THE INTERSTELLAR ^{7}LI/^{6}LI RATIO

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Lithium–7 is now generally accepted to originate in the hot Big Bang nucleosynthesis (BBN), with a primordial abundance (^{7}Li/H)$\simeq 10^{-10}$ in excellent agreement with the observed uniformity of the Li abundance in very metal deficient Pop II stars.

During the galactic evolution, both Li isotopes are created by spallation reactions of galactic cosmic rays (GCR) interacting with the ISM, that yield (^{7}Li/H)$\simeq 2 \times 10^{-10}$ in 10 Gyrs, with a ratio $(^7\mathrm{Li}/^6\mathrm{Li})_{GCR}$=1.4. The major problem is then to explain the observed Pop I Li abundance, $(^7\mathrm{Li/H})_{PopI} \sim 10^{-9}$, of which only 30% is accounted for by BBN and GCR spallation, as well as the high ^{7}Li/^{6}Li ratio measured in meteorites, representative of the solar system formation epoch 4.6 Gyrs ago, $(^7\mathrm{Li}/^6\mathrm{Li})_\odot$=12.3, whereas the above mechanisms predict a ratio around 2.

The existence of an extra stellar source of Li has been suggested. GCR spallation alone tends to decrease the ^{7}Li/^{6}Li ratio with time, and one should observe today an interstellar ratio $\simeq$5–6 without production of Li in stars, or $\gtrsim$6 with a stellar production. Measuring this ISM ratio thus provides a key test for the models of lithium evolution. If it is found to be $\lesssim$5, then another scenario would have to be considered.

One way out would be to consider a primordial abundance (^{7}Li/H)$\gtrsim 10^{-9}$ together with some form of internal mixing that could very well reproduce the observed Pop II stars. However, there is no obvious way of yielding such a high primordial abundance since the inhomogeneous nucleosynthesis models involved up to a few years ago no longer work.

The only accessible resonance lines are the ^{7}Li I doublet around 670.78 nm, and a similar one for ^{6}Li I redshifted by 0.016 nm (or 7.2 km.s^{-1}). Due to the nearly complete ionisation to Li II in the ISM, the strongest equivalent widths observed for ^{7}Li I are of a few tenths of pm on lines of sight already showing a hydrogen column density well over 10^{20} cm^{-2}. The only line of ^{6}Li that one may hope to resolve is the weaker one. Assuming

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a ratio ^{7}Li/^{6}Li $\simeq$ 10, its typical equivalent width is $\sim$ 3 fm, that is a resolution element of 6.7 pm (i.e. a resolving power of 10^5) lowered from the continuum by 0.04%. Moreover, several interstellar components separated by few km.s^{-1} are often present so that the resulting Li I absorption profile may be very complex.

We reported the first actual detection of ^{6}Li in 1993, toward ρ Oph. The observations were acquired with the ESO 3.6m Telescope linked via fiber optics to the CES (Coudé Echelle Spectrometer, resolving power 10^5), providing a signal-to-noise ratio S/N$\sim$ 4000 per pixel of a CCD detector.

Two absorbing clouds were detected, but only the ^{7}Li/^{6}Li ratio in the main one was evaluated to be $12.5^{+4.3}_{-3.4}$ (2σ). This was immediately interpreted as strong evidence for the existence of an extra source of ^{7}Li. Using a more sophisticated profile fitting technique, we recently re-analyzed this sight-line and derived $(^7\text{Li}/^6\text{Li})_A$=11.1 ± 2 (1σ) and $(^7\text{Li}/^6\text{Li})_B \sim 3$, uncertain since $^6\text{Li}_B$ is not formally detected above the photon noise. The $\chi 2$ gives a level of confidence of 71%.

Shortly after, another group reported ^{7}Li/^{6}Li $=6.8^{+1.4}_{-1.7}$ toward ζ Oph and $5.5^{+1.3}_{-1.1}$ toward ζ Per, values which cast severe doubt as to the existence of a stellar source of ^{7}Li, hence on the "canonical" scenario for the galactic evolution of lithium. However, these results are questionable because only the main component was taken into account in the profile fitting in each case. Indeed, two IS absorptions are well detected in their spectra. These values seem thus to be biased, and at most average values, *a priori* not representative of the general ISM.

We obtained new data toward ζ Oph with the ESO 3.6m – CES configuration, showing a S/N=7500 per pixel. The limiting detectable equivalent width is 1.8 fm, or 5 fm including systematics. We were thus able to derive:

$$(^7\text{Li}/^6\text{Li})_A=8.6 \pm 0.8\ (\pm 1.4) \quad \text{and} \quad (^7\text{Li}/^6\text{Li})_B=1.4\ ^{+1.2}_{-0.5}\ (\pm 0.6)$$

where the error bars within brackets are associated to systematics and were estimated by fitting different sets of spectra reduced using different techniques. The $\chi 2$ gives a level of confidence of 61%. As toward ρ Oph, we find an extremely atypical ^{7}Li/^{6}Li ratio.

The only standard way to obtain a ratio as low as $\sim$2 in the ISM comes through a massive interaction of the GCR with the material of cloud B, a scenario which seems unrealistic as for now. Recently, a very elegant explanation has been suggested which involves a SNII explosion inside an IS cloud, able to indeed produce a ratio $\simeq$ 3.

Obtaining a representative value of the interstellar ^{7}Li/^{6}Li ratio is no longer a matter of a few measurements. Just as for the D/H ratio on QSO lines of sight, it is a matter of statistics at a long term. The highest possible spectral resolution and S/N ratios are mandatory.