Chemodynamical Analysis of Six Low-Metallicity Stars in the Halo System of the Milky Way

Main coauthors
Vinicius Placco

mardini@nao.cas.cn

The Astrophysical Journal, 882:27 (16pp), 2019 September 1 https://doi.org/10.3847/1538-4357/ab3047

Metal-poor Stars Observed with the Automated Planet Finder Telescope. II. Chemodynamical Analysis of Six Low-metallicity Stars in the Halo System of the Milky Way

Mohammad K. Mardini[1,2], Vinicius M. Placco[3,4], Ali Taani[5], Haining Li[1], and Gang Zhao[1,2]

[1] Key Lab of Optical Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, People's Republic of China; lhn@nao.cas.cn, gzhao@nao.cas.cn
[2] School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing, People's Republic of China
[3] Department of Physics, University of Notre Dame, Notre Dame, IN 46556, USA
[4] JINA Center for the Evolution of the Elements, USA
[5] Physics Department, Faculty of Science, Al-Balqa Applied University, Al-Salt, Jordan
Received 2019 May 15; revised 2019 July 1; accepted 2019 July 4; published 2019 August 28

Abstract

In this work, we study the chemical compositions and kinematic properties of six metal-poor stars with [Fe/H] < -2.5 in the Galactic halo. From high-resolution ($R \sim 110{,}000$) spectroscopic observations obtained with the Lick/Automated Planet Finder, we determined individual abundances for up to 23 elements, to quantitatively evaluate our sample. We identify two carbon-enhanced metal-poor stars (J1630+0953 and J2216+0246) without enhancement in neutron-capture elements (CEMP-no stars), while the rest of our sample stars are carbon-intermediate. By comparing the light-element abundances of the CEMP stars with predicted yields from nonrotating zero-metallicity massive-star models, we find that the possible progenitors of J1630+0953 and J2216+0246 could be in the 13–25 $M_{\odot}$ mass range, with explosion energies $(0.3–1.8) \times 10^{51}$ erg. In addition, the detectable abundance ratios of light and heavy elements suggest that our sample stars are likely formed from a well-mixed gas cloud, which is consistent with previous studies. We also present a kinematic analysis, which suggests that most of our program stars likely belong to the inner-halo population, with orbits passing as close as ~2.9 kpc from the Galactic center. We discuss the implications of these results on the critical constraints on the origin and evolution of CEMP stars, as well as the nature of the Population III progenitors of the lowest-metallicity stars in our Galaxy.

Key words: Galaxy: halo – stars: abundances – stars: atmospheres – stars: fundamental parameters – stars: kinematics and dynamics – techniques: imaging spectroscopy

Supporting material: machine-readable table

mardini@nao.cas.cn

The Astrophysical Journal, 882:27 (16pp), 2019 September 1 https://doi.org/10.3847/1538-4357/ab3047

Metal-poor Stars Observed with the Automated Planet Finder Telescope. II. Chemodynamical Analysis of Six Low-metallicity Stars in the Halo System of the Milky Way

Mohammad K. Mardini[1,2], Vinicius M. Placco[3,4], Ali Taani[5], Haining Li[1], and Gang Zhao[1,2]

[1] Key Lab of Optical Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, People's Republic of China; lhn@nao.cas.cn, gzhao@nao.cas.cn

[2] School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing, People's Republic of China

[3] Department of Physics, University of Notre Dame, Notre Dame, IN 46556, USA

[4] JINA Center for the Evolution of the Elements, USA

[5] Physics Department, Faculty of Science, Al-Balqa Applied University, Al-Salt, Jordan

Received 2019 May 15; revised 2019 July 1; accepted 2019 July 4; published 2019 August 28

