

















Evidence of Truly Young high- α Dwarf Stars

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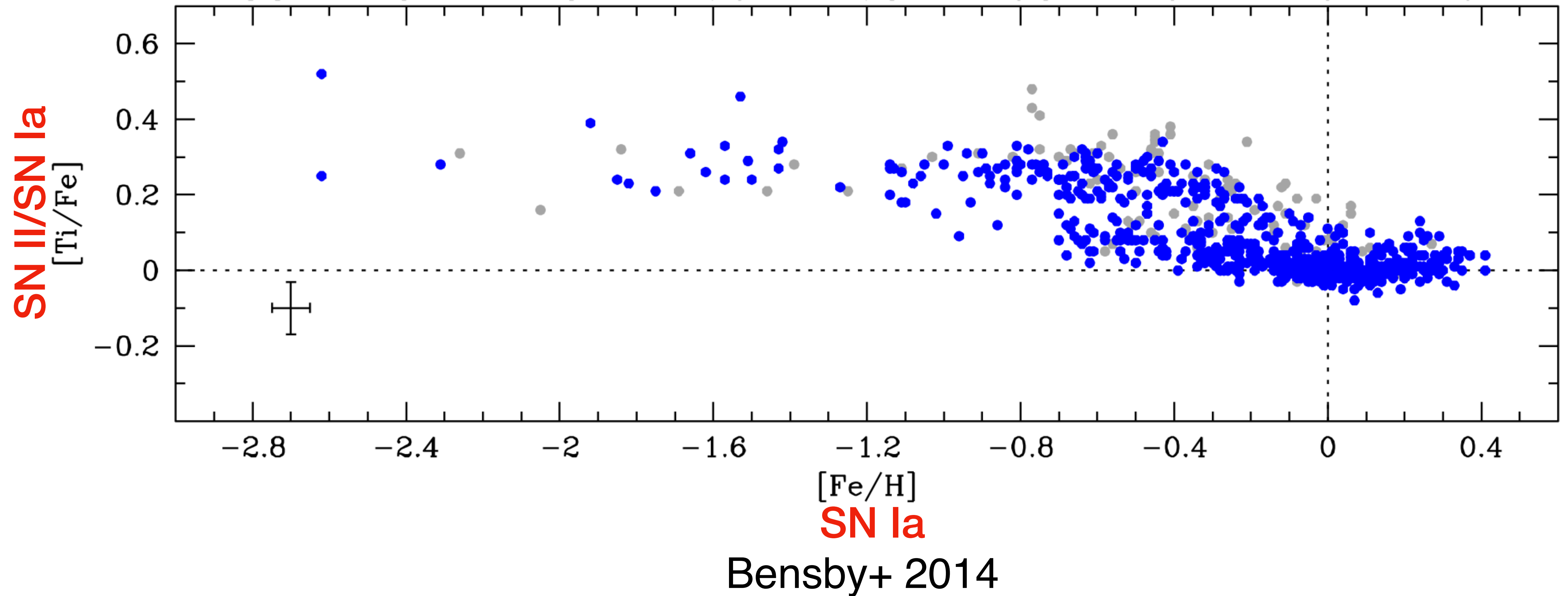
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¹⁰*Montana State University, P.O. Box 173840, Bozeman, MT, USA*

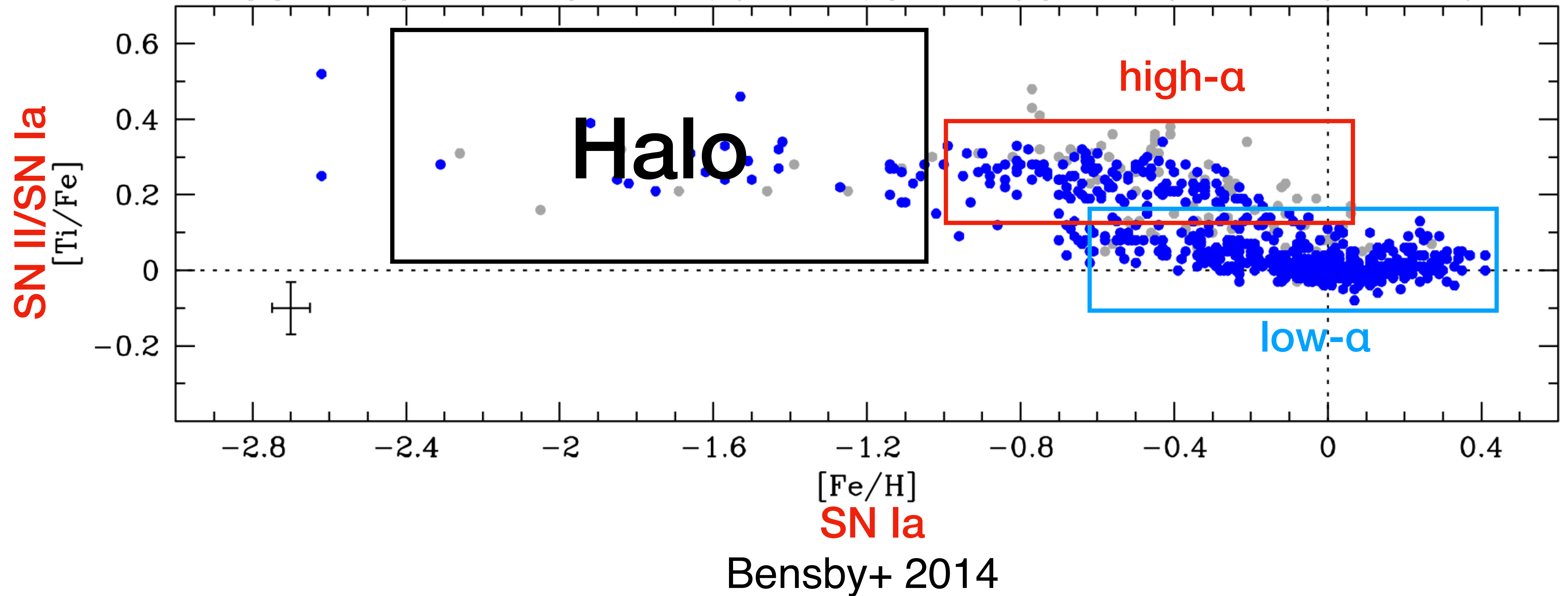
¹¹*Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA*

¹²*Department of Astronomy, University of Florida, 211 Bryant Space Science Center, Gainesville, FL 32611, USA*

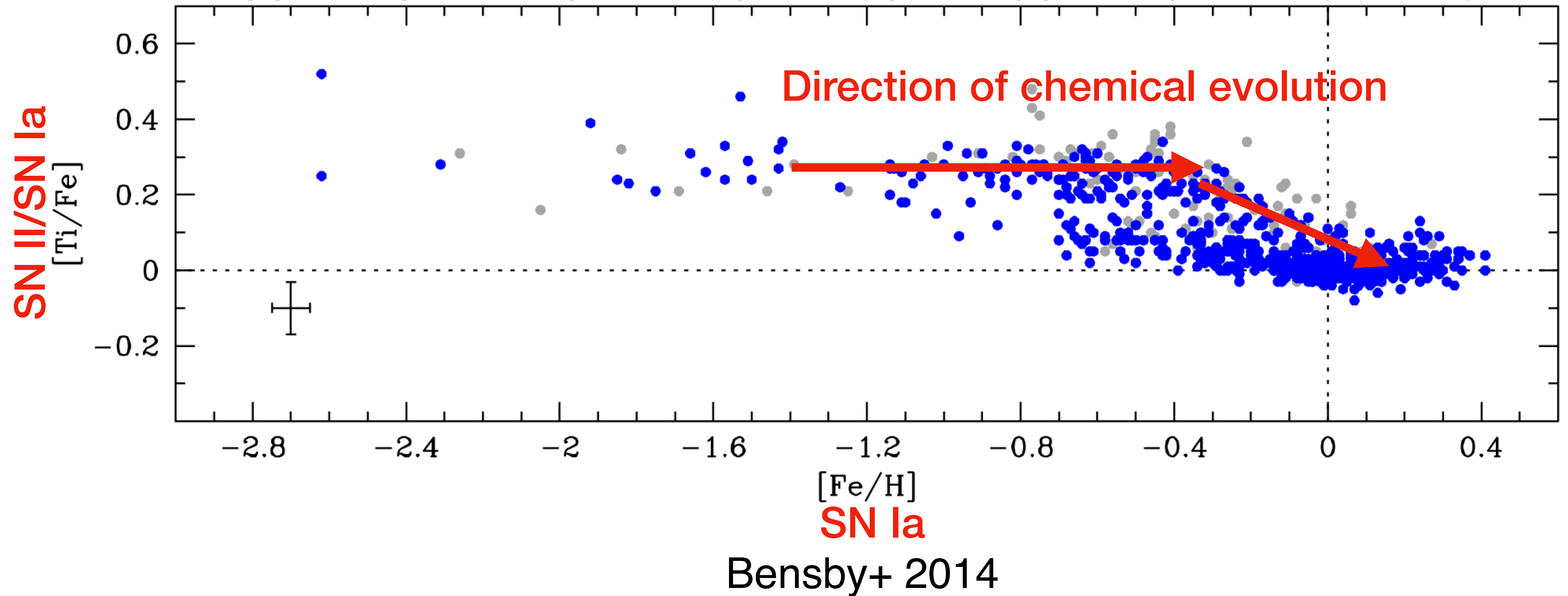
Introduction: The bi-modality of the Milky Way disk



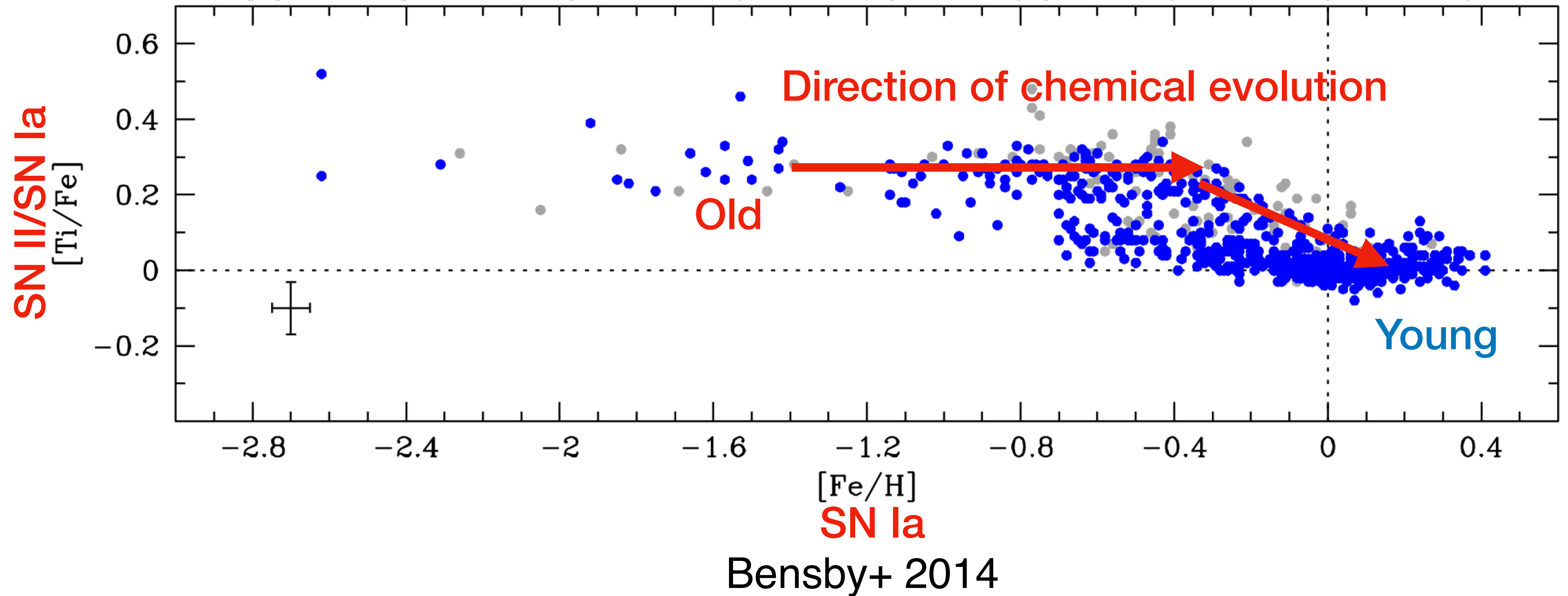
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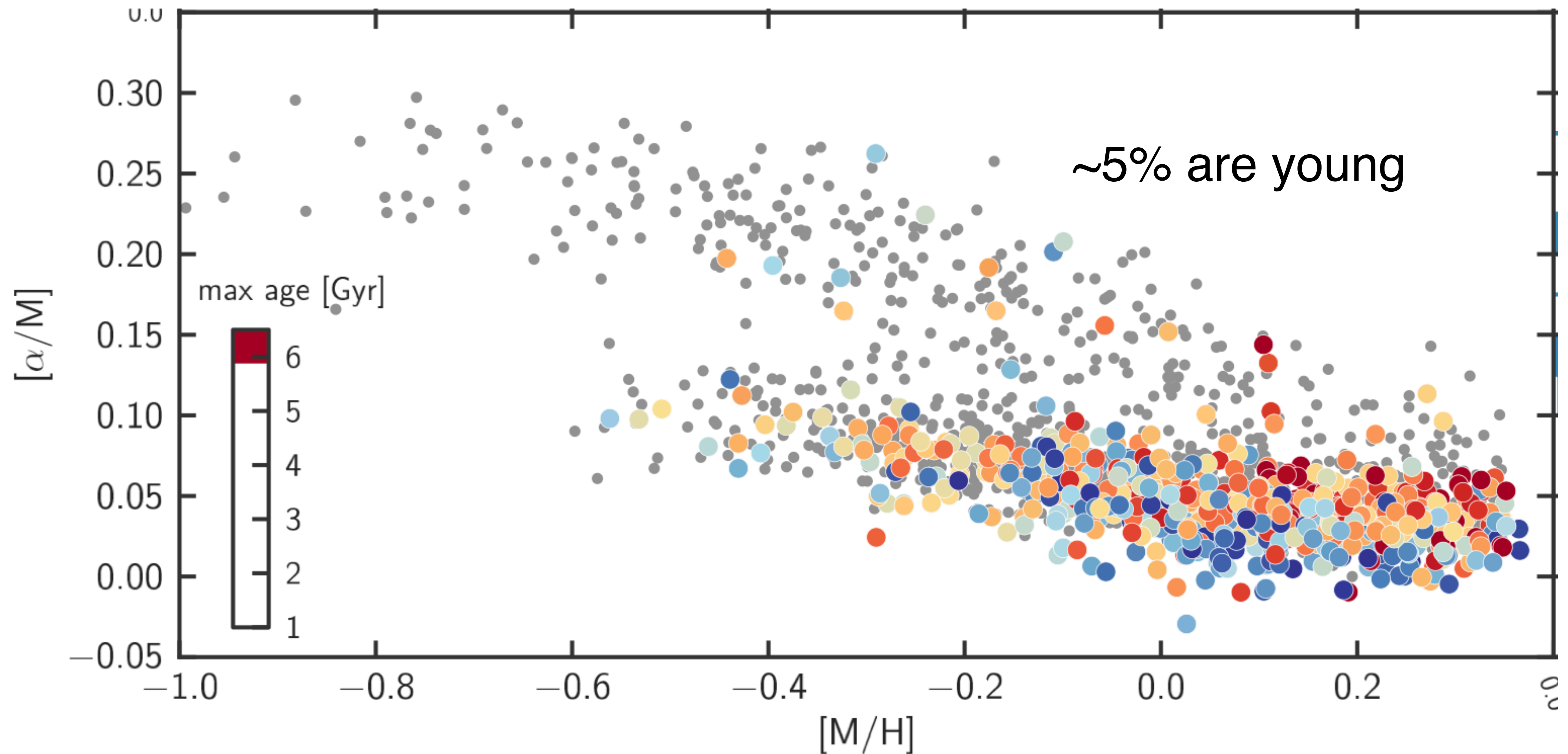
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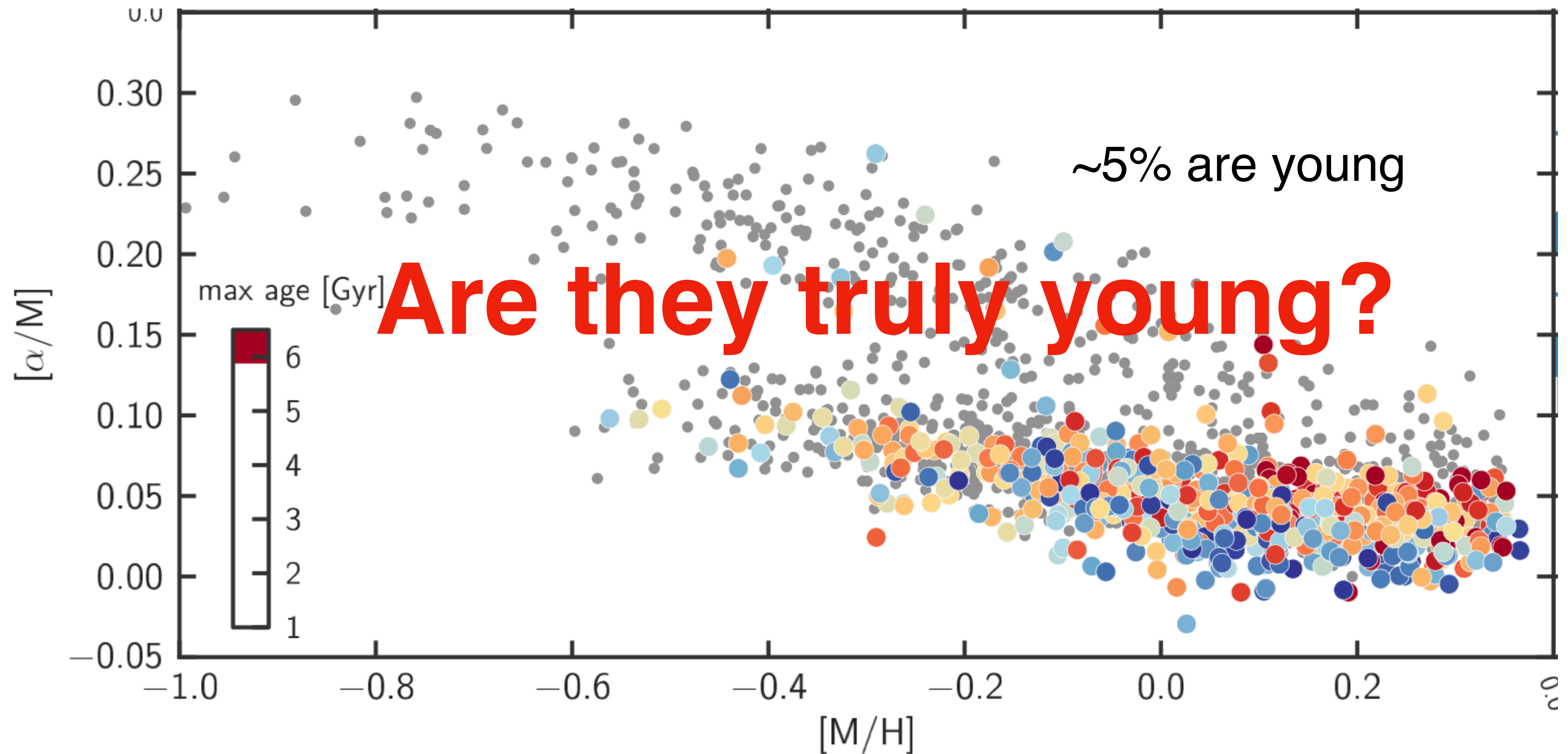


