16 Cygni: A key binary system for the study of the planet-star chemical connection

Marcelo Tucci Maia
mmaia@lna.br
@TucciMTM

SAMPA
Stellar Atmospheres, Planets and Abundances

CNPq

LNA

Colaborators:
Jorge Melendez IAG-USP
Diego Lorenzo IAG-USP
Lorenzo Spina IAG-USP

Why 16 Cygni?

A well known binary system

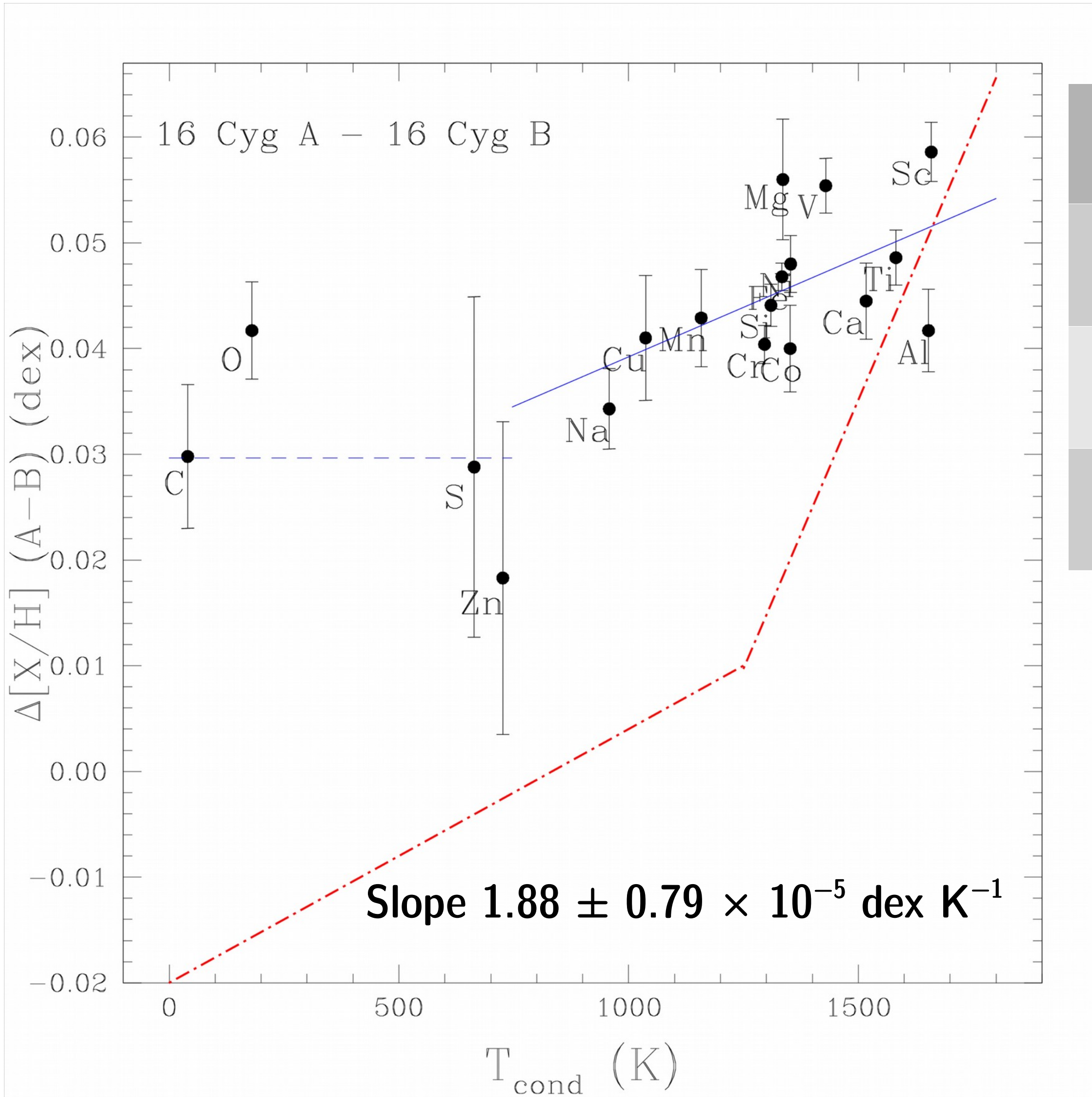
16 Cyg B has a Jupiter size planet (M $>$ 1.5 Cochram et al 1997) while A has no planets

Both stars are solar twins born from the same cloud:
-Differential abundances ($\sim$0.01 dex)

Galactic chemical evolution and birthplace effects minimized

Reveal possible effects of planet formation or planet accretion on stellar surface composition

