遠方クエーサー分子吸収線系における リチウム同位体比の測定

ALMA cycle 6 プロジェクト “Lithium isotope ratio in ISM at z=0.68” の概要

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Cosmic Shadow 2018 ~クェーサー吸収線系でみる宇宙~
@石垣島 2018.11.24 - 25

Outline

- **Lithium isotope ratio measurement at high-z**
  - ✓ Cosmological lithium problem
  - ✓ Difficulties in existing probes
  - ✓ ALMA cycle 6 project
- **High-z millimeter wave molecular absorption line systems (short talk)**
  - ✓ Unique laboratories at high-z
  - ✓ Only a handful of absorbers are known to date.
  - ✓ Survey to detect new absorbers
    - ➡ many attempts but many failures
  - ✓ What is the next survey strategy?

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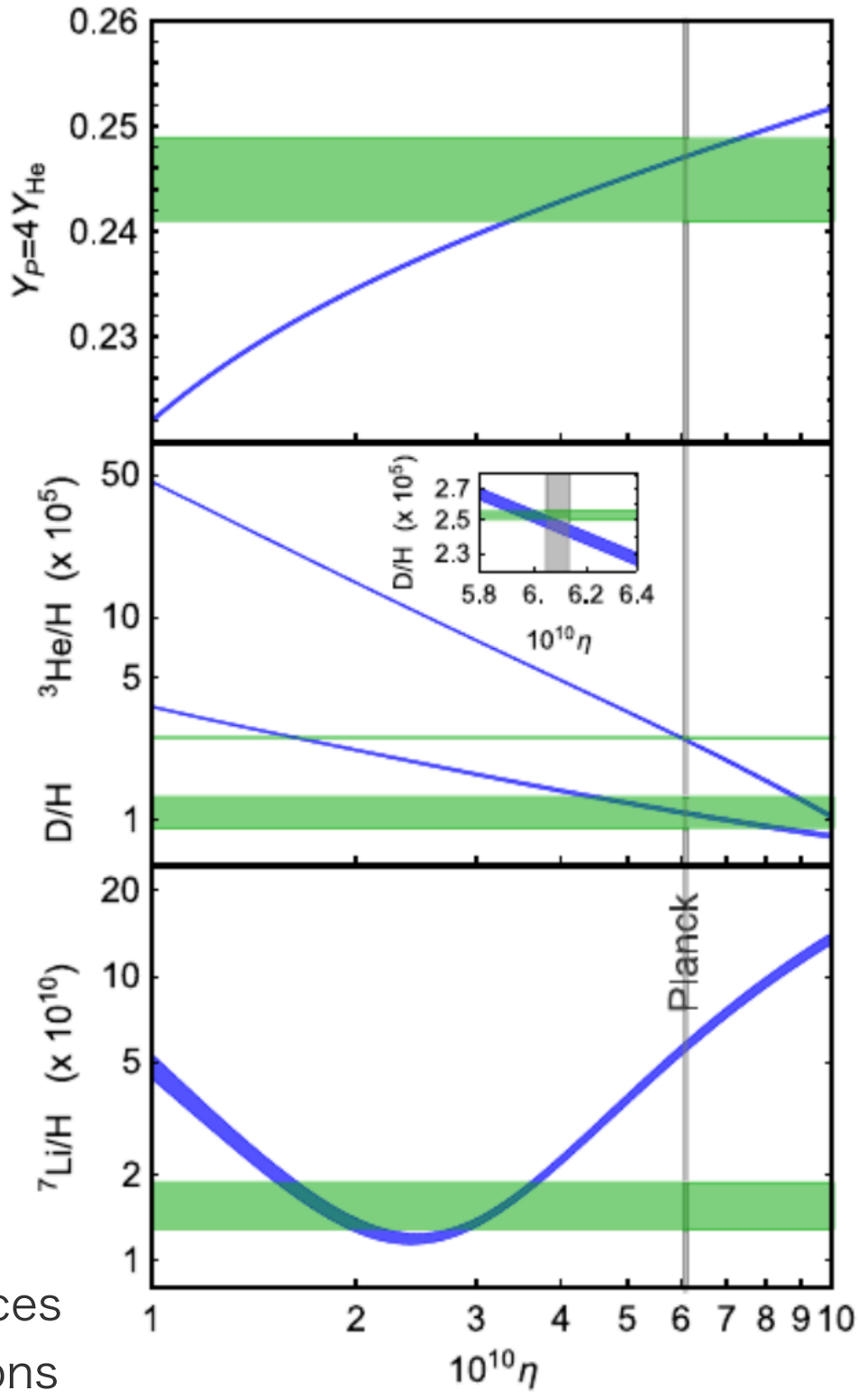
Introduction: Cosmological lithium problem

- **SBBN+CMB prediction of primordial abundances of the light elements**
  - ✓Deuterium and ^{4}He
    - ➡ Good agreement with observations
      (e.g., Cooke+14, Izotov+14)
  - ✓^{7}Li (and ^{6}Li?)
    - ➡ **Significant mismatch with observations**
      (e.g., Asplund+06)
    - ➡ **The lithium problem**

- **Possible solutions to the lithium problem**
  - ✓Astrophysical systematics in observations
  - ✓Miscalculation in nuclear reactions
  - ✓Physics beyond the standard model

