Simultaneous Weak Events

a new temporal analysis project

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grating dispersed events
Flares on HD 189733 that seem to be tied to planetary phase

Pillitteri et al. 2012, Cool Stars 17
Procyon: is there any variability?
Limitations in current analyses

• Likelihoods are constructed with no regard to data order

  • ignoring auto-regression and ICA/SCA

  • fluctuations in consecutive bins, or groups of like fluctuations require human intervention via residual analysis
Limitations in current analyses

- Likelihoods are constructed with no regard to data order
  - ignoring auto-regression and ICA/SCA
  - fluctuations in consecutive bins, or groups of like fluctuations require human intervention via residual analysis
- Coincidences cannot be evaluated non-parametrically in multiple data streams
  - we are more likely to believe that something is real if a signal is seen simultaneously in independent data streams
Simulation

• Generate 500 draws from $\mathcal{N}(0,1)$

• Find all fluctuations at >1, 1.5, 2, 2.5, 3 sigma

• Repeat 100 times

• During each repetition, check how often a similar fluctuation is coincident with original fluctuation

• Compute average frequency of coincidence

• Repeat 100 times

• Compare coincidence frequency with nominal probability of seeing coadded fluctuations of same sizes
Type I Error: 
Fraction of fluctuations that exceed $k\sigma$

<table>
<thead>
<tr>
<th>$k$</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mathcal{N}(\cdot)$</td>
<td>0.16</td>
<td>0.067</td>
<td>0.022</td>
<td>0.006</td>
<td>0.0013</td>
</tr>
<tr>
<td>$&lt;\mathcal{N}(\cdot)\mid \mathcal{N}(\cdot)&gt;$</td>
<td>0.025</td>
<td>0.0045</td>
<td>0.0005</td>
<td>0.0004</td>
<td>$8 \times 10^{-7}$</td>
</tr>
<tr>
<td>$\mathcal{N}(\cdot)+\mathcal{N}(\cdot)$</td>
<td>0.078</td>
<td>0.017</td>
<td>0.002</td>
<td>0.00015</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>$\mathcal{N}(\cdot)^2$</td>
<td>0.025</td>
<td>0.0045</td>
<td>0.0005</td>
<td>0.0005</td>
<td>$4 \times 10^{-6}$</td>
</tr>
</tbody>
</table>
Procyon: is there any variability?
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Not the first time someone has tried to figure this out.

Stetson & Welch 1993
Lehner et al. 2010
• variability index for two simultaneous streams
• first compute variance-weighted means
• then compute $\delta \chi$ for each stream
• compute variability index as sum of $\delta \chi^{(1)} \times \delta \chi^{(2)}$
Lehner et al. 2010, PASP 122, 959

• Not the first time someone has tried to figure this out.
• Lehner et al. constructed a rank-ordered p-value statistic to find occultation events.
• \( p(Z > z_j = -\ln\left(\prod_{i=1}^{T} r_{ij} / N_{pT}\right) \) 
• Optimized for occultation events with no large time-scale trends in the intensities
• Requires that statistical noise is not large
Type I is (relatively) easy; Type II is not.

Still can't deal with grouped fluctuations.

Want to detect weak events in streams dominated by background and statistical noise.