Introduction: The bi-modality of the Milky Way disk



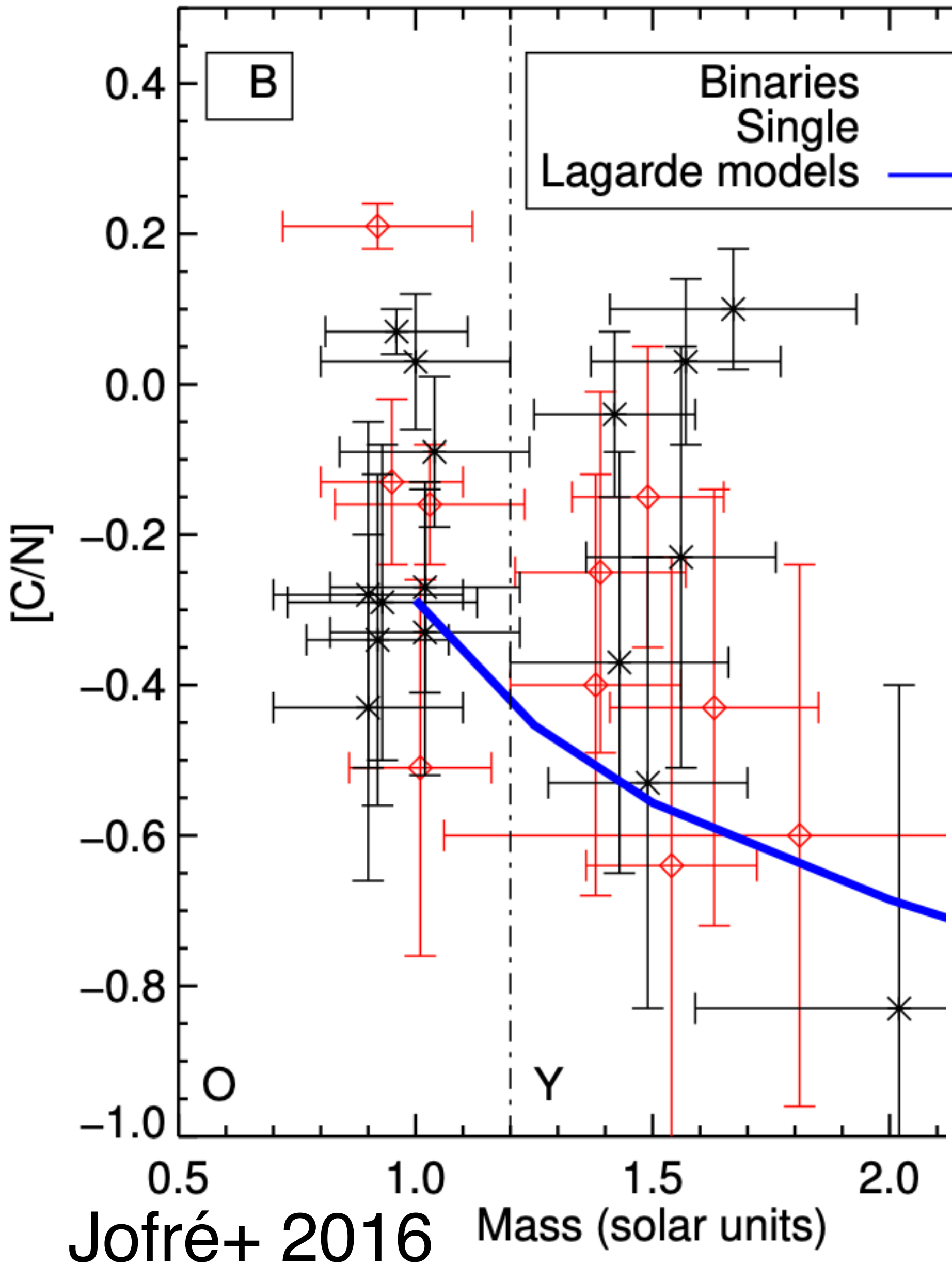
Martig+ 2015, Using APOKASCe ages from Pinsonneault+ 2014

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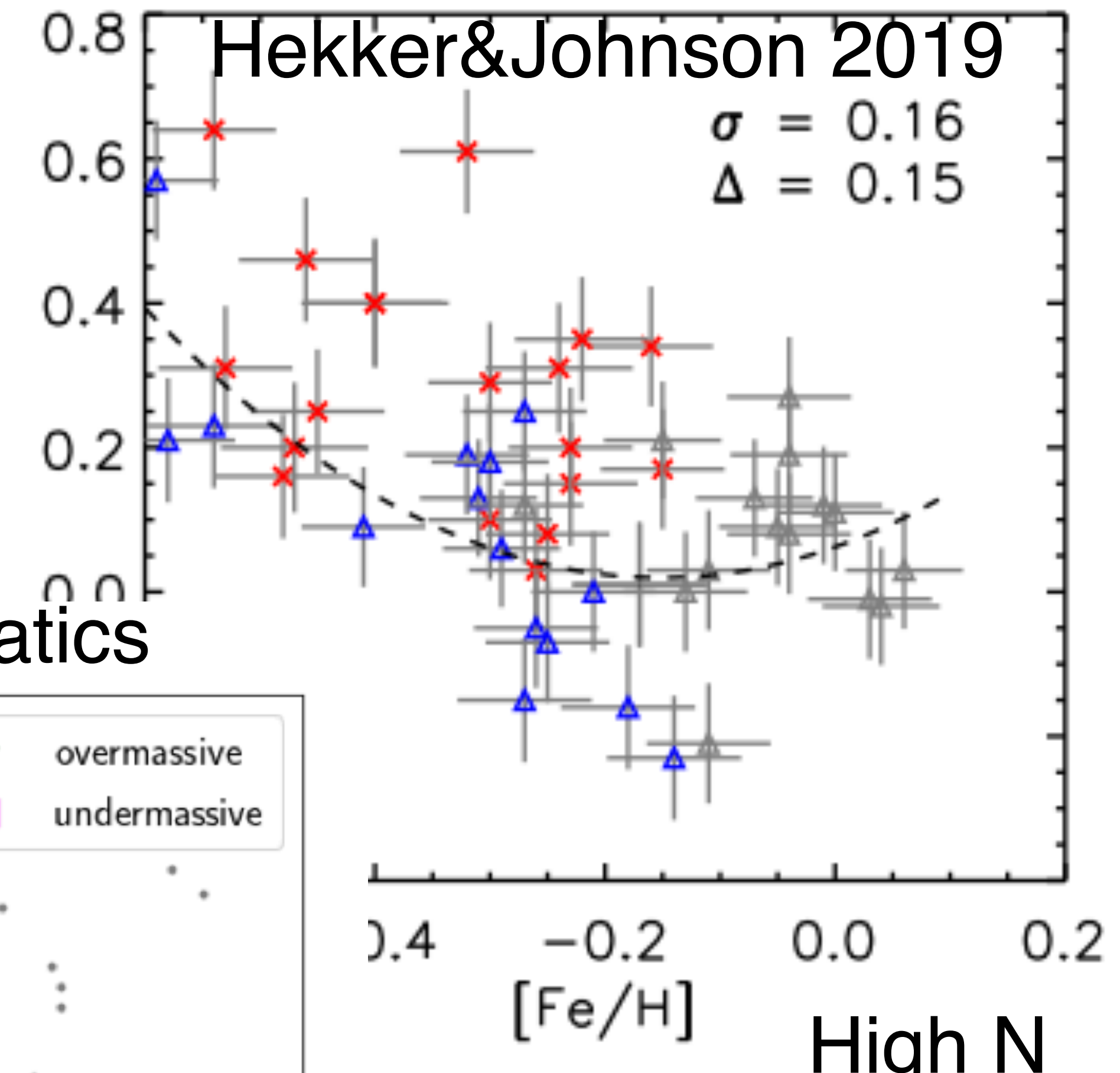


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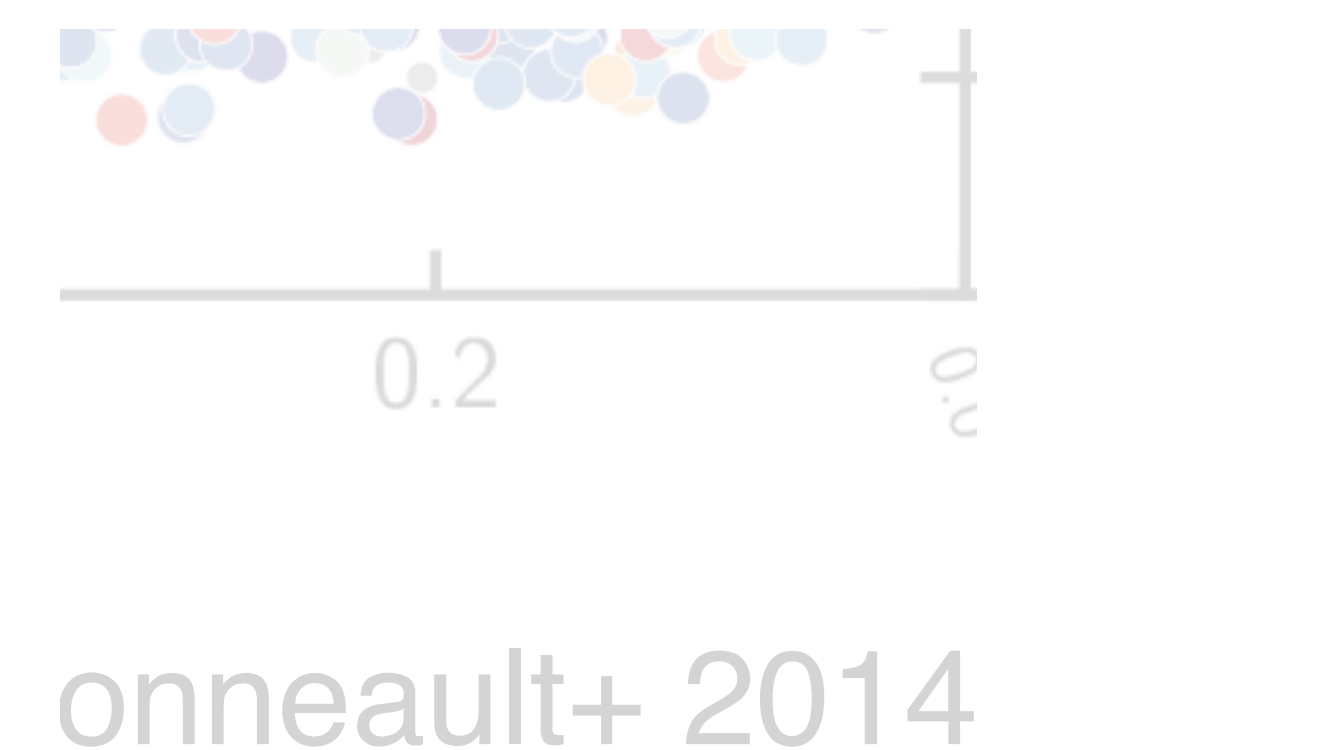
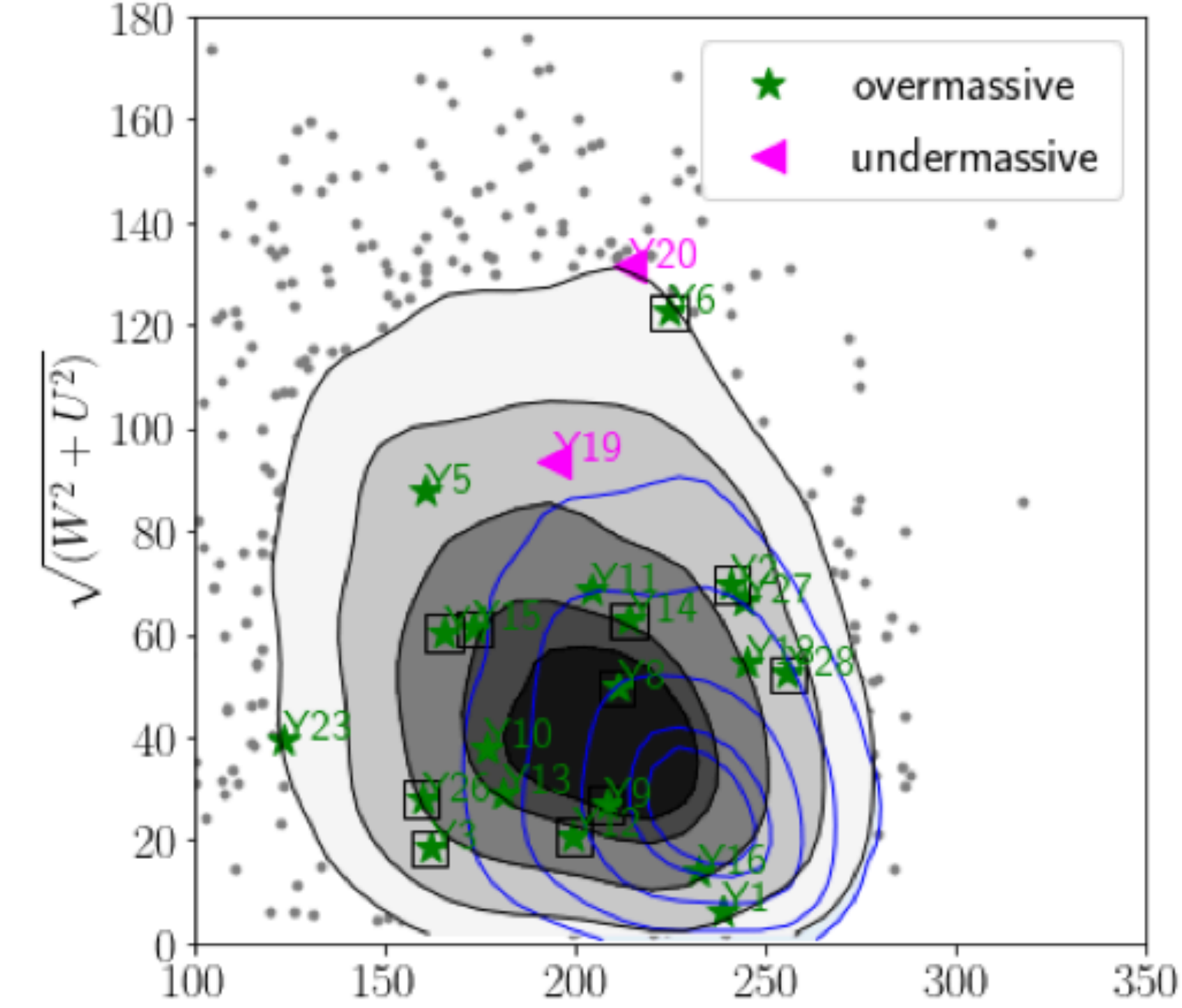
High fraction of binaries