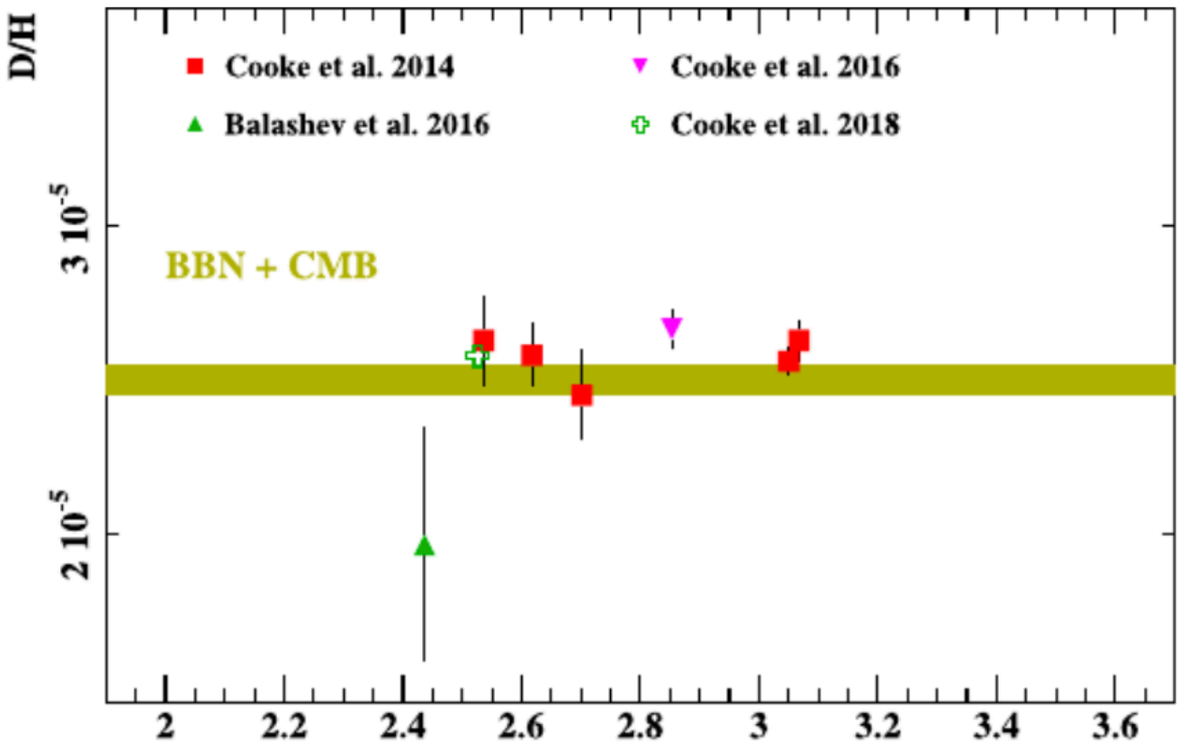


Green: observational abundances
Blue: Standard model predictions

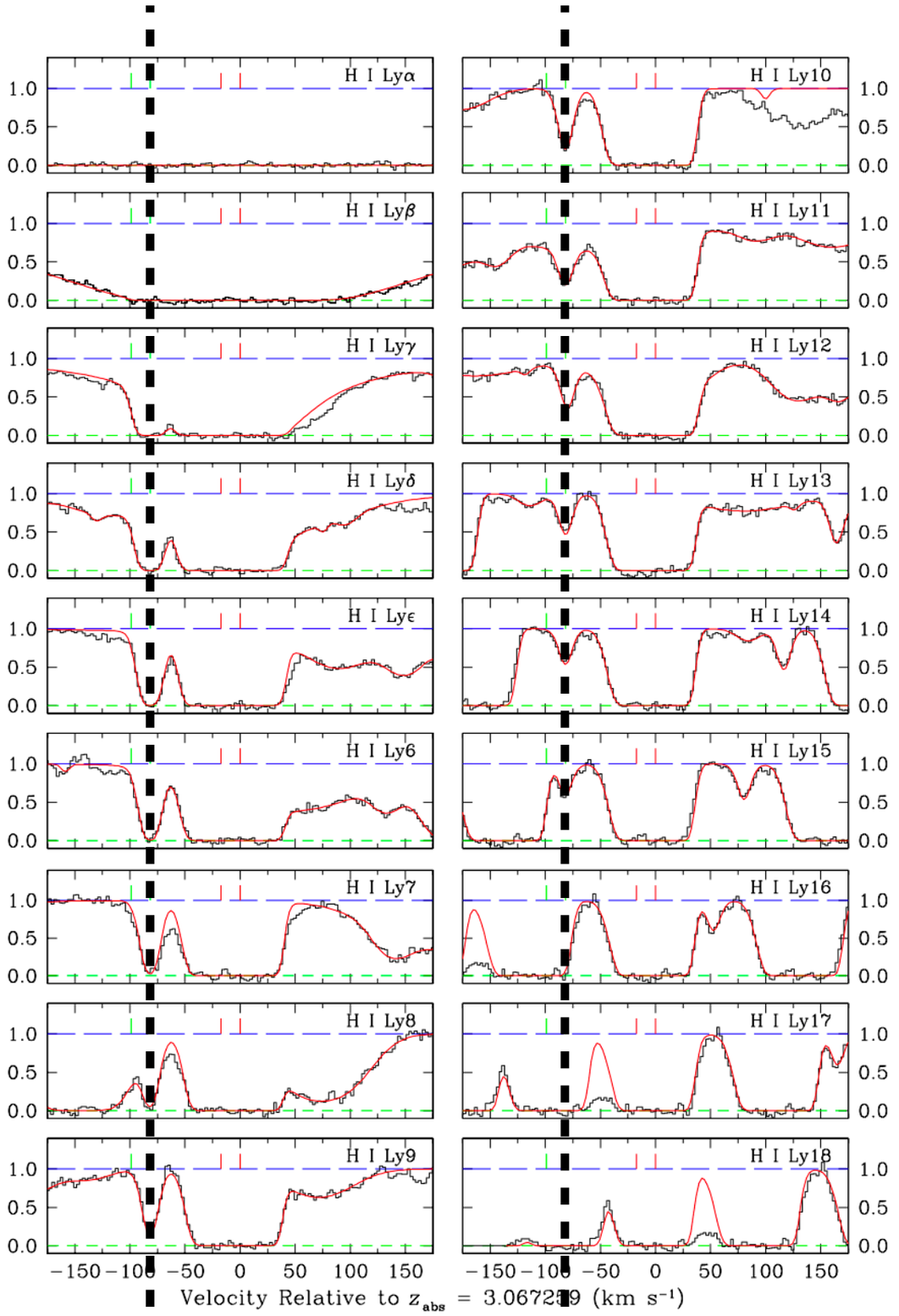
Pitrou et al. 2018

Deuterium abundance measurements

- **Very metal-poor high-z DLA**
  - ✓Deuterium production sources are unspecified
    - ➡Observed value will be primordial
  - ✓Strong dependence on the baryon density
    - ➡Not so affected by effective neutrino number



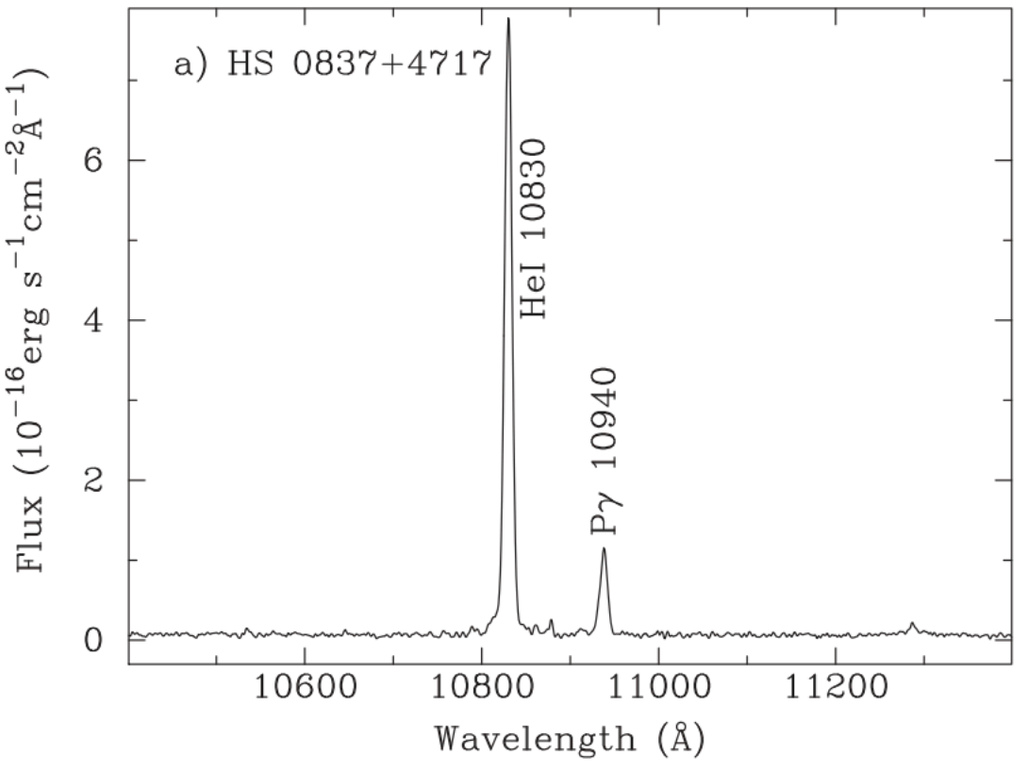
Pitrou et al. 2018

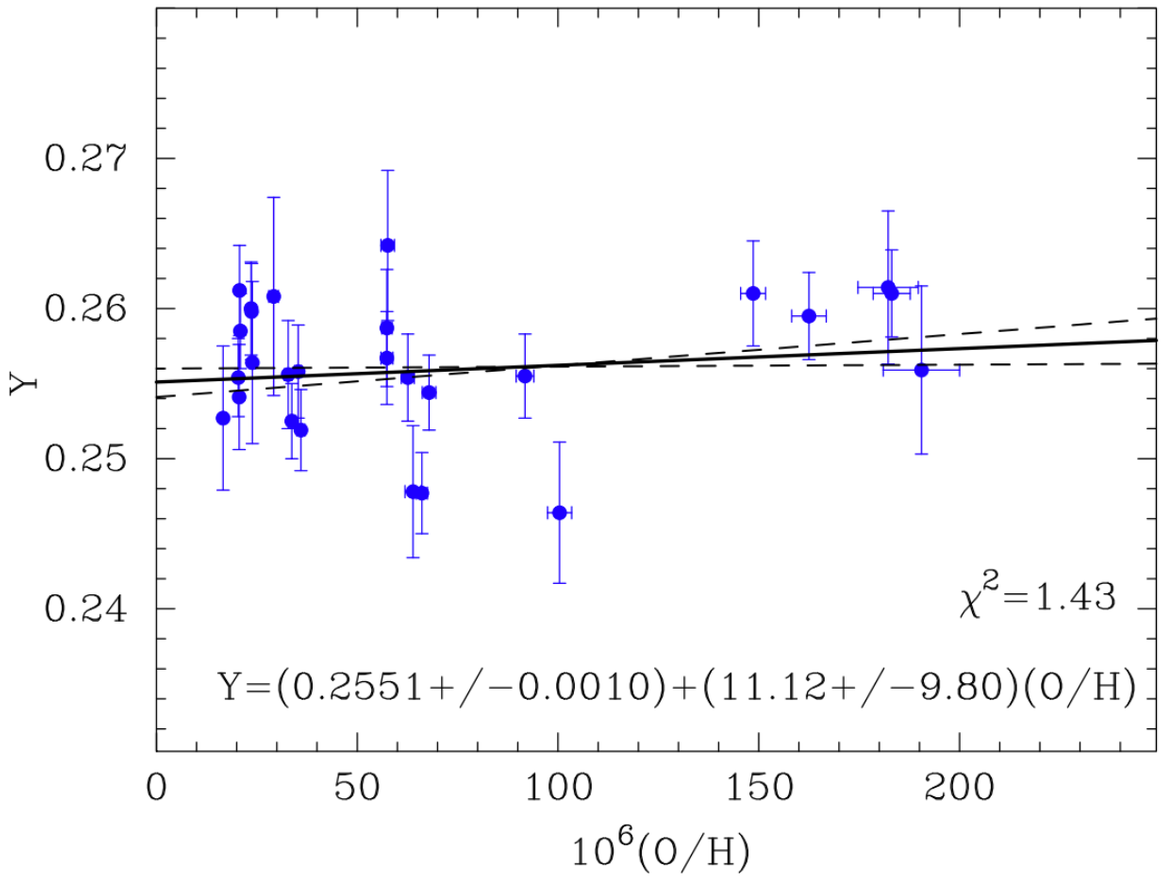


DI Cooke et al. 2014 DI

^{4}He abundance measurement

- **Low metallicity HII region in nearby galaxies**
  - ✓ Assume linear relationship between Y_p and O/H
  - ✓ Extrapolate the relationship to O/H = 0



