Variability “Profiles” for T Tauri Variables and Related Objects, from AAVSO Visual Observations

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Outline

- T Tauri stars and their variability
- Previous analysis of CCD and visual observations
- Data and methods of analysis
- Results, spurious and otherwise
- Discussion and conclusions
- Acknowledgements, and educational dimensions
T Tauri Stars

- Young stellar objects in various stages of birth, with or without an accretion disc
- Defined spectroscopically: various emission lines; lithium line present
Nature and Cause of their Variability

- **Strict periodicity** (periods 0.5 to several days) due to rotation of a spotted star; the amplitude varies on time scales of years because of starspot cycles.
- **Rapid flickering** due to accretion onto the star.
- **Slow variation** due to variation in the rate of accretion.
- **Possible quasi-periodic variation** due to effects of a companion, or inhomogeneities in the accretion disc.
- **Study of the variability provides information on star formation processes** (e.g. accretion) and properties (e.g. rotation, companion stars, brown dwarfs, or planets).
Herbst Variability Classes

- CTTS: classical T Tauri stars: have accretion discs
- WTTS: weak-lined T Tauri stars: accretion disc is no longer visible
- GTTS: G-type T Tauri stars
- HAEBE: Herbig Ae/Be stars: more massive analogues to T Tauri stars
- FUORs: FU Orionis stars: have long-lasting photometric brightenings
Some Previous Related Studies

- Bill Herbst (Wesleyan University) and his students and other collaborators have amassed long-term CCD photometry of hundreds of T Tauri and related stars, and have used Fourier analysis to study them.

- Percy, Gryc, Wong, and Herbst (2006 PASP 118, 1390) showed that self-correlation analysis is a useful adjunct technique for time-series analysis; Percy, Grynko, and Seneviratne (2009, submitted) have extended this work.

- AAVSO visual observers have measured T Tauri stars for several decades, but the data were only recently validated; Percy and Palaniappan (2006 JAAVSO 35, 290) showed that these data have scientific value.

- AAVSO HQ has now validated visual measurements of more stars.
Source of Data
AAVSO International Database
Visual Observations
Methods of Analysis: Fourier Analysis

*Period04: S CrA, period 6.0 days*
Methods of Analysis: Self-Correlation
www.astro.utoronto.ca/~percy/students.html
S CrA, period 6.0 days
Results: RY Tau

Spurious One-Month and One-Year Periodicity?

27 days
Results: T Cha
Spurious One-Year and One-Month Periodicity?
Results

Rotational Variability: AQ Dra, period 5.1 days
Results
Longer Period than Rotation?
RU Lupi – period 225 days
Results
Longer Period than Rotation?
R CrA Self-Correlation, period 66 days

![R CrA Self-Correlation Graph](image)
Results

Non-Periodic: “Profile” of Variability

Self-correlation diagram for T Cha
<table>
<thead>
<tr>
<th>Star</th>
<th>Sigma</th>
<th>Range</th>
<th>P (d)</th>
<th>Timescales (d)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>SU Aur</td>
<td>0.16</td>
<td>0.25</td>
<td>–</td>
<td>1-800</td>
<td>–</td>
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<tr>
<td>YZ Cep</td>
<td>0.23</td>
<td>0.26</td>
<td>–</td>
<td>1-100</td>
<td>Y</td>
</tr>
<tr>
<td>DI Cep</td>
<td>0.21</td>
<td>0.28</td>
<td>–</td>
<td>1-50</td>
<td>–</td>
</tr>
<tr>
<td>T Cha</td>
<td>0.25</td>
<td>1.5!</td>
<td>3.3</td>
<td>1-20</td>
<td>M, no Y</td>
</tr>
<tr>
<td>T CrA</td>
<td>0.22</td>
<td>0.5:</td>
<td>–</td>
<td>1-1000</td>
<td>M? Y?</td>
</tr>
<tr>
<td>AQ Dra</td>
<td>0.3:</td>
<td>0.5</td>
<td>5.5</td>
<td>1-10</td>
<td>no M or Y</td>
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<tr>
<td>RU Lup</td>
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<td>0.4</td>
<td>230</td>
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<td>Y, M</td>
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<tr>
<td>GQ Lup</td>
<td>0.33</td>
<td>0.55</td>
<td>–</td>
<td>1-100</td>
<td>Y</td>
</tr>
<tr>
<td>HT Lup</td>
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<td>0.23</td>
<td>6.25</td>
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<td>Y</td>
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<tr>
<td>T Ori</td>
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<td>0.6</td>
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<td>1-40</td>
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<tr>
<td>RY Ori</td>
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<td>0.7</td>
<td>–</td>
<td>1-1000</td>
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<tr>
<td>UX Ori</td>
<td>0.30</td>
<td>0.0</td>
<td>200</td>
<td>1-100</td>
<td>no M or Y</td>
</tr>
<tr>
<td>BF Ori</td>
<td>0.28</td>
<td>0.7</td>
<td>6</td>
<td>1-30</td>
<td>Y</td>
</tr>
<tr>
<td>BN Ori</td>
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<tr>
<td>V350 Ori</td>
<td>0.21</td>
<td>0.5</td>
<td>–</td>
<td>1-10, 10-100</td>
<td>Y, no M</td>
</tr>
<tr>
<td>TU Phe</td>
<td>0.10:</td>
<td>0.25</td>
<td>200</td>
<td>– –</td>
<td>–</td>
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<tr>
<td>RZ Psc</td>
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<td>–</td>
<td>1-2000</td>
<td>no M</td>
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<tr>
<td>NX Pup</td>
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<td>0.38:</td>
<td>–</td>
<td>1-70</td>
<td>Y?</td>
</tr>
<tr>
<td>AK Sco</td>
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<td>0.24</td>
<td>–</td>
<td>1-100</td>
<td>Y</td>
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<tr>
<td>V856 Sco</td>
<td>0.15:</td>
<td>0.5</td>
<td>–</td>
<td>1-100</td>
<td>no M or Y</td>
</tr>
<tr>
<td>RR Tau</td>
<td>0.27</td>
<td>0.7</td>
<td>–</td>
<td>1-20</td>
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<tr>
<td>RY Tau</td>
<td>0.22</td>
<td>0.5:</td>
<td>–</td>
<td>1-150</td>
<td>Y</td>
</tr>
</tbody>
</table>
Discussion and Conclusions

- Some stars showed spurious one-year and possibly one-month periods, presumably due to the Ceraski effect.
- Several stars showed periodic behaviour. The shorter periods (<10 days) are presumably rotation periods; the nature of the longer periods is not clear.
- For all stars, the self-correlation diagram shows the “profile” of the variability – the amount of variability on time scales of one to hundreds of days.
- AAVSO visual observations of T Tauri stars have scientific value!
Acknowledgements and Educational Dimensions

- We thank the AAVSO observers and HQ staff, especially Elizabeth Waagen, for making, validating, and archiving the measurements.

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