Abstract

In this work, we study the chemical compositions and kinematic properties of six metal-poor stars with [Fe/H] < −2.5 in the Galactic halo. From high-resolution ($R \sim 110,000$) spectroscopic observations obtained with the Lick/Automated Planet Finder, we determined individual abundances for up to 23 elements, to quantitatively evaluate our sample. We identify two carbon-enhanced metal-poor stars (J1630+0953 and J2216+0246) without enhancement in neutron-capture elements (CEMP-no stars), while the rest of our sample stars are carbon-intermediate. By comparing the light-element abundances of the CEMP stars with predicted yields from nonrotating zero-metallicity massive-star models, we find that the possible progenitors of J1630+0953 and J2216+0246 could be in the 13–25 $M_\odot$ mass range, with explosion energies $(0.3\text{–}1.8) \times 10^{51}$ erg. In addition, the detectable abundance ratios of light and heavy elements suggest that our sample stars are likely formed from a well-mixed gas cloud, which is consistent with previous studies. We also present a kinematic analysis, which suggests that most of our program stars likely belong to the inner-halo population, with orbits passing as close as ~2.9 kpc from the Galactic center. We discuss the implications of these results on the critical constraints on the origin and evolution of CEMP stars, as well as the nature of the Population III progenitors of the lowest-metallicity stars in our Galaxy.

Key words: Galaxy: halo – stars: abundances – stars: atmospheres – stars: fundamental parameters – stars: kinematics and dynamics – techniques: imaging spectroscopy

Supporting material: machine-readable table

mardini@nao.cas.cn

The LAMOST-APF Project

- Increase the statistics of CEMP stars, especially at [Fe/H] < -4.0.
- Derive as accurate as possible light elements abundances in these new halo stars.
- Determine the role of metal-poor stars as tracers of the accretion history of the Milky Way halo.

mardini@nao.cas.cn

Overall Phases and Approach

Phase I: Data selection.

Phase II: High-resolution observations.

Phase III: Data Reduction.

Phase IV: Abundance Analysis.

Phase V: Modeling observational data.

Phase VI: Kinematics and Dynamics.

mardini@nao.cas.cn

Data Selection.

- The Large sky Area Multi-Object fiber Spectroscopic Telescope (LAMOST).

- Spectrum (Gray &Corbally 1994), ATLAS9 (Castelli & Kurucz 2004).

- Estimation of stellar parameters.

27 Line indices from lick indices and SEGUE.

Direct comparison in the wavelength range from 4360 to 5500 Å.

Overall Phases and Approach

Phase I: Data selection.

Phase II: High-resolution observations.

Phase III: Data Reduction.

Phase IV: Abundance Analysis.

Phase V: Modeling observational data.

Phase VI: Kinematics and Dynamics.

mardini@nao.cas.cn

Overall Phases and Approach

Phase I: Data selection.

Phase II: High-resolution observations.

Phase III: Data Reduction.

Phase IV: Abundance Analysis.