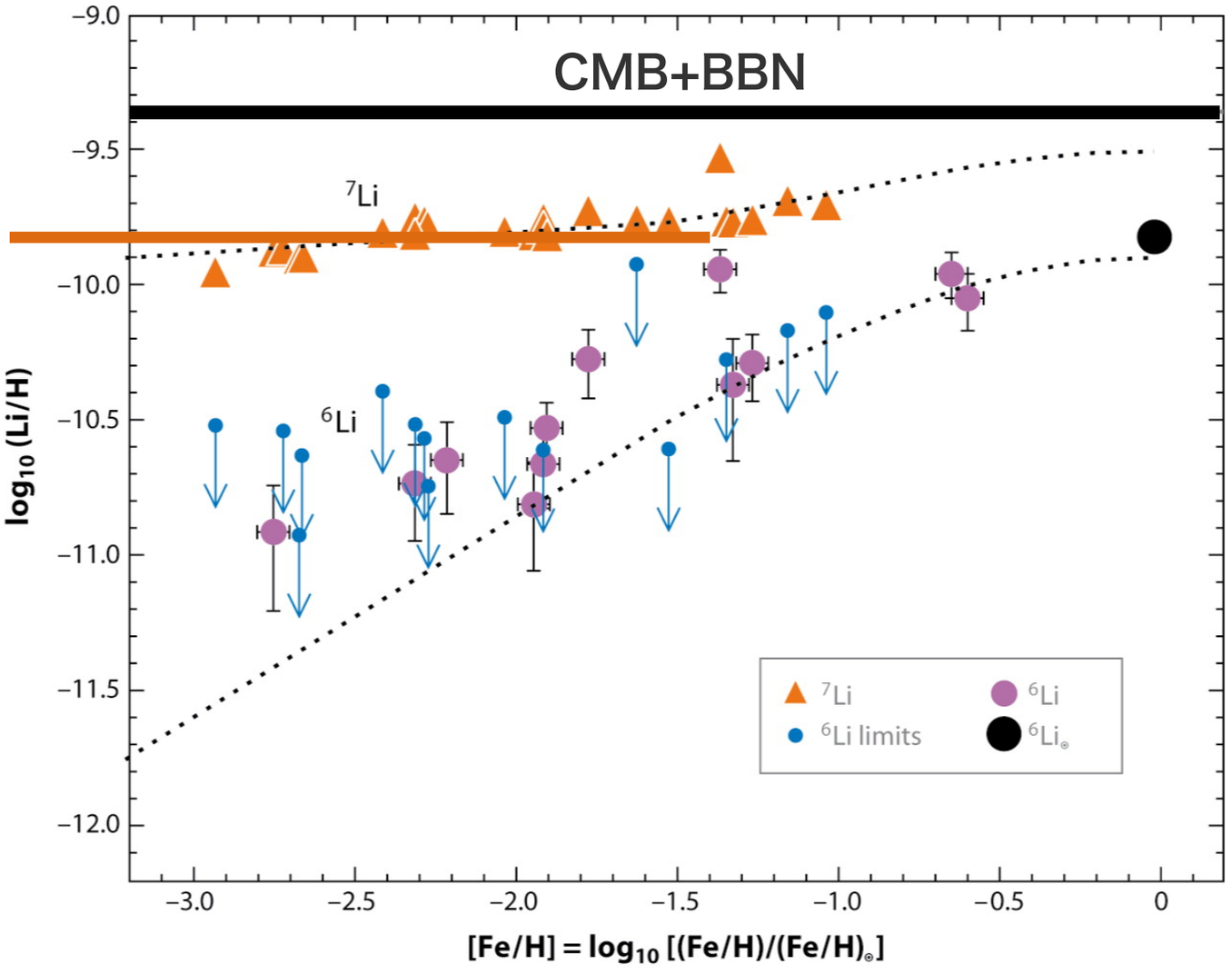


Izotov et al. 2014

^{7}Li abundance measurements

- **Spite plateau** (Spite & Spite 1982)
  - ✓Lithium abundances have been measured in unevolved halo-stars.
  - ✓^{7}Li abundances are almost constant in wide metallicity range.
    - ➡ Independent of the Galactic chemical evolution -> **primordial**

Spite plateau



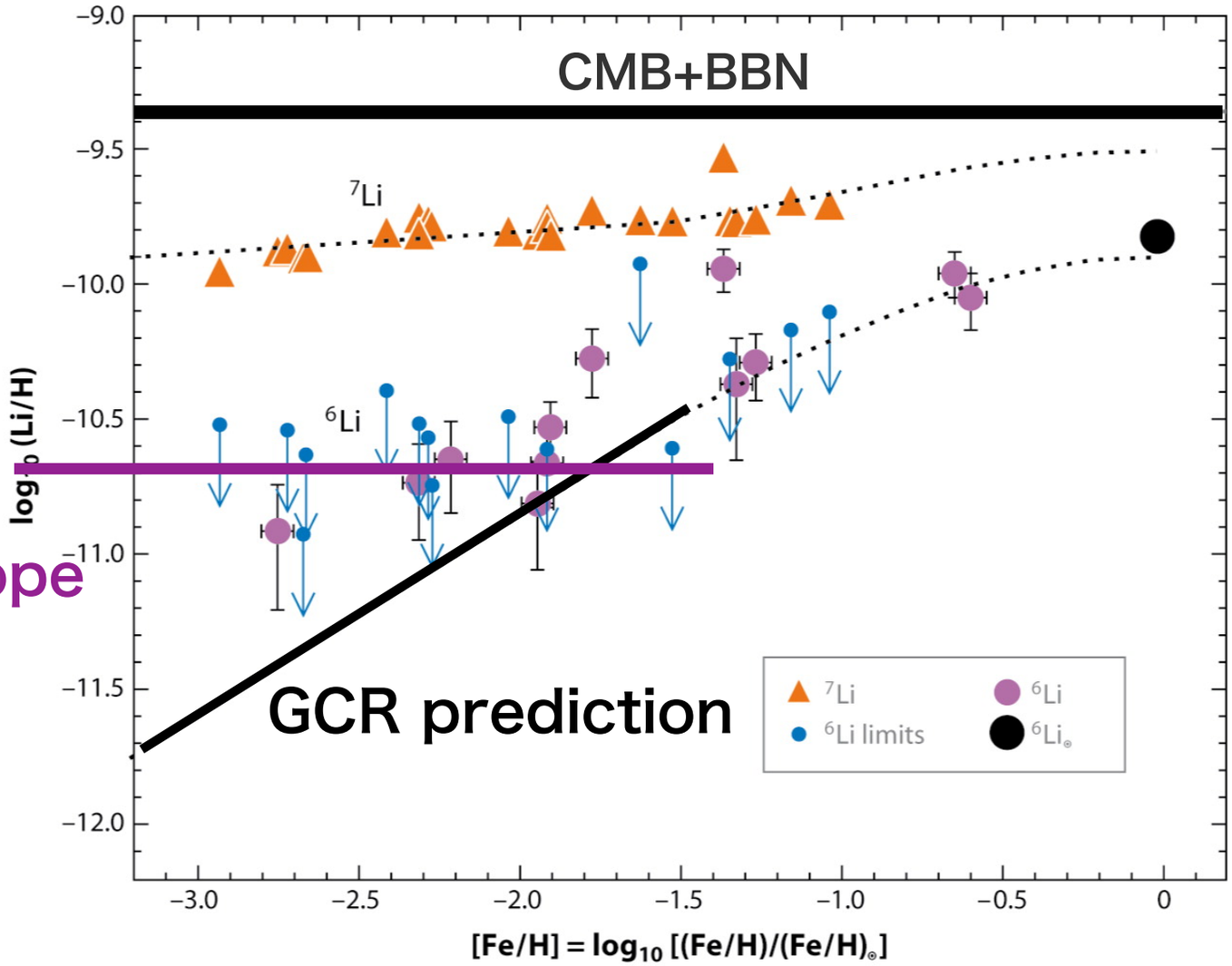
Disagreement

Fields et al. 2011

^{6}Li abundance measurements

- **Asplund upper envelope** (Asplund et al. 2006)
  - ✓ ^{6}Li production in BBN is negligibly small.
  - ✓ Main source of ^{6}Li is Galactic Cosmic-Rays (GCR) spallation of CNO nuclei.
  - ✓ Observational abundances of ^{6}Li are inconsistent to GCR prediction.

