“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”

Lauri Jetsu
Department of Physics, University of Helsinki,
lauri.jetsu@helsinki.fi

www-link to this publication
Jetsu & Porceddu, 2016, PLOS ONE 10(12), e0144140
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0144140
Appendix: Main result summarized
What confirmed?
*ApJ* 2013 (20m)

How confirmed?
PLOS ONE 2015 (25m)

Data

- Papyrus Cairo 86637 is the best preserved Calendar of Lucky and Unlucky days
- **cc** = “Cairo Calendar”
- Approximate date 1244 – 1163 B.C.
- Partly damaged – Some days lost – Ants etc ...
- Word *’Horus’* inside superimposed black rectangle
• 'Horus': Egyptian Falcon-god, “lord of the sky”, symbol of divine kingship, “the high”, “the far-off”, “the distant one”

• **Prognosis for 3 parts** of each day

• Prognosis was lucky or unlucky

• Notation (Leitz 1994):
  - $G$ = Gut = Good
  - $S$ = Schlecht = Bad
  - “–” = Damaged = No prognosis

• **Descriptive text** for each day

• Egyptian year had 365 days

• 12 months (M)

• Every month = 30 days (D)

• Year = 3 seasons

• Every season = 4 months: Akhet (Flood), Peret (Winter) and Shemu (Harvest)

• 5 additional epagomenal days

• I Akhet 25 had “GGS”: 1st and 2nd parts of this day were good, but 3rd part was bad

• Next page: all CC prognoses
<table>
<thead>
<tr>
<th>Akhet I</th>
<th>Akhet II</th>
<th>Akhet III</th>
<th>Akhet IV</th>
<th>Peret I</th>
<th>Peret II</th>
<th>Peret III</th>
<th>Peret IV</th>
<th>Shemu I</th>
<th>Shemu II</th>
<th>Shemu III</th>
<th>Shemu IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>M = 1</td>
<td>M = 2</td>
<td>M = 3</td>
<td>M = 4</td>
<td>M = 5</td>
<td>M = 6</td>
<td>M = 7</td>
<td>M = 8</td>
<td>M = 9</td>
<td>M = 10</td>
<td>M = 11</td>
</tr>
<tr>
<td>1</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
</tr>
<tr>
<td>2</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
</tr>
<tr>
<td>3</td>
<td>GGS</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>SSS</td>
<td>GGG</td>
</tr>
<tr>
<td>4</td>
<td>GGS</td>
<td>SGS</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
</tr>
<tr>
<td>5</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>6</td>
<td>SSG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>7</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>8</td>
<td>GGS</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>9</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
</tr>
<tr>
<td>10</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>11</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>12</td>
<td>SSS</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>13</td>
<td>GSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>15</td>
<td>GSS</td>
<td>GSS</td>
<td>SSS</td>
<td>—</td>
<td>GGG</td>
<td>—</td>
<td>SSS</td>
<td>GGG</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>16</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>17</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GSS</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
</tr>
<tr>
<td>18</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>19</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>20</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>21</td>
<td>GGG</td>
<td>SSG</td>
<td>GGG</td>
<td>SSG</td>
<td>GGG</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>22</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>23</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>GGS</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>24</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
</tr>
<tr>
<td>25</td>
<td>GGS</td>
<td>SSS</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>SSS</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
</tr>
<tr>
<td>26</td>
<td>SSS</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>—</td>
<td>GG</td>
<td>SSS</td>
<td>GGG</td>
</tr>
<tr>
<td>27</td>
<td>GGG</td>
<td>SGG</td>
<td>GGG</td>
<td>—</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>—</td>
<td>SSS</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>28</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>—</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
</tr>
<tr>
<td>29</td>
<td>SGG</td>
<td>GGG</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>SSS</td>
</tr>
<tr>
<td>30</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>GGG</td>
<td>—</td>
<td>GGG</td>
<td>SSS</td>
<td>GGG</td>
</tr>
</tbody>
</table>
Creating data: Time points \( t_1, t_2, \ldots, t_n \)
- Gregorian days: Seasons ⇒ Day & night length
  
  \[ N_G = \begin{cases} 
  N_E + N_0 - 1, & N_E \leq 366 - N_0 \\
  N_E + N_0 - 366, & N_E > 366 - N_0, 
  \end{cases} \]
- "Egyptian days": \( N_E = 30(M - 1) + D \)
- Day length? Declination of the Sun
  \[ \delta_\odot(N_G) \approx -23.45^\circ \cos \left[ 360^\circ (N_G + 10) / (365.25) \right] \]
- Daytime [h] at Middle Egypt (\( \phi = 26^\circ 41' \))
  \[ l_D(N_G) = (24/180^\circ) \left\{ \arccos \left[ \frac{\sec(\phi)}{\tan(\delta_\odot(N_G))} \right] \right\} \]
- Three prognoses within days: 1st alternative
  \[ t_1(N_E) = (N_E - 1) + (1/6)[l_D(N_G)/24] \]
  \[ t_2(N_E) = (N_E - 1) + (3/6)[l_D(N_G)/24] \]
  \[ t_3(N_E) = (N_E - 1) + (5/6)[l_D(N_G)/24] \]
- Three prognoses within days: 2nd alternative
  \[ t_1(N_E) = (N_E - 1) + (1/4)[l_D(N_G)/24] \]
  \[ t_2(N_E) = (N_E - 1) + (3/4)[l_D(N_G)/24] \]
  \[ t_3(N_E) = (N_E - 1) + 1/2 + (1/2)[l_D(N_G)/24] \]
- Alternatives: Analyse G and S separately
- Alternatives: Remove G at \( D = 1 \) and S at \( D = 20 \)
- Aim: Show that results do not depend ...

