Stellar Lighthouses: Characterizing and Detecting Non-Astrophysical Sources of Stellar Variability in Time Domain Surveys

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John Templeton Foundation: New Frontiers in Astronomy and Cosmology
The Idea:

**ET may Signal by Perturbing a Variable Star**

A neutrino beam is a good way to perturb the marginally unstable core of a variable star -- but may not be the most efficient choice overall.
These cartoons convey the basic idea of tapping the radiant output of a star to send a message, thus solving the problem of producing a hugely powerful signal.
The Kepler Data:
168,418 Quarter 14 light curves

Carry out Automated Time Series Analysis:

Bayesian Blocks (time domain)

Fourier Transform Power Spectrum
(based on Edelson and Krolik ACF)

Other Statistical Measures
Data Mode

- Photon events
- Time-to-Spill
- Counts in bins
- Flux measurements
- Any Mode/Sampling!

Universal Time Series Analysis Machine

Cross-

- Correlation Function
- Fourier Power Spectrum
- Fourier Phase Spectrum
- Wavelet scalgram
- Wavelet scaleogram
- Structure Function
- Time-Frequency Distribution
- Time-Scale Distribution
- ...

Jeff Scargle

Extension of Edelson & Krolik Algorithm for Correlation Function of Unevenly Sampled Data
<table>
<thead>
<tr>
<th>Function</th>
<th>Domain</th>
<th>Range</th>
<th>Auto-</th>
<th>Cross-</th>
<th>Physical Interp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayesian blk. Light Curve</td>
<td>Time</td>
<td>Flux</td>
<td>☑</td>
<td>☑</td>
<td>Flares, events etc.</td>
</tr>
<tr>
<td>Scatter Plot</td>
<td>Flux 1</td>
<td>Flux 2</td>
<td></td>
<td>☑</td>
<td>Dependency (not just cor.)</td>
</tr>
<tr>
<td>Correlation</td>
<td>Lag</td>
<td>&lt;X^2&gt;, &lt;XY&gt;</td>
<td>☑</td>
<td></td>
<td>Correlated behavior/lags</td>
</tr>
<tr>
<td>Spectrum</td>
<td>Frequency</td>
<td>Power</td>
<td>☑</td>
<td>☑</td>
<td>Periodicity 1/f noise ...</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td></td>
<td>☑</td>
<td></td>
<td>Shifts, lags</td>
</tr>
<tr>
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<td>Lag</td>
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<td>Scalogram</td>
<td>Scale/Time</td>
<td>Power</td>
<td>☑</td>
<td></td>
<td>Dynamic behavior</td>
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<td>Power</td>
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<td>1/f noise QPOs</td>
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The Analysis:

(A) Bayesian Blocks
(B) Power Spectrum
  • Linear Detrend
  • Interpolation to Even Spacing
  • Fourier Transform

Derived Parameters:

1. Slope of 1/f component of spectrum (B)
2. Number of change points (A)
3. Peak frequency (B)
4. Number of peaks (A)
5. Average period (intervals between peaks) (A)
6. Standard deviation of (5) (A)
7. Total variation (A)
8. \( \frac{dF}{dt} \) (A)
9. \( \max(\text{Flux}) \) / \( \min(\text{Flux}) \)
10. Peak amplitude / Continuum amplitude (B)
Blind automated analysis means that one has to look at a few selected results -- as a reality check. Here is a non-variable case.
Blind automated analysis means that one has to look at a few selected results -- as a reality check. Here is a periodic case.
Interesting variability!

Monday, November 11, 2013
From the distribution of derived parameters one can select regular periodic variables as good star tickling candidates. This is a delta Scuti star.
Time Series Analysis in
The Age of Digital Astronomy

Catalina Transient Survey

Panoramic Survey Telescope & Rapid Response System

Sloan Digital Sky Survey

Palomar Transient Factory

Large Scale Synoptic Survey

LSST

BigBOSS: Baryon Acoustic Oscillation Experiment

Dark Energy Survey