Asplund upper envelope

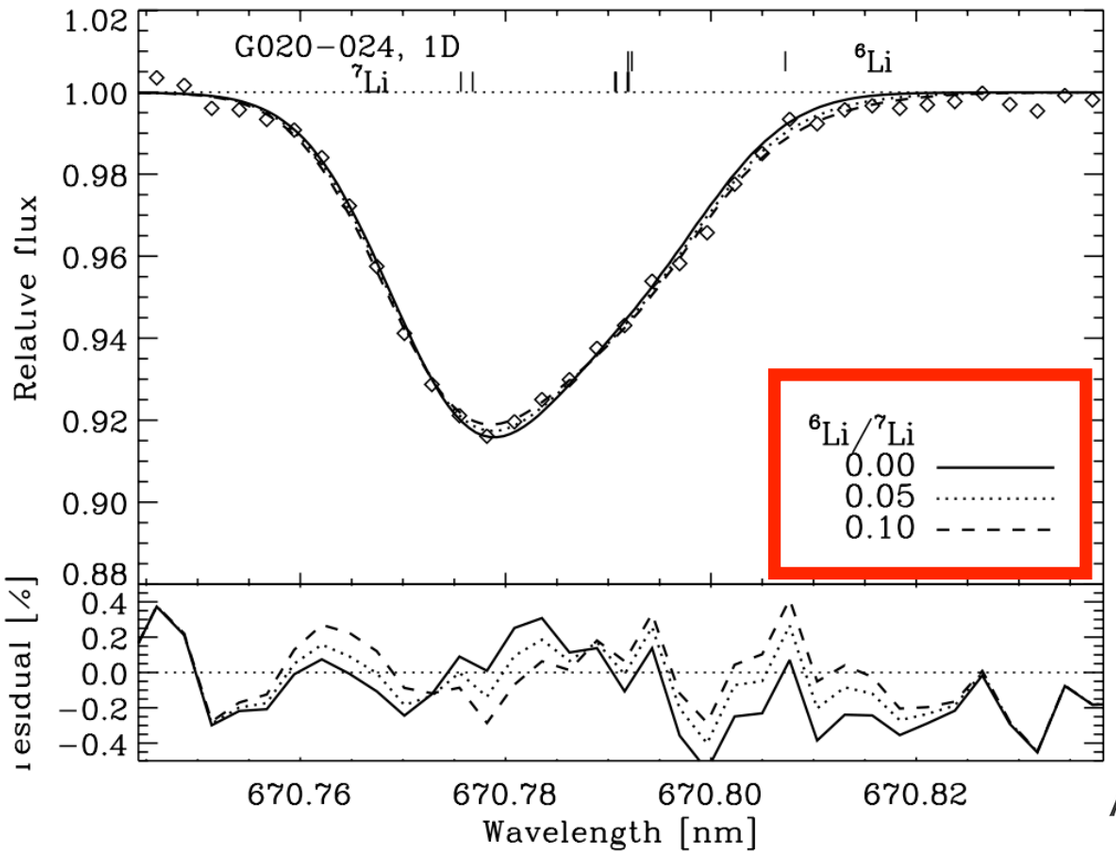


Fields et al. 2011

Difficulties of the observation toward stellar atmospheres

- **Difficulties of the modeling of stellar atmospheres**
  - ✓Li depletion processes are possible (but **unspecified**).
  - ✓^{6}Li can be detected with 1D LTE (Asplund et al. 2006),
    but NOT with 3D non-LTE (Lind et al. 2013).

- **Line broadening**
  - ✓Wavelength of the isotoplogue atomic absorption lines are very close.

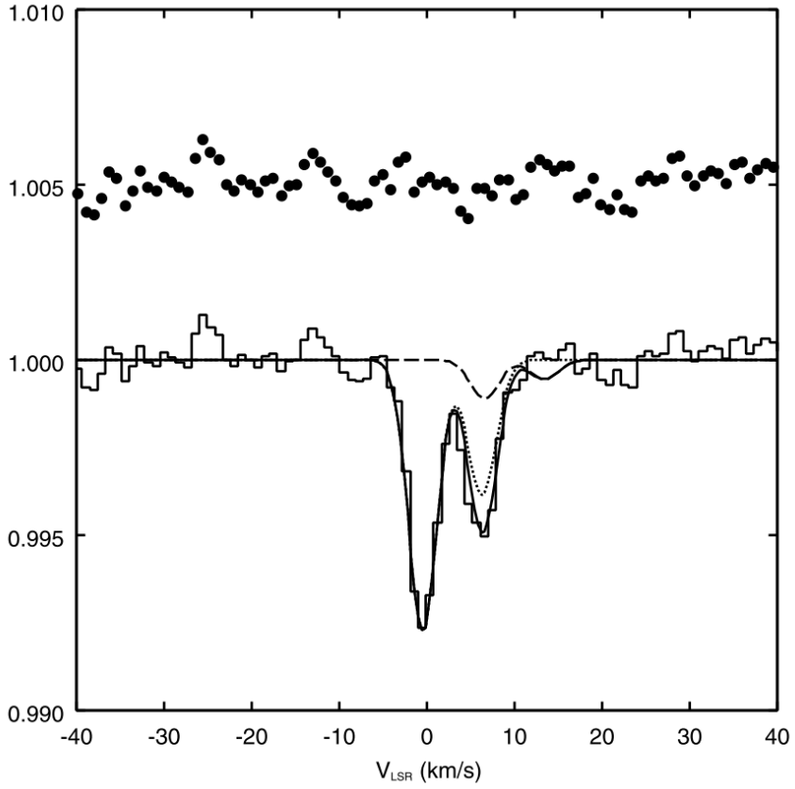


Asplund et al. 2006

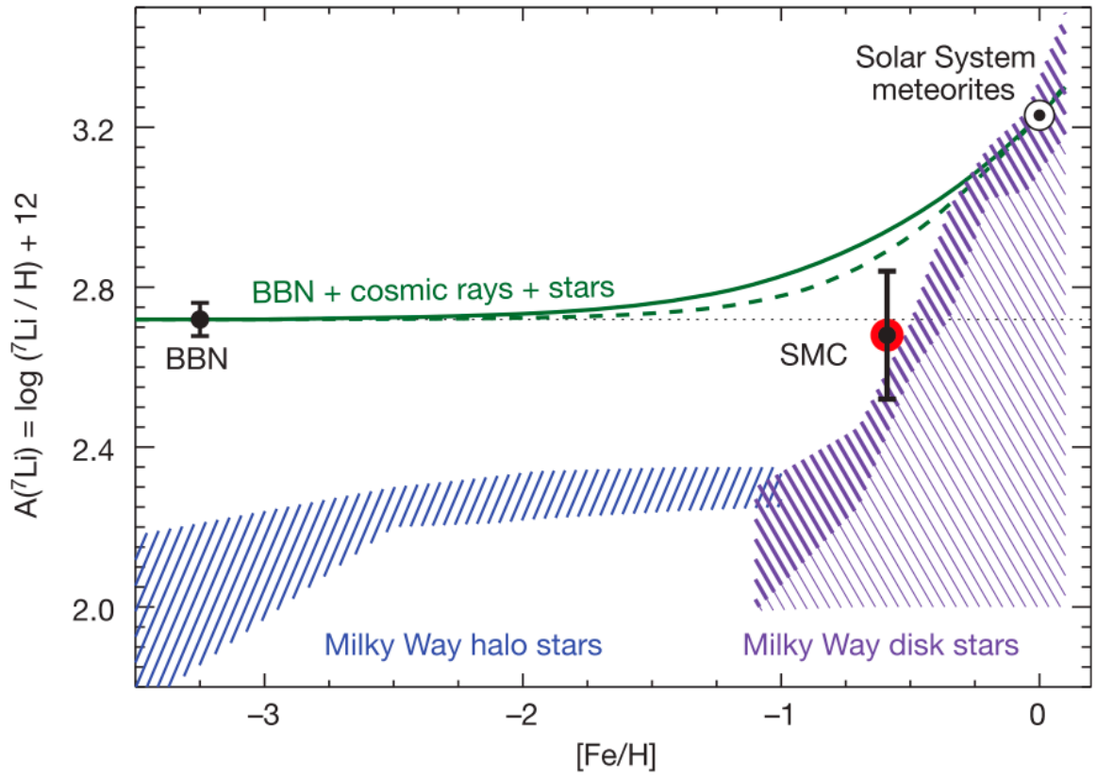
Lithium abundance in ISM

- **Li absorption has been detected along the sight lines of bright stars**
  - ✓In MW ISM (e.g., Kawanomoto+09) and in SMC ISM (Howk+12)

- **Li isotope ratio ^{6}Li/^{7}Li in ISM**
  - ✓Line broadening is less significant than in stellar atmosphere
  - ✓The effects of ionization and dust-depletion are canceled



Kawanomoto et al. 2009



Howk et al. 2012

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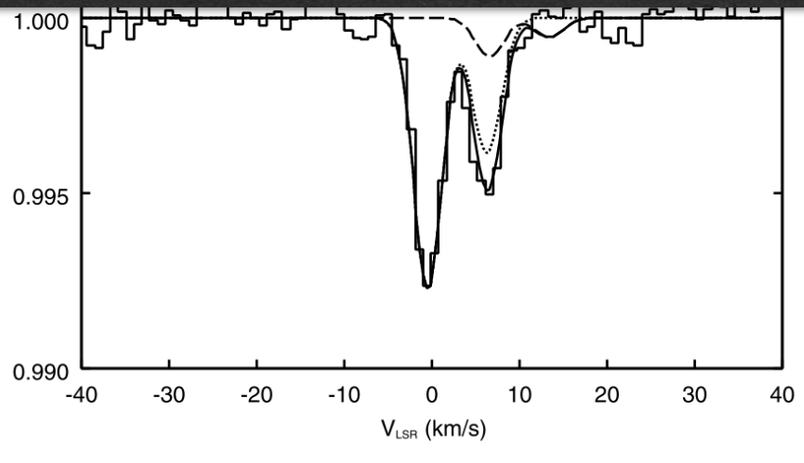
Existing observations are limited in the local universe and have some difficulties.

We need **new (independent)**

and **distant** probes of Li abundance!