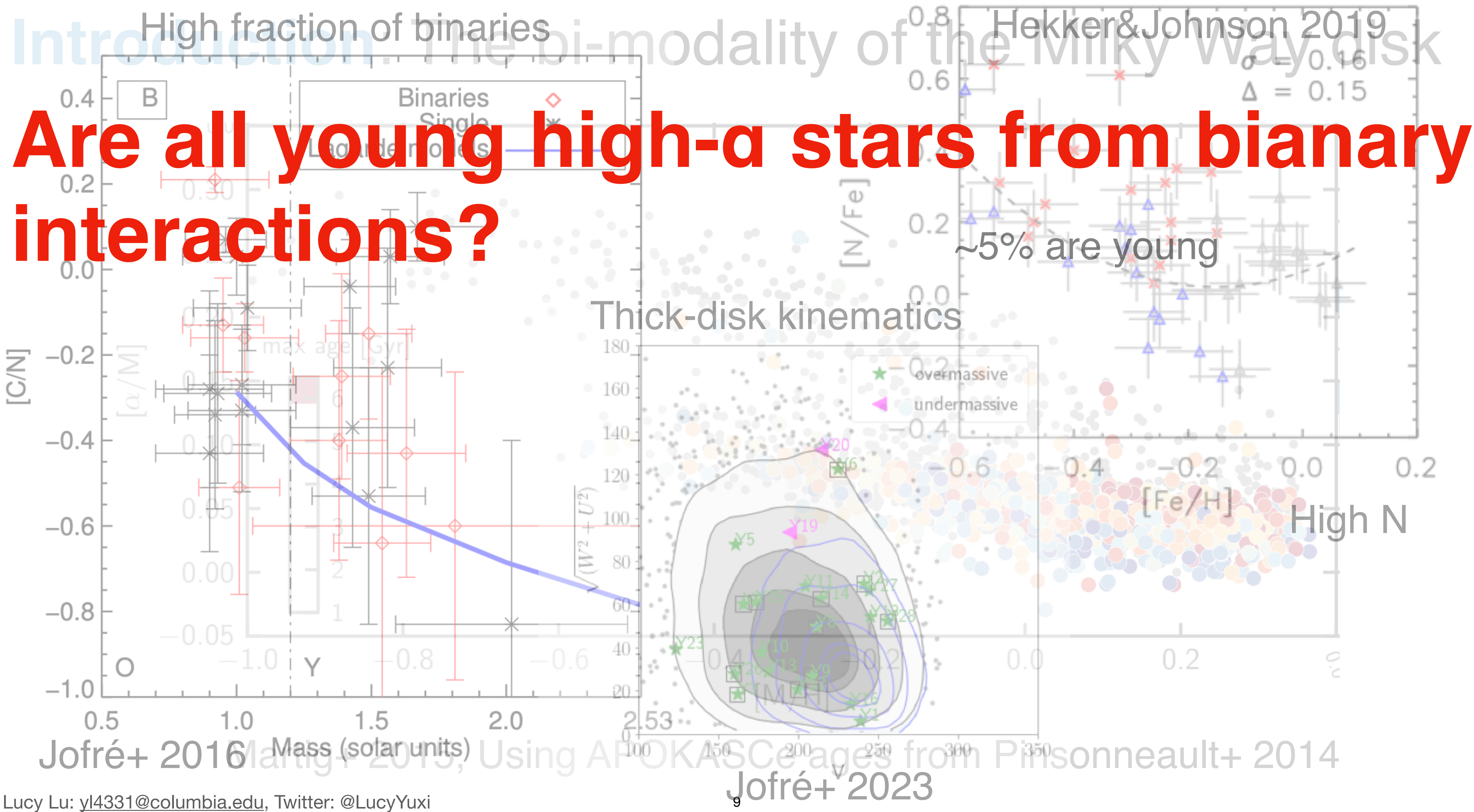
odali



Thick-disk kinematics

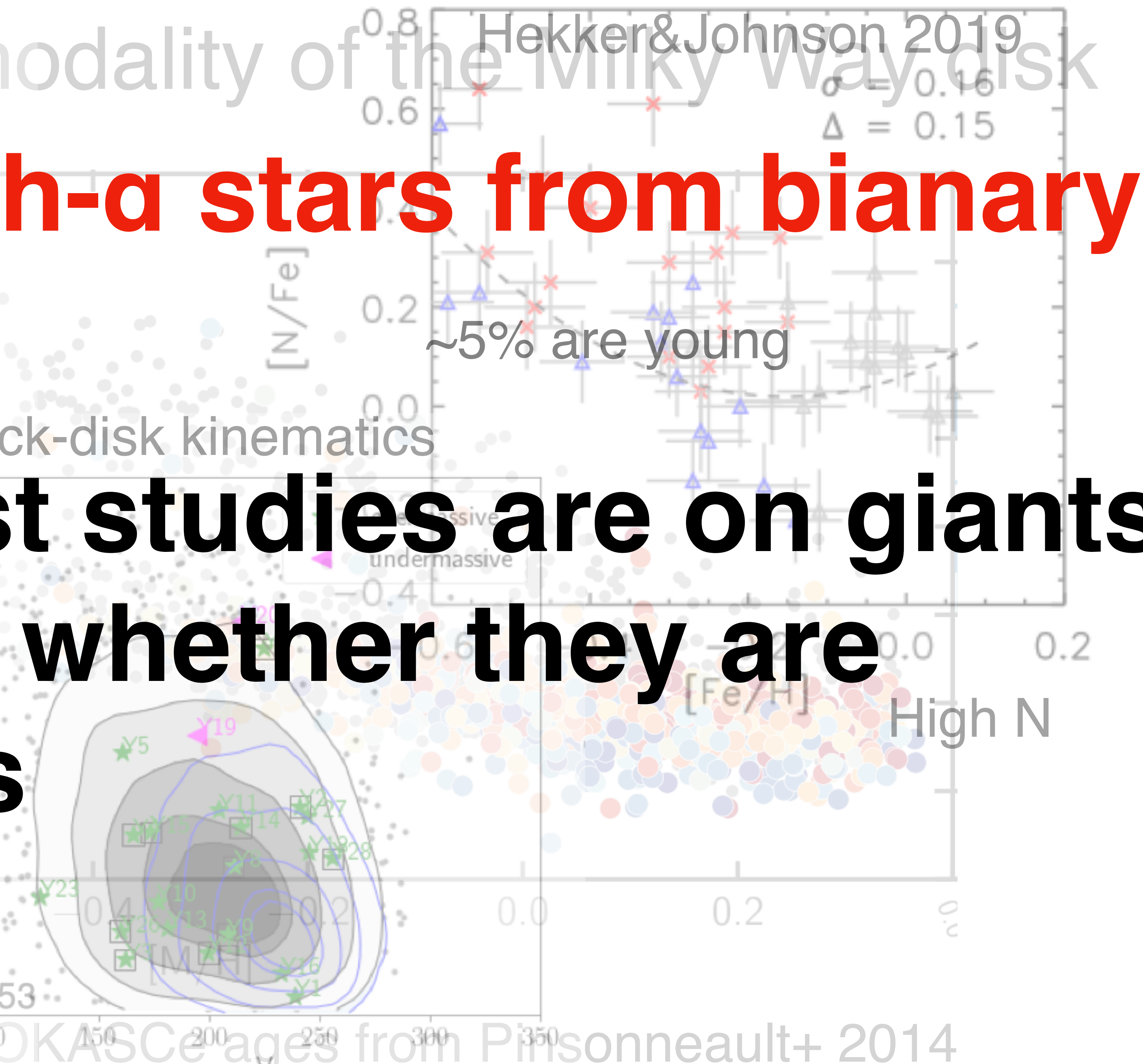
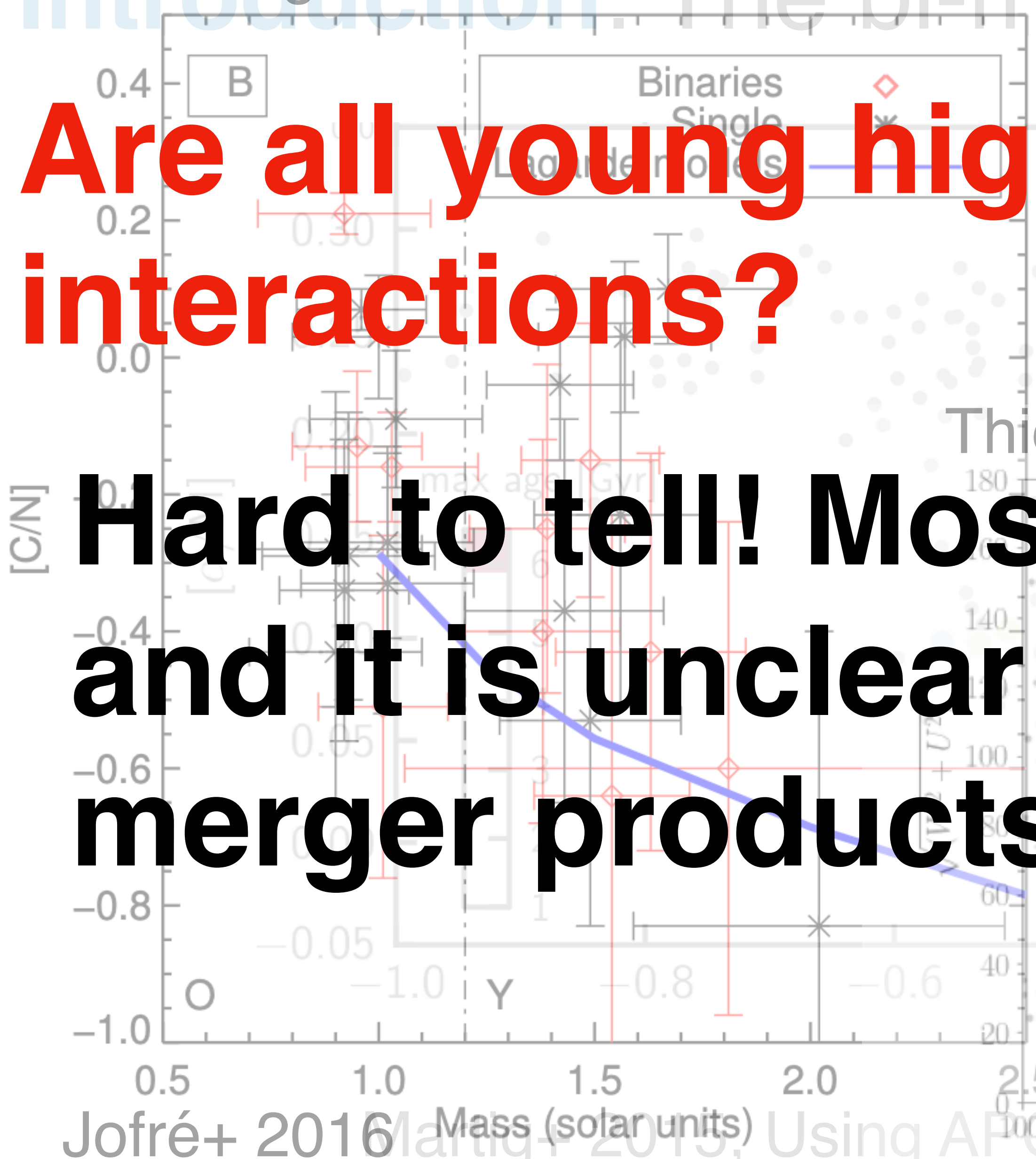


Are all young high- α stars from binary interactions?



Are all young high- α stars from binary interactions?

Hard to tell! Most studies are on giants and it is unclear whether they are merger products



Introduction: Finding young high- α stars in dwarfs

Indication of youth: Rotation (e.g., Skumanich 1978, Barnes 2002)

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- **Caveat:** Can be spun-up by binary interactions
 1. **Close-by companion**
 2. **Stellar mergers**
 3. **Planet engulfments**

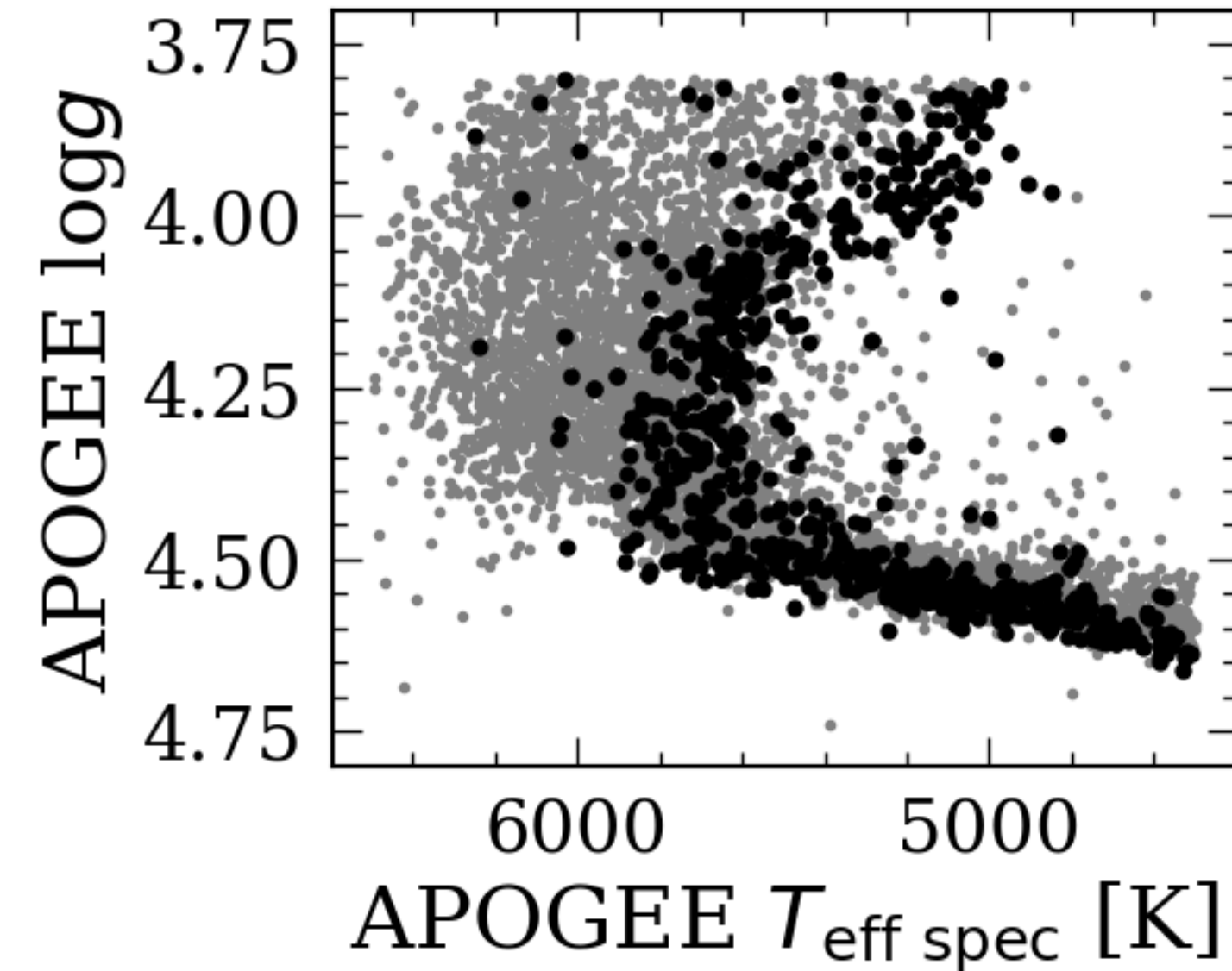
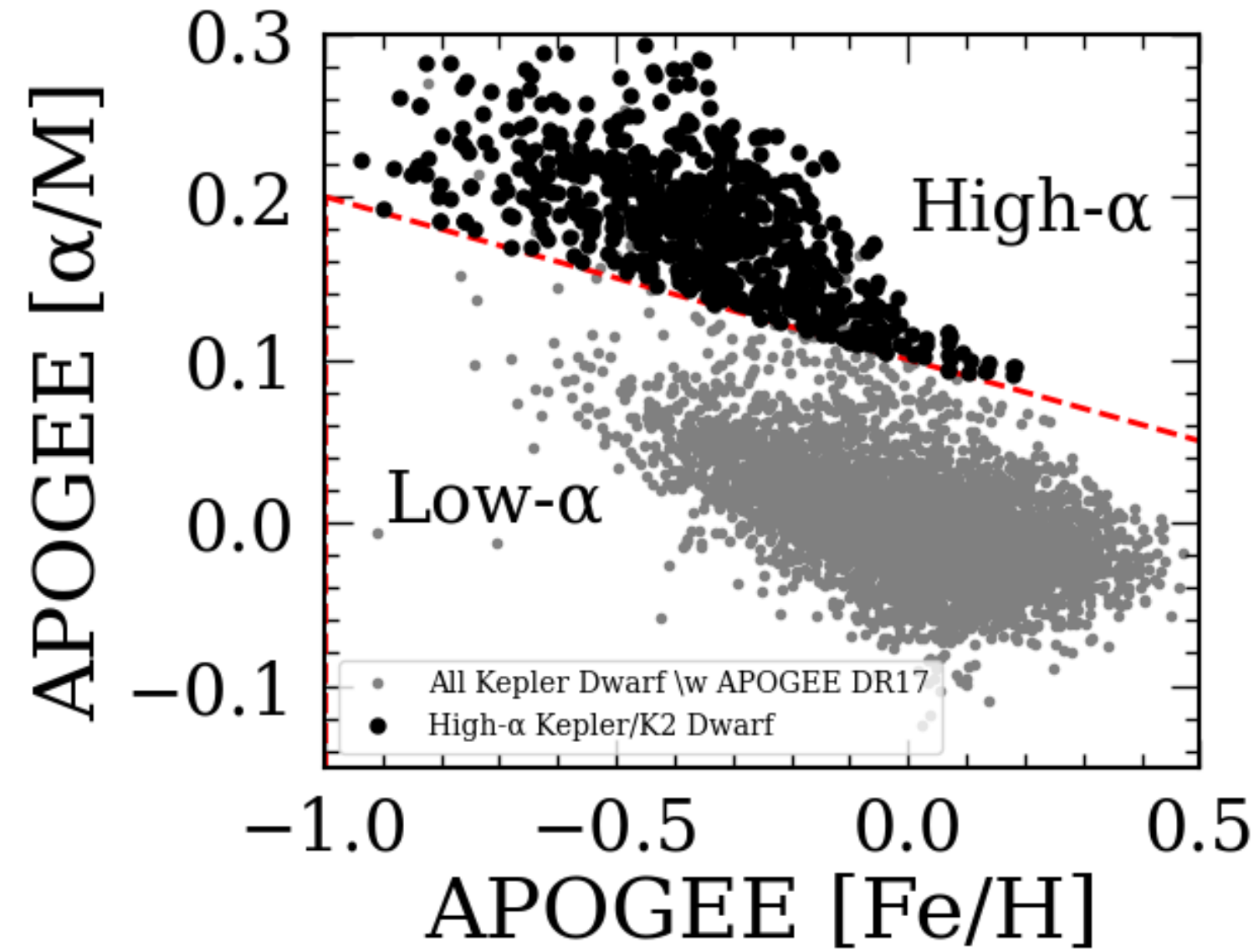
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Indication of youth: Rotation (e.g., Skumanich 1978, Barnes 2002)

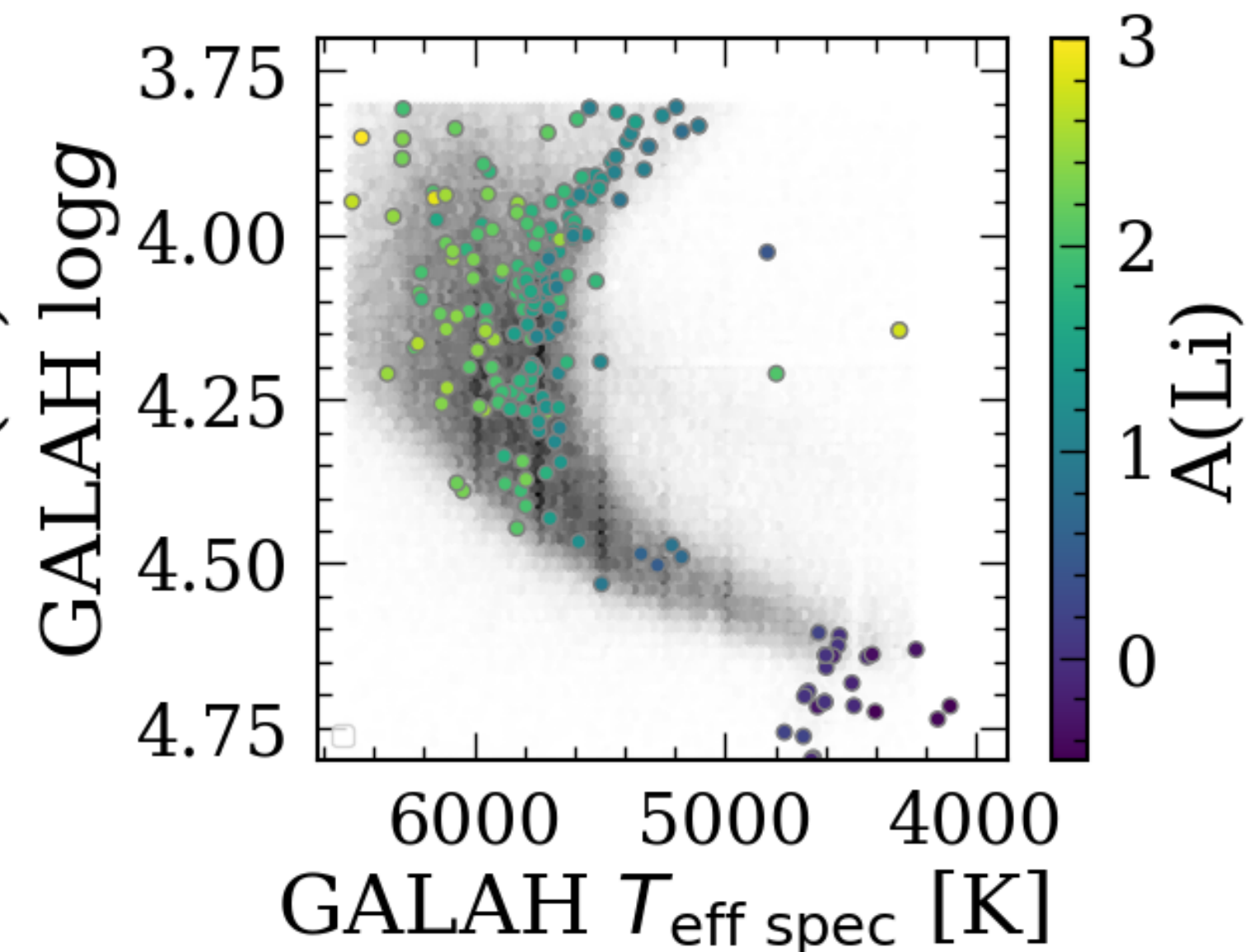
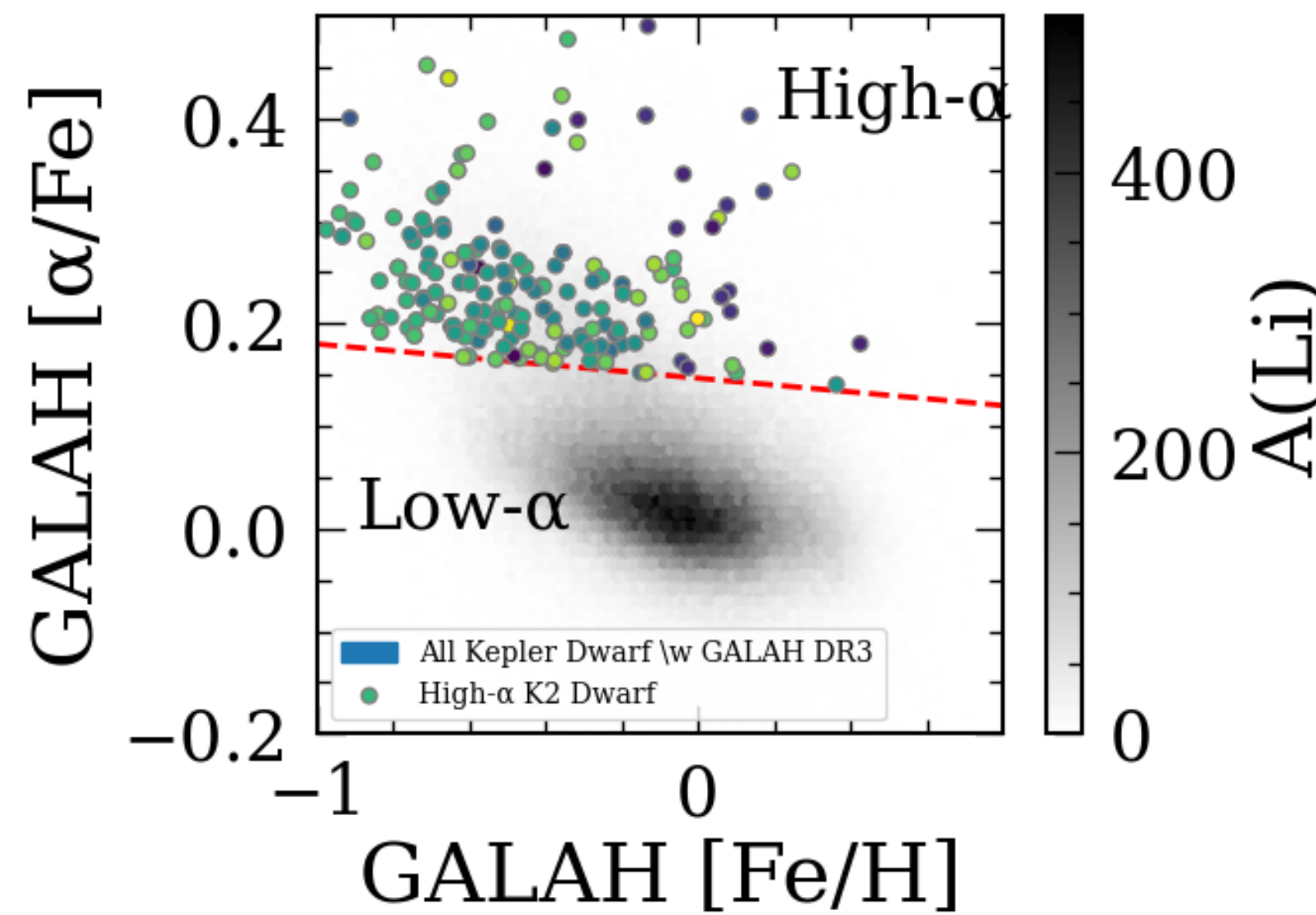
- **Caveat:** Can be spun-up by binary interactions
 1. **Close-by companion** — Exclude binaries with RVs
 2. **Stellar mergers** — Lithium (e.g., Ryan+ 2001; Pinsonneault+ 2002; Ryan+ 2002)
 3. **Planet engulfments** — Refractory elements (e.g., Ramirez+ 2009, Teske+ 2016, Melendez+ 2017, Spina+ 2021)