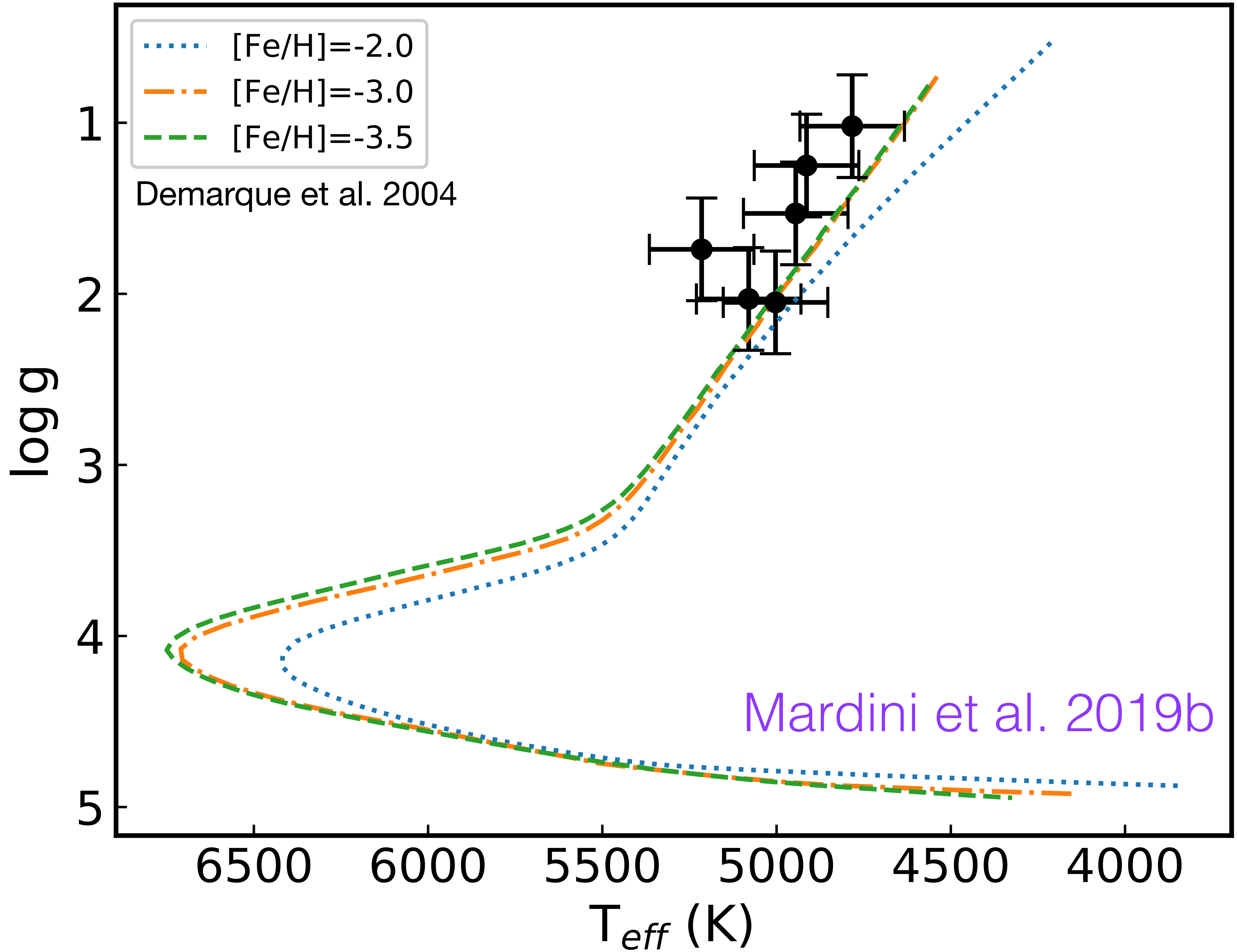
Phase V: Modeling observational data.

Phase VI: Kinematics and Dynamics.

mardini@nao.cas.cn

Data Reduction

- The Image Reduction and Analysis Facility (IRAF).
- Heliocentric corrections (Mg I triplet).
- Equivalent widths (TAME; Kang & Lee 2015)
- Determination of stellar parameters (Frebel et al. 2013)



mardini@nao.cas.cn

Overall Phases and Approach

Phase I: Data selection.

Phase II: High-resolution observations.