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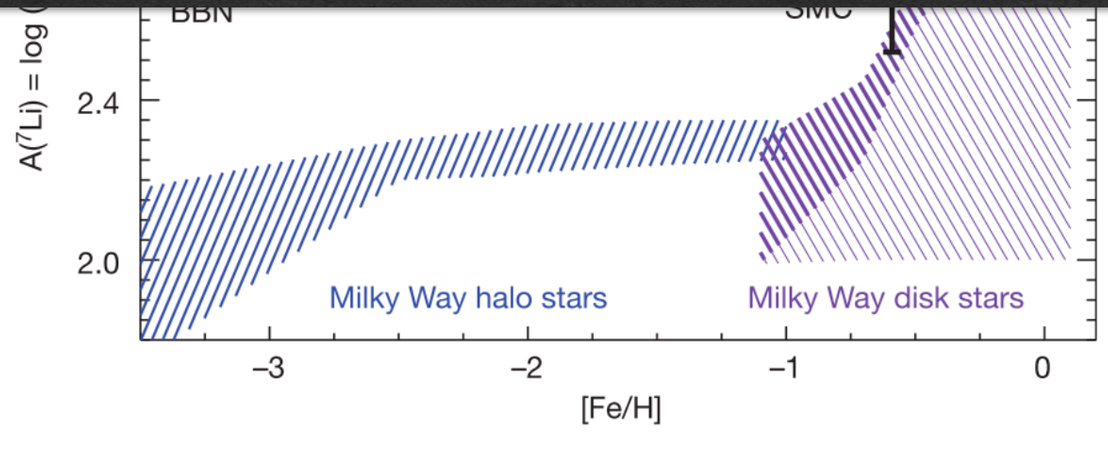
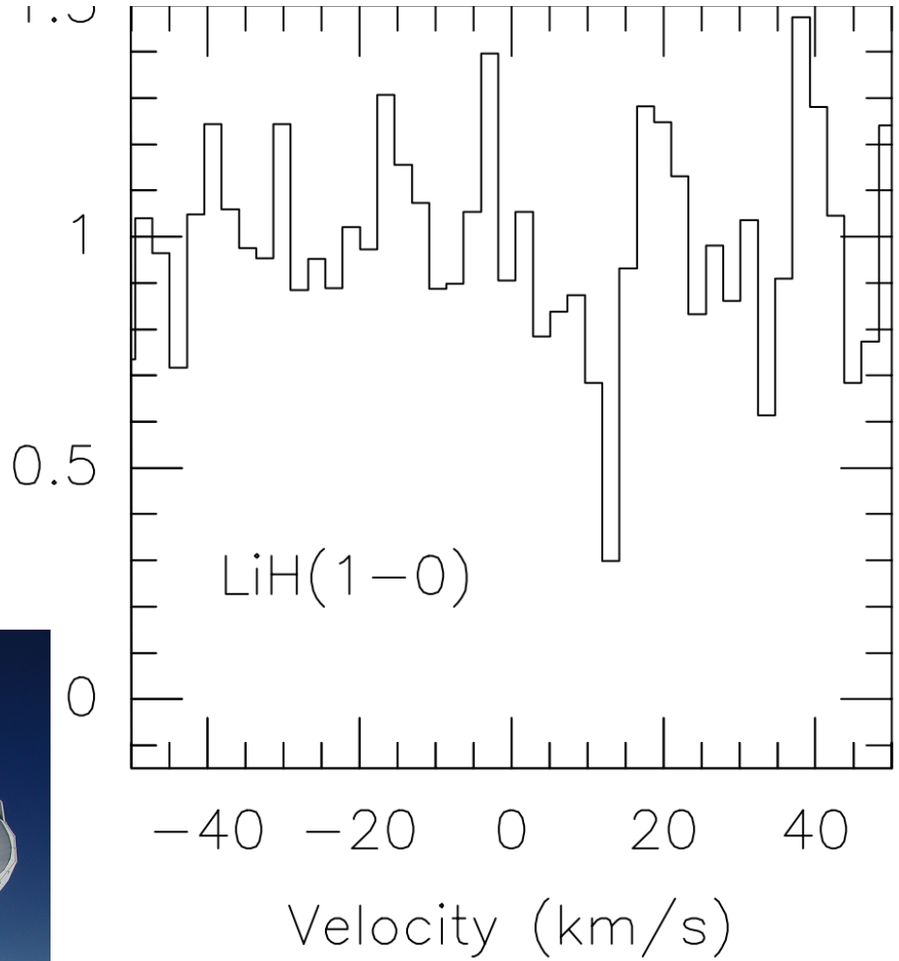


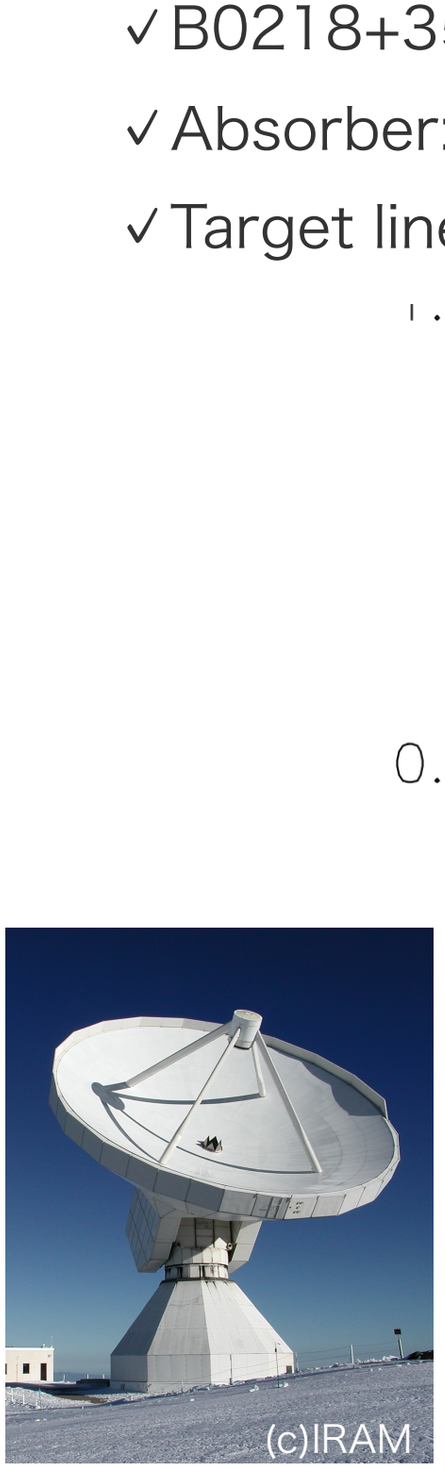
Howk et al. 2012

LiH as a new and independent probe of Li

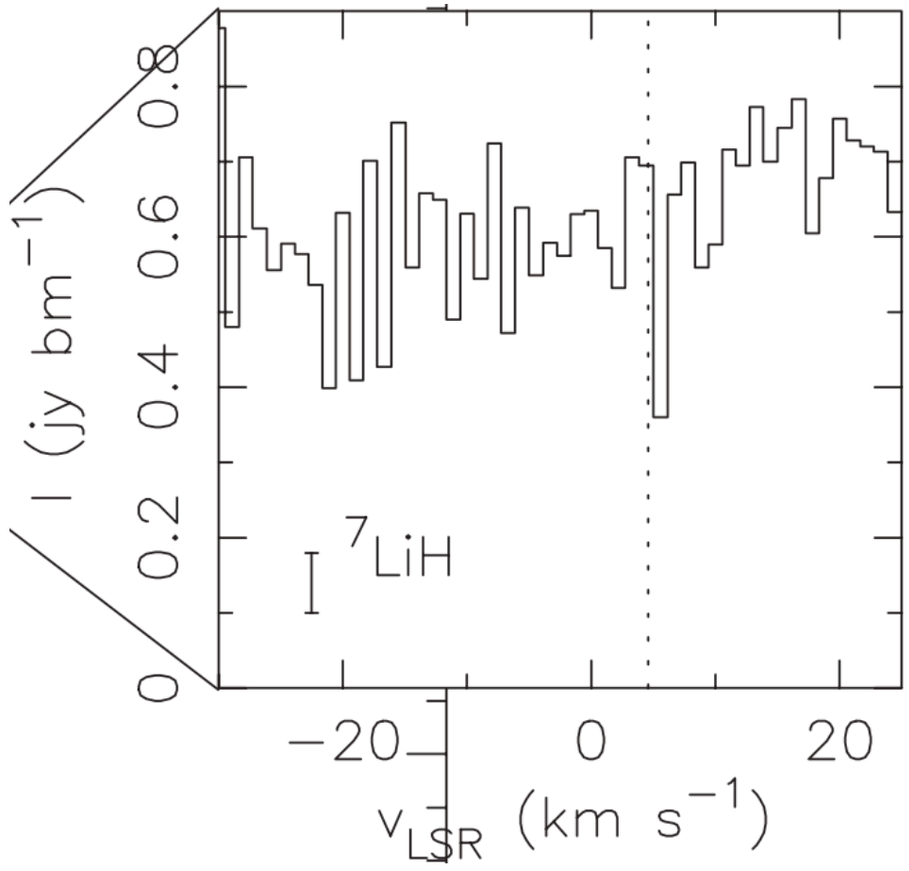
LiH as a new and independent probe of Li

- **Tentative (~3σ) detections of LiH toward B0218+357(?)**
  - ✓B0218+357: BL Lac object at z~0.94
  - ✓Absorber: spiral galaxy at z = 0.68466
  - ✓Target line: ^{7}LiH (1-0) at 444GHz (rest-frame)