Data: Finding young high- α stars in dwarfs

APOGEE sample
— No Lithium
measurements but
are single

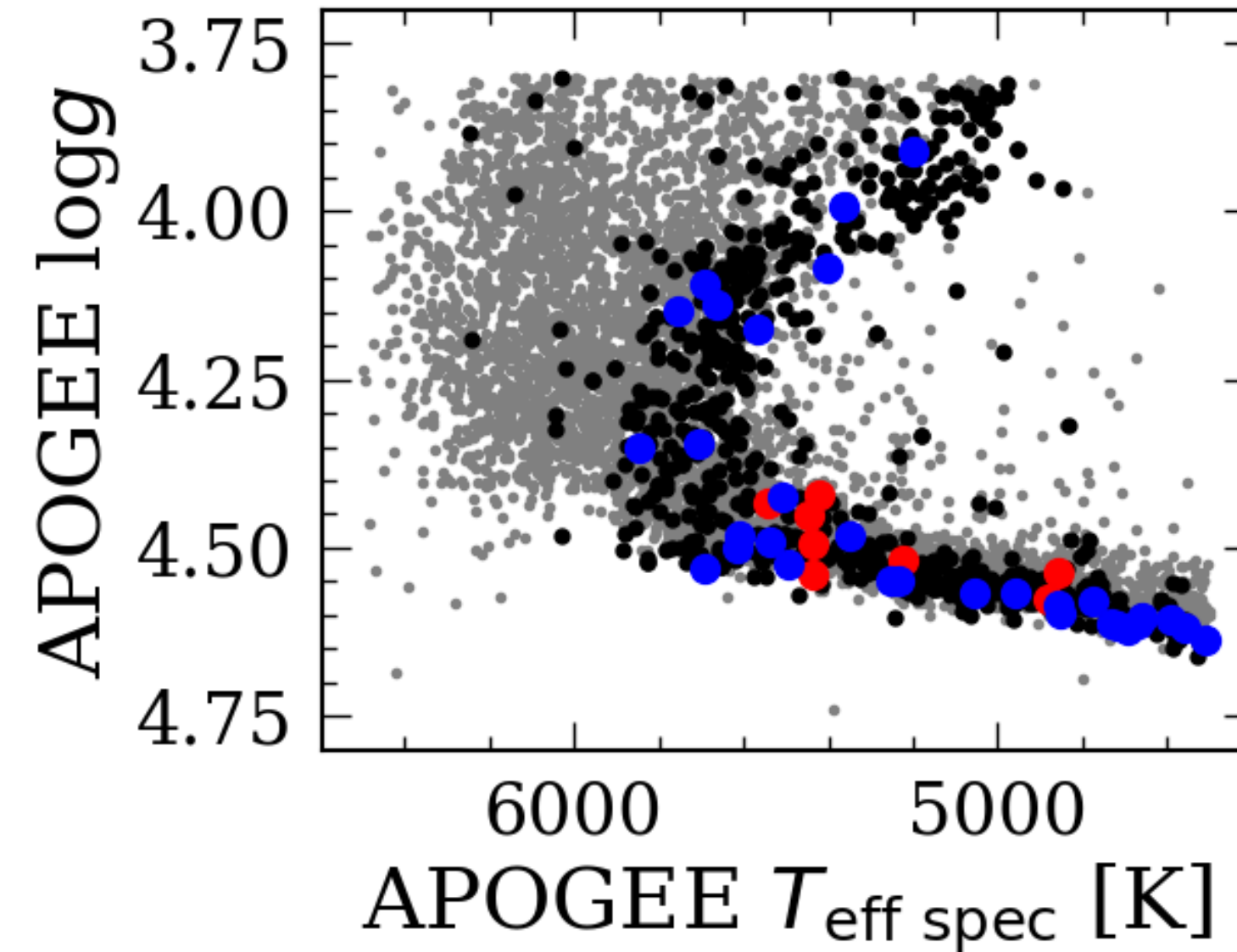
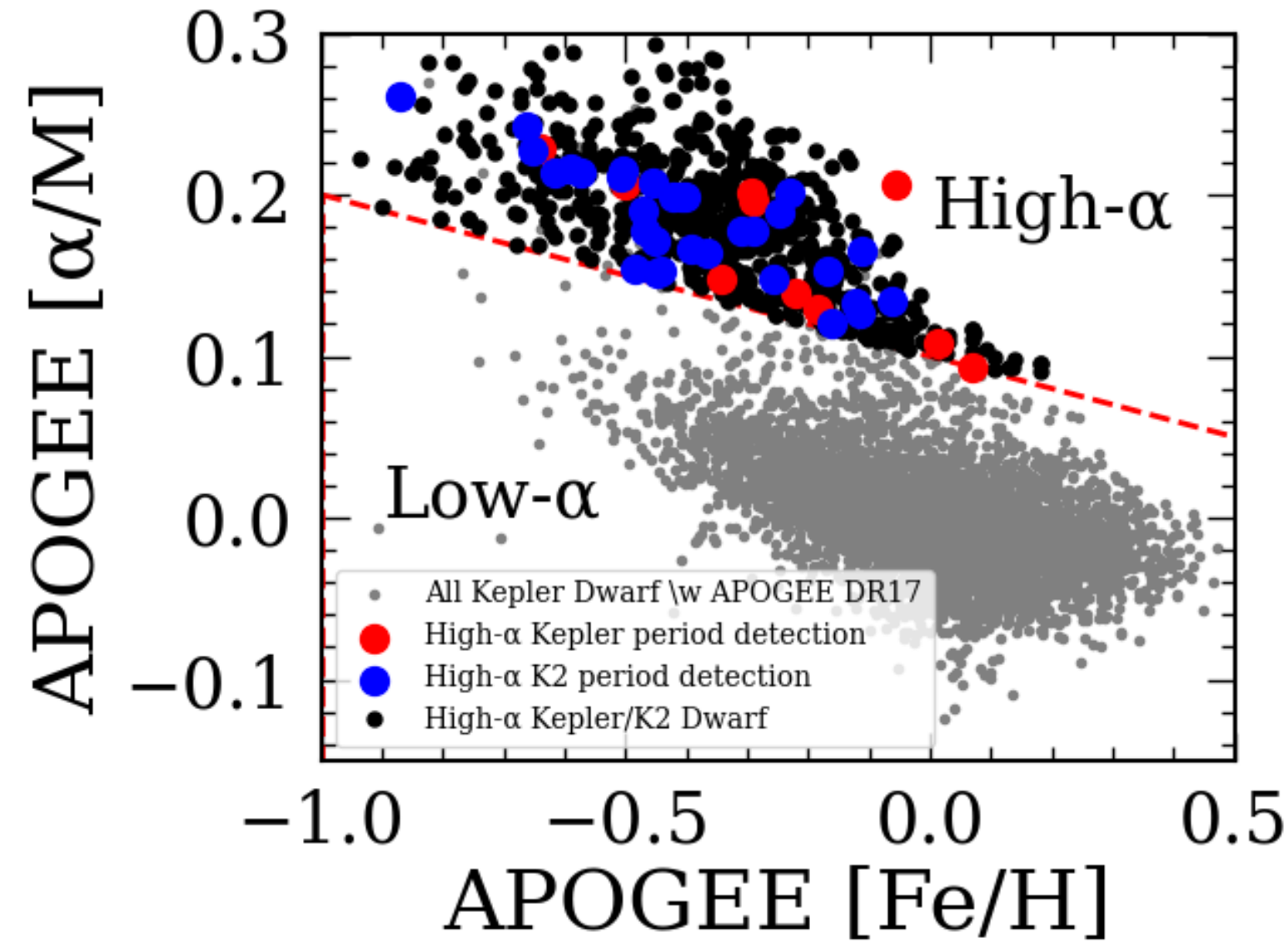


GALAH sample
Lithium
measurements but
unclear in binarity



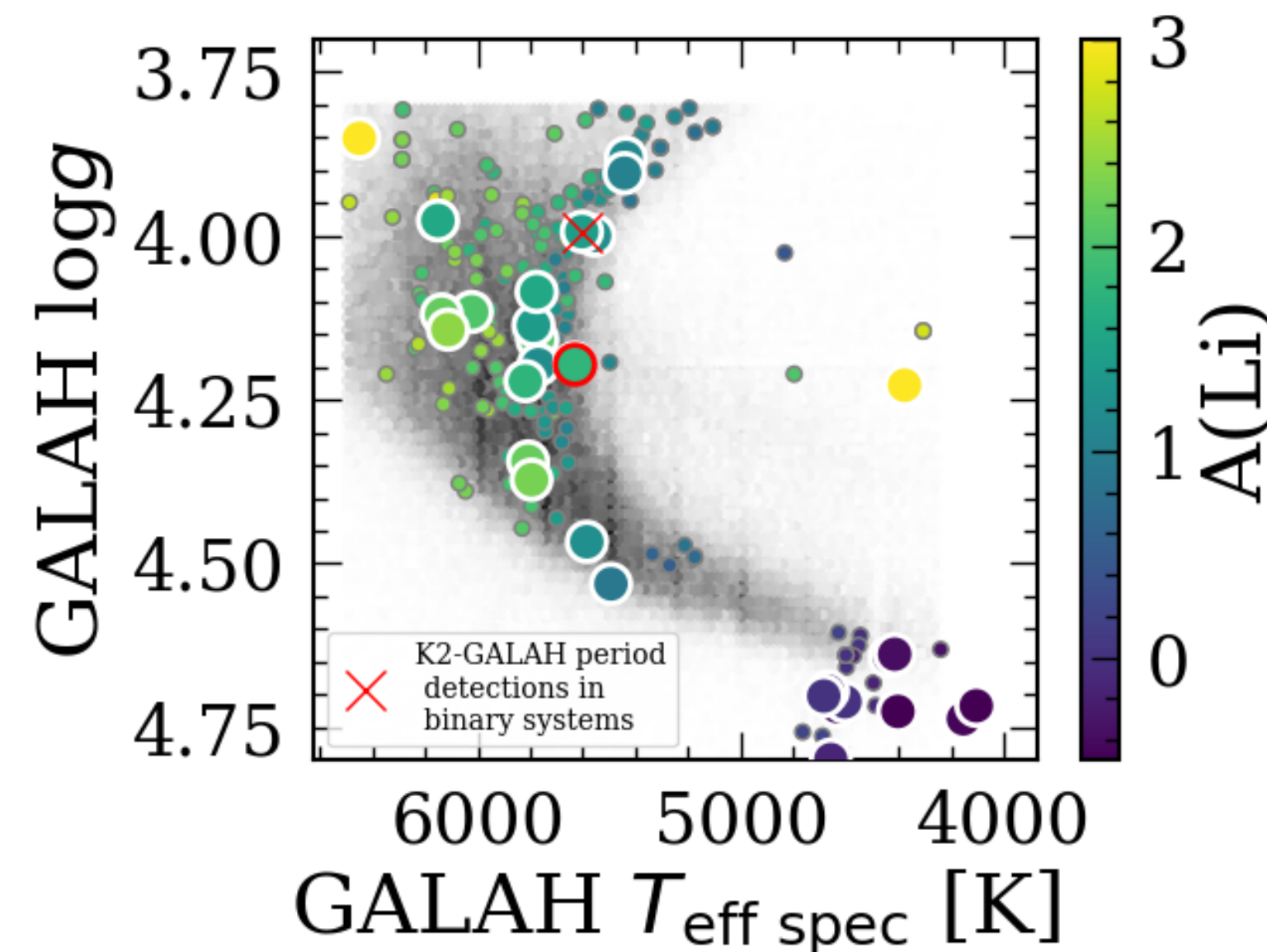
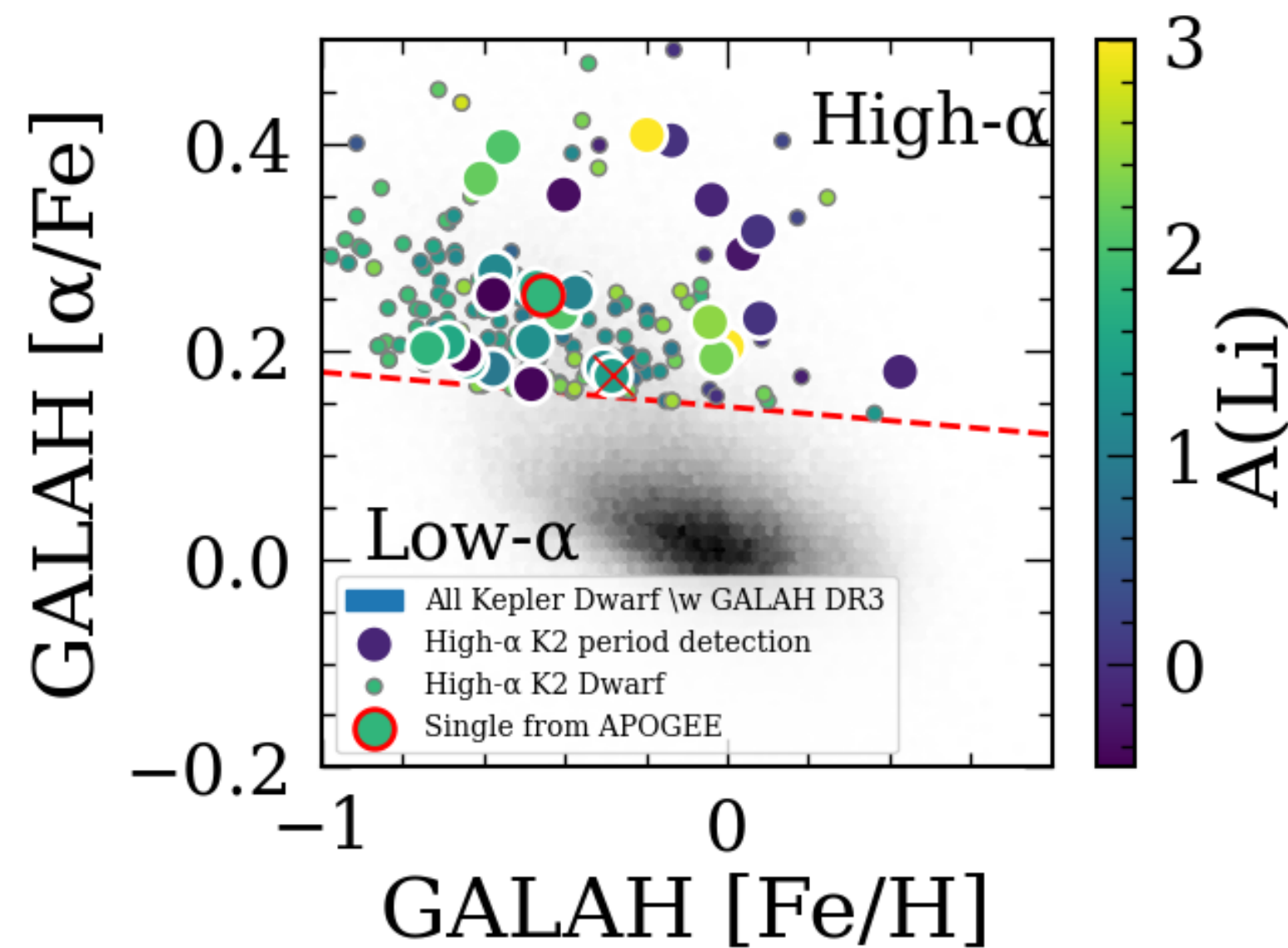
Result: Evidence of young high- α stars in dwarfs

APOGEE sample
— No Lithium measurements but are single



Total 41 stars

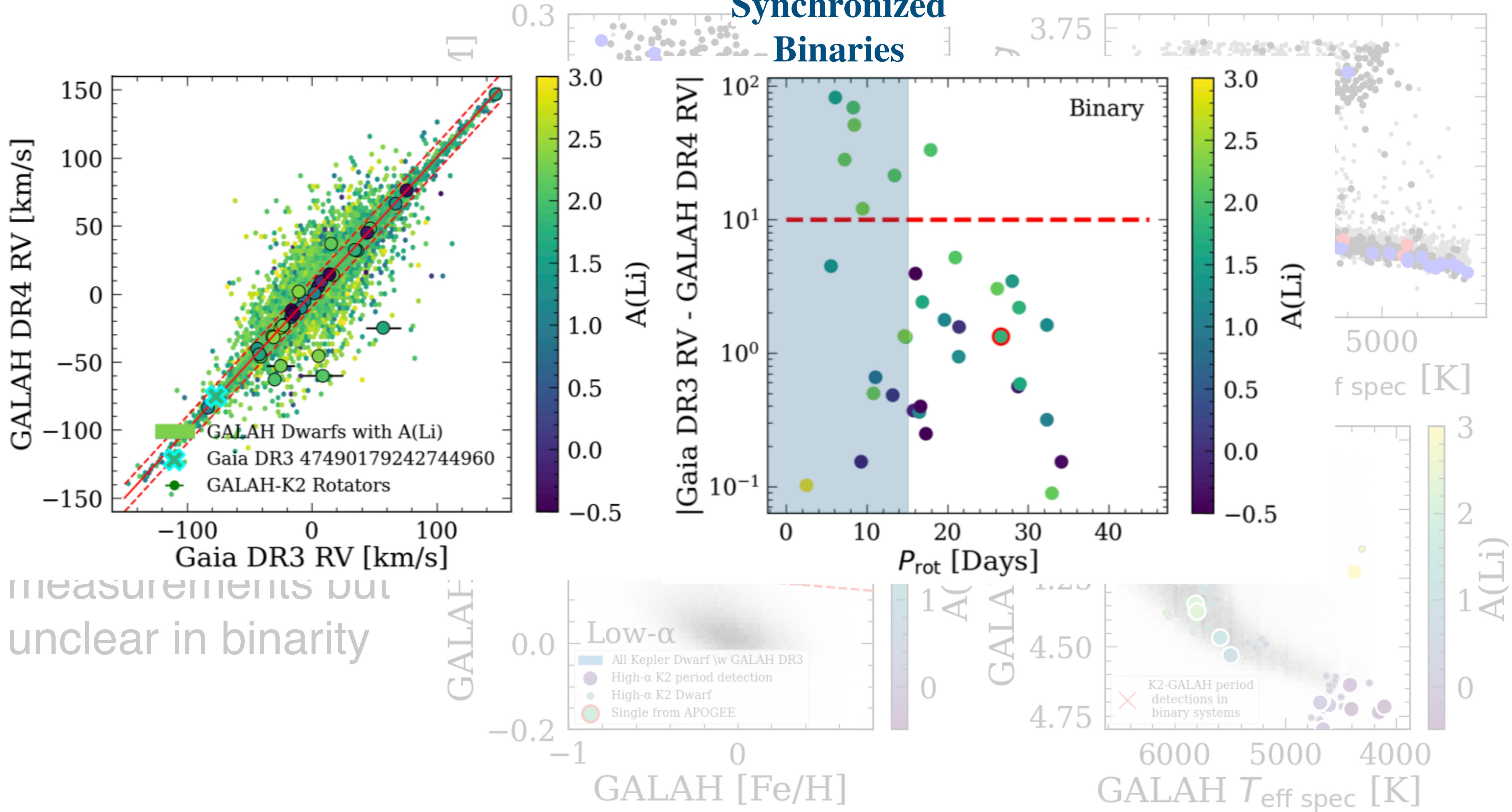
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Synchronized Binaries

