# "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

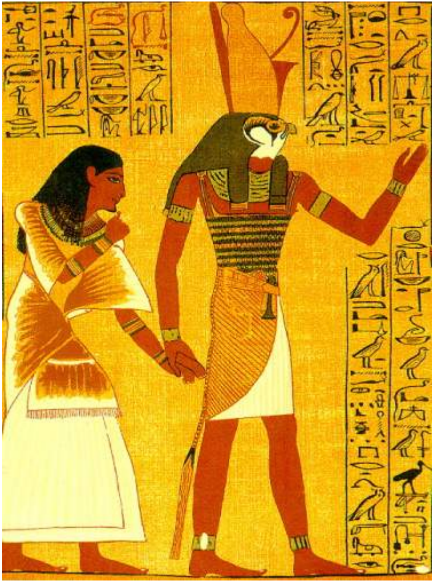
- **What** confirmed? **ApJ 2013** $(20^{m})$
- **How** confirmed? **PLOS ONE 2015** $(25^{m})$

## 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

# Image: @www.philvaz.com

- **'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 " **G G S**": 1st and 2nd parts of this day were good, but 3rd part was bad
- **Next page**: all **CC** prognoses



| | Akhet I | Akhet II | Akhet III | Akhet IV | Peret I | Peret II | Peret III | Peret IV | Shemu I | Shemu II | Shemu III | Shemu IV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $D$ | $M=1$ | $M=2$ | $M=3$ | $M=4$ | $M=5$ | $M=6$ | $M=7$ | $M=8$ | $M=9$ | $M=10$ | $M=11$ | $M=12$ |
| 1 | GGG | GGG | GGG | GGG | GGG | GGG | GGG | GGG | GGG | GGG | GGG | GGG |
| 2 | GGG | GGG | — | GGG | GGG | GGG | GGG | GGG | — | — | GGG | GGG |
| 3 | GGS | GGG | GGG | SSS | GGG | — | — | SSS | GGG | GGG | SSS | SSS |
| 4 | GGS | SGS | — | GGG | GGG | GGG | GSS | GGG | SSS | SSS | GGG | SSG |
| 5 | GGG | SSS | — | GGG | GSS | GGG | GGG | SSS | — | GGG | SSS | GGG |
| 6 | SSG | GGG | GGG | SSS | GGG | — | GGG | SSS | GGG | — | — | SSS |
| 7 | GGG | SSS | GGG | SSS | SSS | GGG | SSS | GGG | GGG | SSS | SSS | — |
| 8 | GGS | GGG | — | GGG | GGG | GGG | GGG | GGG | — | GGG | SSS | GGG |
| 9 | GGG | GGG | SSS | GGG | GGG | GGG | GGG | — | GGG | GGG | GGG | GGG |
| 10 | GGG | GGG | GGG | GGG | SSS | SSS | SSS | — | — | GGG | SSS | GGG |
| 11 | SSS | GGG | GGG | GGG | SSS | GGG | GGG | SSS | — | SSS | SSS | SSS |
| 12 | SSS | SSS | — | SSS | — | GGG | GGG | SSS | — | GGG | — | GGG |
| 13 | GSS | GGG | SSS | GGG | GGG | SSS | GGG | SSS | — | GGG | — | GGG |
| 14 | — | GGG | SSS | GGG | SSS | SGG | — | — | — | GGG | SSS | GGG |
| 15 | GSS | GSS | SSS | — | GGG | — | SSS | GGG | — | SSS | GGG | SSS |
| 16 | SSS | GGG | GGG | GGG | GGG | — | SSS | GGG | GGG | GGG | SSS | GGG |
| 17 | SSS | GGG | — | — | SSS | GGG | SSS | SSS | GGG | SSS | — | GGG |
| 18 | GGG | SSS | SSS | SSS | GGG | SSS | GGG | — | GGG | SSS | SSS | SSG |
| 19 | GGG | GGG | SSS | SSS | SSS | GSS | — | GGG | GGG | SSS | SSS | GGG |
| 20 | SSS | SSS | SSS | SSS | SSS | SSS | SSS | — | SSS | SSS | SSS | — |
| 21 | GGG | SSG | GGG | SSG | GGG | — | — | — | SSS | SSG | GGG | GGG |
| 22 | SSS | — | — | GGG | GGG | GGG | SSS | SSS | GGG | SSS | SSS | GGG |
| 23 | SSS | — | SSS | GGS | GGG | GGG | GGG | — | GGG | GGG | SSS | SSS |
| 24 | GGG | SSS | GGG | — | GGG | SSS | SSS | SSS | — | GGG | GGG | GGG |
| 25 | GGS | SSS | GGG | — | GGG | GGG | — | SSS | GGG | GGG | GSG | GGG |
| 26 | SSS | SSS | GGG | GGG | SSS | — | SSS | — | GGG | SSS | GGG | GSG |
| 27 | GGG | SSS | GGG | GGS | GGG | — | SSS | SSS | — | SSS | SSS | SSS |
| 28 | GGG | GGG | GGG | SSS | GGG | GGG | GGG | GGG | — | GGG | SSS | GGG |
| 29 | SGG | GGG | GGG | SSS | GGG | SSS | GGG | GGG | GGG | GGG | GGG | GGG |
| 30 | GGG | GGG | GGG | GGG | GGG | SSS | GGG | GGG | GGG | GGG | GGG | GGG |