Combes & Wiklind 1998,
using IRAM 30m



Friedel et al. 2011,
using CARMA

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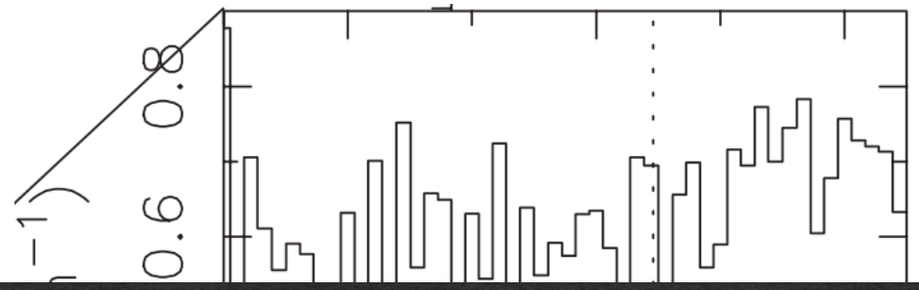
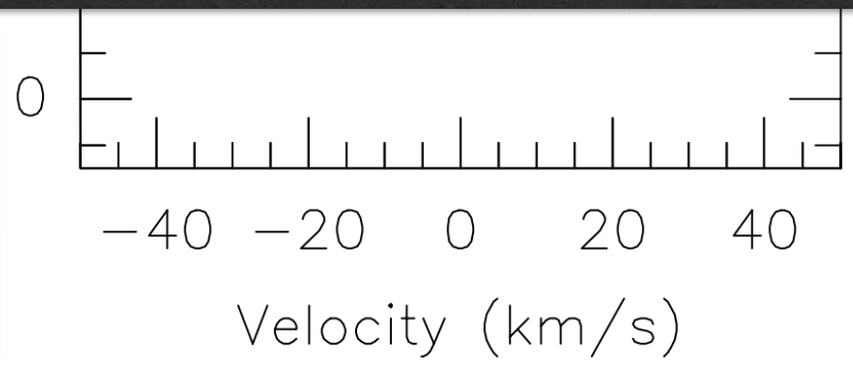


Primarily due to the **lack of sensitivity**,
previous detections are uncertain.



Combes & Wiklind 1998,
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Friedel et al. 2011,
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ALMA cycle 6 project

- Approved and now waiting for the data delivery

Lithium isotope ratio 6Li/7Li in ISM at z=0.68 **2018.1.00187.S**

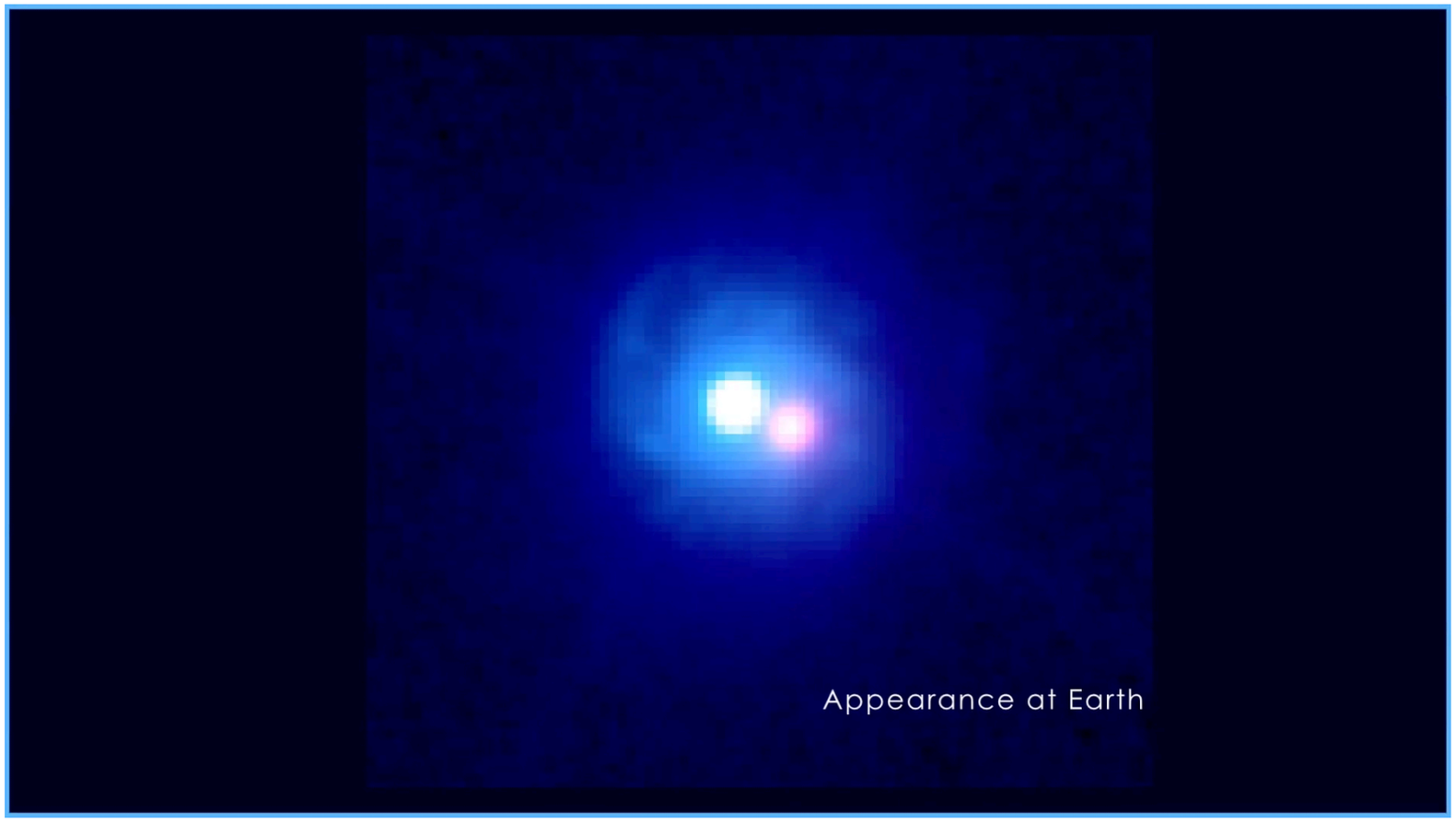
ABSTRACT

Both 7Li and 6Li abundances observed in atmospheres of unevovled halo stars are known to be significantly inconsistent with the standard Big Bang Nucleosynthesis (BBN) prediction (lithium problems). However, whether the standard model should be modified to explain the observed values is contraversial dut to the difficulties of modeling stellar atmosphere and suggested Li destruction processes in stars. Here we propose to observe 7LiH and 6LiH molecular absorption lines in ISM as a new and independent probe of the Li abandunce. Our target is z=0.68 absorber in front of the BL Lac object B0218+357, in which two tentative but indepedent detections of the 7LiH(1-0) absorption line have been reported. We measure the isotope ratio 6Li/7Li in ISM at the cosmic time diffrent from our Galaxy, which definitly provide us with a new and strong constraint toward the standard model.

PI NAME:	Yuki Yoshimura			**SCIENCE CATEGORY:**	ISM, star formation and astrochemistry
ESTIMATED 12M TIME:	**6.0 h**	**ESTIMATED ACA TIME:**	**0.0 h**	**ESTIMATED NON-STANDARD MODE TIME (12-M):**	**0.0 h**
CO-PI NAME(S): (Large & VLBI Proposals only)					
CO-INVESTIGATOR NAME(S):	Kotaro Kohno; Tadafumi Matsuno; Wako Aoki; Yuri Nishimura; Yoichi Tamura; Takuma Izumi; Bunyo Hatsukade; Minju Lee				
DUPLICATE OBSERVATION JUSTIFICATION:					

Target: B0218+357

- **A high-z molecular absorption line system at z=0.68**
  - ✓Lensed BL Lac object at z~0.94
  - ✓Lensing galaxy is a spiral galaxy at z=0.68 and its ISM is absorber.
    - ➡ LiH absorption lines are redshifted into the atmospheric window.
  - ✓Molecular absorption was first discovered by Wikinlind & Combes 95.
  - ✓Many molecules have been discovered (e.g., Wallstrom+16).