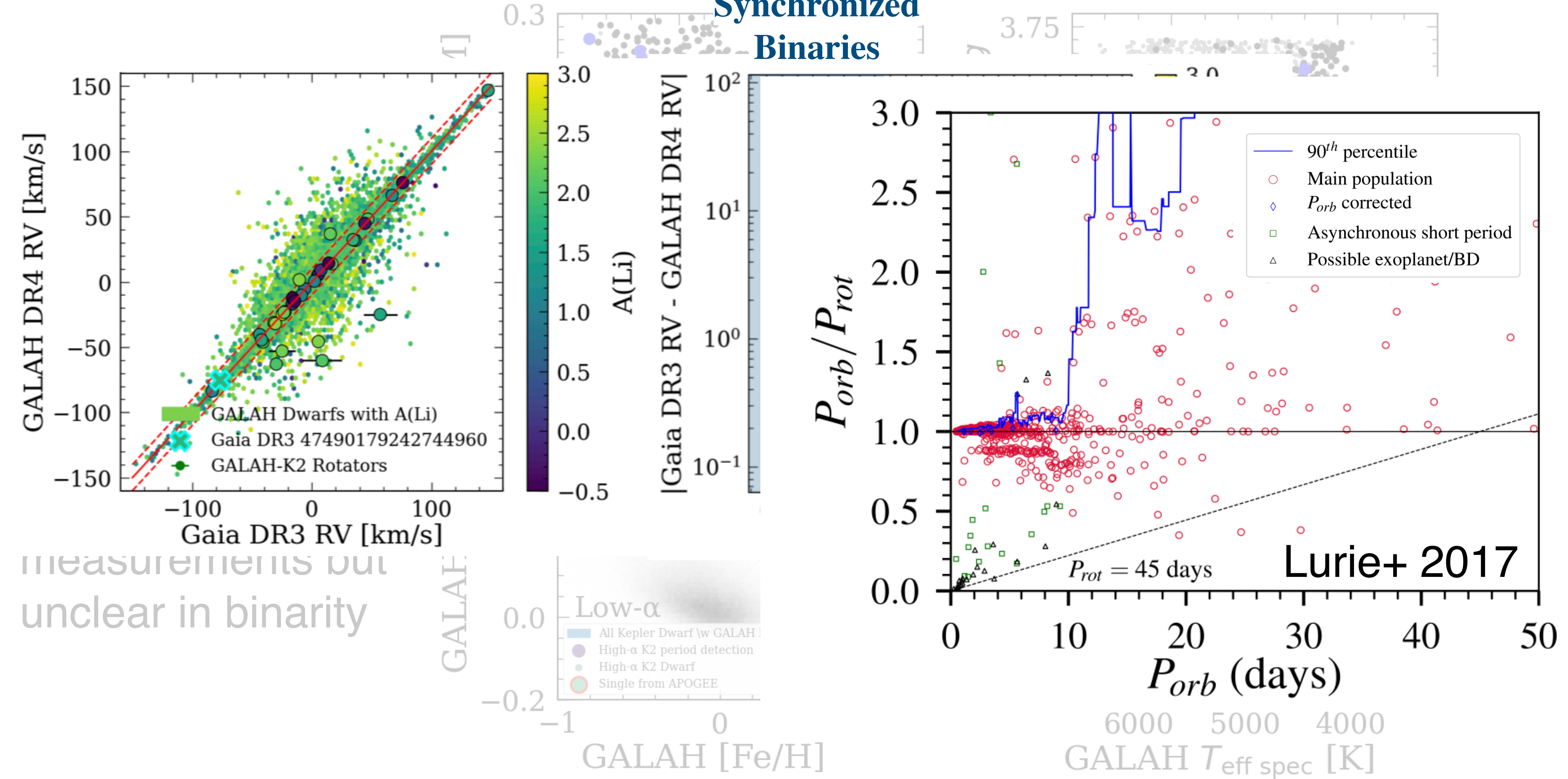
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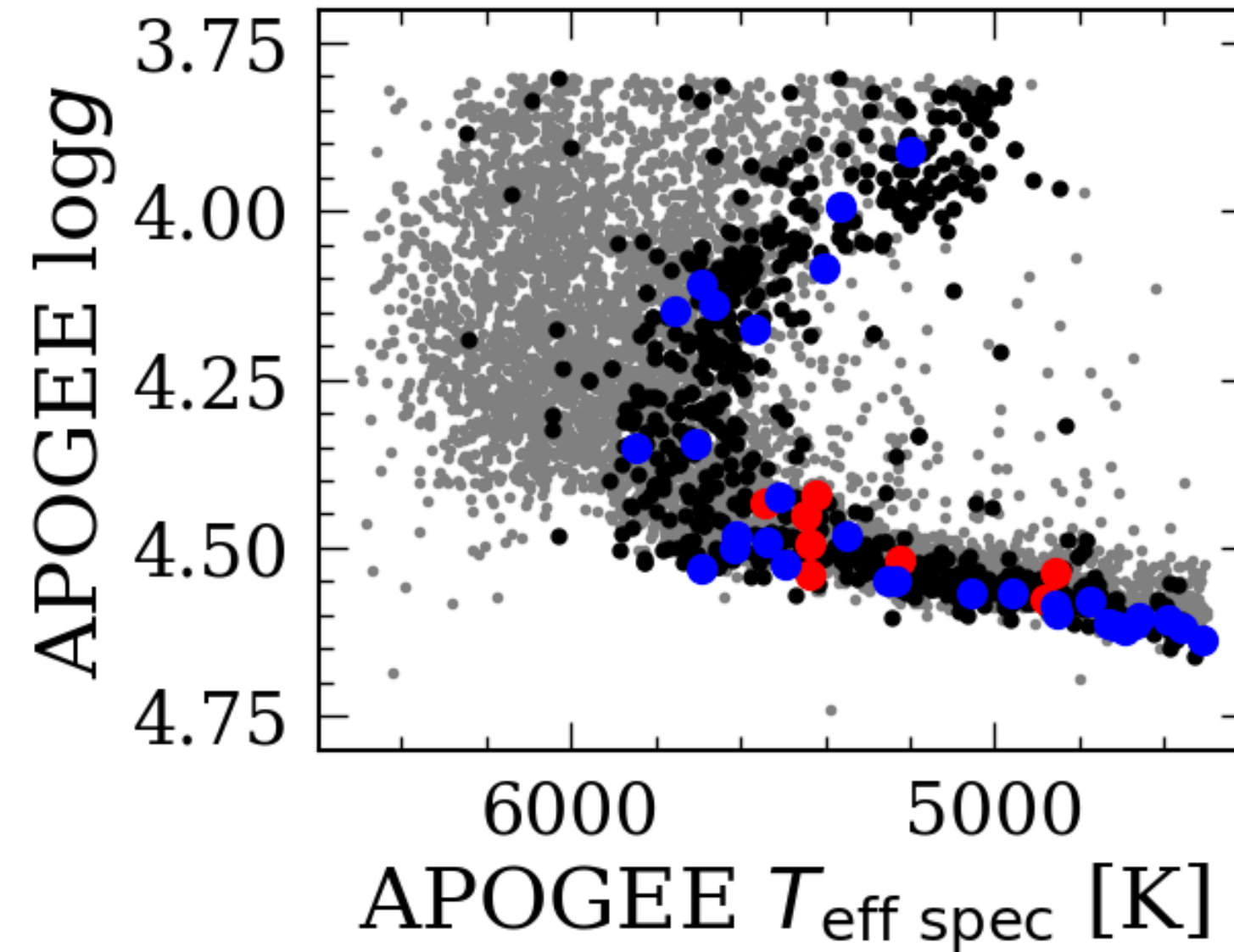
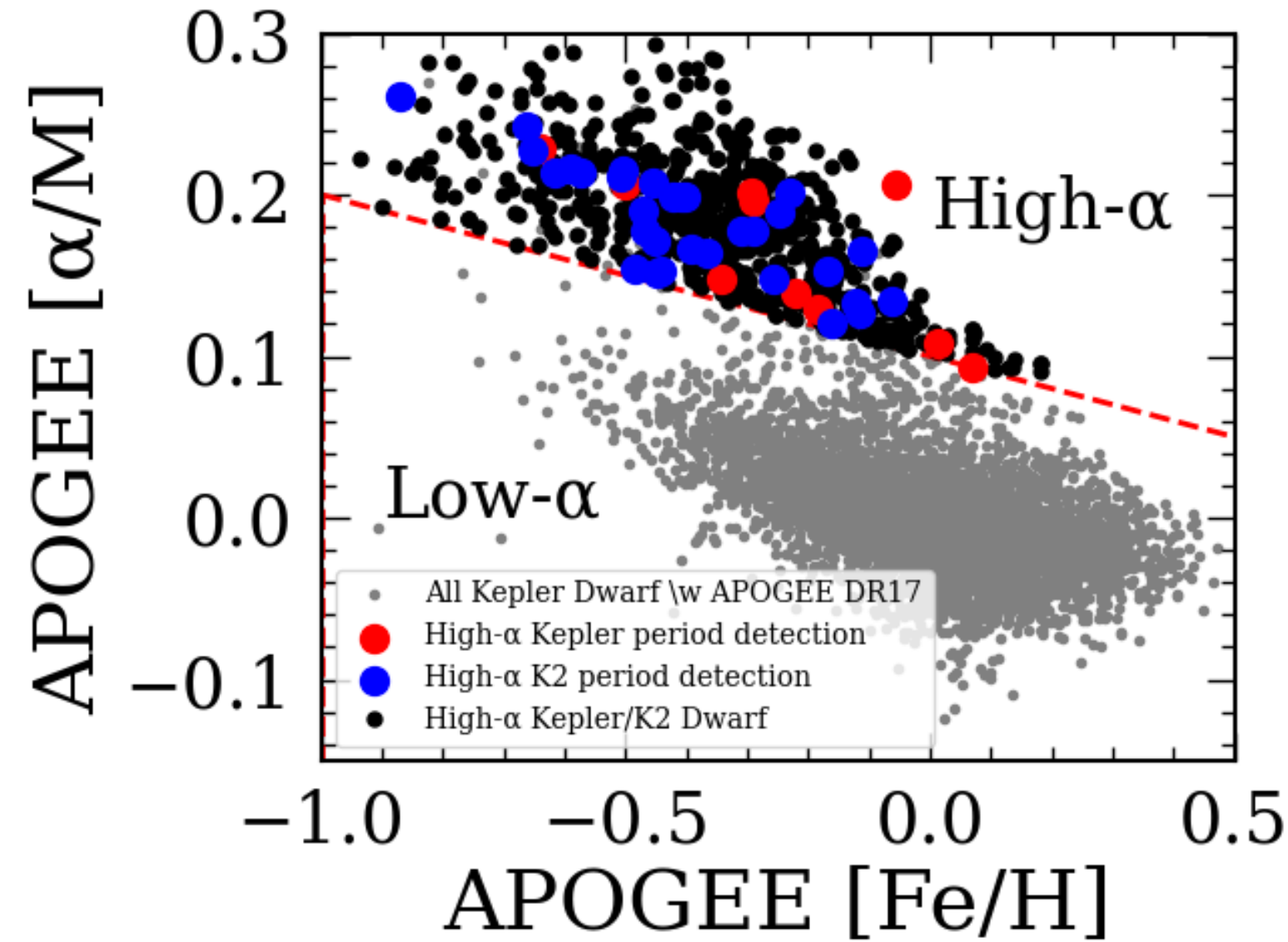


41

measurements but unclear in binarity

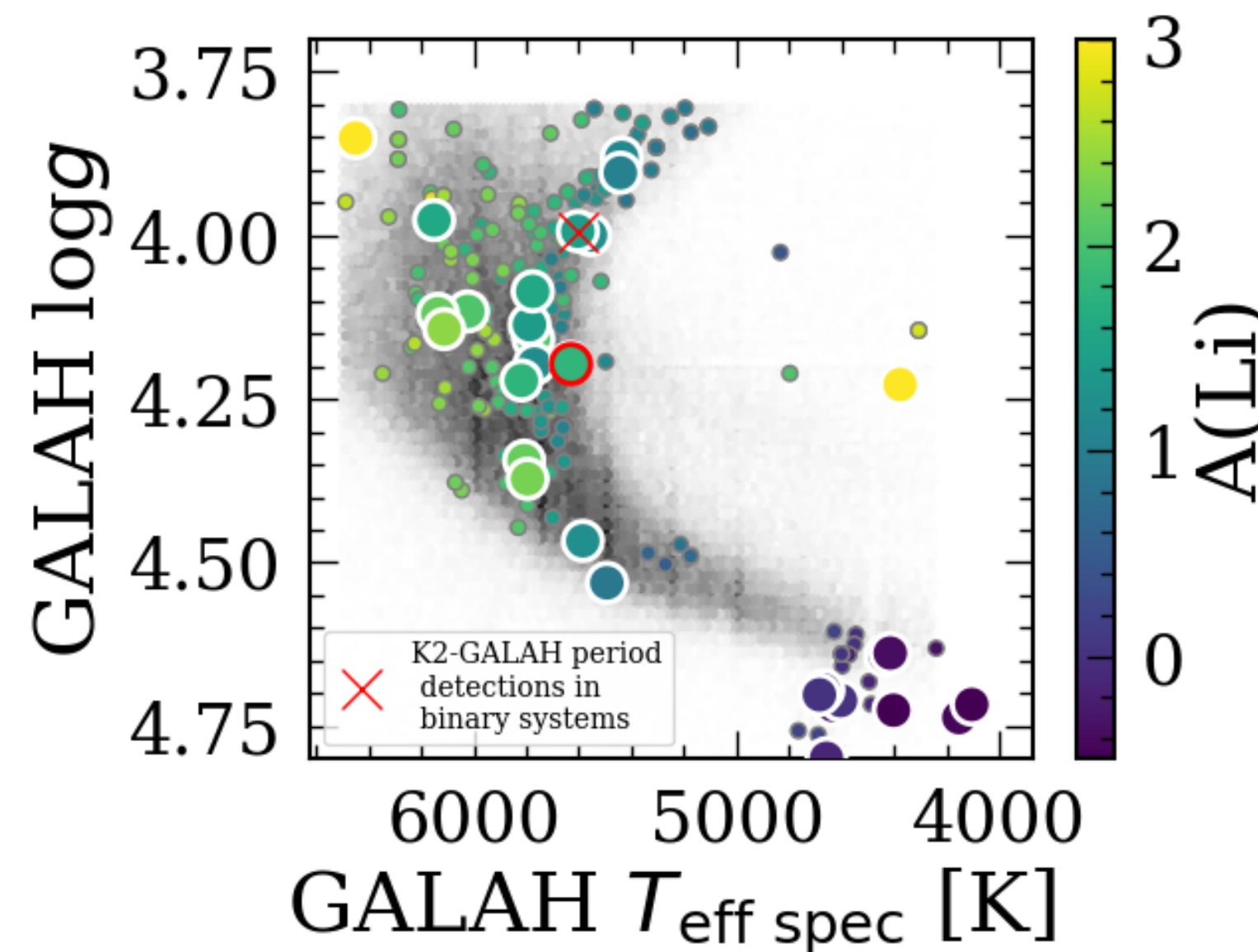
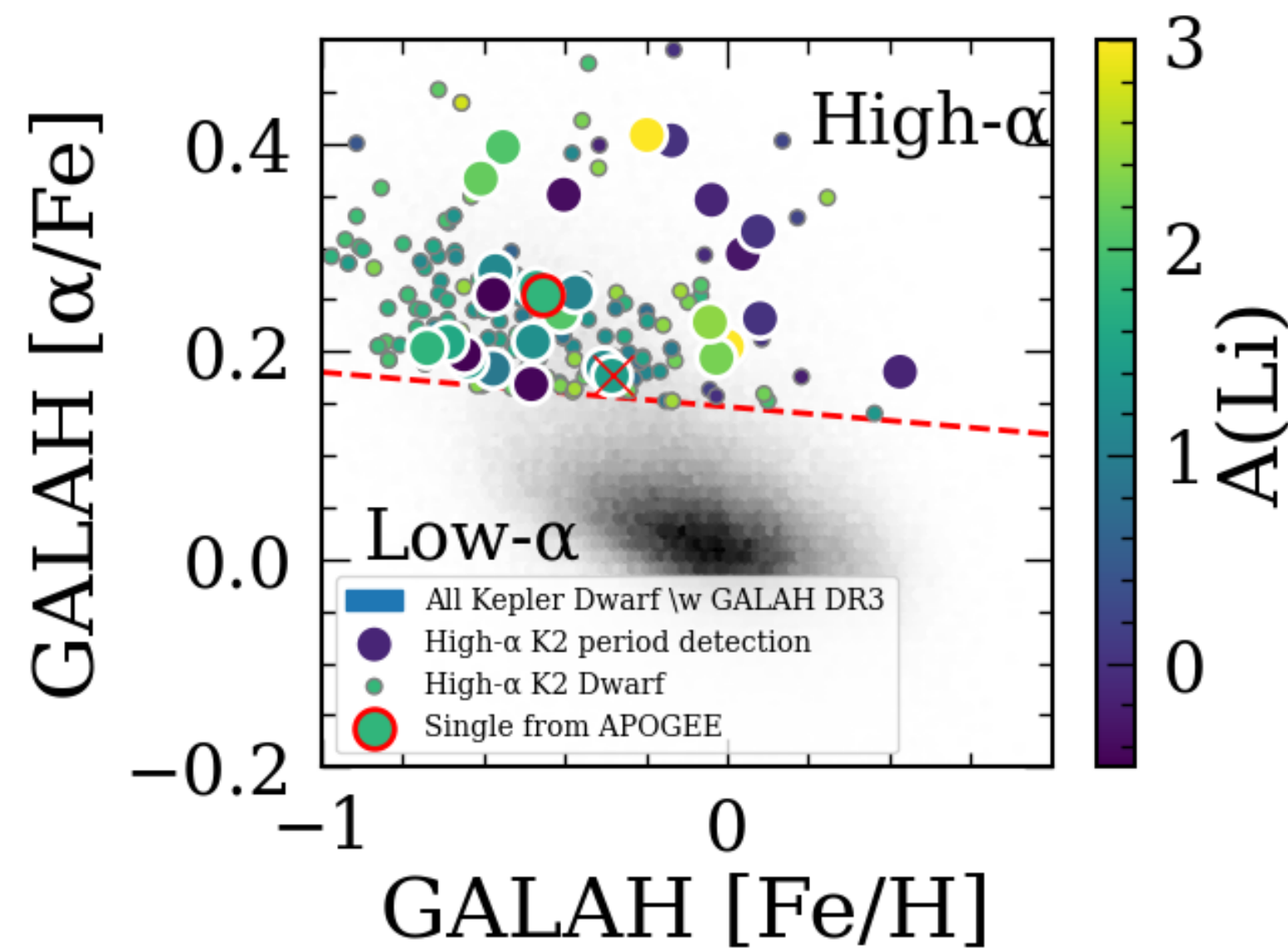
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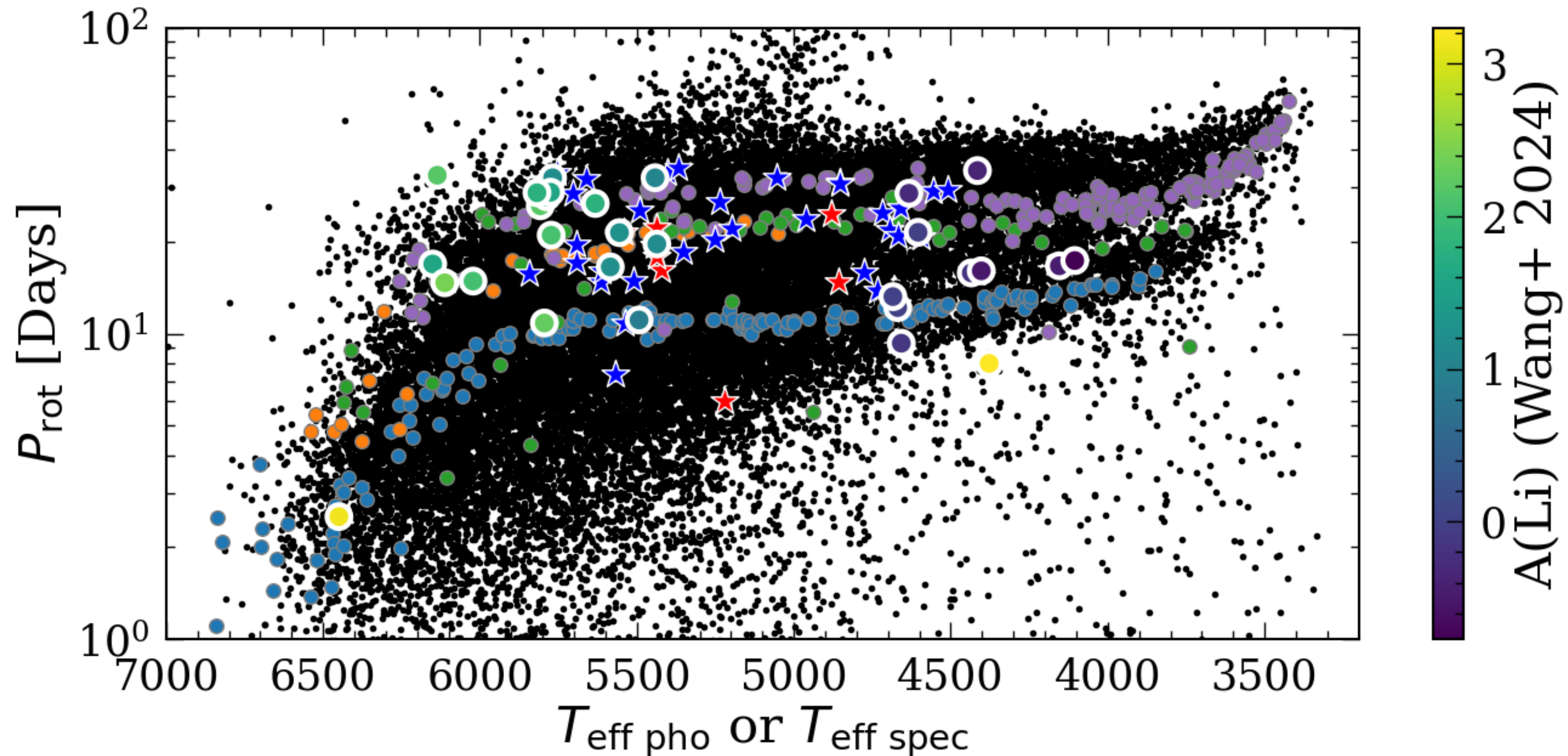
GALAH sample
Lithium measurements but unclear in binarity



