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A 30 Million Year Old Mini-Neptune in the Kepler Field

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ABSTRACT

The Gaia satellite is revolutionizing our understanding of nearby open clusters and moving groups. Here, we focus on the underappreciated δ Lyr cluster. Based on rotation periods and lithium measurements, we find the age of the cluster to be $30 \pm XX$ Myr. Kepler 1627 is a binary system in the cluster, serendipitously observed by the Kepler satellite because the primary is nearby and Sun-like, and not because it is young. Kepler 1627A was found to host a $3.7 \pm X.X\,R_{\oplus}$ mini-Neptune on a 7.2 day orbit. We re-validate the existence of Kepler 1627Ab, and cement it as the youngest planet with a well-measured age observed by the main Kepler mission. Newly derived ages from Gaia offer the opportunity to significantly expand the census of age-dated planets. The properties of Kepler 1627Ab are may also help clarify how the orbits and atmospheres of the mini-Neptune planets evolve.

Keywords: planetary evolution (XXXX), stellar associations (1582), open star clusters (1160), stellar ages (1581),

1. INTRODUCTION

At the time of the main Kepler mission (2009–2013), only four open clusters were known in the Kepler field: NGC 6866, NGC 6811, NGC 6819, and NGC 6791, with ages spanning 0.7 Gyr to 9 Gyr (Meibom et al. 2011).

Section 2. Section 3. In Section 4, we discuss. Section 5 gives our conclusions.

2. FIRST

3. SECOND

4. DISCUSSION

5. CONCLUSION

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Software: `astrobase` (Bhatti et al. 2018), `astropy` (Astropy Collaboration et al. 2018), `astroquery` (Ginsburg et al. 2018), `corner` (Foreman-Mackey 2016), `exoplanet` (Foreman-Mackey et al. 2020), and its dependencies (Agol et al. 2020; Kipping 2013; Luger et al. 2019; Theano Development Team 2016), `IPython` (Pérez & Granger 2007), `matplotlib` (Hunter 2007), `numpy` (Walt et al. 2011), `pandas` (McKinney 2010), `PyMC3` (Salvatier et al. 2016), `scipy` (Jones et al. 2001), `TESS-point` (Burke et al. 2020), `wotan` (Hippke et al. 2019).

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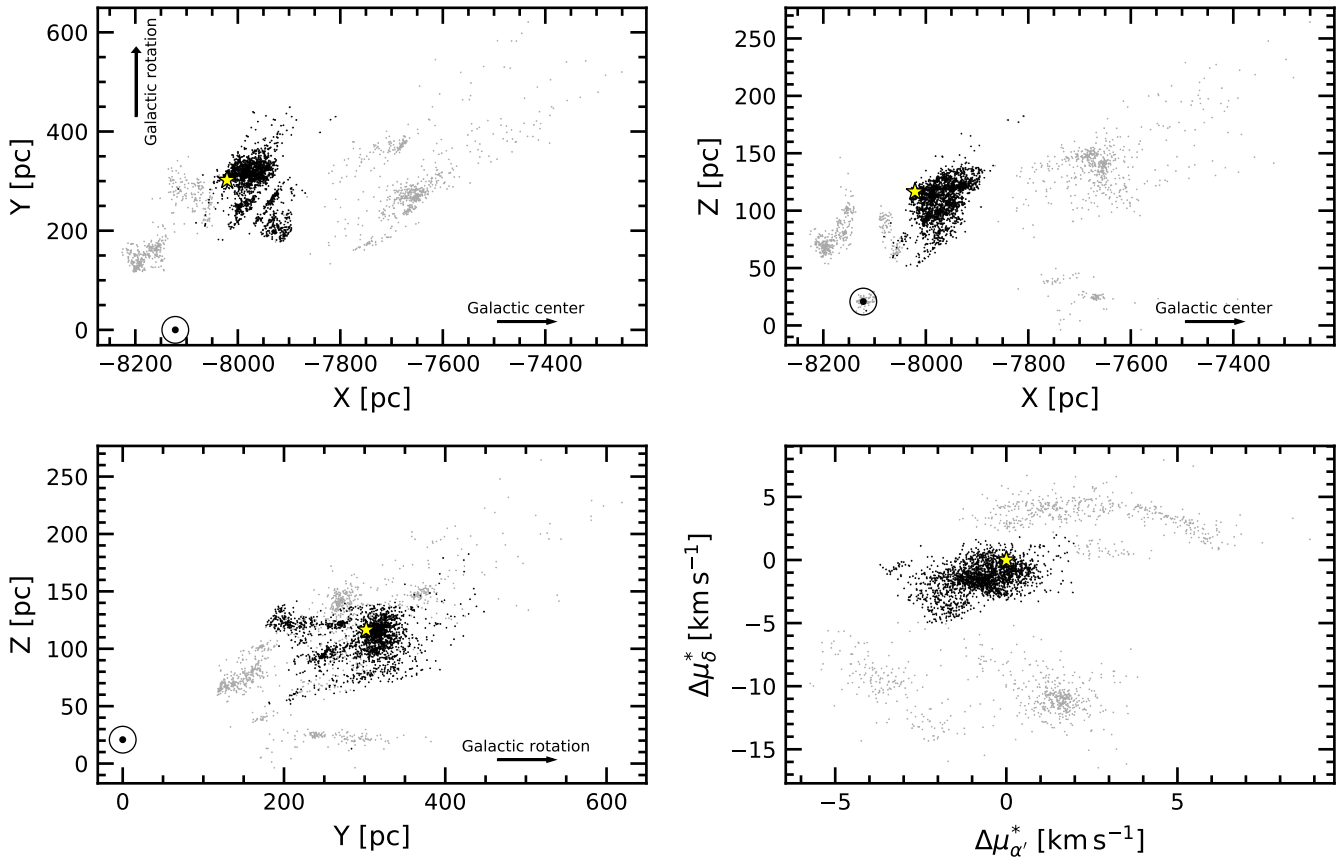