24 different SSTP
- Samples of Series of Time Points

<table>
<thead>
<tr>
<th>SSTP</th>
<th>( N_0 )</th>
<th>Div</th>
<th>X</th>
<th>Remove</th>
<th>( n )</th>
<th>( \Delta T )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>(a)</td>
<td>G</td>
<td>none</td>
<td>564</td>
<td>359.3</td>
</tr>
<tr>
<td>2</td>
<td>62</td>
<td>(a)</td>
<td>G</td>
<td>( D = 1 )</td>
<td>528</td>
<td>358.3</td>
</tr>
<tr>
<td>3</td>
<td>187</td>
<td>(a)</td>
<td>G</td>
<td>none</td>
<td>564</td>
<td>359.4</td>
</tr>
<tr>
<td>4</td>
<td>187</td>
<td>(a)</td>
<td>G</td>
<td>( D = 1 )</td>
<td>528</td>
<td>358.4</td>
</tr>
<tr>
<td>5</td>
<td>307</td>
<td>(a)</td>
<td>G</td>
<td>none</td>
<td>564</td>
<td>359.3</td>
</tr>
<tr>
<td>6</td>
<td>307</td>
<td>(a)</td>
<td>G</td>
<td>( D = 1 )</td>
<td>528</td>
<td>358.3</td>
</tr>
<tr>
<td>7</td>
<td>62</td>
<td>(b)</td>
<td>G</td>
<td>none</td>
<td>564</td>
<td>359.6</td>
</tr>
<tr>
<td>8</td>
<td>62</td>
<td>(b)</td>
<td>G</td>
<td>( D = 1 )</td>
<td>528</td>
<td>358.6</td>
</tr>
<tr>
<td>9</td>
<td>187</td>
<td>(b)</td>
<td>G</td>
<td>none</td>
<td>564</td>
<td>359.6</td>
</tr>
<tr>
<td>10</td>
<td>187</td>
<td>(b)</td>
<td>G</td>
<td>( D = 1 )</td>
<td>528</td>
<td>358.6</td>
</tr>
<tr>
<td>11</td>
<td>307</td>
<td>(b)</td>
<td>G</td>
<td>none</td>
<td>564</td>
<td>359.6</td>
</tr>
<tr>
<td>12</td>
<td>307</td>
<td>(b)</td>
<td>G</td>
<td>( D = 1 )</td>
<td>528</td>
<td>358.6</td>
</tr>
<tr>
<td>13</td>
<td>62</td>
<td>(a)</td>
<td>S</td>
<td>none</td>
<td>351</td>
<td>354.0</td>
</tr>
<tr>
<td>14</td>
<td>62</td>
<td>(a)</td>
<td>S</td>
<td>( D = 20 )</td>
<td>321</td>
<td>354.0</td>
</tr>
<tr>
<td>15</td>
<td>187</td>
<td>(a)</td>
<td>S</td>
<td>none</td>
<td>351</td>
<td>354.0</td>
</tr>
<tr>
<td>16</td>
<td>187</td>
<td>(a)</td>
<td>S</td>
<td>( D = 20 )</td>
<td>321</td>
<td>354.0</td>
</tr>
<tr>
<td>17</td>
<td>307</td>
<td>(a)</td>
<td>S</td>
<td>none</td>
<td>351</td>
<td>354.0</td>
</tr>
<tr>
<td>18</td>
<td>307</td>
<td>(a)</td>
<td>S</td>
<td>( D = 20 )</td>
<td>321</td>
<td>354.0</td>
</tr>
<tr>
<td>19</td>
<td>62</td>
<td>(b)</td>
<td>S</td>
<td>none</td>
<td>351</td>
<td>354.0</td>
</tr>
<tr>
<td>20</td>
<td>62</td>
<td>(b)</td>
<td>S</td>
<td>( D = 20 )</td>
<td>321</td>
<td>354.0</td>
</tr>
<tr>
<td>21</td>
<td>187</td>
<td>(b)</td>
<td>S</td>
<td>none</td>
<td>351</td>
<td>354.0</td>
</tr>
<tr>
<td>22</td>
<td>187</td>
<td>(b)</td>
<td>S</td>
<td>( D = 20 )</td>
<td>321</td>
<td>354.0</td>
</tr>
<tr>
<td>23</td>
<td>307</td>
<td>(b)</td>
<td>S</td>
<td>none</td>
<td>351</td>
<td>354.0</td>
</tr>
<tr>
<td>24</td>
<td>307</td>
<td>(b)</td>
<td>S</td>
<td>( D = 20 )</td>
<td>321</td>
<td>354.0</td>
</tr>
</tbody>
</table>

Lauri Jetsu Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

"Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed"
“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
Rayleigh test

- **Period range**: \( P_{\text{min}} = 1.45 < P < P_{\text{max}} = 90^d \)
- **Phases**: \( \phi_i = \text{FRAC}[(t_i - t_0)f] \)
  FRAC\([x]\) removes integer part of \( x \)
- **Frequency** \( f = P^{-1} \), **Epoch** \( t_0 \) (arbitrary)
- **Phase angles** \( \theta_i = 2\pi \phi_i \), **Unit vectors** \( r_i = [\cos \theta_i, \sin \theta_i] \), **Sum vector** \( R = \sum_{i=1}^n r_i \)
- **Rayleigh test statistic**: \( z(f) = |R|^2/n \)
- **Null hypothesis**: \( H_0: \text{"Phases } \phi_i \text{ calculated with an arbitrary tested } P \text{ have a random distribution between 0 and 1."} \)
  - Random directions \( \theta_i \Rightarrow |R| \approx 0 \)
  - Perfect periodicity \( \theta_i \) coincide
  \( \Rightarrow |R| = n \Rightarrow \text{Reject } H_0 \)
- **Probability density function**: \( z = z(f) = e^{-z} \Rightarrow P(z \leq z_0) = F(z_0) = 1 - e^{-z_0} \)
- **Independent statistical tests**
  \( m = \text{INT}[(f_{\text{max}} - f_{\text{min}})/f_0] \)
  INT\([x]\) removes decimal part of \( x \)
  \( f_0 = 1/\Delta T \) distance between independent \( f \)

- **Standard critical level**
  \( Q_z = Q(z_0) = P(z(f) > z_0) = 1 - (1 - e^{-z_0})^m \)
  Probability that \( z(f) \) exceeds a fixed \( z_0 \) level in \( m \) independent statistical tests
- **Standard \( H_0 \) rejection criterion**
  \( Q_z < \gamma = 0.001 \)
  \( \gamma \) is preassigned significance level
- **Are standard \( Q_z \) estimates reliable for CC data?**
  \( \Rightarrow \text{Simulating similar data as in CC} \)
- **Different daily prognosis combinations in CC**

<table>
<thead>
<tr>
<th>Prognosis combination</th>
<th>SSTP=1, 3, ..., 35 Days</th>
<th>SSTP=2, 4, ..., 36 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>G</td>
<td>S</td>
</tr>
<tr>
<td>GGG</td>
<td>177</td>
<td>531</td>
</tr>
<tr>
<td>GGS</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>GSG</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>GSS</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>SSS</td>
<td>105</td>
<td>0</td>
</tr>
<tr>
<td>SSG</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>SGG</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>SGS</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>305</td>
<td>564</td>
</tr>
<tr>
<td>“—”</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>360</td>
<td>564</td>
</tr>
</tbody>
</table>
SSTP=1: GGG, D = 1: Yes

- (a) $z(f)$ periodogram
  \[ P_1 = 29.4 \ (Q_z = 0.0000034) \]
  \[ P_2 = 2.850 \ (Q_z = 0.0012) \]

- (b) Noise periodogram $z^*(f)$
  - **Median** level should be
    \[ z_0 = 0.693 \equiv Q_z = 0.5 \]
  - Peaks of $z^*(f)$ at integer $k \geq 4$
    \[ f = f(\Delta T, k) = [P(\Delta T, k)]^{-1} \]
    \[ \equiv P(\Delta T, k) = \Delta T / (k + 1/2) \]
  - **Unreliable** $Q_z$ estimates