Previous Work

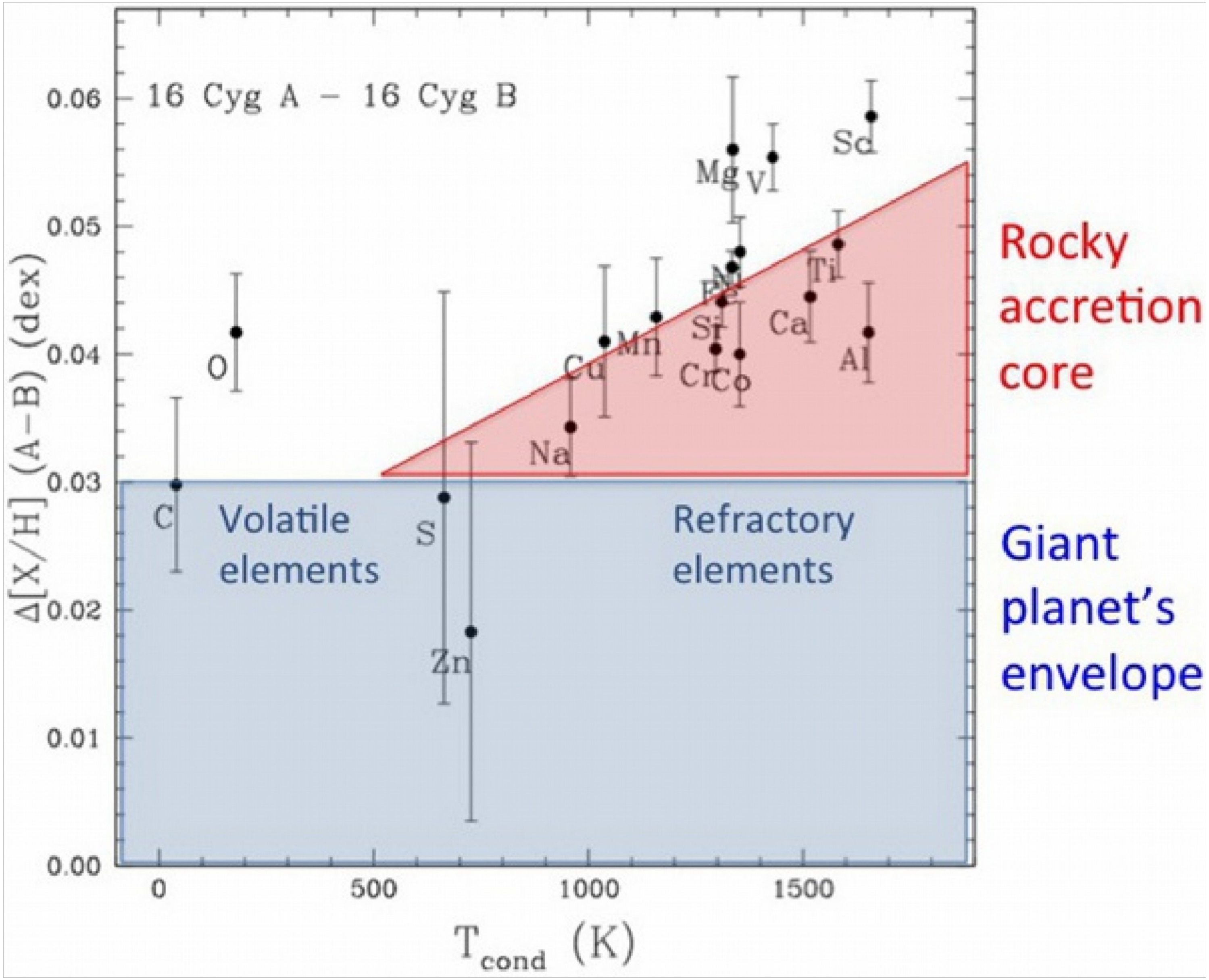


	A	B
Teff [K]	5830 ± 11	5751 ± 11
Log g [dex]	4.300 ± 0.02	4.350 ± 0.02
[Fe/H] [dex]	0.101 ± 0.008	0.054 ± 0.008

Δ[Fe/H] (A-B) = 0.047 ± 0.008

Ramirez et al. 2011

Tucci Maia et al. 2014



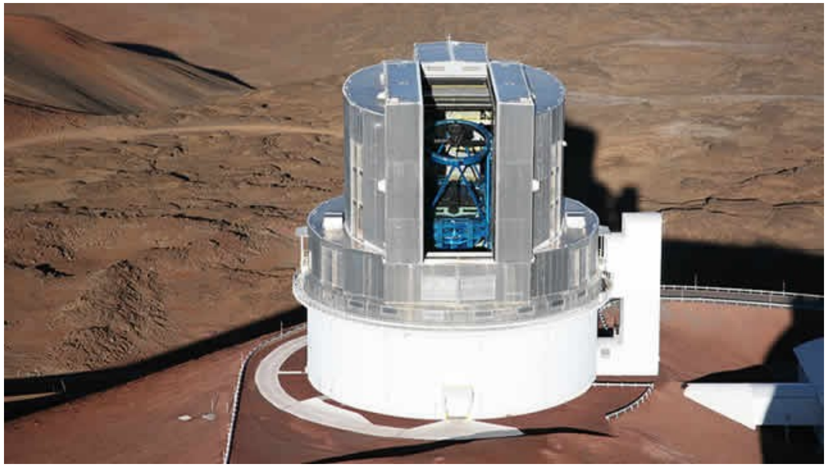
Rocky Core ∼ 1.5 – 6 Earth Masses

Why reanalyse 16 Cygni?

Better data!

CFHT – ESPADONS

R ~ 81 000
S/N ~700 around 600 nm



Subaru – HDS

R ~ 160 000
S/N ~ 1000 around 600 nm

Do not found different [Fe/H] between A and B:
Deliyannis et al. 2000; Schuler et al. 2011; Takeda et al. 2011

The "new" surface stellar parameters

	A	B
Teff [K]	5832 ± 5	5763 ± 5
Log g [dex]	4.310 ± 0.014	4.360 ± 0.014
[Fe/H] [dex]	0.103 ± 0.004	0.063 ± 0.004

Δ[Fe/H] (A-B) = 0.040 ± 0.004

Tucci Maia et al. 2017, in prep

	A	B
Teff [K]	5830 ± 11	5751 ± 11
Log g [dex]	4.300 ± 0.02	4.350 ± 0.02
[Fe/H] [dex]	0.101 ± 0.008	0.054 ± 0.008

Δ[Fe/H] (A-B) = 0.047 ± 0.008

Tucci Maia et al. 2014

	A	B
Teff [K]	5816 ± 10	5763 ± 10
Log g [dex]	4.291 ± 0.01	4.356 ± 0.01
[Fe/H] [dex]	0.093 ± 0.007	0.062 ± 0.007