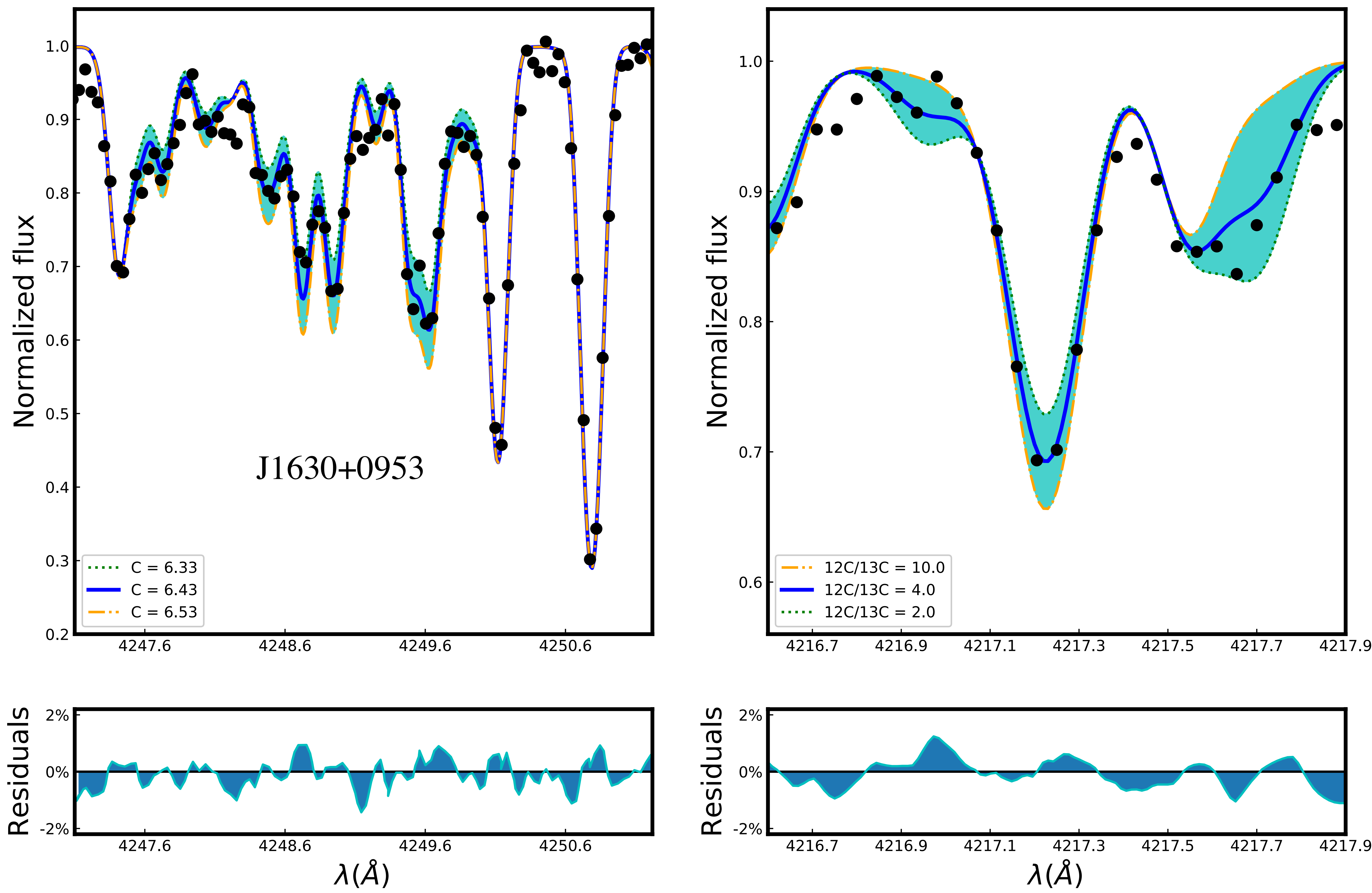
Phase III: Data Reduction.

Phase IV: Abundance Analysis.

Phase V: Modeling observational data.

Phase VI: Kinematics and Dynamics.

mardini@nao.cas.cn



Mardini et al. 2019b

mardini@nao.cas.cn

Overall Phases and Approach

Phase I: Data selection.

Phase II: High-resolution observations.

Phase III: Data Reduction.