Total 25 stars after excluding binaries with Gaia

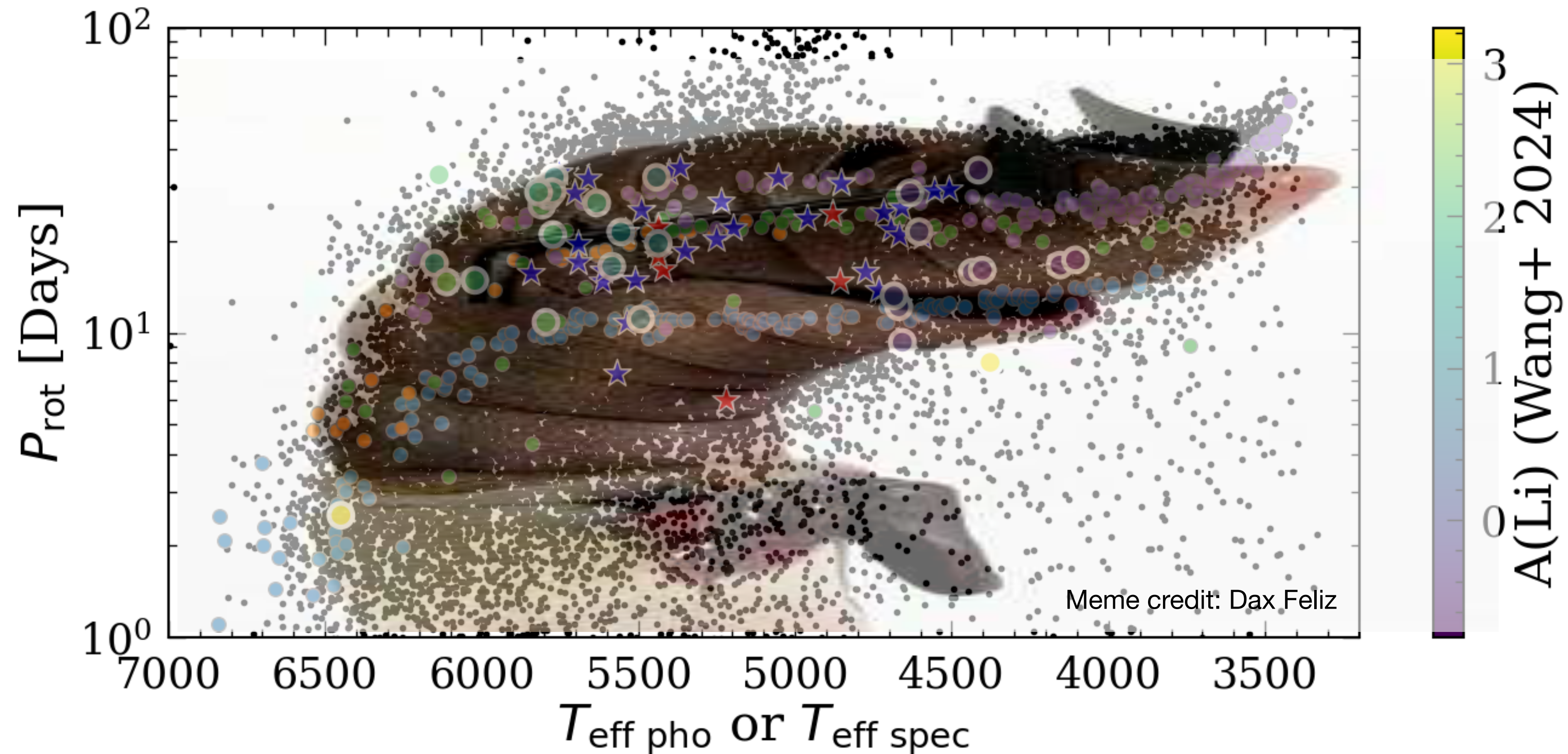
Result: Evidence of young high- α stars in dwarfs

- Field stars (Santos+ 2021)
- NGC 6811, 1 Gyr (Curtis+ 2020)
- NGC 6819, 2.5 Gyr (Curtis+ 2020)
- Ruprecht 147, 2.7 Gyr (Curtis+ 2020)
- M67, 4 Gyr (Dungee+ 2022, Gruner+ 2023)
- High- α APOGEE-Kepler Stars (this work)
- High- α APOGEE-K2 Stars (this work)
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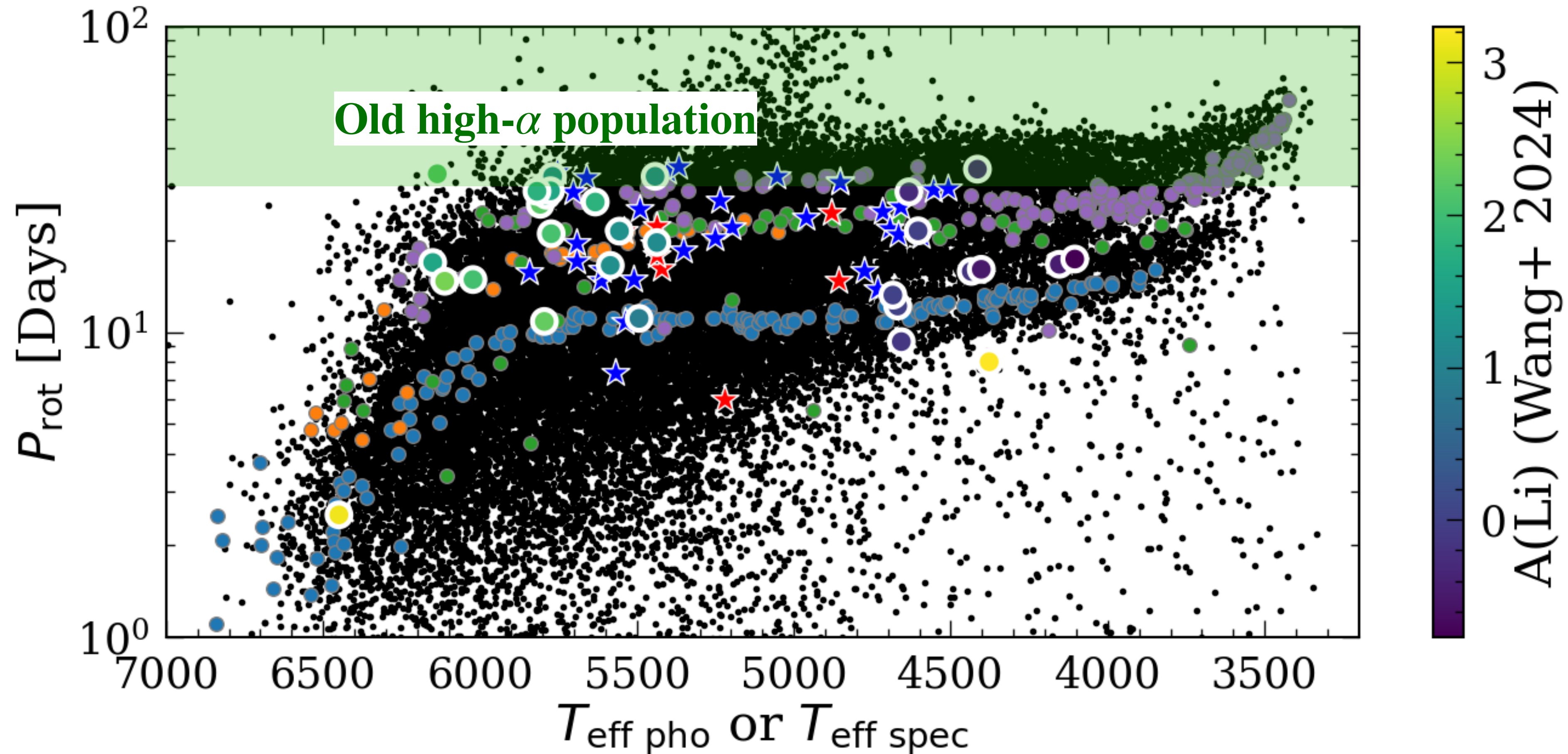
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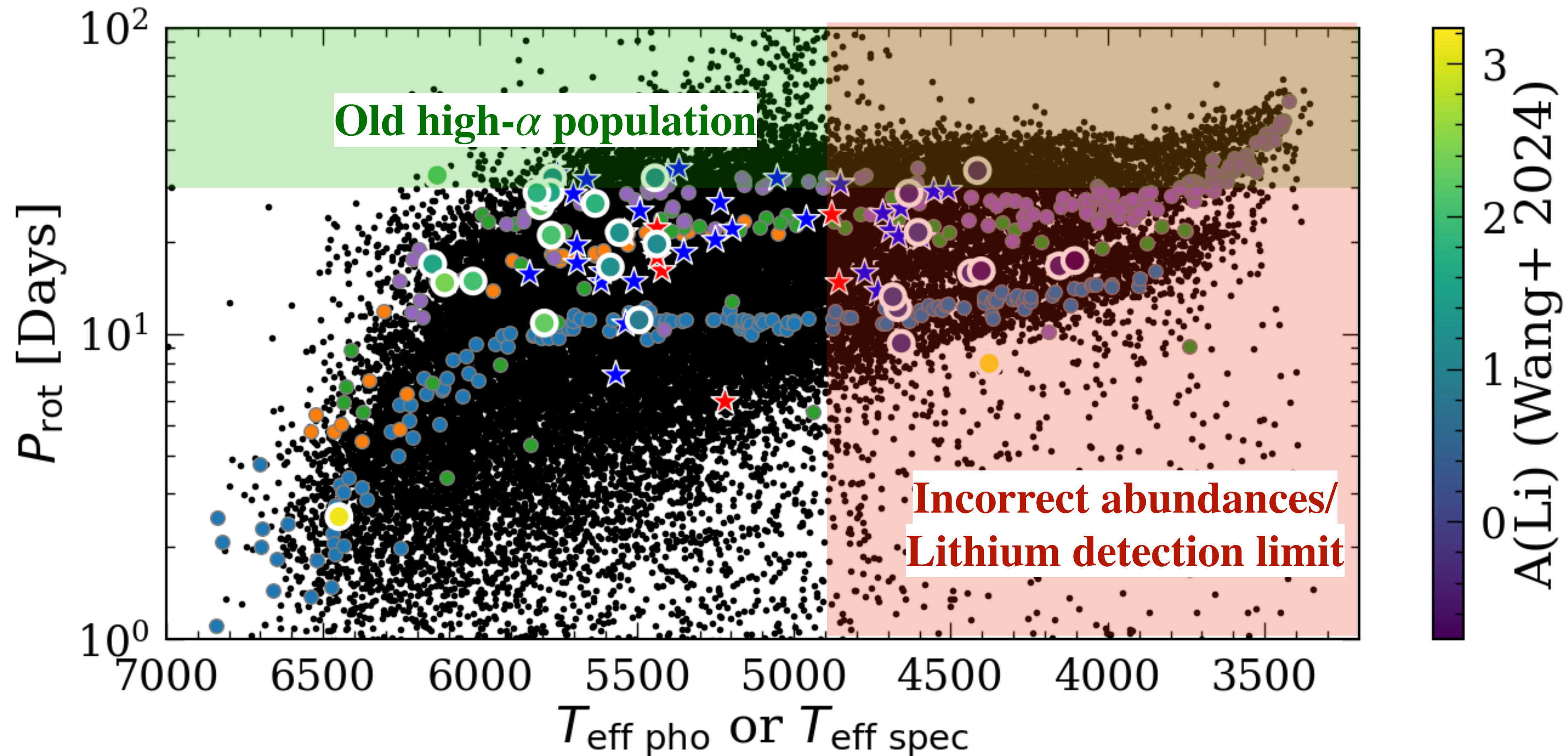
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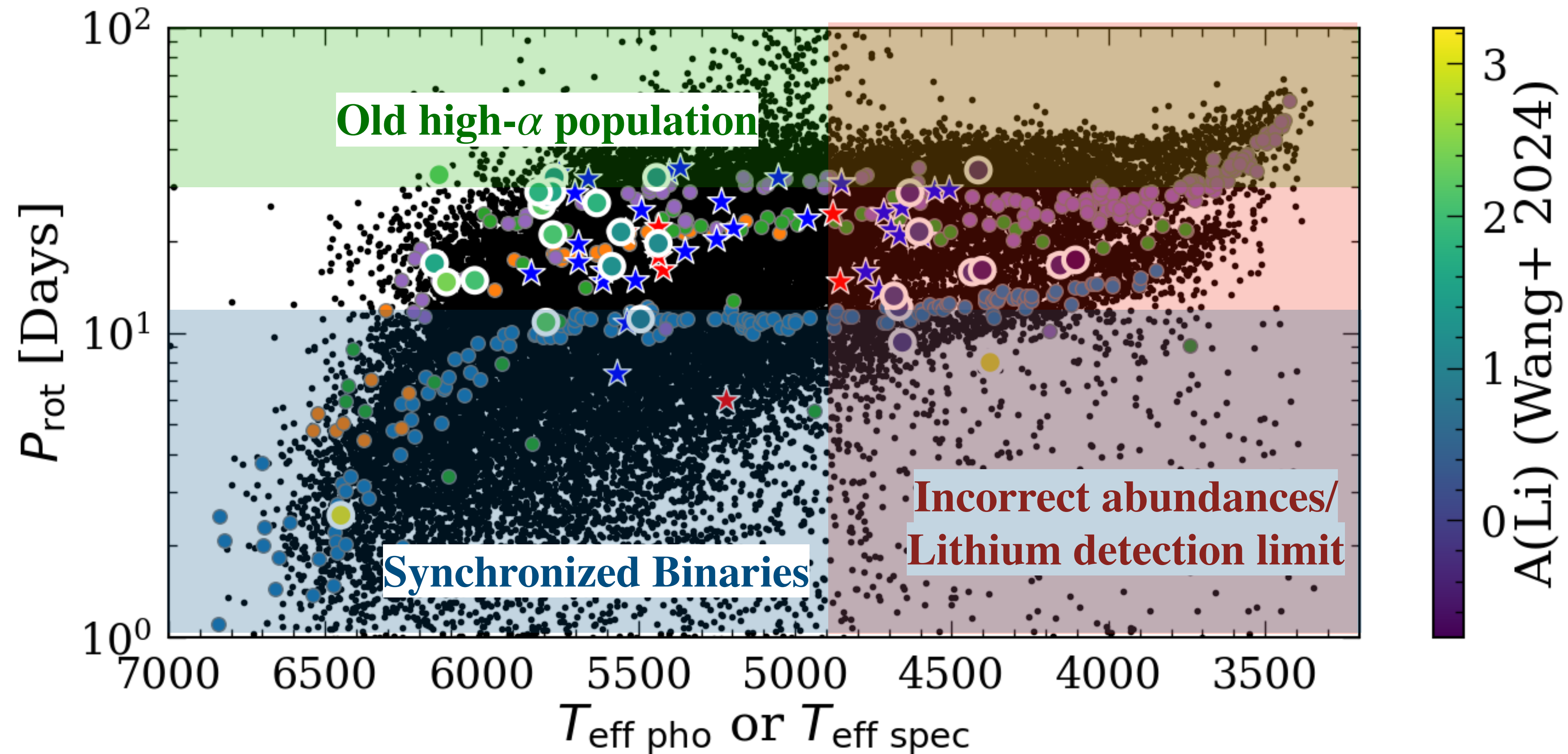
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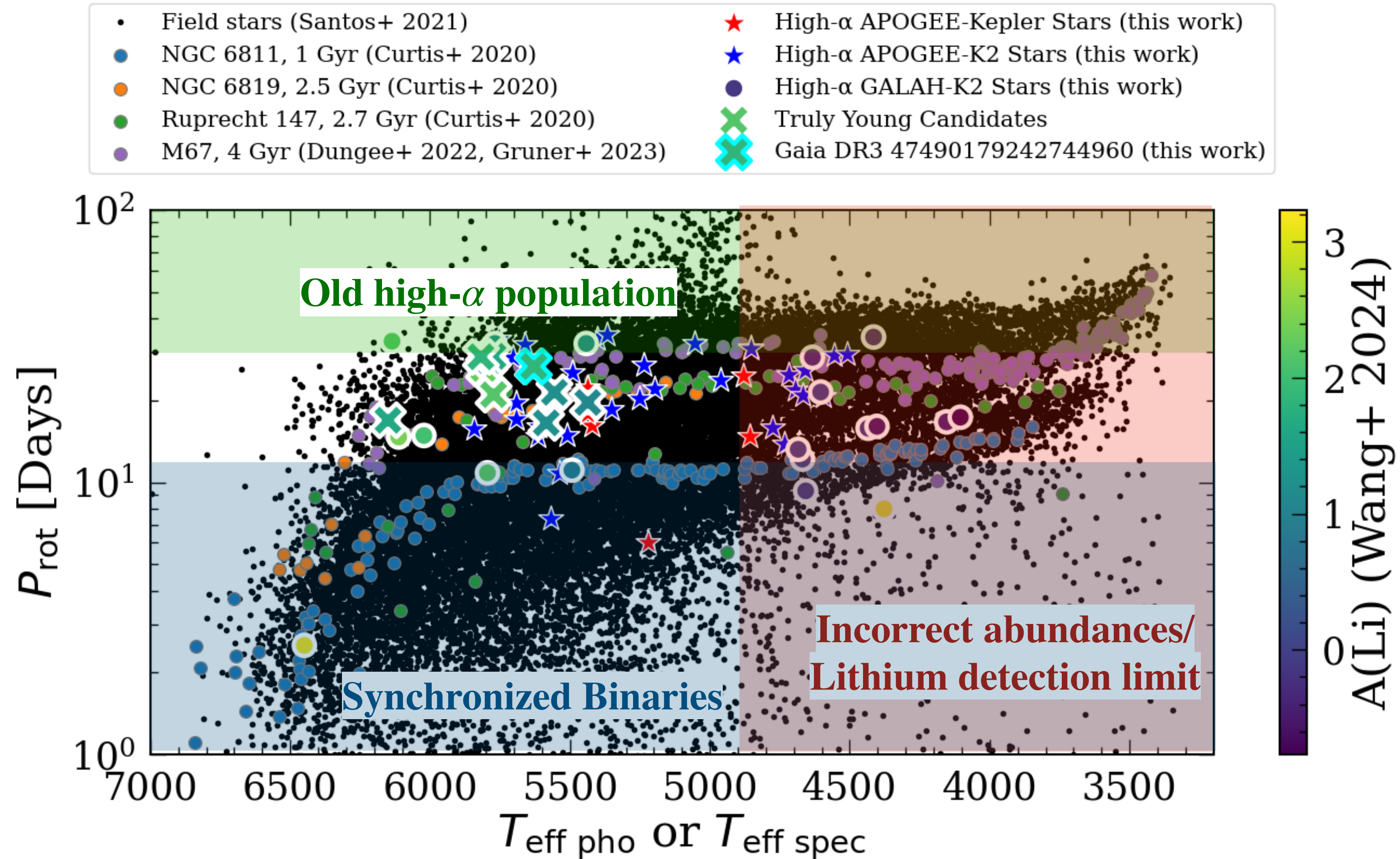