- (c) Normalized periodogram $z_N(f) = z(f)/z^*(f)$
  - Simulated critical levels
    \[ Q_z^* < \gamma = 0.001 \Rightarrow \text{Reject } H_0 \]
    \[ P_1 = 29.6 \ (Q_z^* = 0.000012 > Q_z) \]
    \[ P_2 = 2.850 \ (Q_z^* = 0.00014 < Q_z) \]
  - Shift of 29.4 to 29.6
  - Unreal periods
    \[ P_3 = 1.5401 \ (Q_z^* = 0.00091) \]
    \[ P_4 = 7.48 \ (Q_z^* = 0.00091) \]

SSTP=3, 5, 7, 9, 11: Same results!
SSTP=2  GGG, D = 1: No

- GGG at D = 1 removed

- (a) Highest $z(f)$ peaks at $P_1 = 2.d85$ and $P_2 = 64.d8$
- Peaks at $P_1 = 29.d6$ (Moon) and $P_2 = 7.d48$ (Unreal) vanished

- (b) Many new peaks in noise periodogram $z^*(f) \Rightarrow Q_z$ estimates certainly unreliable

- (c) Normalized periodogram $z_N(f) = z(f)/z^*(f)$
- Simulated critical levels $Q_z^* < \gamma = 0.001 \Rightarrow$ Reject $H_0$
  $P_1 = 2.d85$ ($Q_z^* = 0.000094$)
  $P_2 = 1.d54$ ($Q_z^* = 0.00059$)
- Peak at 64.d8 replaced by 1.d54
- Unreal period 1.d54 caused by $P_0 = 1.d0$ window and 2.d85
- GGG at D = 1 removed $\Rightarrow$ 2.d85 significance increased $Q_z^* = 0.00014 \rightarrow 0.000094$

SSTP=2, 6, 8, 10, 12: Same results!

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

"Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed"
Period analysis results

- Many peaks in \( z(f) \)

(a) Normalized \( z_n(f) \)

\[ \Rightarrow \text{Many peaks vanished} \]

\[ \Rightarrow \text{Reliable statistics} (Q^*_z) \]

- Best periods in \( G \)

29.6 days = The Moon
2.85 days = Algol?

- Unreal periods in \( G \)

7.48 and 1.54 days

(b) Remove \( GGG \) at \( D = 1 \)

29.6 and 7.48 days vanish
2.85 and 1.54 days remain
1.54 days unreal
only real period is 2.85 days

- Results for \( G \) do not depend on
  - Placing of seasons
  - Chosen day division
  - Removing/Not removing some days

- No significant periodicity in \( S \) prognoses
Astrophysics

- No period increase in over 200 years, minor irregular alternating changes (seconds)
- "Law": Heavier stars evolve faster
- **Algol paradox**
  Algol B (0.8 $M_\odot$): Subgiant (K2 IV)
  Algol A (3.7 $M_\odot$): Main sequence (B8 V)
- **Roche lobe**: "Region around a star in a binary system within which orbiting material is gravitationally bound to that star"
- Outside Roche lobe: material can escape
- **Formation**: Algol B ($m_B = 2.81M_\odot$) more massive than Algol A ($m_A = 2.50M_\odot$)
- Algol B evolved to a giant ⇒ Filled its Roche lobe ⇒ **Mass Transfer (MT)** to Algol A ⇒ Algol A became more massive ⇒ **Now**: $m_A = 3.7M_\odot$ ja $m_B = 0.8M_\odot$
- MT from less to more massive companion should increase $P_{\text{orb}}$ (Kwee 1958)
  \[
  \dot{P}_{\text{orb}} / P_{\text{orb}} = - \left[ 3 \dot{m}_B (m_A - m_B) \right] / (m_A m_B)
  \]
- $\dot{P}_{\text{orb}} = \text{Rate of } P_{\text{orb}} \text{ change}$
- $m_A$ and $m_B = \text{Masses of gainer and loser}$
- $\dot{m}_B = \text{MT rate}$
- **Test**: $P_{\text{orb}}$ was $2.850$ in 1224 B.C and has increased to $2.867328$ today ⇒ constant $\dot{P}_{\text{orb}}$ gives $\dot{m}_B = -2.2 \times 10^{-7}M_\odot$ per year.
- "Best fitting" evolutionary model (Sarna 1993) predicted $\dot{m}_B = -2.9 \times 10^{-7}M_\odot$
- **Conclusion**: MT would explain a 0.017 days period increase in three millennia
- Numerous other MT estimates between $10^{-13}M_\odot$ and $10^{-7}M_\odot$
- Long quiescent periods with weak MT ⇒ Short MT bursts ⇒ Explains low observed MT values ⇒ Our MT estimate = Long-term MT burst average
Eclipses in Ancient Egypt?

- Pigott (1805): Algol’s brightness must have been constant in Antiquity
- Kopal (1946): Ancient discoveries buried in the ashes of the Library of Alexandria
- Algol is a triple system
- Third companion Algol C perturbs Algol A–B system orbital plane ⇒ $i_1$ changes ⇒ Eclipses may not always occur
- $\Psi = 95^\circ \pm 3^\circ$ (Csizmadia et al. 2009) ⇒ $P_{i_1} = 25,000$ years
- $\Psi = 86^\circ \pm 5^\circ$ (Zavala et al. 2010) ⇒ $P_{i_1} = 31,000$ years
- Lower $P_{i_1}$ limits were 14,000 and 16,000 years ⇒ Eclipses: Yes or No in Ancient Egypt?

- After submitting our paper: $\Psi = 90.0^\circ 2 \pm 0.32$ (Baron et al. 2012) ⇒ Eclipses in Ancient Egypt similar to those observed now ⇒ We predicted this!

<table>
<thead>
<tr>
<th>Orbital elements A–B system</th>
<th>Orbital elements AB–C system</th>
<th>Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1 = 2.3 \pm 0.1$</td>
<td>$a_2 = 93.8 \pm 0.2$</td>
<td>$m_A = 3.7 \pm 0.2$</td>
</tr>
<tr>
<td>$i_1 = 98.6$</td>
<td>$i_2 = 83.7 \pm 0.1$</td>
<td>$m_B = 0.8 \pm 0.1$</td>
</tr>
<tr>
<td>$\Omega_1 = 7.4 \pm 5.2$</td>
<td>$\Omega_2 = 132.7 \pm 0.1$</td>
<td>$m_C = 1.5 \pm 0.1$</td>
</tr>
<tr>
<td>$e_1 = 0$</td>
<td>$e_2 = 0.225 \pm 0.005$</td>
<td></td>
</tr>
<tr>
<td>$P_1 = 2.867328$</td>
<td>$P_2 = 679.85 \pm 0.04$</td>
<td></td>
</tr>
</tbody>
</table>

$[a_1] = [a_2] = " /1000,$
$[i_1] = [i_2] = [\Omega_1] = [\Omega_2] = 0,$
$[e_1] = [e_2] = $dimensionless
$[P_1] = [P_2] = d$
$[m_A] = [m_B] = [m_C] = M_⊙$