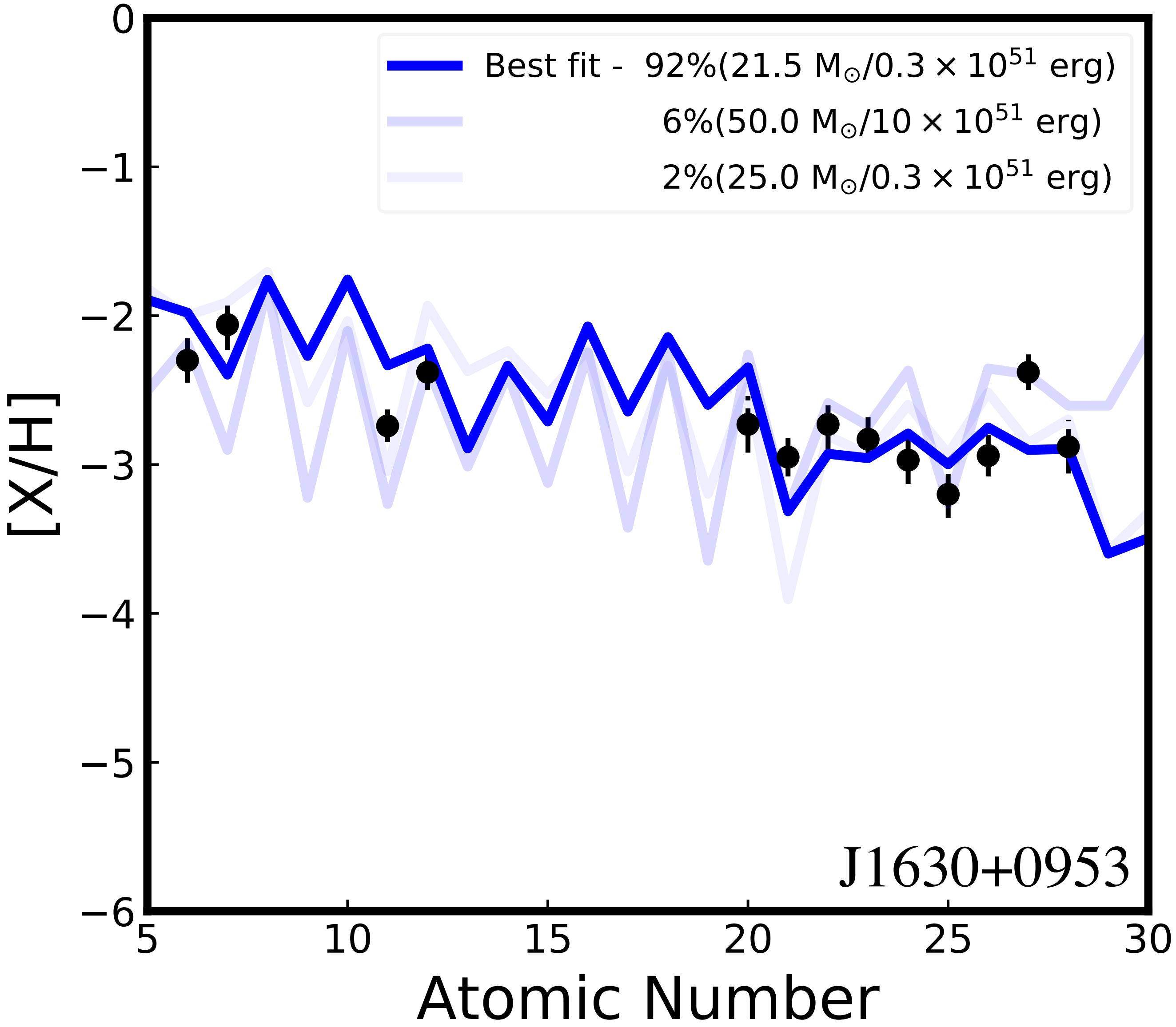
Phase IV: Abundance Analysis.