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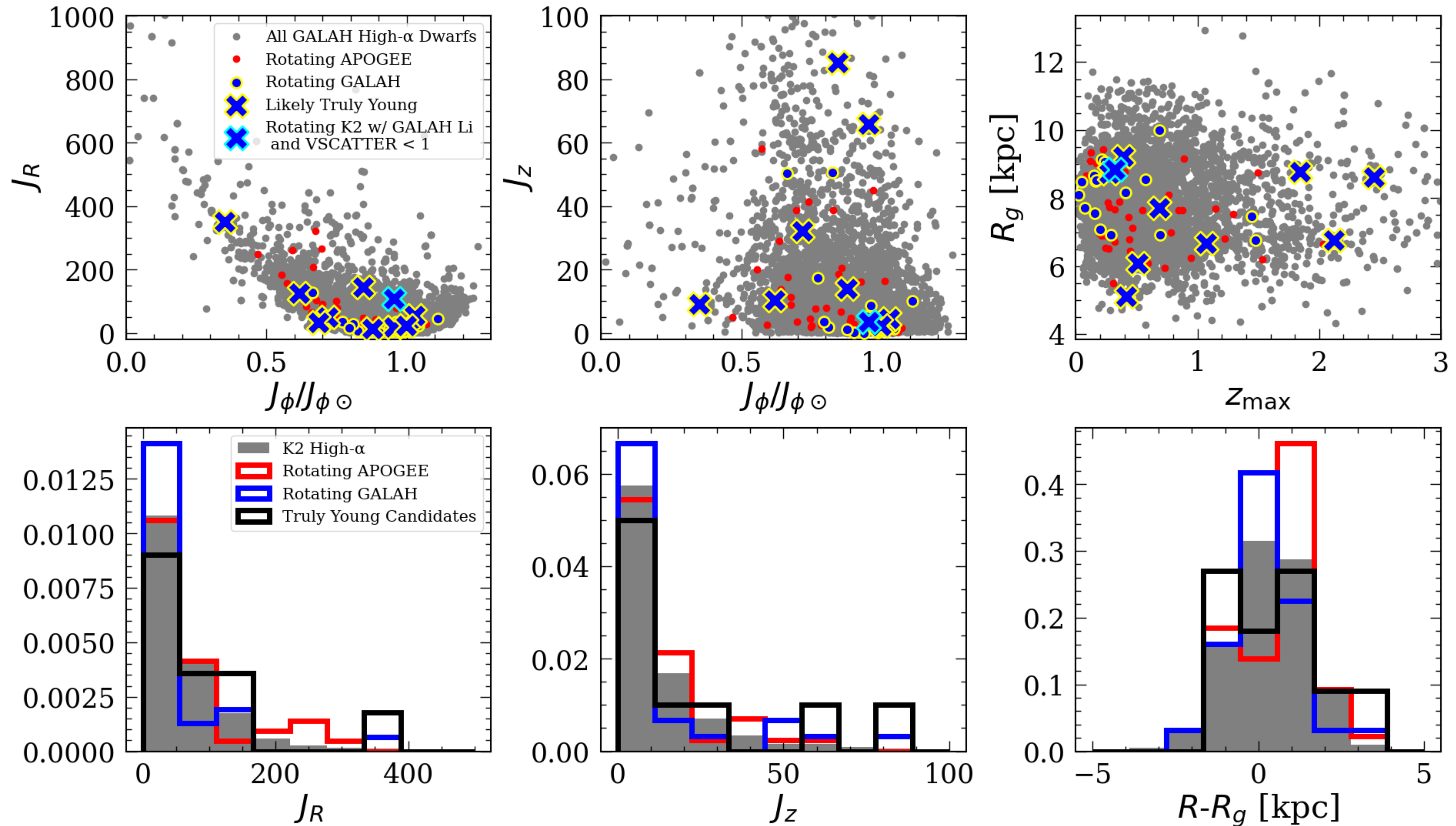
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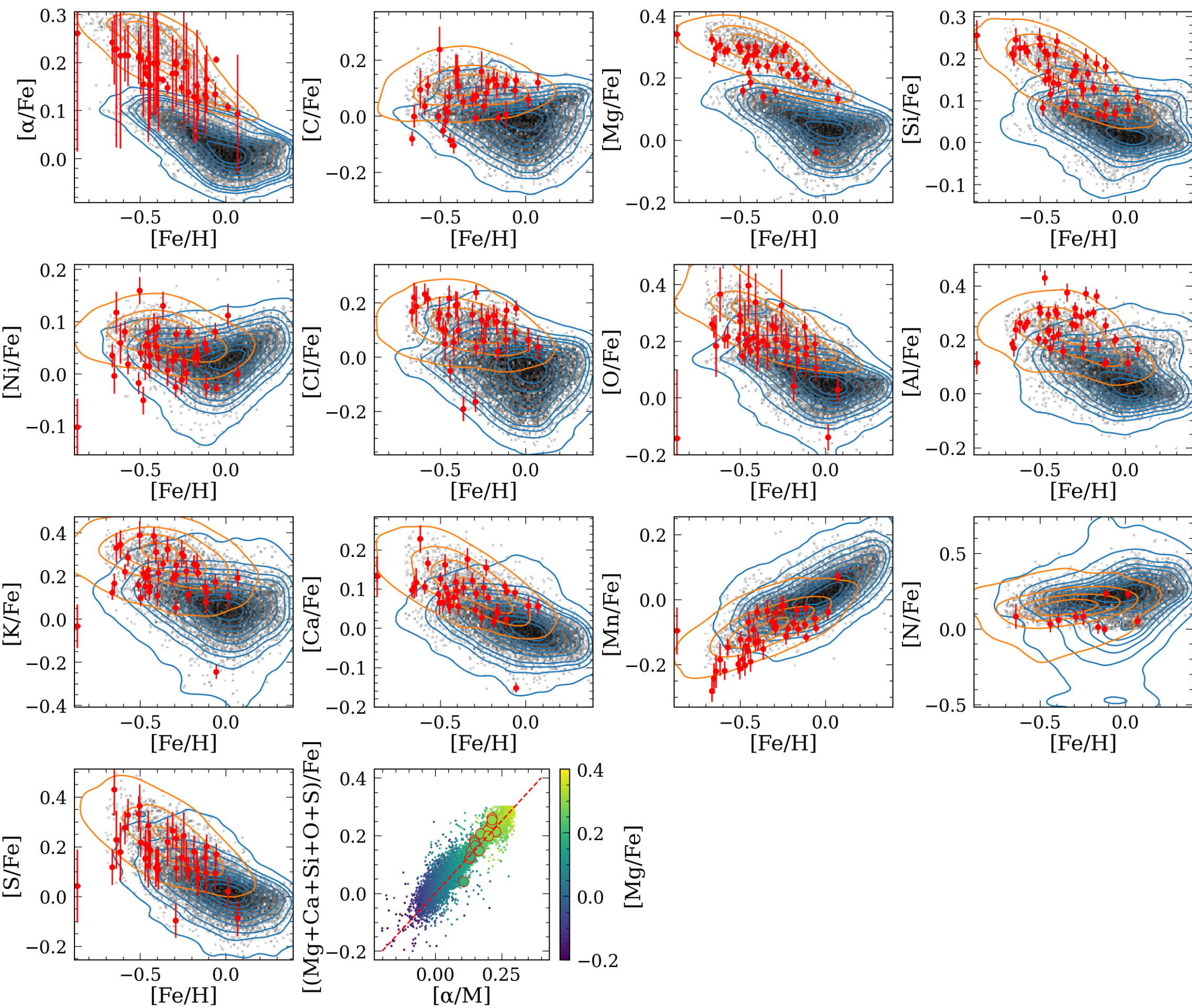


Result: Kinematic and abundance properties

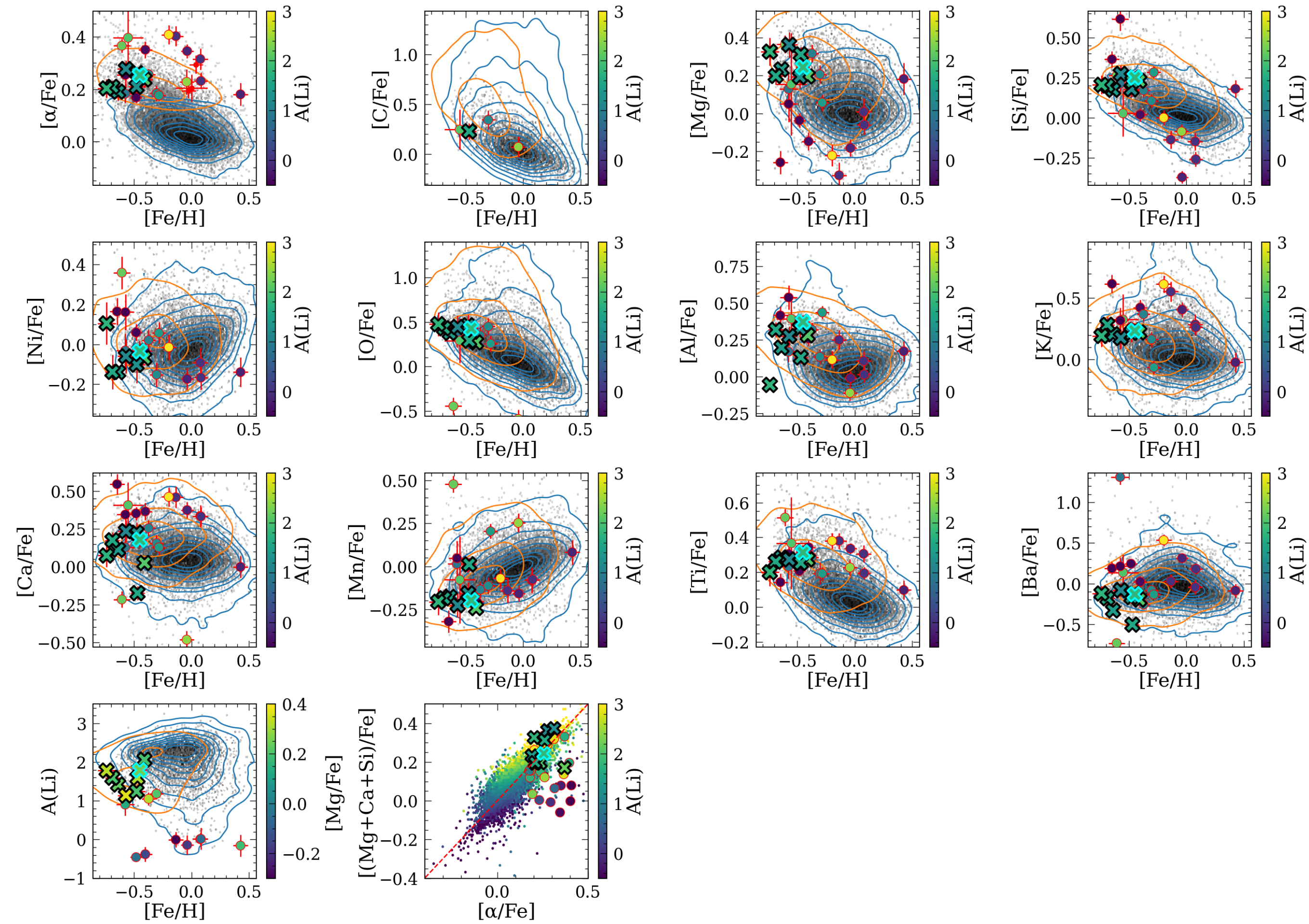


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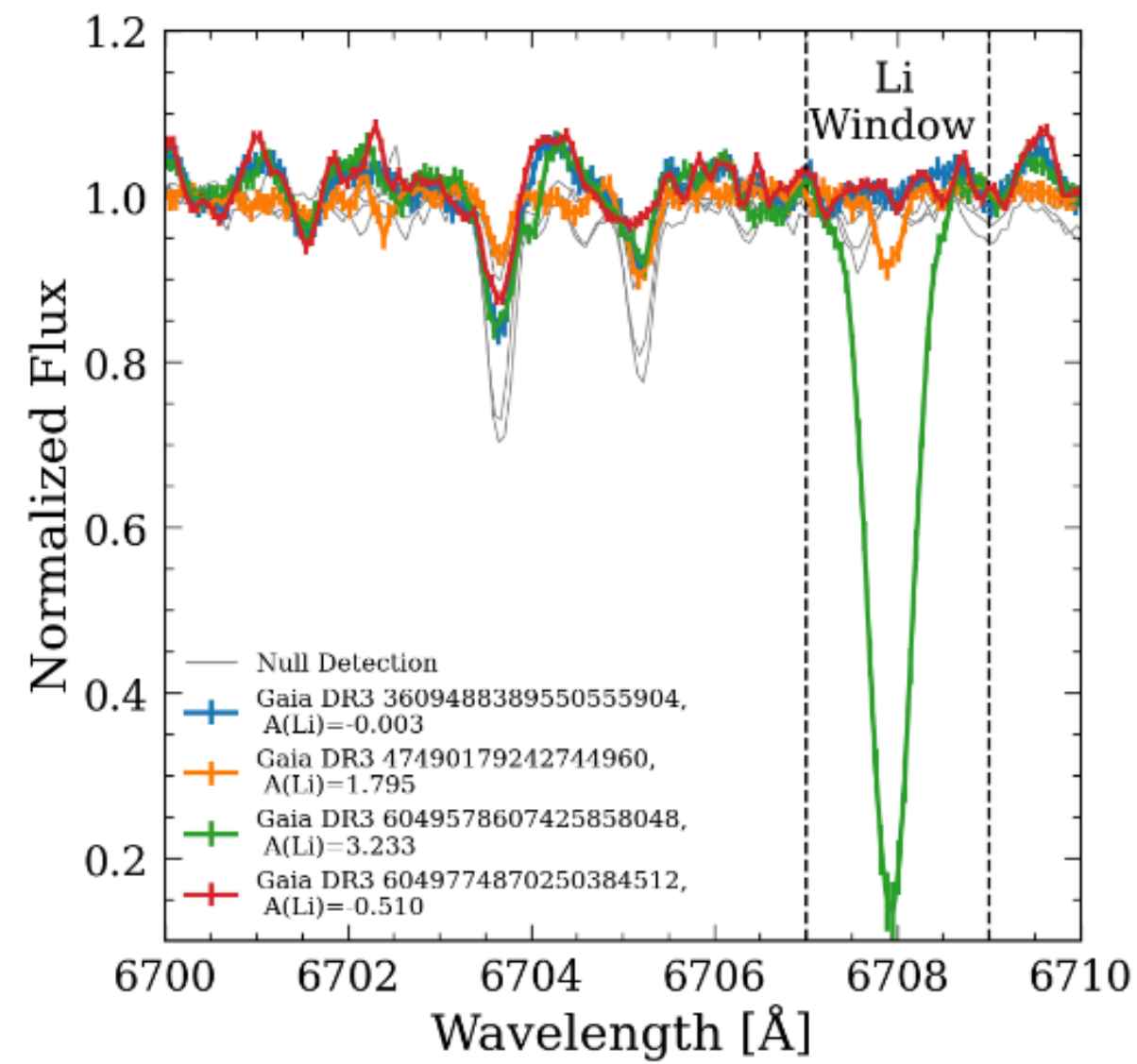
APOGEE sample