- Period of $i_1$ changes (Soderhjelm 1975)

$$P_{i_1} = \frac{4 [1 + (m_A + m_B)/m_C] (P_2^2/P_1)(1 - e_2^2)^{3/2}}{3 [(G_1/G_2)^2 + 2(G_1/G_2) \cos \Psi + 1]^{1/2} \cos \Psi},$$

where $G_1 = m_1 [Ga_1(1 - e_1)^2(m_A + m_B)]^{1/2}$,

$m_1 = (m_A m_B) /

(m_A + m_B)$,

$G_2 = m_2 [Ga_2(1 - e_2)^2(m_A + m_B + m_C)]^{1/2}$,

$m_2 = [(m_A + m_B)m_C] / (m_A + m_B + m_C), G = gravitational constant$

- Angle between orbital planes of A–B and AB–C systems

$$\cos \Psi = \cos i_1 \cos i_2 + \sin i_1 \sin i_2 \cos (\Omega_1 - \Omega_2)$$

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
Modern history of variable stars

- **1596**: Fabricius (1564–1617) discovered 1st periodic variable star: *Mira*

- **1638**: Holwarda (1618–1651) ⇒ *Mira* disappears and reappears in 11 months
- *Mira* expands and contracts ⇒ Variability

- **1667**: Montanari (1633–1687) discovered 2nd periodic variable star *Algol* (β Per)
- Montanari did not notice *Algol*’s periodicity
- *Algol* is an eclipsing binary ⇒ Variability

- **1783**: Goodricke (1764–1786) discovered *Algol*’s 2.867 days period with naked eyes
- Amateur astronomer: deaf, mute and died at the age of 21 years, received Copleyn Medal (Royal Society of London) for his outstanding discovery

- Eclipsing binary: Two stars orbit same centre of mass, orbital plane nearly coincides with line sight ⇒ Eclipses
- Correct hypothesis: eclipse or spots
• Algol B larger than Algol A
• Algol B dimmer than Algol A
• Two eclipses: = Two minima
  Primary (Naked eye),
  Secondary (Not naked eye)

• How did Goodricke determine periodicity?

• Naked eye: Algol bright, except for 10h primary eclipses
• Naked eye: Detects 0.1 m differences of close-by stars
• Ideal comparison star: Variable becomes at least 0.1 m brighter and at least 0.1 m dimmer ⇒ Algol has six!

<table>
<thead>
<tr>
<th>Algol</th>
<th>2.1</th>
<th>1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star</td>
<td>m</td>
<td>Δm</td>
</tr>
<tr>
<td>Goes below</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stays below</td>
<td></td>
<td></td>
</tr>
<tr>
<td>α Per</td>
<td>1.8</td>
<td>–</td>
</tr>
<tr>
<td>γ And</td>
<td>2.3</td>
<td>–</td>
</tr>
<tr>
<td>ζ Per</td>
<td>2.8</td>
<td>–</td>
</tr>
<tr>
<td>ε Per</td>
<td>2.9</td>
<td>0.1</td>
</tr>
<tr>
<td>γ Per</td>
<td>2.9</td>
<td>–</td>
</tr>
<tr>
<td>β Tri</td>
<td>3.0</td>
<td>–</td>
</tr>
<tr>
<td>δ Per</td>
<td>3.0</td>
<td>–</td>
</tr>
</tbody>
</table>

• Goodricke made notes ⇒ Determined mid eclipse epochs ⇒ These occured at multiples of 2.867 days

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
Naked eye astronomy

- **Problem:** What could Ancient Egyptians observe with **naked eyes** that follows a periodicity between 1.5 and 90 days?

- **Candidates:** the Sun, the Moon, Planets, Stars

- the Sun or Planets have $P > 90$ days ⇒ **No!**

- the Moon has $P = 29.6$ ⇒ **Yes, it is in CC!**

- Some variable stars ⇒ **Which ones?**

- **Problem:** Which ones of all known 40 000 variable stars could be found in CC?

- **Solution:** Apply eight selection criteria

  - **Naked eye:** Limit magnitude $6^m$
  
  - **Naked eye:** Limit magnitude difference $0.0^m$

  - $C_1$: **Variability fulfils** $m_{\text{max}} \leq 4.0$ and $\Delta m \geq 0.4$ ⇒ 109 candidates

  - $C_2$: **Period known and fulfils** $1.5^d \leq P \leq 90^d$ ⇒ 13 candidates

  - $C_3$: **Variable was not below, or too close to horizon** ⇒ 10 candidates

  - $C_4$: **Variability could be predicted** ⇒ 7 candidates

    - 4 **cepheids:** ζ Gem, I Car, η Aql and δ Cep
    
    - 3 **eclipsing binaries:** Algol, λ Tau and β Lyr

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol's Period Confirmed”
Same magnitude scale:

Algol brightest

$\text{Algol}$ has largest amplitude

$\Delta m = 1.27$
$C_5$: Variability can be detected during a single night

- (a–g) 12 hours long nights $\Rightarrow$ Vertical lines show nightly variability
- $\zeta$ Gem and 1 Car - Eliminated?
- $\beta$ Lyr, $\eta$ Aql and $\delta$ Cep - Mostly constant
- Algol and $\lambda$ Tau - Largest variability
- (h) Same scale

Algol’s 10 hours eclipse $\Rightarrow$ Observable during a single night
$\lambda$ Tau’s 14 hours eclipse $\Rightarrow$ Never observable during a single night
If not in a single night ⇒ Then during several nights?
Observations recorded
(Mira)

\[ C_6: \text{ Variability changes the constellation pattern} \]

- All close objects
- Brighter stars: \( \star, \bullet \)
- Comparison stars: \( \star, \bullet \)
- Other variable stars
- Altitude \( \equiv \) Extinction
- Light curve period
- Last candidates: Algol, \( \lambda \) Tau, perhaps \( \beta \) Lyr
- \( C_1, \ldots, C_6 \) true ⇒ Variability discovered ⇒ Problem: Period still unknown!
Period of variability could be discovered by Ancient Egyptians

- We assumed $0.1^m$ accuracy (Hipparcos, 190-125 B.C: accuracy $1.0^m$, Ptolemy, 100-125 A.D: accuracy $0.4^m - 1.0^m$)

- **Differential photometry** with suitable comparison stars $\Rightarrow$ **Time series** of irregularly spaced data $m(t_1), m(t_2), ... \Rightarrow$ Cartesian coordinate system or Modern time series analysis $\Rightarrow$

  Discovery of $\zeta$ Gem, 1 Car, $\eta$ Aql, $\delta$ Cep or $\beta$ Lyr periods $\Rightarrow$ **Impossible!**

- Recording eclipse epochs $\Rightarrow$ **Series of time points** $t_1, t_2, ... \Rightarrow$ Multiples of some number $P \Rightarrow$ Discovery of $\lambda$ Tau and Algol periods $\Rightarrow$ **Possible!**

History of modern astronomy: Variability and periodicity was discovered first

- **Algol** $\Rightarrow$ 2nd, Montanari, 1669; Goodricke 1783
- **$\lambda$ Tau** $\Rightarrow$ 18th, Baxendell, 1848

- $C_7 - C_8 \Rightarrow$ Algol best candidate

- **Detective story**: Elimination of 40 000 suspects (variable stars) completed!