Figure 1. Galactic position and tangential velocities of the δ Lyr cluster (also known as Theia 73 and Stephenson 1). Points are candidate cluster members with $\varpi/\sigma_\varpi > 20$, reported to be in the group by Kounkel & Covey (2019). We focus on stars in a small region (black points) in the kinematic vicinity of Kepler 1627 (yellow star). The other candidate cluster members (gray points) may or may not share the ages of the selected kinematic group. The location of the Sun is ($\odot$) is shown.

Facilities: *Astrometry*: Gaia (Gaia Collaboration et al. 2018, 2020). *Imaging*: Second Generation Digitized Sky Survey. *Spectroscopy*: CTIO1.5 m (CHIRON; Tokovinin et al. 2013), AAT (HERMES; Lewis et al. 2002; Sheinis et al. 2015), VLT:Kueyen (FLAMES; Pasquini et al. 2002). *Photometry*: TESS (Ricker et al. 2015).

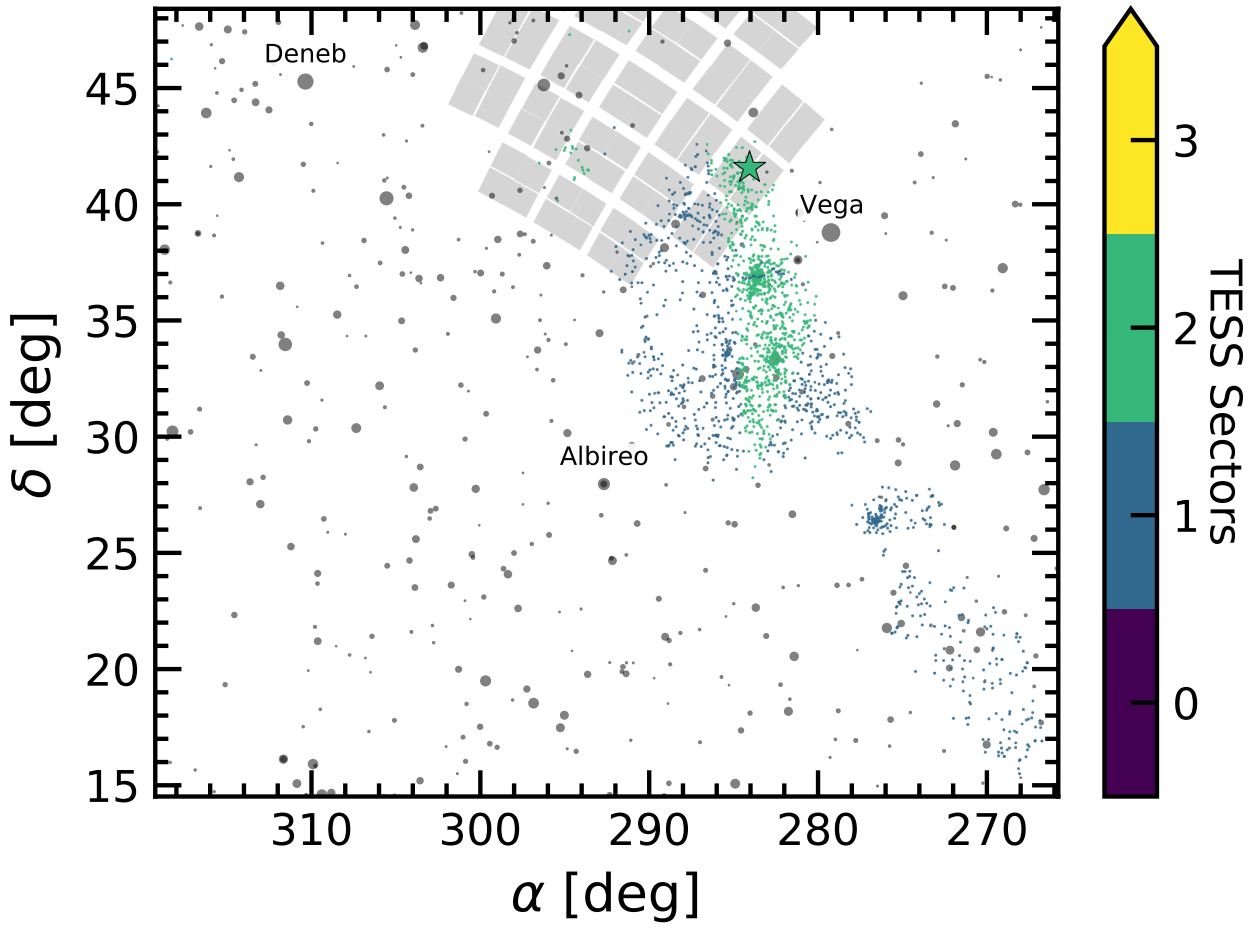

Figure 2. Kepler and TESS views of the δ Lyr cluster. Colored points are kinematically selected members of the δ Lyr cluster (black points in Figure 1). Both Kepler (gray panels) and TESS (colored points) observed members of the cluster. Gray points are naked-eye stars ($m_V < 6.5$), three of which are annotated. Kepler 1627 (green star) was observed for two TESS sectors, and during the entirety of the Kepler mission.

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APPENDIX

A. FIRST APPENDIX