Δ[Fe/H] (A-B) = 0.031 ± 0.007

Nissen et al. 2017, in prep
using seismic surface gravities
from Silva Aguirre et al. (2017)

Our method is consistent

Age, Radius and Mass

	A	B	
M/M_{sun}	1.06 ± 0.01	1.01 ± 0.01	This work
M/M_{sun}	1.08 ± 0.02	1.04 ± 0.02	Metcalfe et al. 2015
R/R_{sun}	1.22 ± 0.01	1.09 ± 0.02	This Work
R/R_{sun}	1.229 ± 0.008	1.116 ± 0.006	Metcalfe et al. 2015
Age [Gyr]	6.4 ± 0.2	7.1 ± 0.3	This work
Age [Gyr]	7.0 ± 0.1	7.0 ± 0.1	van Saders et al. 2016

Abundance Clock

[Y/Mg]

A= 6.2 $\pm$ 1.0 Gyr
B= 6.3 $\pm$ 1.0 Gyr

Tucci Maia et al. 2016

[Al/Mg]

A= 6.6 $\pm$ 1.0 Gyr
B= 6.8 $\pm$ 1.0 Gyr

Spina et al. 2016

Stellar parameters using automated EW measurement tools

DAOSPEC

	A	B
Teff	5838± 4	5757± 4
Log g	4.330± 0.012	4.360± 0.011
[Fe/H]	0.104± 0.004	0.059± 0.004

Δ[Fe/H] = 0.045 ± 0.004

ARES

	A	B
Teff	5833± 19	5781± 18
Log g	4.340± 0.046	4.420± 0.054
[Fe/H]	0.107± 0.016	0.058± 0.017

Δ[Fe/H] = 0.049 ± 0.023

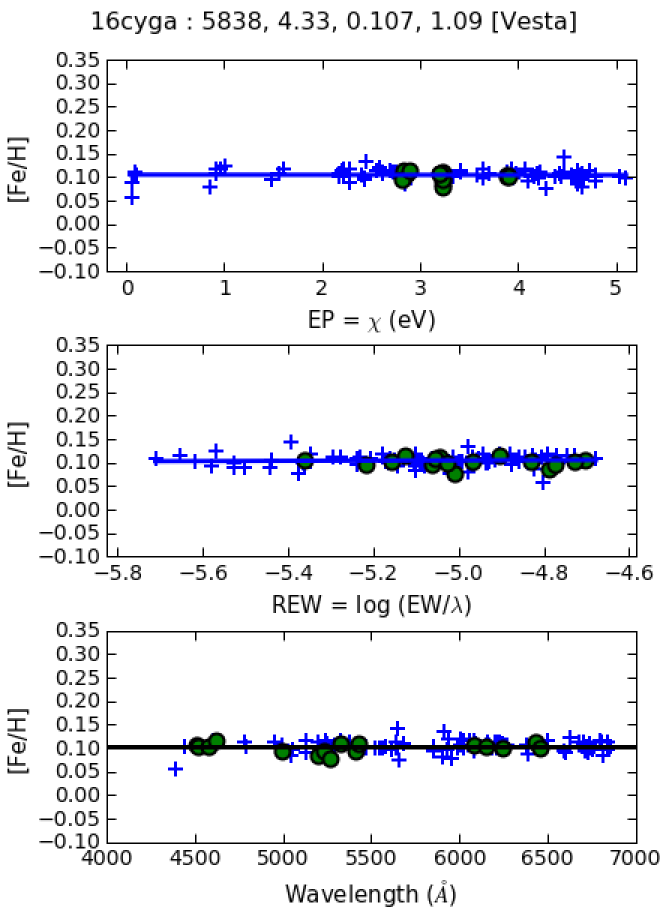
ISPEC

	A	B
Teff	5830± 5	5744± 4
Log g	4.350± 0.015	4.370± 0.013
[Fe/H]	0.104± 0.006	0.049± 0.005