- Only Algol and the Moon detected in CC

Main results in 2013

1. **First variable** star was discovered three millennia before Fabricius (1596) discovered Mira
2. Period of variable star was **first** discovered three millennia before Goodricke (1783) discovered Algol’s period
3. CC is **probably** oldest preserved historical document of these discoveries
4. Algol’s period was **2.850** d in 1224 B.C.
5. Period has **increased** to **2.867** d
6. Increase **observed for the first time**, 230 years after discovery
7. Increase gives an MT rate estimate
8. Eclipses observed in Ancient Egypt $\Leftrightarrow$ Algol A–B and Algol AB–C orbital planes nearly perpendicular $\Rightarrow$ Prediction confirmed later
9. Algol in CC for **religious reasons**
10. “The Raging One” in CC $\Rightarrow$ Algol?
Research after 2013

“Professor Bordwell illustrates his views on visual storytelling (Algol)”
@www.davidbordwell.net

- **Claim**: Ancient Egyptian religious texts contain astrophysical information about an eclipsing binary
- **Similar claim**: “The Bible contains information that there is no life in Mars”
- Periods discovered only in G prognoses, but to which words or phenomena are they connected?
- Is possible to identify Algol in mythological texts describing CC prognoses
- **Problem**: References to Algol or the Moon indirect and presented through myths

- Some G prognoses periodic *(signal)* and some aperiodic *(noise)* ⇒ Separate signal from noise?
- Which G time points cause this signal?
- Which words describing these G time points connected to Algol

**Solution**
- Determine the phase of periodic signal
- Test many words
- Which words have correct phase?
Selected words ‘SWs’

- **Self evident:** We can not analyse All words in CC
- **Selection criterion:** Deities, nouns and locations with significant mythological properties and multiple occurrences in CC text \( n \geq 3 \)
- **Two stages:** Identification of SW dates and Transformation of SW dates into series of time points

Identification

- Compound words rejected (e.g. “House of Horus”): Which one or both?
- Composite deities rejected (e.g. “Ra-Horakhti”): Which one or both?
- Heterogenous prognoses rejected (e.g. “SSG” at D=6 and M=1): Good or bad SW prognosis?
- Unknown (damaged) prognoses rejected (e.g. “---” at D=17 and M=3): Good or bad SW prognosis?

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
Two earlier CC translations: Bakir (1966: English) and Leitz (1994: German) ⇒ Compared our 460 SWs identifications to those ⇒ Bakir (439 x “Yes”, 21 x “No”, e.g. 12 x ‘Heart’) and Leitz (460 x “Yes”, 0 x “No”)
Citing any CC prognosis text: We always use Bakir’s English text ⇒ Not translating and/or explaining CC prognosis Ancient Egyptian texts or translated German texts for our own purposes

\[ n_G = \text{Number of GGG dates in CC containing some particular SW} \]
\[ n_S = \text{Number of SSS dates in CC containing some particular SW} \]
\[ N_G = 177 = \text{Number of all days in CC with GGG prognosis} \]
\[ N_S = 105 = \text{Number of all days in CC with SSS prognosis} \]

Transformation

Three time points a day in earlier analysis (Jetsu et al. 2013: Eqs 2 and 3)
\[ t_i = N_E - 1 + a_i \]
\[ N_E = 30(M - 1) + D = \text{“Egyptian day”} \]
\[ a_i = 3 \text{ decimal parts a day (3 season alternatives, 2 day division alternatives)} \]
Algol and the Moon discovered in SSTP=1, 3, 5, 7, 9, 11
⇒ Mean of \( a_i \) all these samples \((n = 6 \times 564 = 3384)\) is \( m_t = 0.33 \)
⇒ Suitable time point for an SW
\[ t_i = t_i(D, M) = N_E - 1 + m_t \]
Time points of old study “synchronized” with time points of new study
⇒ “Synchronized” phases for old and new time points connected to the
\[ P_{\text{Algol}} = 2.4^{85} \text{ and } P_{\text{Moon}} = 29.4^{6} \text{ signals} \]
Method

- **Period:** \( P \)
- **Phases:** \( \phi_i = \text{FRAC}[(t_i - t_0)/P] \)
- **Phase angles:** \( \Theta_i = 360^\circ \phi_i \)
- **Unit vectors:** \( r_i = [\cos \Theta_i, \sin \Theta_i] \)
- **Sum vector:** \( R = \sum_{i=1}^{n} r_i \)
- **Rayleigh test statistic:** \( z = |R|^2/n \)
- **Critical level:** \( Q_z = 1 - (1 - e^{-z})^m \)
- **Angle of \( R \):** \( \Theta_R = \arctan(R_y/R_x) \)
- **Phase of \( R \):** \( \phi_R = \Theta_R/(360^\circ) \)
- **Zero epoch ephemeris:** \( t_E = t_0 + P \phi_R \)

1. \( \Rightarrow \) **Shift epoch** \( t_0 \) of \( \phi_i \) to **zero epoch** \( t_E \)
2. \( \Rightarrow \) **Sum vector** \( R \) points to \( \Theta = \Theta_R = 0^\circ \)
3. \( \Rightarrow r_i \) with \( -90^\circ < \Theta_i < 90^\circ \) strengthen \( P \) signal
4. \( \Rightarrow \) Other \( r_i \) weaken \( P \) signal

3. **"Impact"** of any subsample \( t^* \) on \( P \) signal
\[
z_x = (R_x/|R_x|)(R_x^2/n)
\]

**Note:** \( R_x \) computed only for \( n = n^* \) values \( t^* \)

3a. \( z_x > 0 \equiv t^* \) strengthen \( P \) signal
3b. \( z_x < 0 \equiv t^* \) weaken \( P \) signal
3c. \( z_x \approx 0 \equiv t^* \) represent noise

4. **Old** data samples \( \text{SSTP}=1, 3, 5, 7, 9, 11 \) had
\[
t_E = 0.53 \pm 0.09 \text{ for } P_A = 2.85
\]
\[
t_E = 3.50 \pm 0.09 \text{ for } P_M = 29.6
\]

\( \Rightarrow \) This gave two ephemerides
\[
t_0 = t_E = 0.53, \quad P = P_A = 2.85(\text{Algol}) \quad (1)
\]
\[
t_0 = t_E = 3.50, \quad P = P_M = 29.6(\text{Moon}) \quad (2)
\]

5. Prognoses of any SW are a **subsample** of all prognoses of CC \( \Rightarrow \) Compute impact \( z_x \) for **new** samples \( t_i \) of each SW with above ephemerides

6. \( P_A = 2.85 \) and \( P_M = 29.6 \) detected **only** in \( G \)

\( \Rightarrow \) \( t_i \) of **GGG** and **SSS** of SW days separated

\( \Rightarrow \) Notations \( g_i \) and \( s_i \)

Respective **unit vectors** \( r_i \) are \( g_i \) and \( s_i \)

7. **Identification:** For example, SW with **GGG**

"Connected to the \( P_A = 2.85 \) signal"

