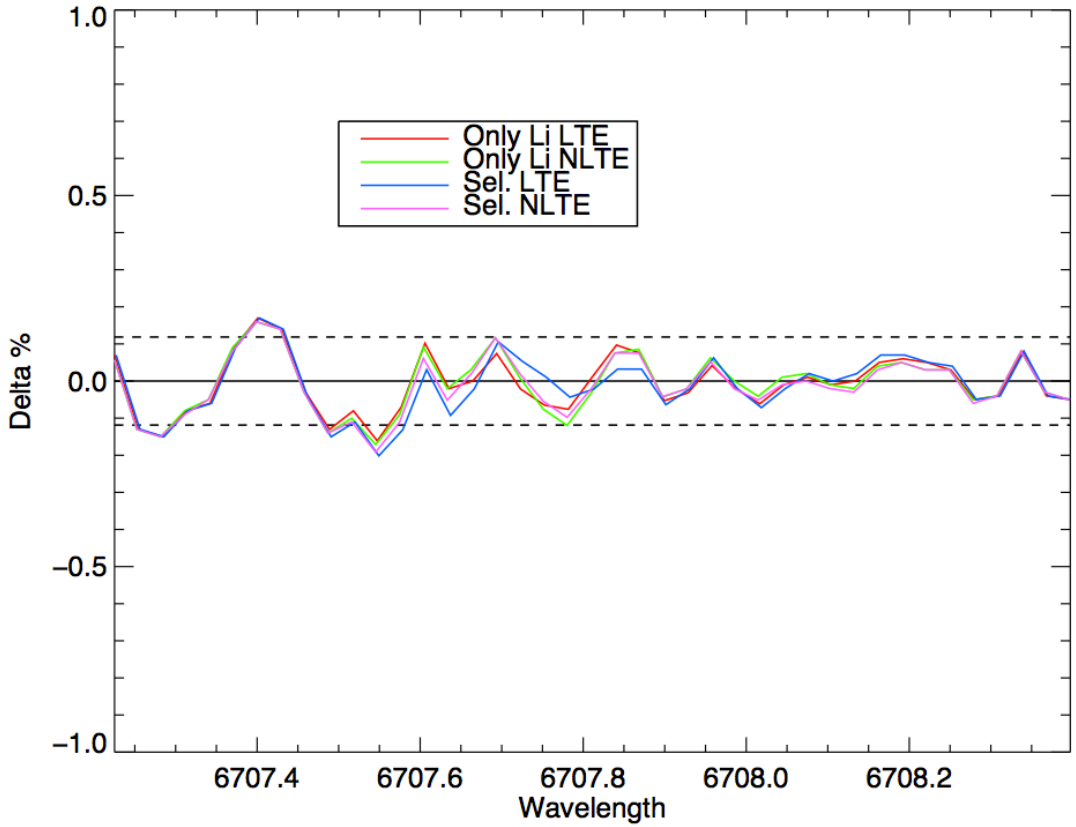
Results: HD84937

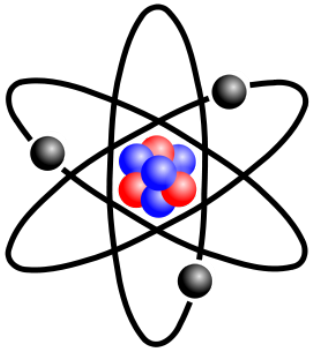
[Fe/H]=-2.0
T_{eff}=6250K
log(g)=4.0

Method (3D)	vsini	7Li	6Li/7Li
Only Li LTE	3.51±0.26	1.956	2.9±2.1%
Only Li NLTE	2.25±0.42	2.151	0.7±1.0%
Sel. LTE (10)	2.82±0.03	1.944	5.5±1.3%
Sel. NLTE (3)	1.99±0.04	2.150	0.8±0.8%

Results: HD84937

[Fe/H]=-2.0
T_{eff}=6250K
log(g)=4.0





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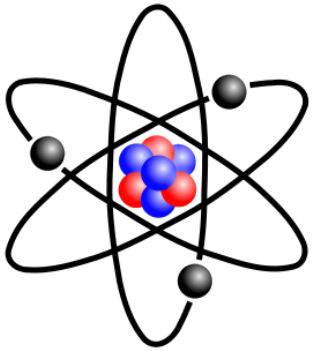
  - **Has ^{6}Li been detected? YES MAYBE NO**

Significant isotopic ratios (~5%) are found when constraining broadening by other neutral lines in LTE. It is <u>possible</u> that these are artificially produced by the LTE assumption.



Outline

WARNING!

Differences and inconsistencies w.r.t. previous work have not yet been carefully investigated

- ^{7}Li
- M

Significant isotop hen constraining broadening by othe E. It is possible that these are artificially prod by the LTE assumption.