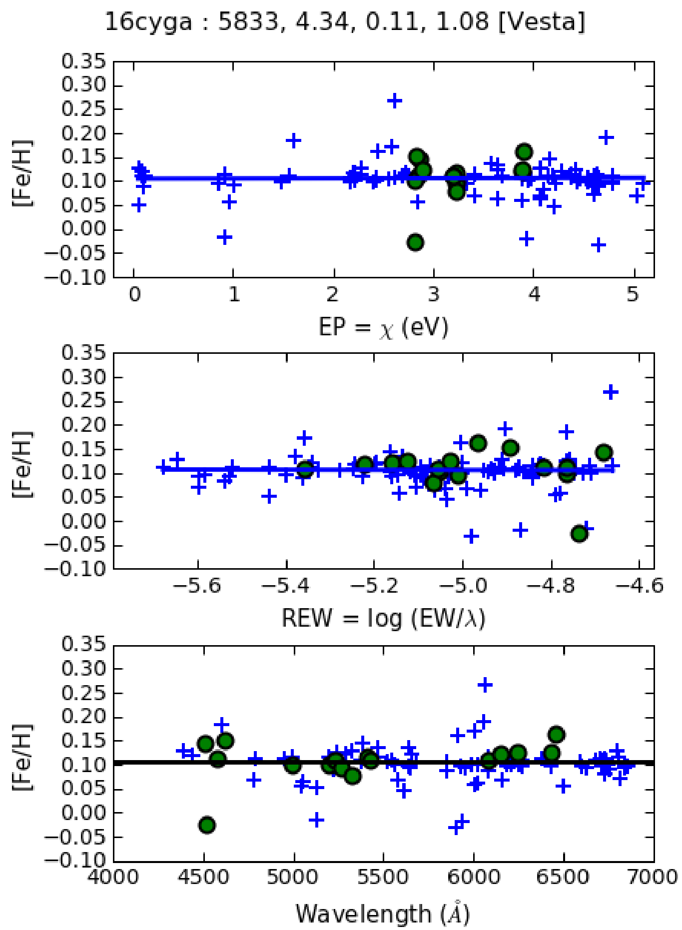
Δ[Fe/H] = 0.055 ± 0.008

16 Cyg A is ∼ 0.04 dex richier than B

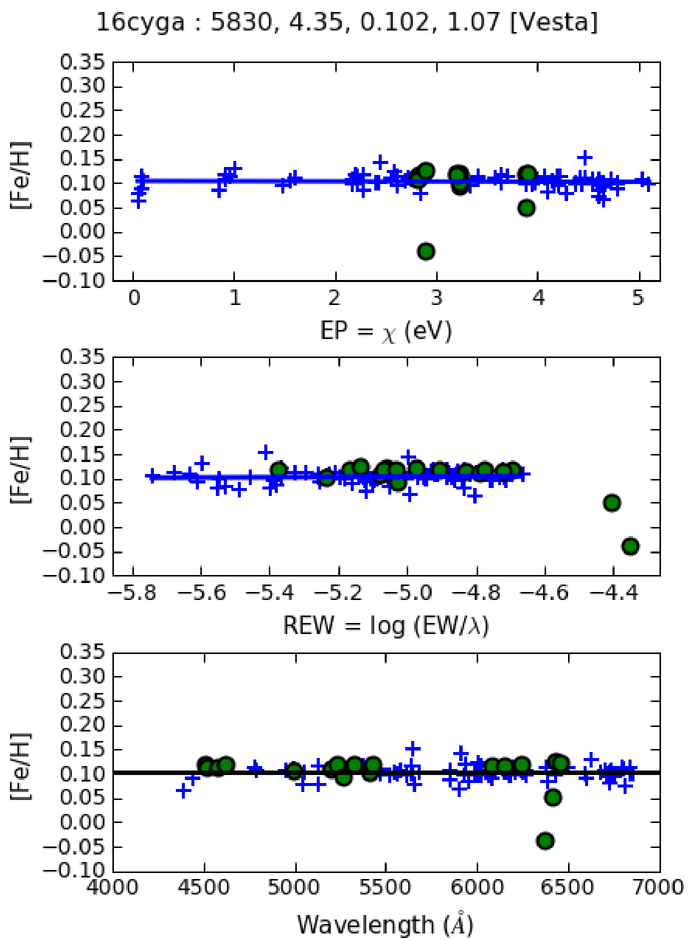
Stellar parameters using automated EW measurement tools