\( \equiv z_x \geq 1.0 \) and \( Q_z \leq 0.2 \) with Eq. 1

---

Lauri Jetsu
Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

"Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed"
• \( Q_z = \text{Probability for concentration of } \text{all } n_G \text{ and } n_S \) directions of \( g_i \) and \( s_i \) of each SW

• Many \( Q_z \) estimates based on \textit{small} samples (\( n_G \) or \( n_S \)) are \textit{unreliable}

\[ \text{Binomial distribution probability} \]

• \( g_i \) and \( s_i \) of any SW are subsamples of \textit{all} \( g_i \) \( (N_G = 177) \) and \( s_i \) \( (N_S = 105) \)

1. Choose direction \( \Theta_R \) of \( R \) for some SW

2. Identify \( n_1 \) directions of \( g_i \) or \( s_i \) of this SW that are among \( n_2 \) of all \( N_G \) or \( N_S \) directions closest to \( \Theta_R \)

3. Compute

\[ Q_B = P(n_1, n_2, N) = \sum_{i=n_1}^{n_2} \binom{n_2}{i} q_B^i (1 - q_B)^{n_2-i}, \]

where \( N = N_G \) or \( N_S \), and \( q_B = n_G/N_G \) or \( n_S/N_S \)

• \( Q_B \) = Probability for that directions of a particular SW occur \( n_1 \) times, or more, among all \( n_2 \) directions closest to \( \Theta_R \) \( \Rightarrow \text{Concentration probability} \)

• \( Q_B \) estimates based on large samples (\( N_G = 177 \) or \( N_S = 105 \)) are \textit{reliable}

• \textbf{Finding ‘Horus’}

• Of all SWs, ‘Horus’ has largest \( z_x \) with ephemeris of Eq. 1

\( \Rightarrow \) Most probable SW connected to Algol

• \textbf{Appendix: Main result summarized}

• ‘Horus’ found in \( n_G = 14 \) GGG days

\( \Rightarrow \) \( D \) and \( M \) values

\( \Rightarrow t = t(D, M) = N_E - 1 + 0.33 \) values

• \textbf{Meaning of Eq 1:} \( G \) prognoses connected to \( P_{Algol} = 2.85 \) concentrated around epochs \( Aa = 0.53 + i P_{Algol} \)

where \( i = 0, 1, 2, \ldots, 126 \) in 360 days of CC

• \textbf{Same meaning:} What happened at regular \( 2.85 \) intervals on 0.53, 3.38, ... and 359.63

• \textbf{Rounds} after first Aa moment at 0.53

\( K = (t - 0.53)/P_{Algol} = (t - 0.53)/2.85 \)

\( \Rightarrow \) Project to angles \( \Theta = K \times 360^\circ \) on unit circle

\( \Rightarrow \) Same locations on unit circle after full rounds

\( \Rightarrow \) Remove multiples of \( 360^\circ \) (full rounds)

• \textbf{Appendix}

Read ‘Horus’ texts in order of increasing \( \Theta \)

\( \equiv \) Read texts in order of Algol’s phases

\( \equiv \) Follow actions of ‘Horus’ during Algol’s orbital rounds

Lauri Jetsu Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
Appendix: Text, Table & Figure

Aim: Understand Fig 1a ⇒ Understand better other Figures & Whole paper

• ‘Horus’: 14 angles $\Theta = K \times 360^\circ$

• ‘Horus’: $\Theta_R = 11^\circ \equiv$ Symbol “●”

• On this unit circle, time runs to counter clock-wise direction through points Aa, Ab, Ac ja Ad, as the rounds $K$ rotate and change angle $\Theta$

Appendix: Read ‘Horus’ texts in order of increasing $\Theta$ ⇒ Think! ⇒ Conclusion: GGG texts describe bright phases (not eclipse phases). Aa must be in the middle of brighest phase

• Aa: Coincides with mid epoch of secondary eclipse not observable with naked eye

• Ac: Must be mid epoch of primary eclipse

• Ac: Coincides with mid epoch of primary eclipse observable with naked eye

• Black arc centered at Ac $\equiv 10^h$ primary eclipse

<table>
<thead>
<tr>
<th>$D$</th>
<th>$M$</th>
<th>$t$</th>
<th>$K$</th>
<th>$\Theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>1</td>
<td>17.33</td>
<td>5.89</td>
<td>2122=322</td>
</tr>
<tr>
<td>27</td>
<td>1</td>
<td>26.33</td>
<td>9.05</td>
<td>3259=19</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>43.33</td>
<td>15.02</td>
<td>5405=6</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
<td>83.33</td>
<td>29.05</td>
<td>10459=19</td>
</tr>
<tr>
<td>27</td>
<td>3</td>
<td>86.33</td>
<td>30.11</td>
<td>10838=38</td>
</tr>
<tr>
<td>28</td>
<td>3</td>
<td>87.33</td>
<td>30.46</td>
<td>10964=164</td>
</tr>
<tr>
<td>29</td>
<td>3</td>
<td>88.33</td>
<td>30.81</td>
<td>11091=291</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>180.33</td>
<td>63.09</td>
<td>22712=32</td>
</tr>
<tr>
<td>23</td>
<td>7</td>
<td>202.33</td>
<td>70.81</td>
<td>25491=291</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>240.33</td>
<td>84.14</td>
<td>30291=51</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>246.33</td>
<td>86.25</td>
<td>31048=88</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>270.33</td>
<td>94.67</td>
<td>34080=240</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>314.33</td>
<td>110.11</td>
<td>39638=38</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
<td>348.33</td>
<td>122.04</td>
<td>43933=13</td>
</tr>
</tbody>
</table>
SW with lucky GGG prognoses

“Connected to the \( P_A = 2.85 \, \text{d} \) signal”
\[ \equiv z_x \geq 1.0 \text{ and } Q_z < 0.2 \text{ with Eq. 1} \]

<table>
<thead>
<tr>
<th>SW</th>
<th>( n_G )</th>
<th>( z_x )</th>
<th>( Q_z )</th>
<th>( Q_B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Horus’</td>
<td>14</td>
<td>+3.5</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>‘Re’</td>
<td>32</td>
<td>+2.5</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>‘Wedjat’</td>
<td>4</td>
<td>+2.0</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>‘Followers’</td>
<td>15</td>
<td>+1.4</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>‘Sakhmet’</td>
<td>4</td>
<td>+1.3</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>‘Ennead’</td>
<td>18</td>
<td>+1.1</td>
<td>0.1</td>
<td>0.02</td>
</tr>
</tbody>
</table>

– Only these six SWs connected to Algol

– ‘Heliopolis’ \((z_x = +0.2)\), ‘Enemy’ \((z_x = -1.0)\)

SW with lucky GGG prognoses

“Connected to the \( P_M = 29.6 \, \text{d} \) signal”
\[ \equiv z_x \geq 1.0 \text{ and } Q_z < 0.2 \text{ with Eq. 2} \]