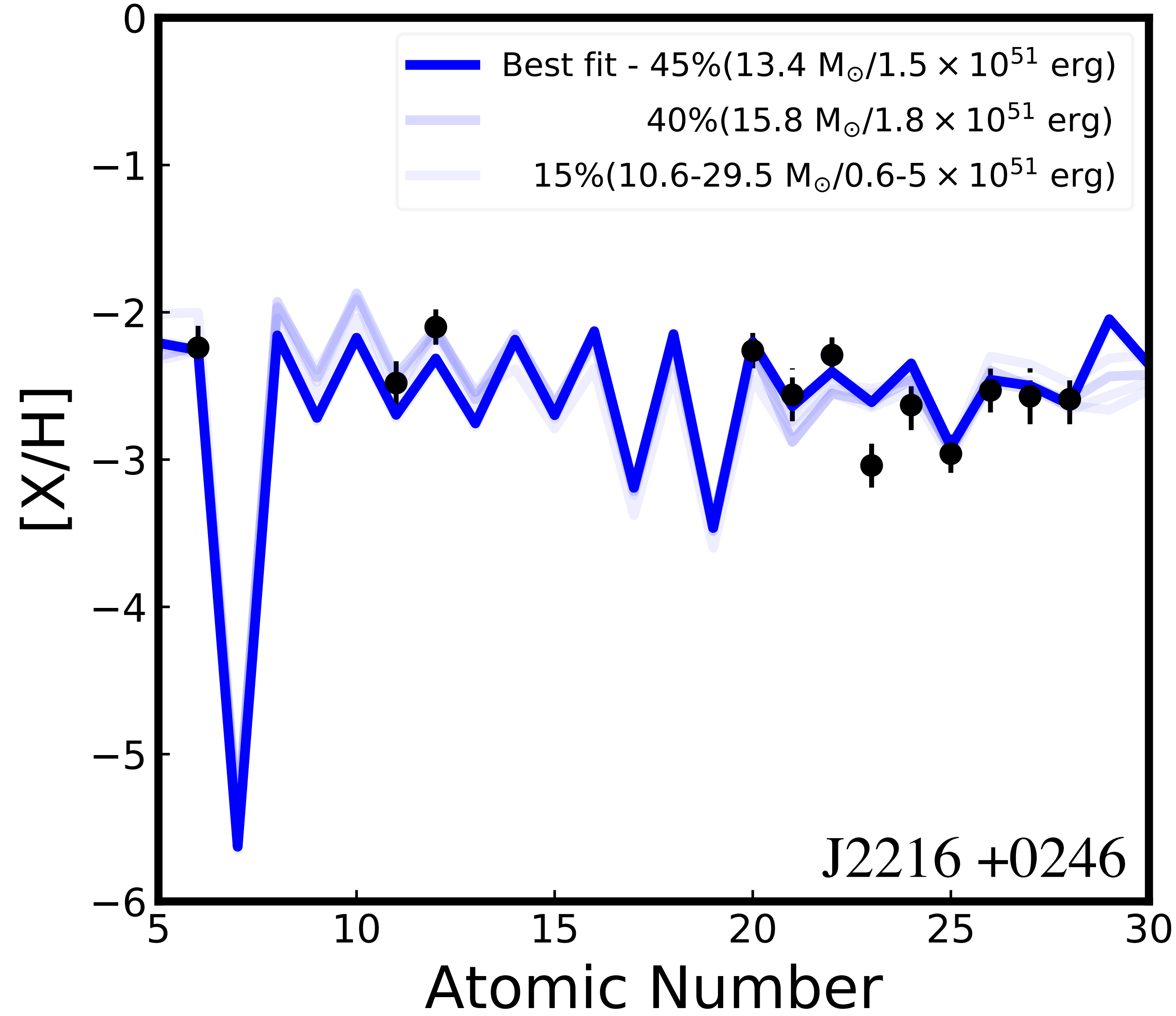
Phase V: Modeling observational data.

Phase VI: Kinematics and Dynamics.

mardini@nao.cas.cn

Heger & Woosley (2010)





Mardini et al. 2019b

mardini@nao.cas.cn

Overall Phases and Approach

Phase I: Data selection.

Phase II: High-resolution observations.

Phase III: Data Reduction.

Phase IV: Abundance Analysis.