DAOSPEC

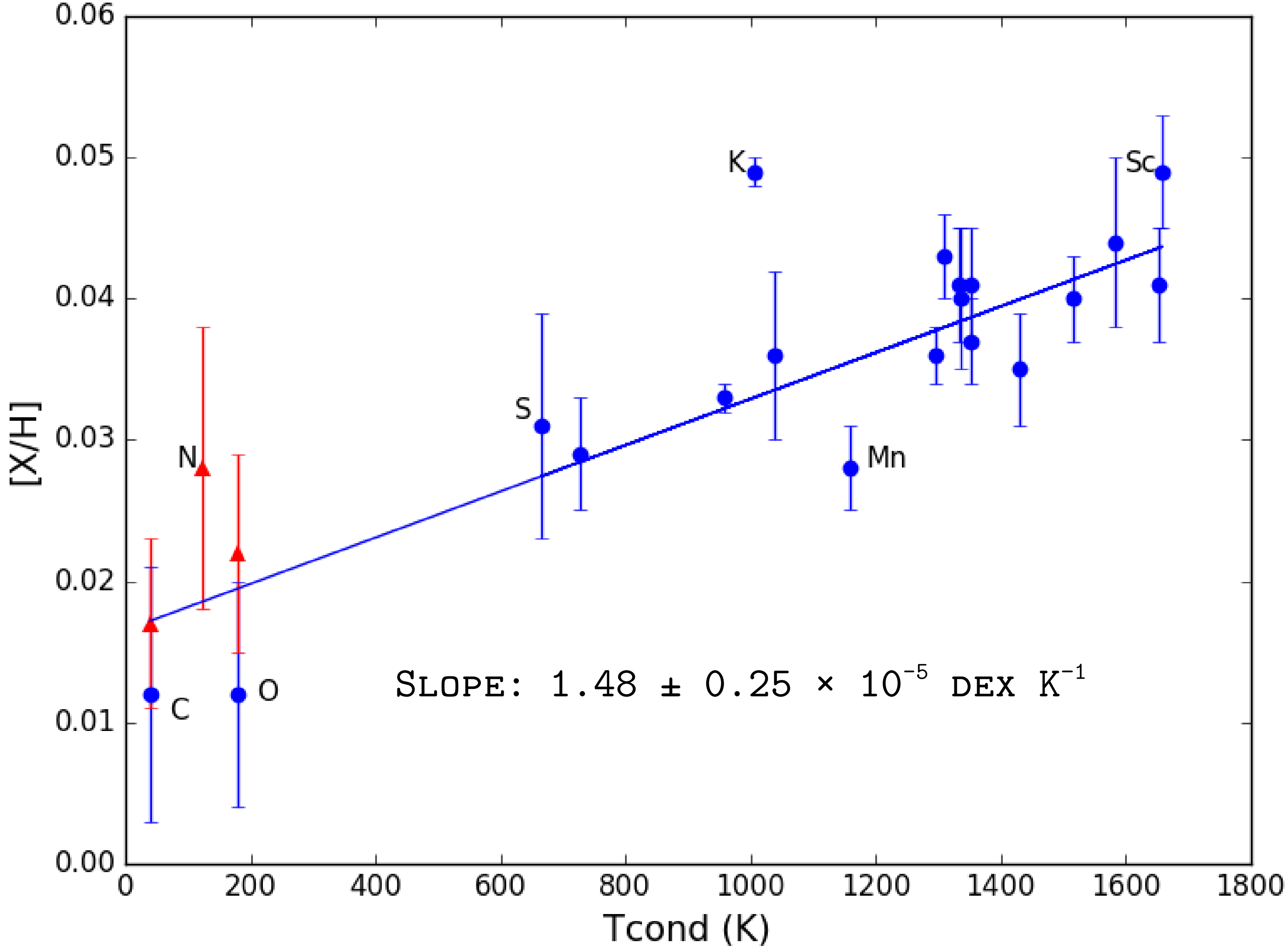


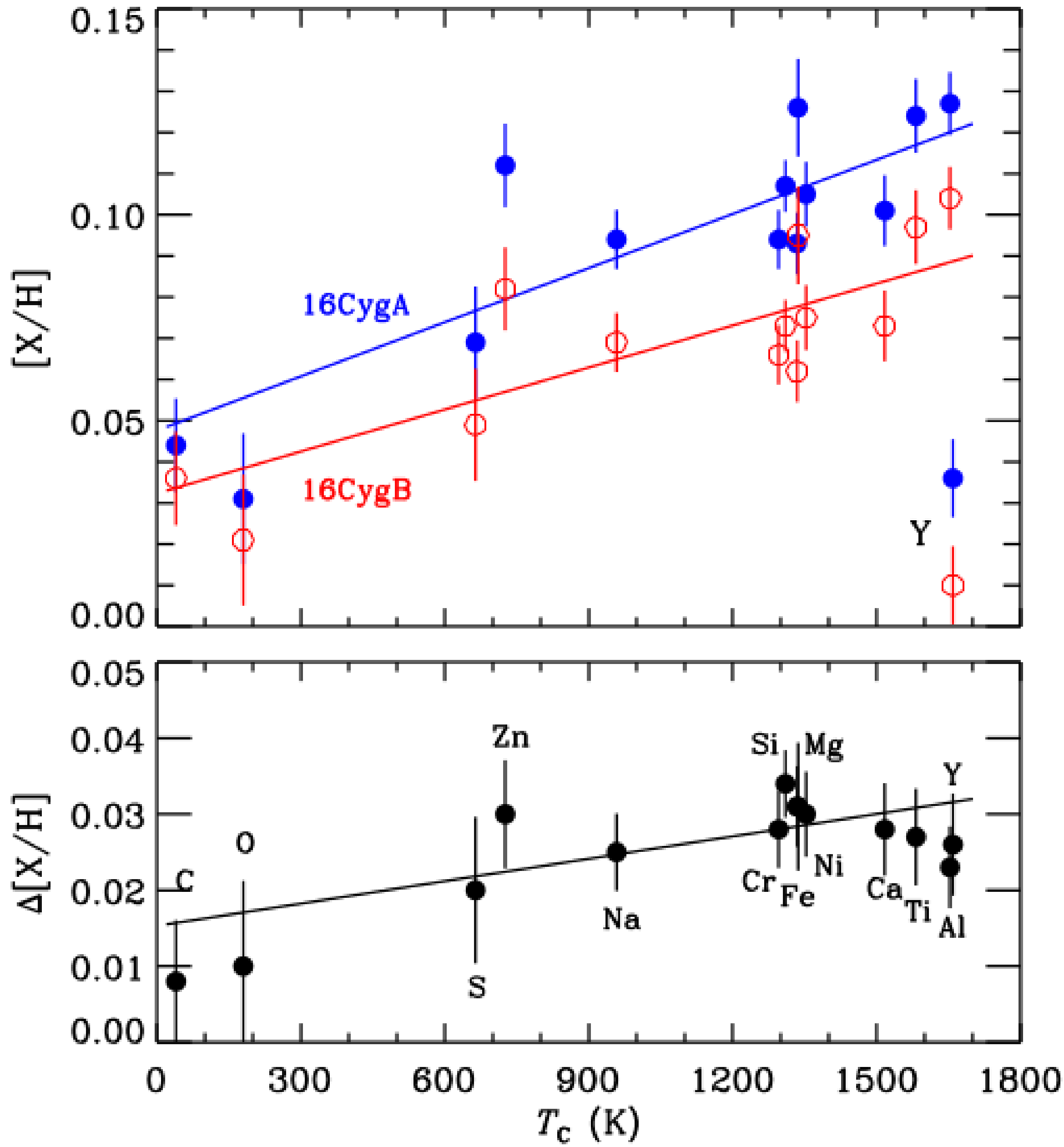
ARES