<table>
<thead>
<tr>
<th>SW</th>
<th>( n_G )</th>
<th>( z_x )</th>
<th>( Q_z )</th>
<th>( Q_B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Earth’</td>
<td>19</td>
<td>+5.3</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>‘Heaven’</td>
<td>19</td>
<td>+3.4</td>
<td>0.03</td>
<td>0.002</td>
</tr>
<tr>
<td>‘Busiris’</td>
<td>4</td>
<td>+3.0</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>‘Rebel’</td>
<td>3</td>
<td>+1.6</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>‘Thoth’</td>
<td>10</td>
<td>+1.3</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>‘Onnophris’</td>
<td>7</td>
<td>+1.0</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

– These six SWs connected to the Moon

– ‘Nut’ \((z_x = -0.1)\)

\( P_A \) and \( P_A \) signals detected in lucky G
\[ \Rightarrow \text{No impact from unlucky S} \]

SW with unlucky SSS prognoses

“Connected to Algol”
\[ Q_z < 0.2 \text{ with Eq. 1} \]

<table>
<thead>
<tr>
<th>SW</th>
<th>( n_S )</th>
<th>( z_x )</th>
<th>( Q_z )</th>
<th>( Q_B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Heart’</td>
<td>5</td>
<td>-3.1</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>‘Nun’</td>
<td>3</td>
<td>-0.8</td>
<td>0.06</td>
<td>0.003</td>
</tr>
</tbody>
</table>

SW with unlucky SSS prognoses

“Connected to the Moon”
\[ Q_z < 0.2 \text{ with Eq. 2} \]

<table>
<thead>
<tr>
<th>SW</th>
<th>( n_S )</th>
<th>( z_x )</th>
<th>( Q_z )</th>
<th>( Q_B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Seth’</td>
<td>9</td>
<td>-3.1</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>‘Osiris’</td>
<td>4</td>
<td>-2.0</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>‘Abydos’</td>
<td>2</td>
<td>-0.8</td>
<td>0.1</td>
<td>0.02</td>
</tr>
<tr>
<td>‘Lion’</td>
<td>6</td>
<td>-0.1</td>
<td>0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>‘Man’</td>
<td>5</td>
<td>+1.4</td>
<td>0.02</td>
<td>0.009</td>
</tr>
<tr>
<td>‘Flame’</td>
<td>4</td>
<td>+3.6</td>
<td>0.03</td>
<td>0.003</td>
</tr>
</tbody>
</table>

SW with unlucky SSS prognoses in antiphase \( z_x < 0 \), except ‘Man’, ‘Flame’

Not connected to Algol or Moon: ‘Eye’, ‘Fire’, ‘Majesty’, ‘Shu’, ‘Sobek’
13 ‘SW’ figures in ~ 10 minutes ⇒ Clarification:

**a&b:** \(180^\circ \equiv 4.2 \text{ hours} \equiv \text{Aa} \rightarrow \text{Ac} (\text{Secondary} \rightarrow \text{Primary eclipse})

**c&d:** \(180^\circ \equiv 14.8 \text{ days} \equiv \text{Ma} \rightarrow \text{Mc} (\text{Full Moon} \rightarrow \text{New Moon})

- Values of \(z, Q_z, z_x\) shown only if \(Q_z \leq 0.2 \equiv \text{At least weak periodicity}
- **Notation:** Symbol \(\nabla \equiv \text{Nothing worth mentioning}
- **Note:** Shift in times can be \(\sigma_t \approx 0.5 \text{ days} \Rightarrow \text{Increasing order in } \Theta \text{ not precise}

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_{\text{Algol}} = 2.85) days</td>
<td>(P_{\text{Algol}} = 2.85) days</td>
</tr>
<tr>
<td>(n_G = \text{GGG} \text{ days} )</td>
<td>(n_S = \text{SSS} \text{ days} )</td>
</tr>
<tr>
<td>Unit vectors (g_i)</td>
<td>Unit vectors (s_i)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_{\text{Moon}} = 29.6) days</td>
<td>(P_{\text{Moon}} = 29.6) days</td>
</tr>
<tr>
<td>(n_G = \text{GGG} \text{ days} )</td>
<td>(n_S = \text{SSS} \text{ days} )</td>
</tr>
<tr>
<td>Unit vectors (g_i)</td>
<td>Unit vectors (s_i)</td>
</tr>
</tbody>
</table>
Horus

a Strongest connection to period
$P_{ Algol } = 2.85$
Describe good things connected to brightest phases of Algol

b Describe anger after eclipse

C No periodicity. Competition between 'Horus' and 'Seth' ends after Md

d 🐇
'Re'

a 2nd strongest connection to period $P_{\text{Algol}} = 2.85$. No concentrations $\equiv$ Casually follows 'Horus'.

b No periodicity. Avoids Aa

c 🐫

d Weak periodicity. Avoids Ma

'Vere' (Sun) sent "the eye of Horus" = 'Wedjat'

...
'Wedjat'

a 3rd strongest connection to period 
\[ P_{\text{Algol}} = 2.85. \]

'Wedjat' is "eye of 'Horus'". Algol bright and the Moon bright

b No periodicity, but close to Ad! G and S phases like 'Horus'

C the Moon bright and Algol bright

d 🐅

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
'Followers'

a 4th strongest connection to period $P_{\text{Algol}} = 2.85$. Algol bright: good!

b Before eclipse:, not good! Concentration $Q_B = 0.003$. Pleiades seem to 'follow' very close to Algol as sky revolves

c

d Weak periodicity
'Sakhmet'

a 5th strongest connection to period
\( P_{\text{Algol}} = 2.85 \).
Algol bright: Good

b After eclipse, Anger: Not good!
\( Q_B = 0.0004 \)
Lotto: Draw 6 balls from 105 and get these 3.

g and S phases same as 'Horus' and 'Wedjat'.
“Eye of 'Horus’” ('Wedjat') transformed into vengeful
'Sakhmet' ...
pacified ... at Ad

c & d: 😈
'Ennead'

a 6th strongest connection to period $P_{\text{Algol}} = 2.85$. Algol bright: good! $Q_B = 0.02$

b After eclipse: not good! Algol in front of Pleiades after eclipse = 'Ennead'

c & d 🙁

LauriJetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol's Period Confirmed”
'Earth'

a 🐐

b Weak periodicity. After Algol’s eclipse: ‘Sakhmet’, ‘Wedjat’, ... ?

c Strongest connection to period $P_{\text{Moon}} = 29.6$. Good times on Earth at Ma = Full Moon

d Weak periodicity

Earth: $P=2.85, n_g=19$
$\theta_R=-61$

Earth: $P=29.60, n_g=19$
$\theta_R=-27$
$z=6.6, Q_z=0.001$
$z_x=5.3$

Earth: $P=2.85, n_g=5$
$\theta_R=-75$
$z=2.9, Q_z=0.06$
$z_x=0.2$

Earth: $P=29.60, n_g=5$
$\theta_R=-119$
$z=1.8, Q_z=0.2$
$z_x=-0.4$
Heaven

a

b

C 2nd strongest connection to period $P_{Kuu} = 29.6$. Strong concentration $Q_B = 0.002$. Good times in heaven at Ma = Full Moon

d Weak periodicity. After Mc = New Moon

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

"Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol's Period Confirmed"
'Busiris'

Busiris is a site in Egypt and one of Osiris' birthplaces.