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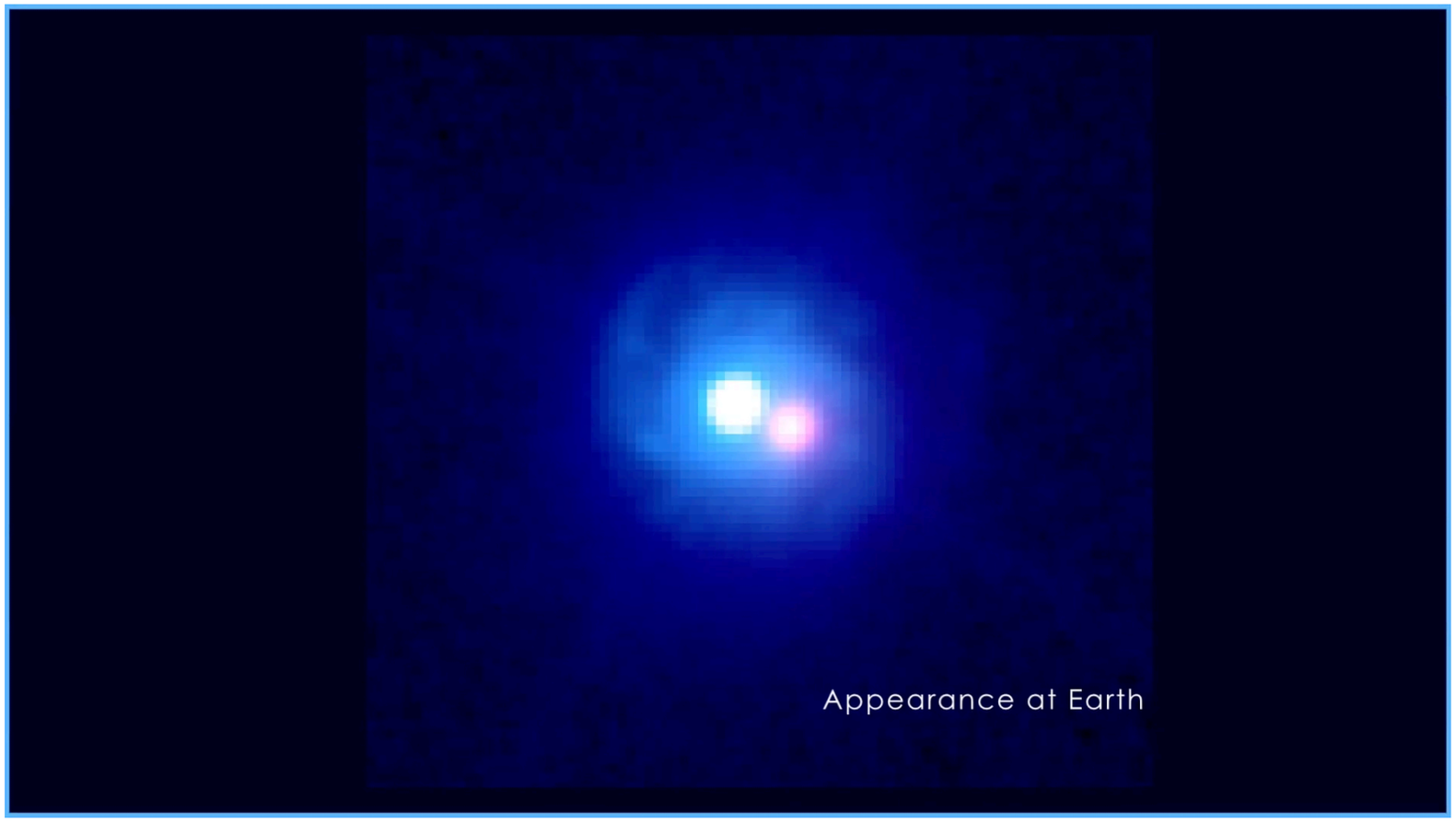

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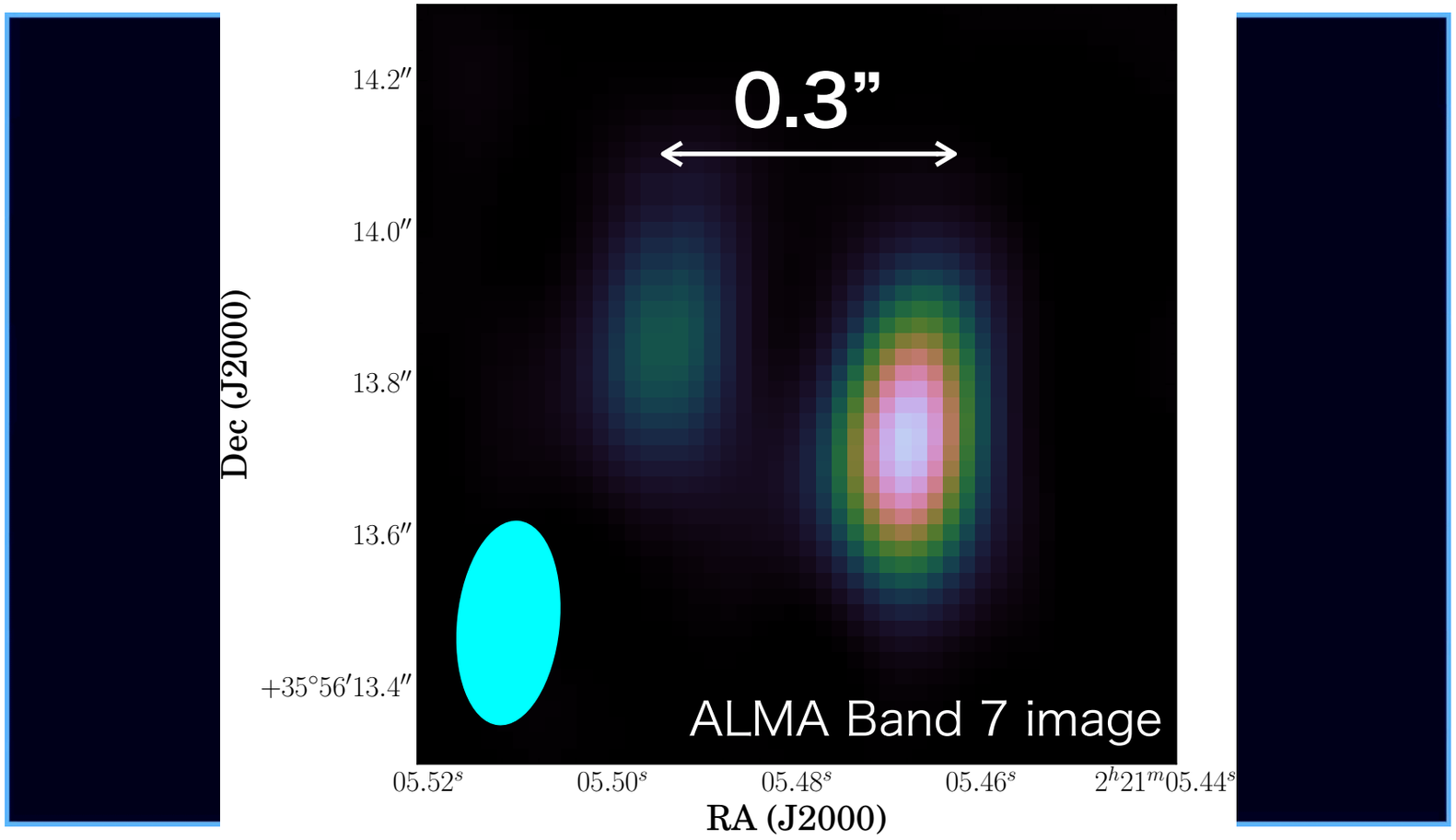