ISPEC

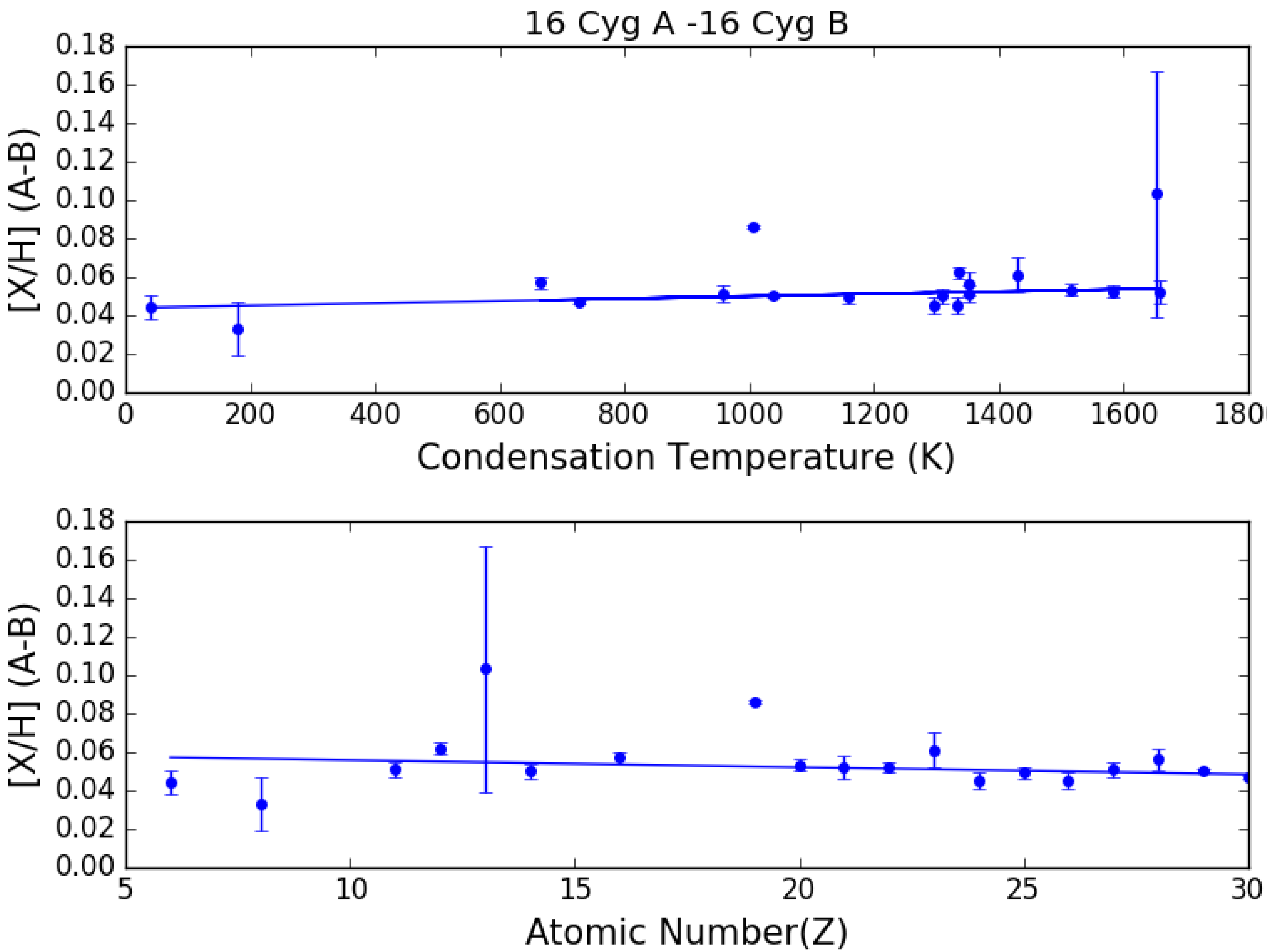
The "new" condensation temperature trend