3rd strongest connection to period
\( P_{Kuu} = 29.6 \).

Good time in Busiris at Ma = Full Moon.

\( P = 2.85, n_g = 4 \)
\( \theta_R = 19 \)

\( P = 29.60, n_g = 4 \)
\( \theta_R = 3 \)
\( z = 3.0, Q_z = 0.05 \)
\( z_x = 3.0 \)

\( P = 2.85, n_s = 3 \)
\( \theta_R = -123 \)

\( P = 29.60, n_s = 3 \)
\( \theta_R = -111 \)
- Algol’s 2.85 days signal discovered only in G prognoses

- Moons’s 29.6 days signal discovered only in G prognoses
  ⇒ Signal amplified by GGG prognoses of ‘Earth’, ‘Heaven’, ‘Busiris’, ‘Rebel’, ‘Thoth’ ‘Onnophris’ (Figures shown only for three first ones)

- Algol’s 2.85 and Moon’s 29.6 days signals discovered only in G prognoses
  ⇒ S prognoses do not amplify these signals
  ⇒ Figures for SSS prognoses of these particular SWs are also shown, because they have $Q_z \leq 0.2$ with Eqs. 1 or 2
’Heart’

Connection to period

\( P_{\text{Algol}} = 2.85 \)

**Note:** This signal discovered in G, not in S prognoses

---

**a**

Periodicity.

Bad times for ‘Heart’ close to \( Ac = \text{Algol's eclipse} \)

---

**b**

Heart: \( P=2.85, n_c=27 \)

\( \Theta_R = -91 \)

---

**c**

Heart: \( P=29.60, n_c=27 \)

\( \Theta_R = 47 \)

---

**d**

Heart: \( P=2.85, n_s=5 \)

\( \Theta_R = -172 \)

\( z=3.2, Q_z=0.04 \)

\( z_x=-3.1 \)
Connection to period $P_{Moon} = 29.6$

Note: This signal discovered in G, not in S prognoses

a 🕵️‍♂️
b 🕵️‍♂️
c 🕵️‍♂️
d Periodicity.

"See you on the dark side of the Moon."

Mc is certainly New Moon (Leitz).

⇒ Ma is certainly Full Moon.

‘Seth’ stops fighting with ‘Horus’ between Md and Ma.
Osiris' Connection to period

$P_{\text{Moon}} = 29.6$

Note: This signal discovered in G, not in S prognoses

a 🡪
b 🡪
c 🡪
d Periodicity.
Bad times close to $\text{Mc} = $ New Moon.
$Q_B = 0.02$
Man

Connection to period

\[ P_{\text{Moon}} = 29.6 \]

**Note:** This signal discovered in G, not in S prognoses

\[ a \]

\[ b \]

\[ c \]

\[ d \] Periodicity. Bad times after Ma = Full Moon.

\[ Q_B = 0.003 \]
Observing eclipses

- Nights 10 h = vertical lines
- $3 + 3 + 13 = 19$ night rule
- end of night – third mid night – third beginning of night – 13th end of night
- 57 night rule
- Open triangles: theoretical observation
- Closed triangles: certain observation
- D=1 always GGG and D=20 always SSS equals $19^d$
- This 19 days period detected in G prognoses ⇒ Only if observed only night time eclipses
- Bright phases good ⇒ Eclipses bad ⇒ 13 unlucky number?
Main results: Algol's name

LE1: Legend of Contendings of ‘Horus’ and ‘Seth’: Various competitions of who will succeed deceased ‘Osiris’ as king. ‘Horus’ beats ‘Seth’ each time.

LE2: Legend of Destruction of Mankind: ‘Re’ sends Eye of ‘Horus’ (‘Wedjat’) to punish mankind. ‘Wedjat’ is transformed into the vengeful goddess ‘Sakhmet’. Other gods deceive ‘Sakhmet’ to drinking human blood (“beer coloured red”). ‘Sakhmet’ is pacified and mankind saved.

Upper: GGG ‘Horus’ (■) ‘Wedjat’ (□) ‘Sakhmet’ (▲)
Lower: SSS ‘Horus’ (■) ‘Wedjat’ (□) ‘Sakhmet’ (▲)

Algol: At Aa, ‘Re’ sends the Eye of ‘Horus’ (‘Wedjat’) to destroy the rebels, as in LE2. At Ab, ‘Horus’ enters the “foreign land” in $g_i(7, 9)$, where he “smote him who rebelled”, as in LE1 or LE2. The “will is written” for him in $g_i(28, 3)$ at the beginning of an eclipse – the only $g_1$ vector of ‘Horus’ overlapping the thick line centered at Ac in Fig 1a. After an eclipse, ‘Wedjat’ returns as ‘Sakhmet’ who is pacified immediately after Ad, as in LE2. And a new cycle begins.

• “Algol’s name”: Mythological actions of ‘Horus’, ‘Wedjat’ and ‘Sakhmet’

Lauri Jetsu  Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”
“Confirmed” 2013 main results

1. First variable star was discovered three millennia before Fabricius (1596) discovered Mira.
2. Period of variable star was first discovered three millennia before Goodricke (1783) discovered Algol’s period.
3. CC is probably oldest preserved historical document of these discoveries.
4. Algol’s period was 2.850 in 1224 B.C.
5. Period has increased to 2.867.
6. Increase observed for the first time, 230 years after discovery.
7. Increase gives an MT rate estimate.
8. Eclipses observed in Ancient Egypt ↔ Algol A–B and Algol AB–C orbital planes nearly perpendicular ⇒ Prediction confirmed later.
9. Algol in CC for religious reasons.
10. “The Raging One” in CC = Algol?

Main results: CC in general

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”

- 1, 2, 3 and 4 confirmed ⇒ Entitled us to use “Shifting milestones”
- 9 and 10 confirmed ⇒ Entitled us to use “confirmed” and remove “probably” from 3
- Algol (’Horus’) and the Moon (’Seth’) control actions of nearly all deities in CC.
- Bright phases of Algol and the Moon were good times in Ancient Egypt.
- Link to PLOS ONE: “Shifting milestones ...
- Link to Media response

Egyptological part: “Submitted”

- Scribes ⇒ Timing from stars ⇒ Observed over thousand years ⇒ 300 clear nigths a year ⇒ Decan star observations ⇒ Timing religious nightly rituals ⇒ Sun passes Underword’s gatekeepers ⇒ Sun rises next morning: No chaos! ⇒ Algol changes constellation pattern: Chaos! ⇒ Not direct description, only indirect mythological description ⇒ Impossible in 45 minutes ⇒ “Accepted”: Invite Porceddu

Lauri Jetsu Department of Physics, University of Helsinki, lauri.jetsu@helsinki.fi

“Shifting Milestones of Natural Sciences: The Ancient Egyptian discovery of Algol’s Period Confirmed”