Rotating Stars from *Kepler* Observed with *Gaia* DR2

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+34,000 Rotation Periods from Kepler
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![Graph showing rotation periods vs. mass](image)

**McQuillan+2014**

**Meibom+2011**

**Periodic Fractions Across the Temperature Range Examined**

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Periodic Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000–6500 K</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Period vs. mass with comparison to previous rotation period measurements. The 34,030 new rotation periods derived using AutoACF are shown as cyan points. The mass was derived using the models of Baraffe et al. (1998, 2011), with gray and black symbols representing objects with young and old disks, respectively. The typical uncertainty associated with the period bimodality in the low-mass half of Figure 1 is around 6,000 K. The four clusters are NGC 6866 (0.5 Gyr), NGC 6811 (1 Gyr), NGC 6819 (2.5 Gyr), and Lyra (1 Gyr). The latter technique is independent of the color–period relation observed among moderate-to-slow rotators in the Hyades and younger clusters. The color–period relation observed among moderate-to-slow rotators in the Hyades and younger clusters (black curve). The surface beyond 3500 K the two peaks are at ∼40 days, with a Hartigan's dip test (Hartigan & Hartigan, 1985) factor of up to 10. The typical uncertainty associated with the period bimodality in the low-mass half of Figure 1 is around 6,000 K.
+34,000 Rotation Periods from Kepler

![Graph showing the relationship between rotation periods, mass, and age for stars. The graph includes data from McQuillan+2014 and Meibom+2011, with additional notes and references for further reading.](image)
A Period Bimodality

First seen in M dwarfs

McQuillan+2013
A Period Bimodality  The Mystery Deepens!

K/M: yes

F/G: no?!

McQuillan+2014
A Period Bimodality

2 Possible Explanations:
1) Variation in Star Formation History
2) New transition phase in stellar spin-down

How to test these?
- Do F/G stars show bimodality?
- Is bimodality everywhere?
- Connect to other age indicators?
Period Bimodality **IS** found in G dwarfs!

Match Kepler to Gaia (DR1/TGAS)

Select **Main Sequence**, filter out subgiants

Before Gaia filtering

Period bimodality **IS** found for G dwarfs!

After

Davenport 2017
Davenport & Covey submitted
arXiv: 1807.09841
Gaia DR2

Davenport & Covey *submitted*

arXiv: 1807.09841
A more complete view

Gaia DR2

Davenport & Covey submitted
arXiv: 1807.09841

~600Myr

$P_{\text{rot}}$ (days)

$G_{BP} - G_{RP}$ (mag)

$0 - 350$ pc

N=2321
A more complete view

Gaia DR2

Kernel Density Estimator
Explore in distance

**Gaia DR2**

- 0 - 350 pc
- N=2321

- 350 - 525 pc
- N=3368

- 525 - 600 pc
- N=1594

- 600 - 700 pc
- N=2122

- 700 - 900 pc
- N=3445

- 900 - 2500 pc
- N=3398
Bimodality drops with Height (Z)

Davenport & Covey submitted
arXiv: 1807.09841
Something *unexpected*

Davenport & Covey *submitted*

arXiv: 1807.09841
Ages on the main sequence?

Davenport & Covey *submitted*

arXiv: 1807.09841
Ages on the main sequence?

0.7 $M_\odot$ evolution

Davenport & Covey *submitted*

arXiv: 1807.09841

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[Image of a graph showing stellar evolution with labels for $G_{BP} - G_{RP}$, $M_G$, $G_{BP} - G_{RP}$ (mag), and $P_{rot}$ (days).]
Next: Extend to K2 & TESS (+Gaia)

- How localized is the bimodality?
- Star formation history on small scales?
- Effects of spiral arms visible?
Next: Extend to K2 & TESS (+Gaia)

K2 (EVEREST) C5,7  d=0 - 300pc

Z. Bell & J. Davenport (in prep)
Aside: Gender Ratios in Talks

Men ask 2 Q’s for every 1 by a Woman

Longer Q/A’s have better gender ratios

Let Jr people speak first!

Let Q/A go longer!

Davenport et al. (2014)
Schmidt & Davenport (2017)
Summary

Kepler: Bimodal rotation period distribution for G/K/M dwarfs!

Implies dip in Star Formation @ 600Myr

Bimodality decreases with height (Z)

Need K2 & TESS!

Period gradient across Main Seq: Ages?

New isochrones needed!