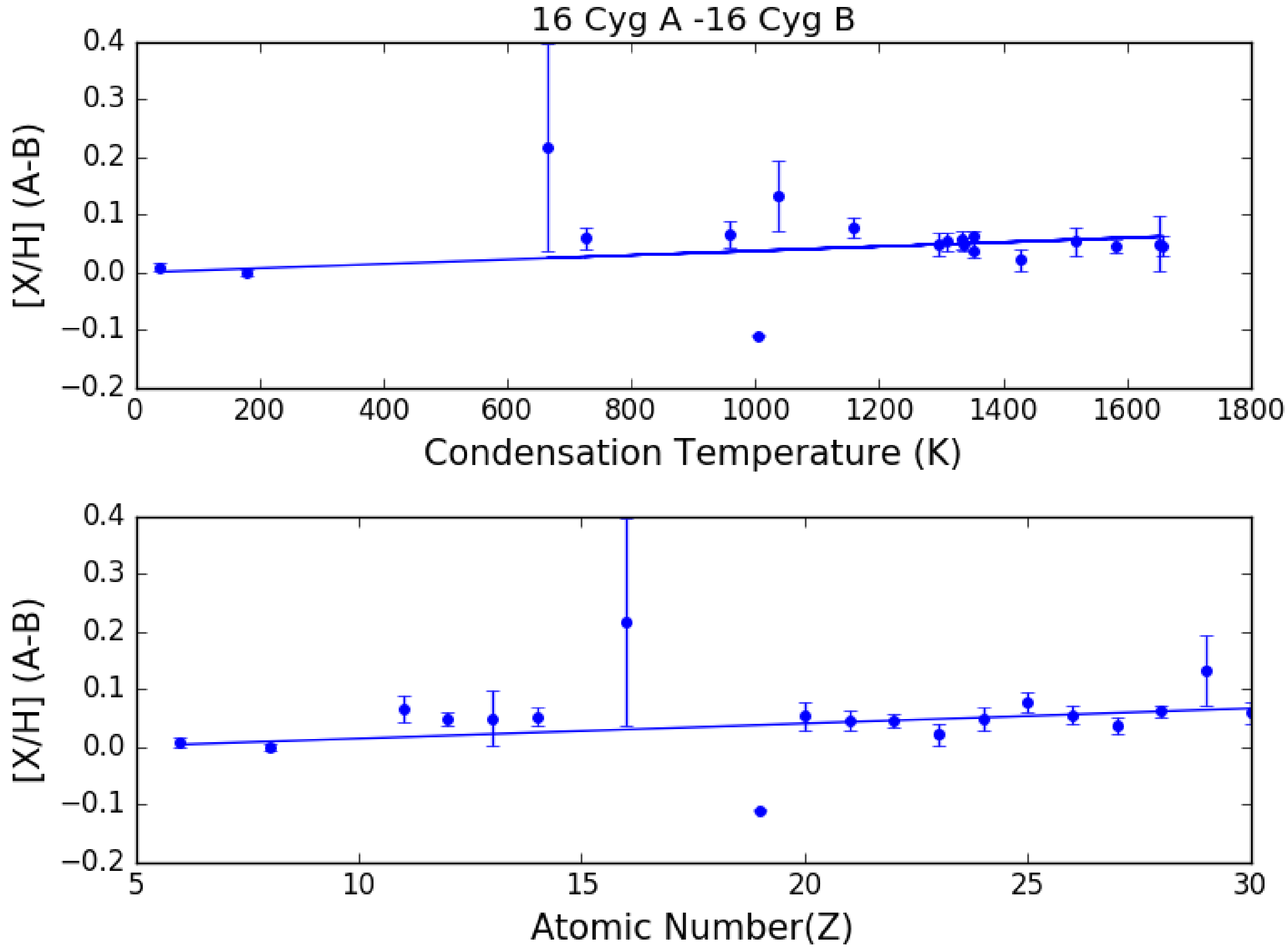
Nissen et al. 2017, in prep

EW tools condensation trend



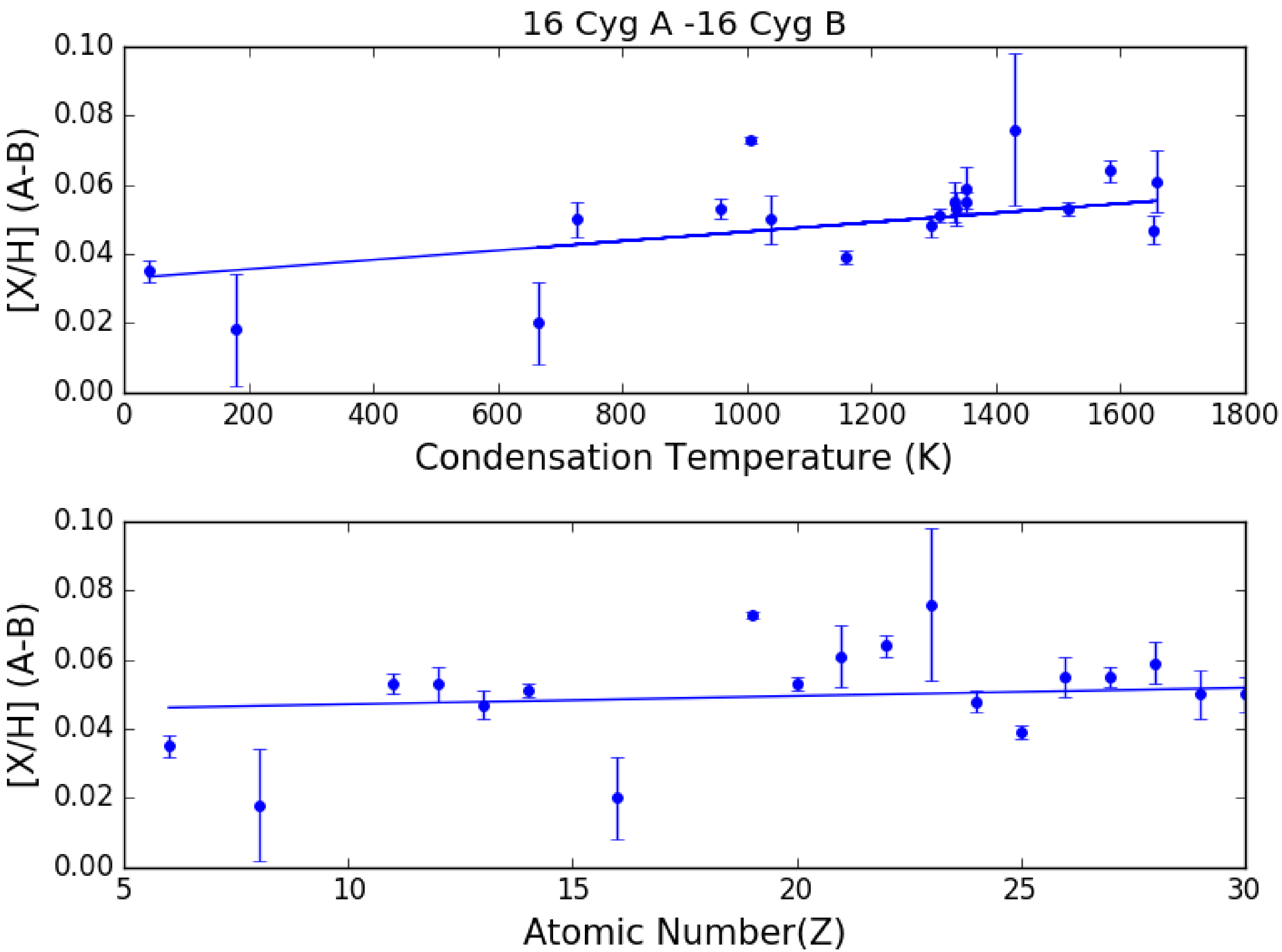
DAOSPEC

EW tools condensation trend



ARES

EW tools condensation trend



ISPEC

Linear fits

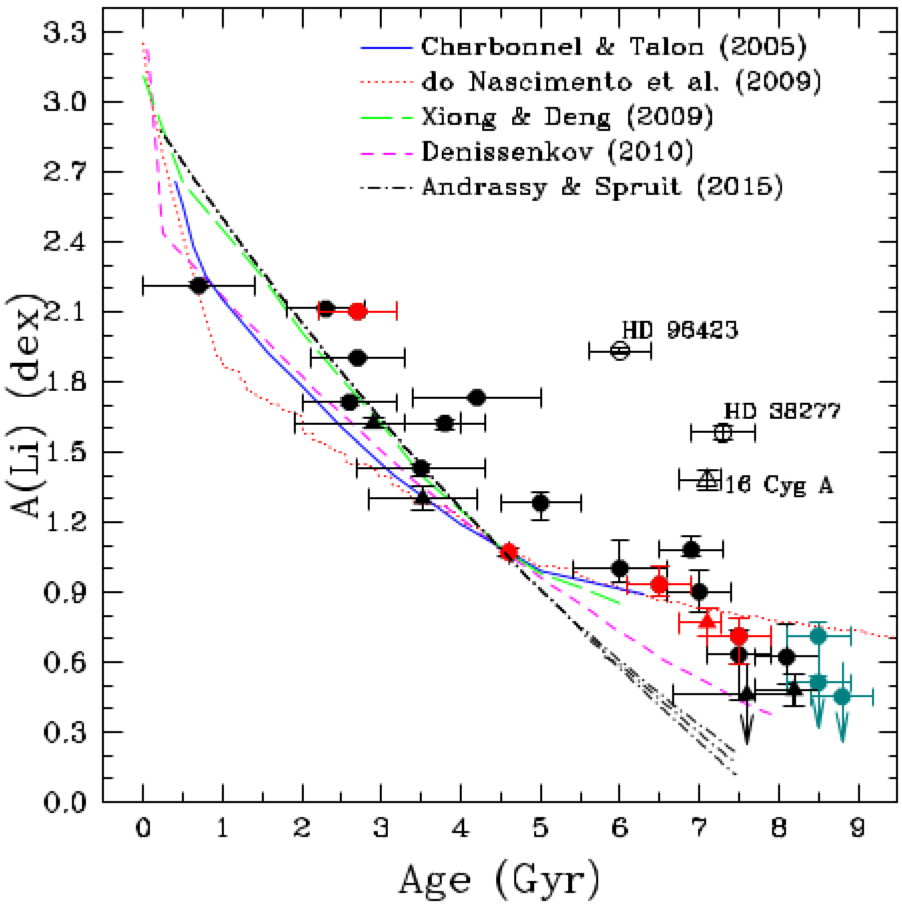
	Slope (dex.K^{-1})	Minium uncertainty (dex)
ours	$1.64 \times 10^{-5} \pm 2.52 \times 10^{-6}$	n.a.
iSpec	$1.45 \times 10^{-5} \pm 3.78 \times 10^{-6}$	0.006
ARES	$2.22 \times 10^{-5} \pm 1.53 \times 10^{-5}$	0.028
Daospec	$5.99 \times 10^{-6} \pm 4.66 \times 10^{-6}$	0.008

All fits show a positive Tcond trend

The condensation temperature trend is a signature of the 16 Cyg Bb rocky core?