**Creating data:** Time points $t_1, t_2, \ldots, t_n$

- Gregorian days: **Seasons** $\Rightarrow$ Day & night length

$$N_{\mathrm{G}} = \begin{cases} N_{\mathrm{E}} + N_0 - 1, & N_{\mathrm{E}} \leq 366 - N_0 \\ N_{\mathrm{E}} + N_0 - 366, & N_{\mathrm{E}} > 366 - N_0, \end{cases}$$

**"Egyptian days"**: $N_{\mathrm{E}} = 30(M-1) + D$

**Three alternatives:** $N_0 = 62, 187$ or $307$

- Day length? Declination of the Sun
$\delta_{\odot}(N_{\mathrm{G}}) \approx -23.45^{\mathrm{o}} \cos\left[360^{\mathrm{o}}(N_{\mathrm{G}}+10)/(365.25)\right]$

- Daytime [h] at Middle Egypt ($\phi = 26^{\mathrm{o}}41'$)
$l_{\mathrm{D}}(N_{\mathrm{G}}) = (24/180^{\mathrm{o}})\ \{\mathrm{acos}[-\tan(\phi)\tan(\delta_{\odot}(N_{\mathrm{G}}))]\}$

- **Three** prognoses within days: **1st alternative**

$$\begin{aligned} t_1(N_{\mathrm{E}}) &= (N_{\mathrm{E}}-1) + (1/6)[l_{\mathrm{D}}(N_{\mathrm{G}})/24] \\ t_2(N_{\mathrm{E}}) &= (N_{\mathrm{E}}-1) + (3/6)[l_{\mathrm{D}}(N_{\mathrm{G}})/24] \\ t_3(N_{\mathrm{E}}) &= (N_{\mathrm{E}}-1) + (5/6)[l_{\mathrm{D}}(N_{\mathrm{G}})/24] \end{aligned}$$

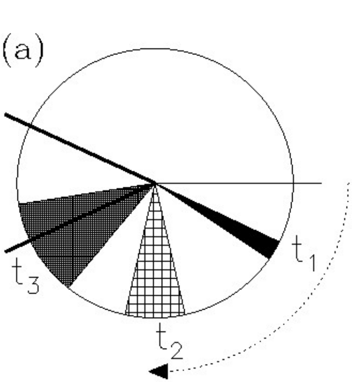
- **Three** prognoses within days: **2nd alternative**

$$\begin{aligned} t_1(N_{\mathrm{E}}) &= (N_{\mathrm{E}}-1) + (1/4)[l_{\mathrm{D}}(N_{\mathrm{G}})/24] \\ t_2(N_{\mathrm{E}}) &= (N_{\mathrm{E}}-1) + (3/4)[l_{\mathrm{D}}(N_{\mathrm{G}})/24] \\ t_3(N_{\mathrm{E}}) &= (N_{\mathrm{E}}-1) + 1/2 + (1/2)[l_{\mathrm{D}}(N_{\mathrm{G}})/24] \end{aligned}$$