GALAH sample

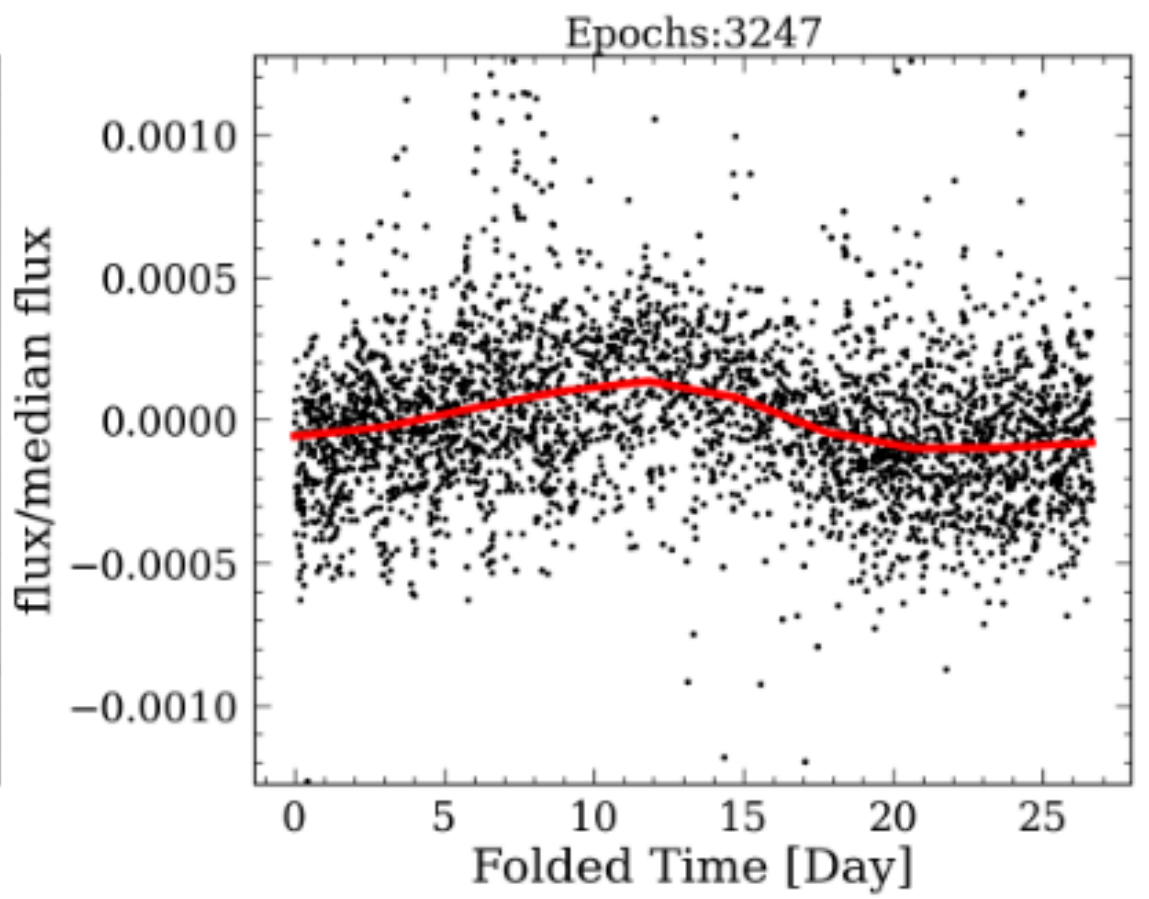
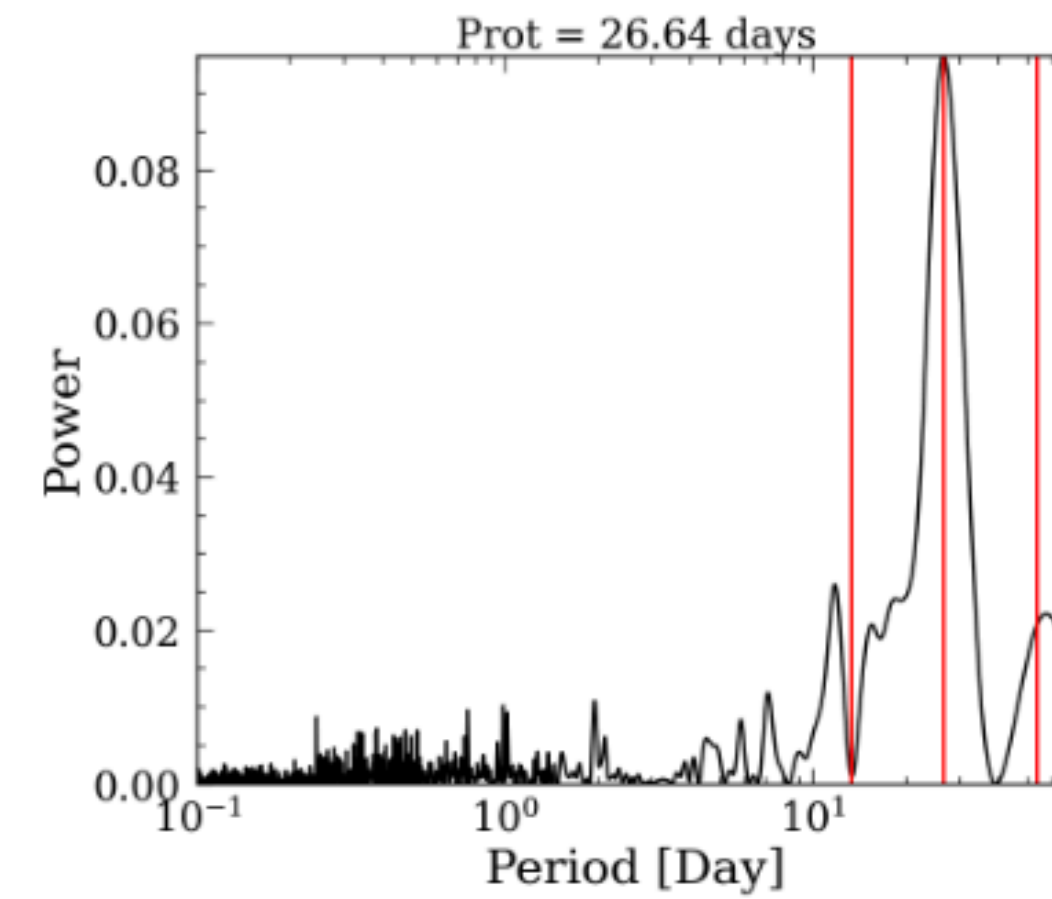
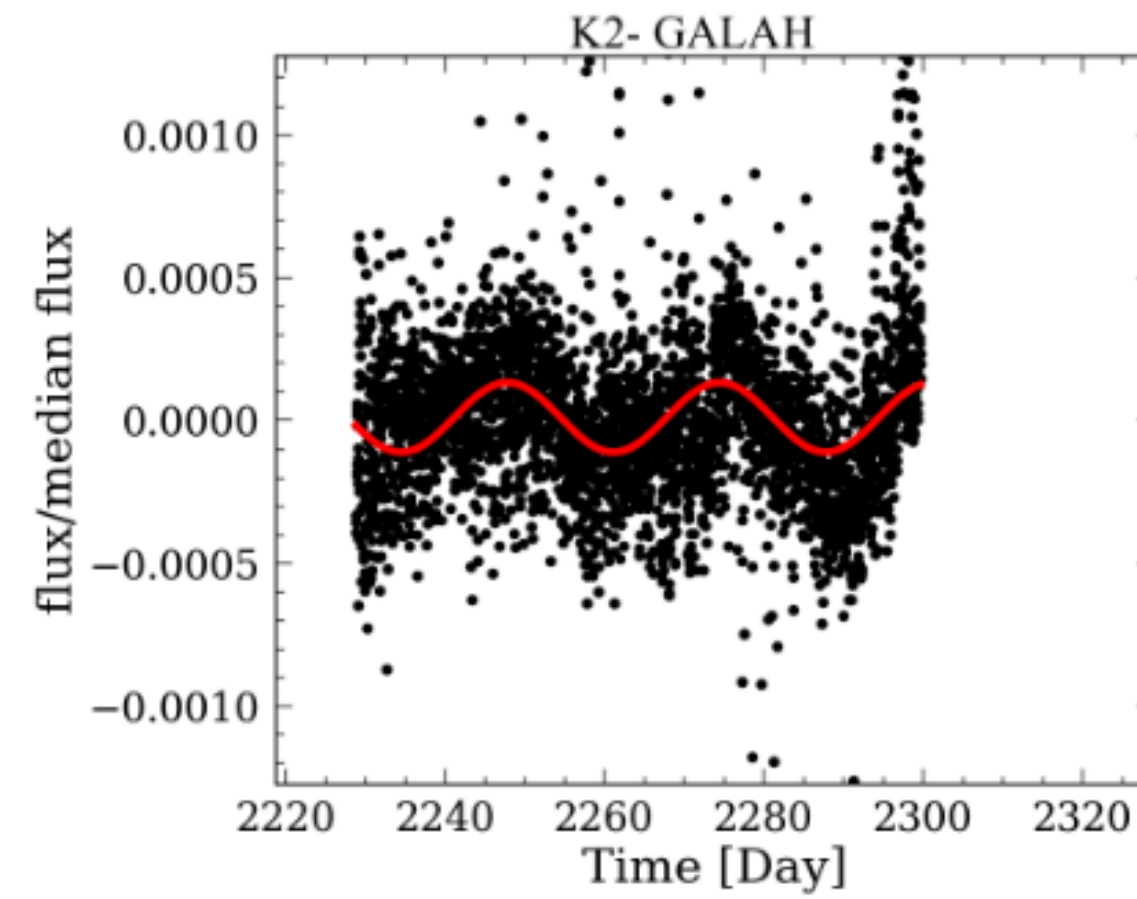
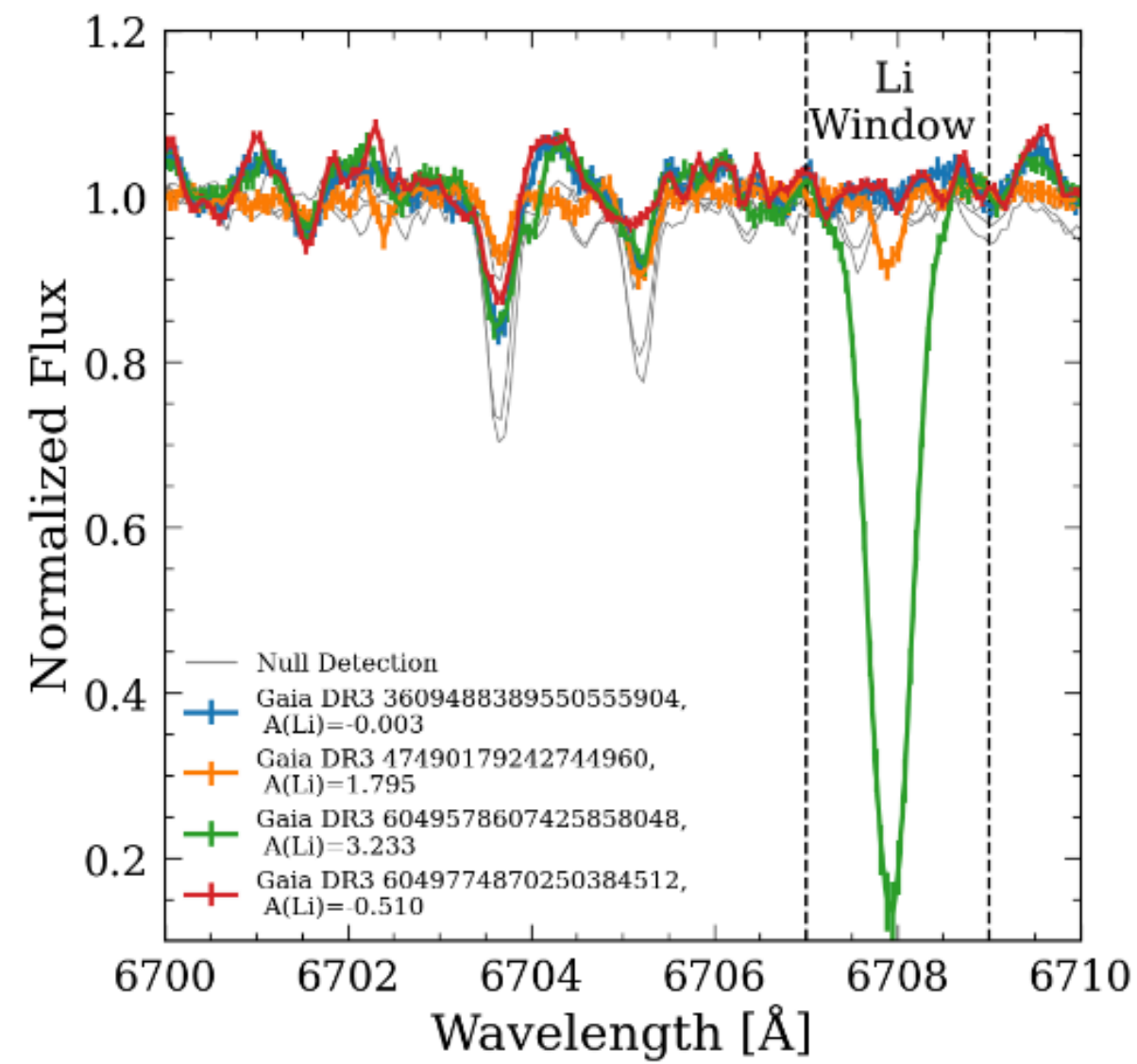


Result: A case study — Gaia DR3 4749017924274496



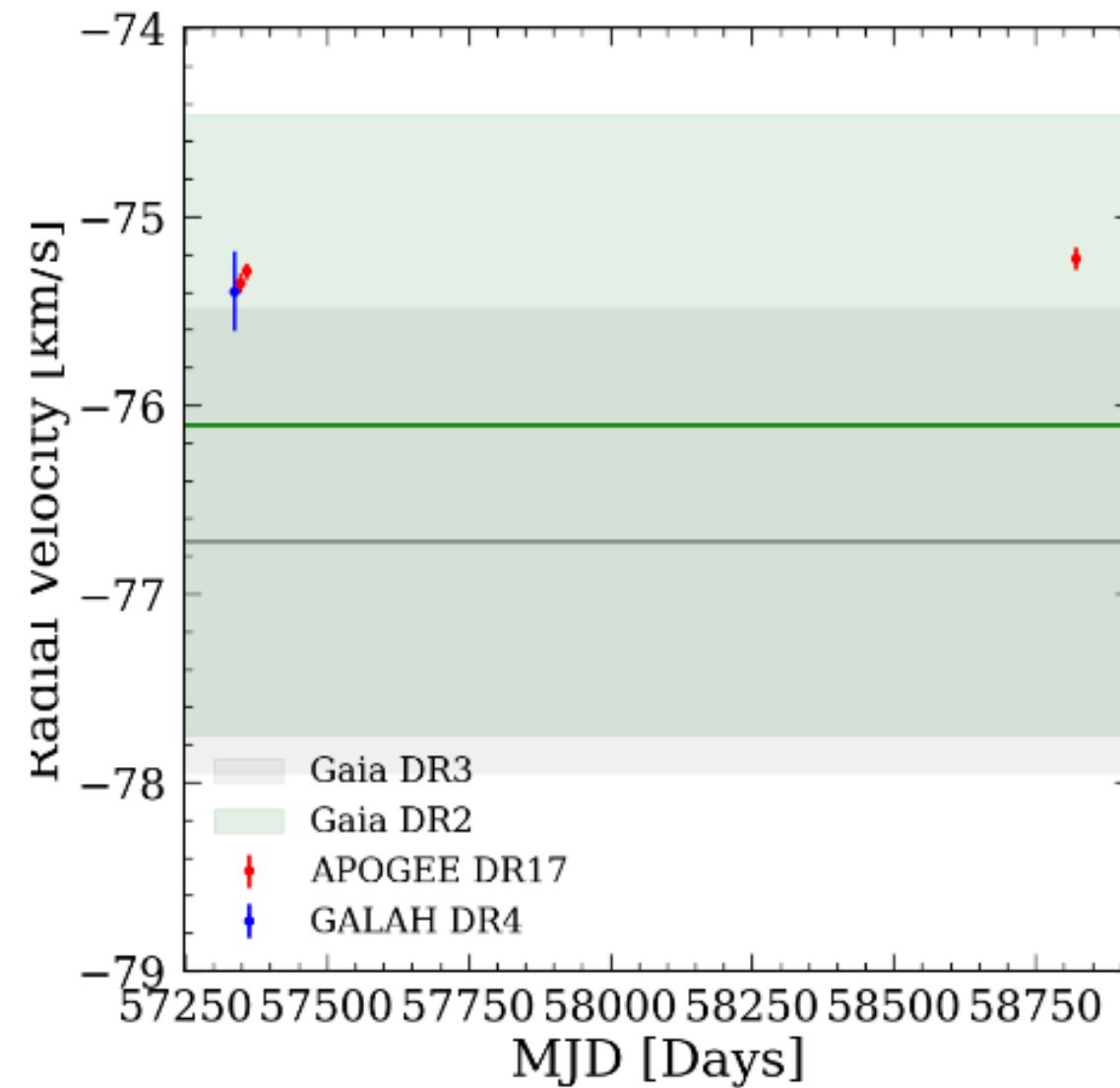
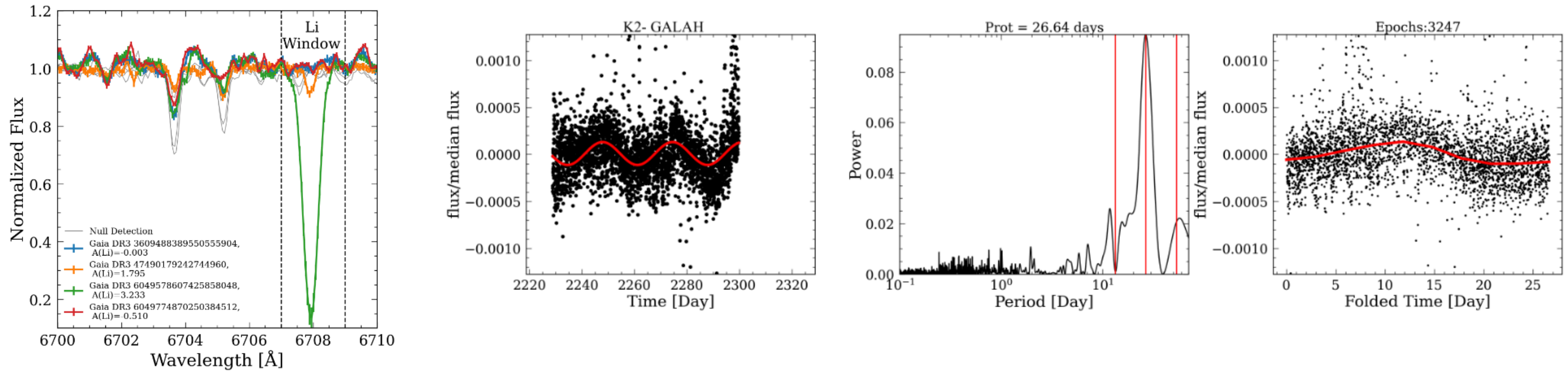
Significant Lithium —
Have not gone through
stellar merger

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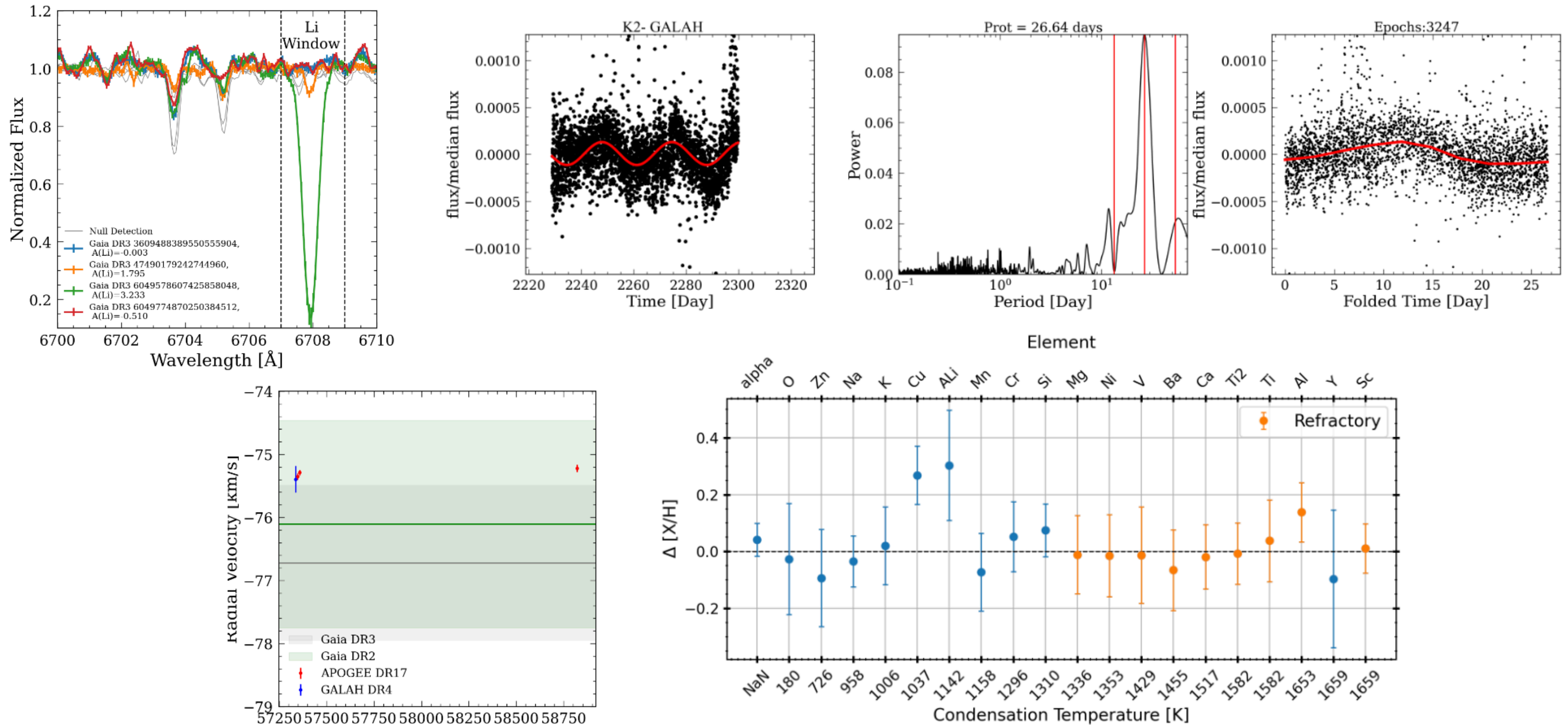
Reliable rotation period measurement — of an age of ~ 2 Gyr

Result: A case study — Gaia DR3 4749017924274496



Agreeing RVs from multiple instruments — Period has not affected by a close-by binary companion

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No signs of planet engulfment

Truly young High- α stars exist, how are they made?