Stabilization of the Convective Zone problem

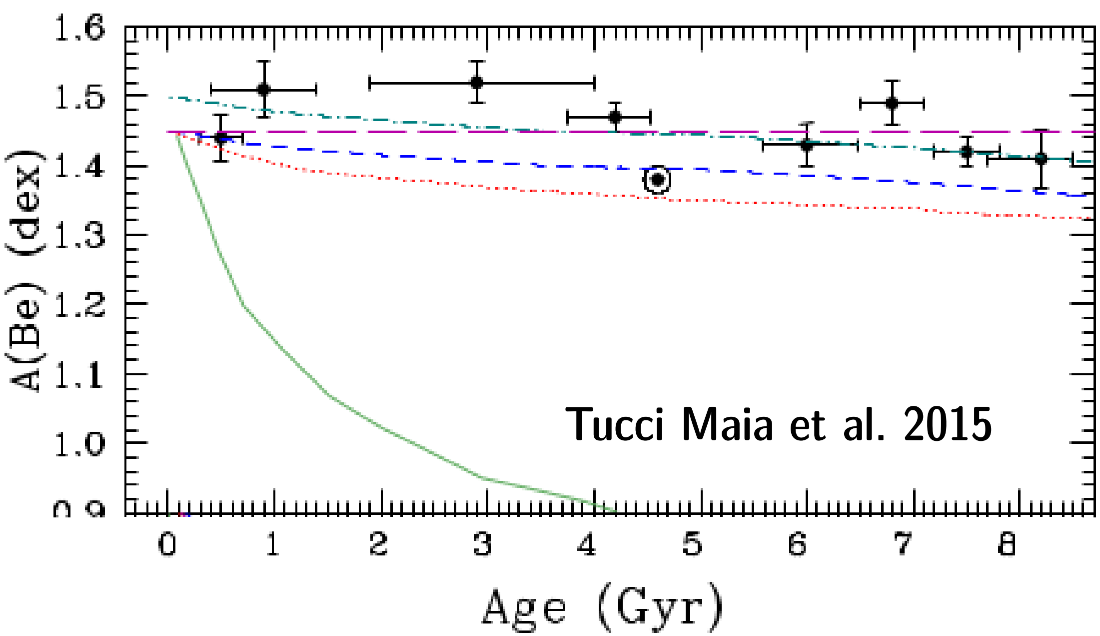
Anomalous Li abundance for the age of 16 Cyg A, while 16 Cyg B seems normal



Carlos et al. 2016

The condensation temperature trend is a signature of the 16 Cyg Bb rocky core?

	16 Cyg A	16 Cyg B
Li (dex)	1.31±0.03	0.61±0.03
Be (dex)	1.50±0.03	1.43±0.03
V_{macro} (km s^{-1})	3.97	3.66
v sin i (km s^{-1})	1.37 ± 0.02	1.22 ± 0.03



Li = 0.70 dex
Be = 0.07 dex

2.5-3.0 Earth-like masses of Earth composition material

Evidence of planet engulfment on 16 Cyg A

Does not exclude the possibility of spectral signature of rocky core formation