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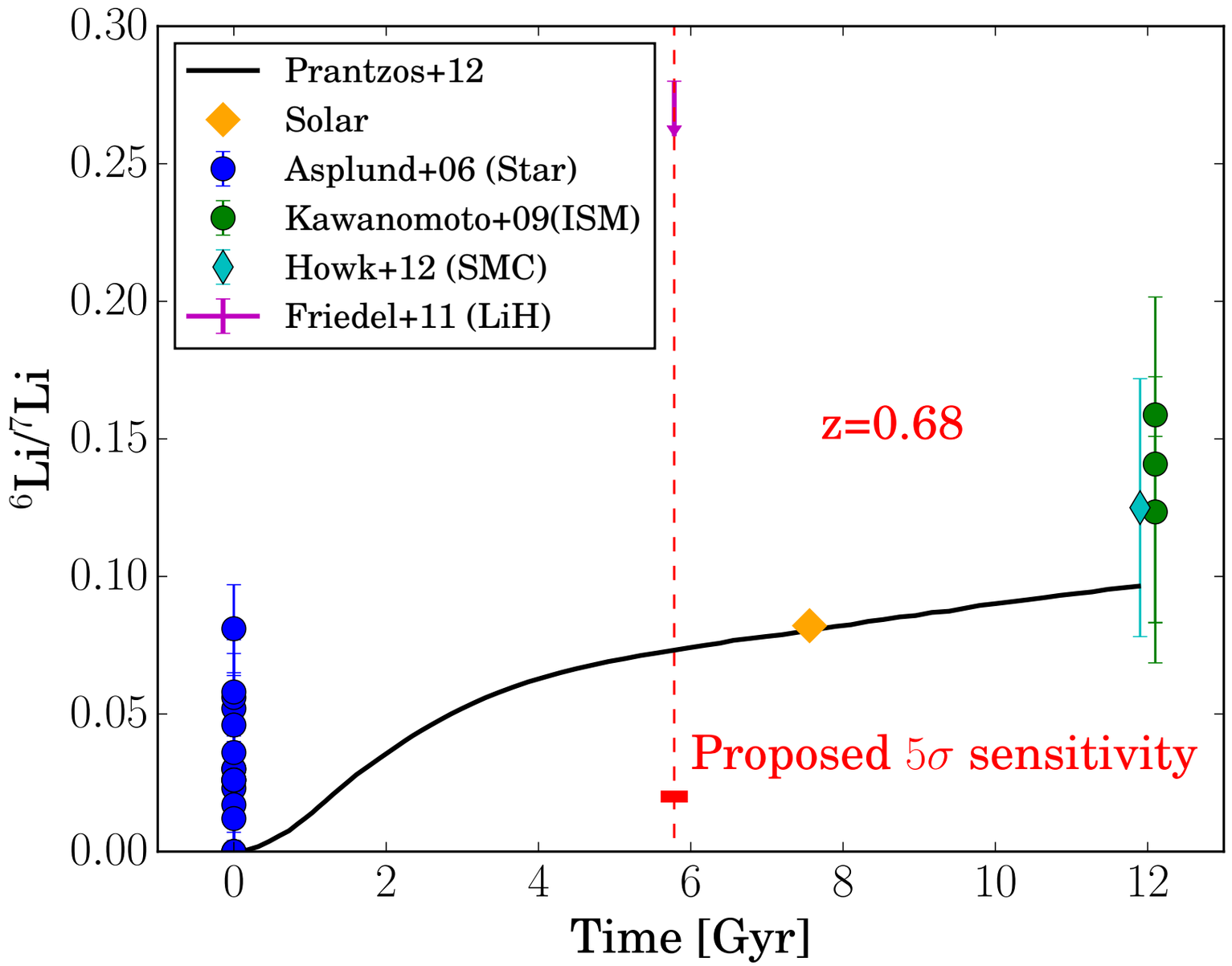
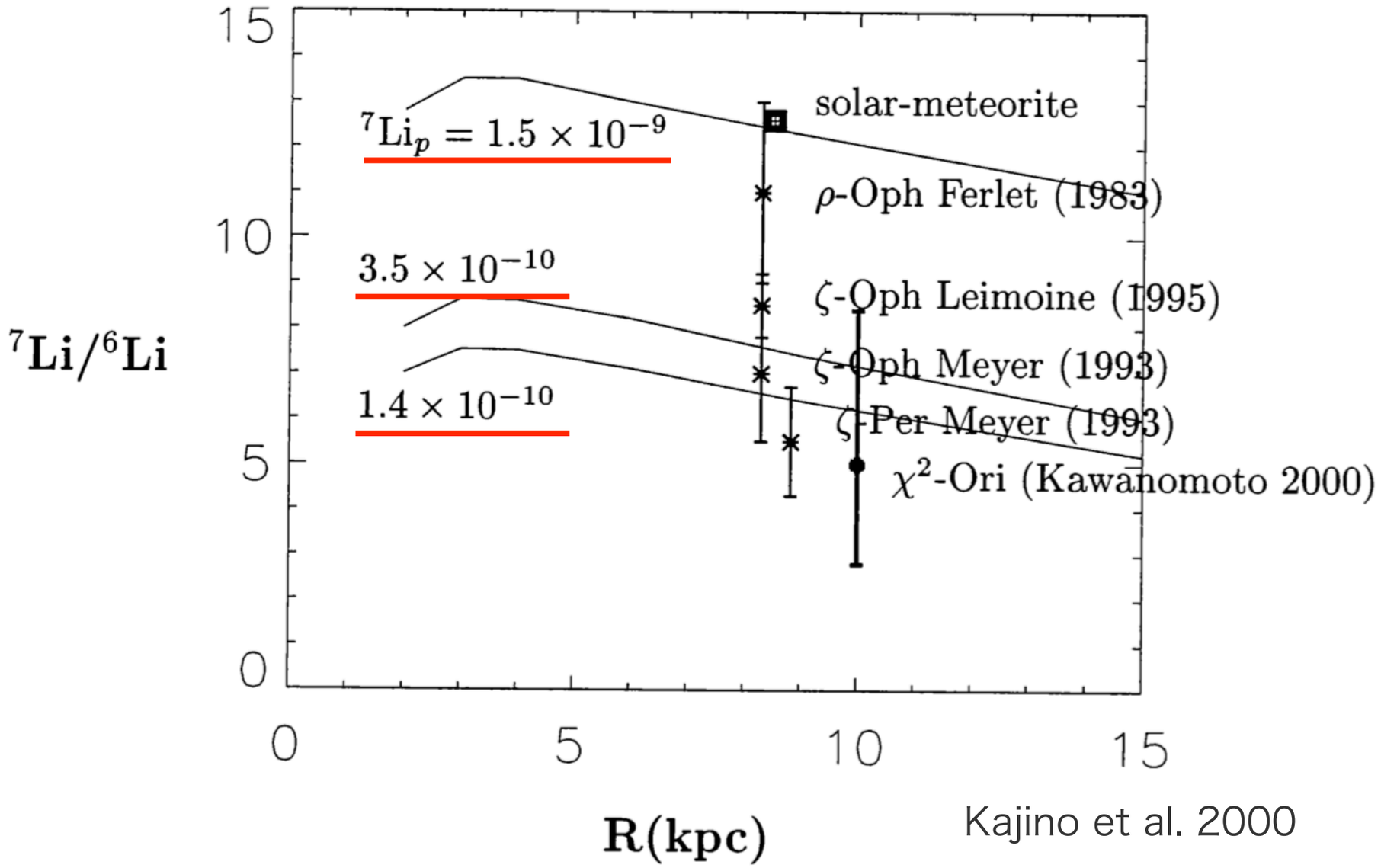
Comparison with a fiducial model

- **A “realistic” model provided by Prantzos et al. 2012**
  - ✓Assuming SBBN, standard GCR and realistic stellar production
  - ✓The dependence of galactcentric distance is also predicted.



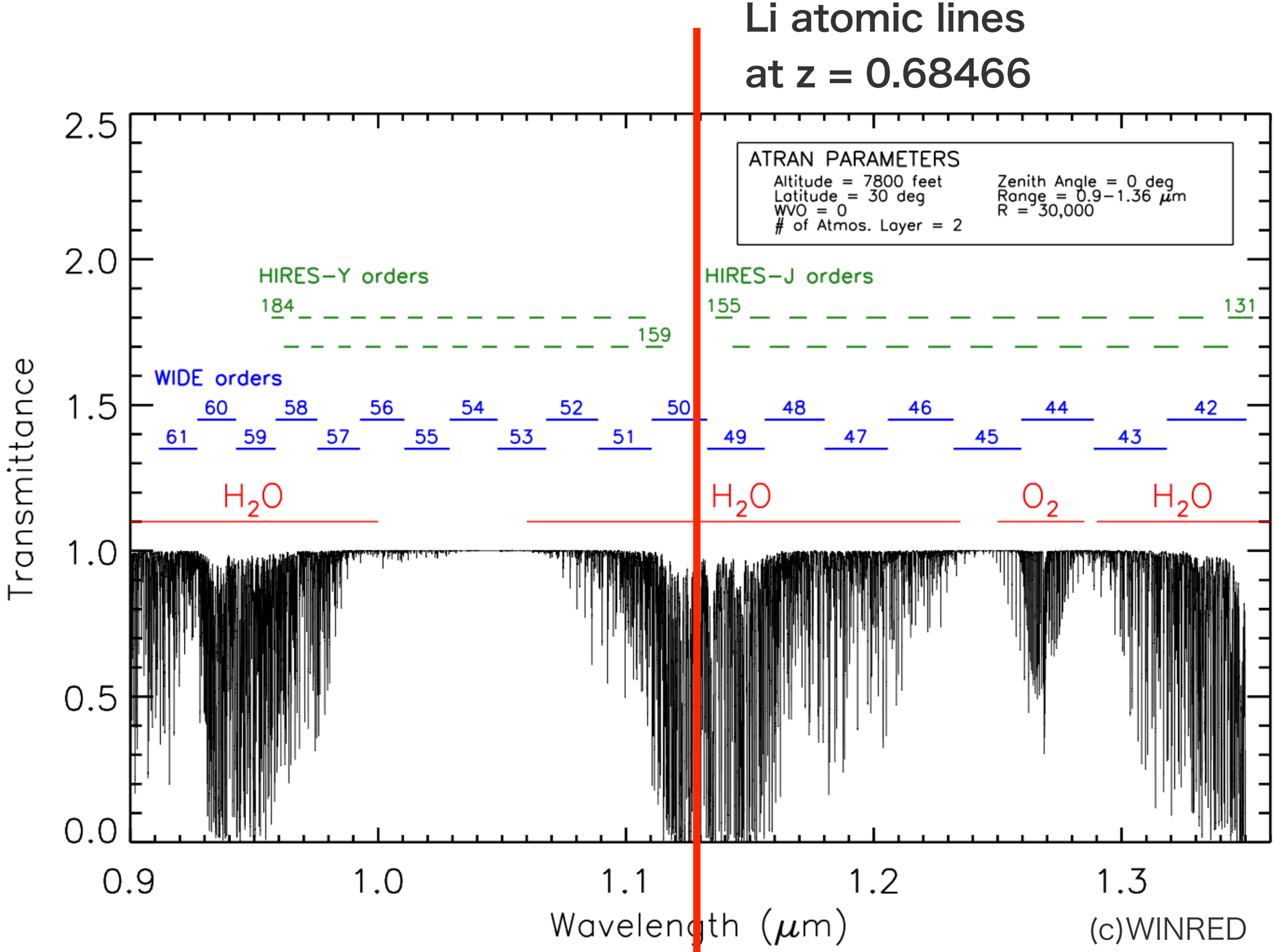
Can we convert ^{6}Li/^{7}Li to ^{7}Li/H?



Kajino et al. 2000

- We need models for galaxies other than MW.
- Further observation toward B0218+357 in other wavelength to determine the detailed profiles (e.g., SFR, [Fe/H],…) of the absorber.

Atomic lines can be detected?



Summary

- **Lithium isotope ratio in ISM at z = 0.68**
  - ✓ There are pressing need for new probes of the (primordial) lithium abundance.
  - ✓ We are conducting the measurement of 6Li/7Li in ISM at z = 0.68 molecular absorber B0218+357 using ALMA.
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