- **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**
= **S**amples of **S**eries of **T**ime **P**oints

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


(a)
$t_1$
$t_2$
$t_3$
(b)
$t_1$
$t_2$
$t_3$

# Rayleigh test

- **Period range**: $P_{\min} = 1.^{\rm d}5 < P < P_{\max} = 90^{\rm d}$
- **Phases**: $\phi_i = \mathrm{FRAC}[(t_i - t_0)f]$

  $\mathrm{FRAC}[x]$ removes integer part of $x$

  **Frequency** $f = P^{-1}$, **Epoch** $t_0$ (arbitrary)
- **Phase angles** $\theta_i = 2\pi\phi_i$, **Unit vectors** $\mathbf{r}_i = [\cos\theta_i, \sin\theta_i]$, **Sum vector** $\mathbf{R} = \sum_{i=1}^{n} \mathbf{r}_i$
- **Rayleigh test statistic**: $z(f) = |\mathbf{R}|^2/n$
- **Null hypothesis**:
  $H_0$: *"Phases $\phi_i$ calculated with an arbitrary tested $P$ have a random distribution between 0 and 1."*

  **Random directions** $\theta_i \Rightarrow |\mathbf{R}| \approx 0$ $\Rightarrow H_0$ **true**

  **Perfect periodicity** $\theta_i$ coincide $\Rightarrow |\mathbf{R}| = n \Rightarrow$ **Reject** $H_0$
- **Probability density function**:
  $z = z(f) = \mathrm{e}^{-z} \Rightarrow P(z \le z_0) = F(z_0) = 1 - \mathrm{e}^{-z_0}$
- **Independent statistical tests**
  $m = \mathrm{INT}[(f_{\max} - f_{\min})/f_0]$

  $\mathrm{INT}[x]$ removes decimal part of $x$

  $f_0 = 1/\Delta T$ **distance between independent** $f$

- **Standard critical level**

  $Q_{\rm z} = Q(z_0) = P(z(f) > z_0) = 1 - (1 - \mathrm{e}^{-z_0})^m$

  Probability that $z(f)$ exceeds a fixed $z_0$ level in $m$ independent statistical tests
- **Standard $H_0$ rejection criterion**

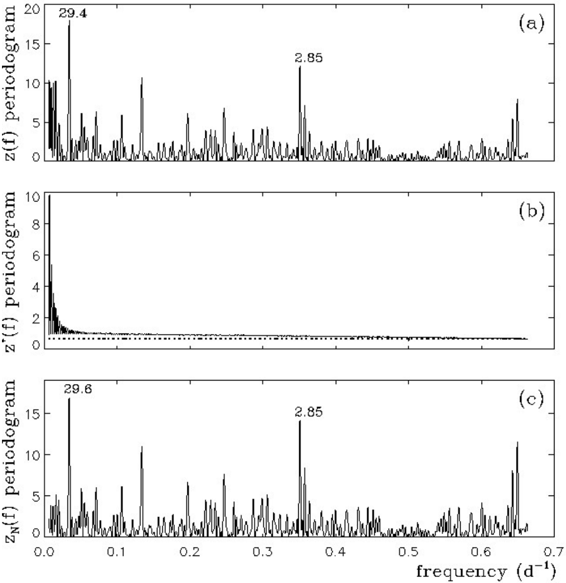
  $$Q_{\rm z} < \gamma = 0.001$$

  $\gamma$ is **preassigned significance level**
- Are standard $Q_{\rm z}$ estimates **reliable** for CC data? $\Rightarrow$ **Simulating similar** data as in **CC**
- Different daily prognosis combinations in **CC**