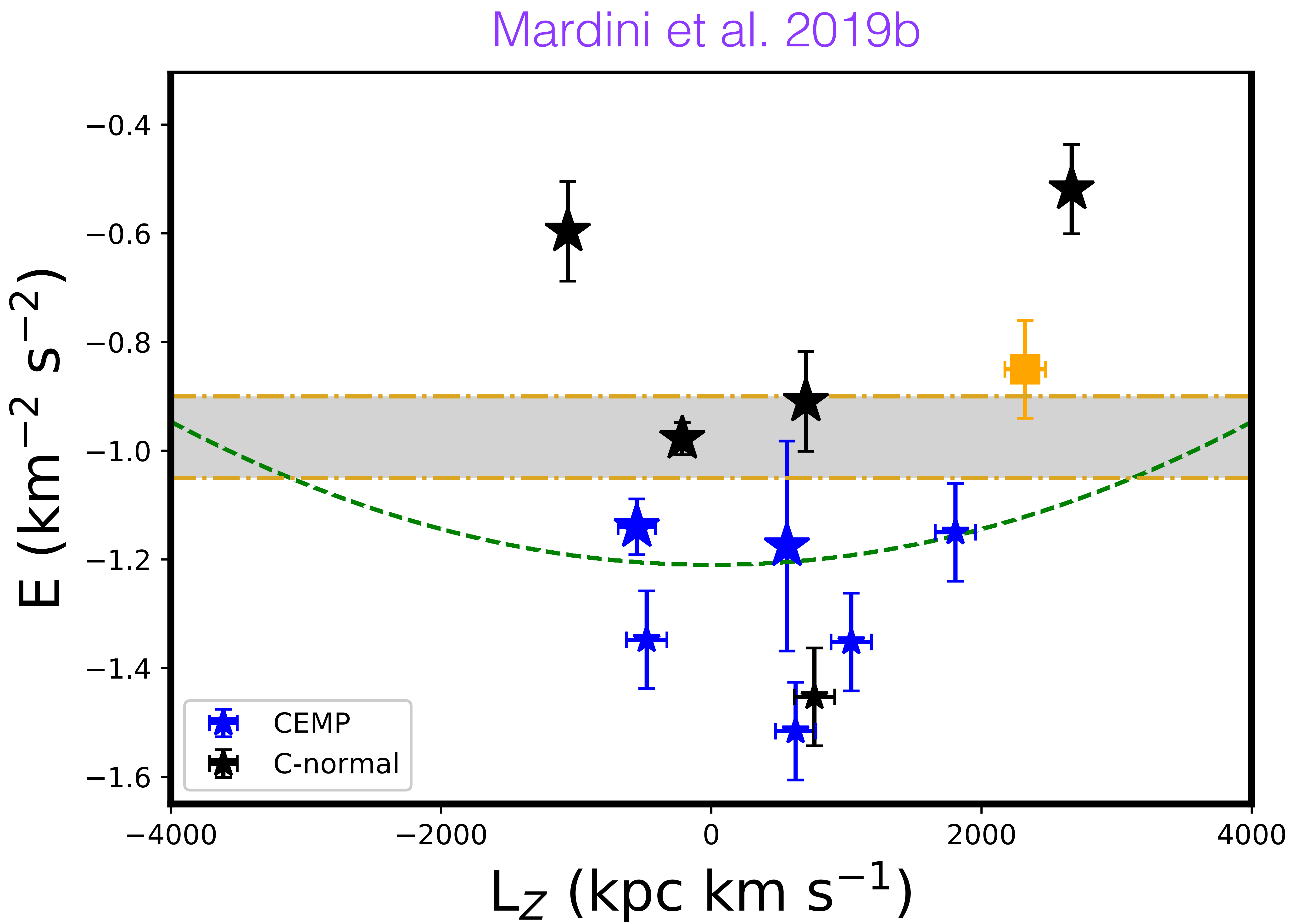
Phase V: Modeling observational data.

Phase VI: Kinematics and Dynamics.

mardini@nao.cas.cn

Kinematics and Dynamics

- TOPCAT (Gaia DR2 and Gaia DR2 distances).
- MWPotential2014
- $e = (r_{apo} - r_{peri})/(r_{apo} + r_{peri})$
- $E = \frac{1}{2}v^2 + \Phi(x)$
- $L_z = R \times V_\phi$



Mardini et al. 2019b
E (km^{-2} s^{-2})
L$_Z$ (kpc km s^{-1})
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
−4000
−2000
0
2000
4000
CEMP
C-normal

THANK YOU

Mohammad Mardini
Ph.D. Student
National Astronomical Observatories of China

mardini@nao.cas.cn