| Prognosis combination | SSTP=1, 3, ..., 35 Days | G | S | SSTP=2, 4, ..., 36 Days | G | S |
|---|---|---|---|---|---|---|
| GGG | 177 | 531 | 0 | 165 | 495 | 0 |
| GGS | 6 | 12 | 6 | 6 | 12 | 6 |
| GSG | 2 | 4 | 2 | 2 | 4 | 2 |
| GSS | 6 | 6 | 12 | 6 | 6 | 12 |
| SSS | 105 | 0 | 315 | 95 | 0 | 285 |
| SSG | 6 | 6 | 12 | 6 | 6 | 12 |
| SGG | 2 | 4 | 2 | 2 | 4 | 2 |
| SGS | 1 | 1 | 2 | 1 | 1 | 2 |
| Total | 305 | 564 | 351 | 283 | 528 | 321 |
| "—" | 55 | 0 | 0 | 53 | 0 | 0 |
| Total | 360 | 564 | 351 | 336 | 528 | 321 |

## SSTP=1: GGG, $D=1$: Yes

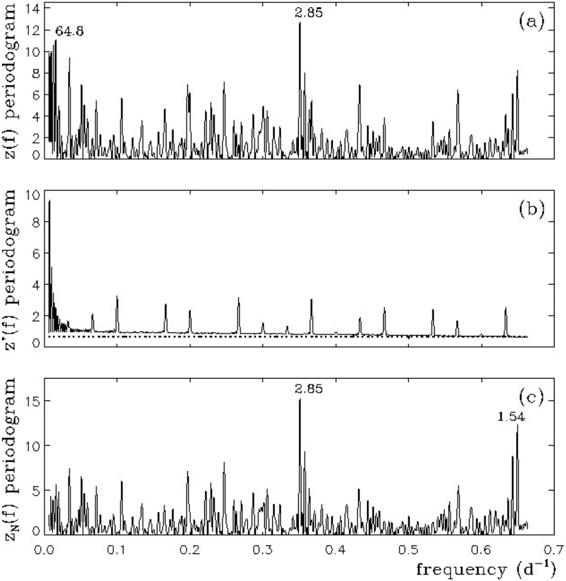
- **(a)** $z(f)$ periodogram
  $P_1 = 29.^{\mathrm{d}}4$ ($Q_z = 0.0000034$)
  $P_2 = 2.^{\mathrm{d}}850$ ($Q_z = 0.0012$)
- **(b) Noise periodogram** $z^\star(f)$
  - **Median** level should be
    $z_0 = 0.693 \equiv Q_z = 0.5$
  - Peaks of $z^\star(f)$ at integer $k \geq 4$
    $f = f(\Delta T, k) = [P(\Delta T, k)]^{-1}$
    $\equiv P(\Delta T, k) = \Delta T/(k+1/2)$
  - **Unreliable** $Q_z$ estimates
- **(c) Normalized** periodogram
  $z_N(f) = z(f)/z^\star(f)$
  - **Simulated** critical levels
    $Q_z^\star < \gamma = 0.001 \Rightarrow$ Reject $H_0$
    $P_1$=$29.^{\mathrm{d}}6$ ($Q_z^\star = 0.000012 > Q_z$)
    $P_2$=$2.^{\mathrm{d}}850$ ($Q_z^\star = 0.00014 < Q_z$)
  - Shift of $29.^{\mathrm{d}}4$ to $29.^{\mathrm{d}}6$
  - Unreal periods
    $P_3 = 1.^{\mathrm{d}}5401$ ($Q_z^\star = 0.00091$)
    $P_4 = 7.^{\mathrm{d}}48$ ($Q_z^\star = 0.00091$)




**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 $P_1 = 2.^{d}85$ and $P_2 = 64.^{d}8$
- Peaks at $P_1 = 29.^{d}6$ ( Moon) and $P_2 = 7.^{d}48$ ( Unreal) vanished
- (b) Many new peaks in noise periodogram $z^{\star}(f) \Rightarrow Q_z$ estimates certainly unreliable
- (c) Normalized periodogram $z_N(f) = z(f)/z^{\star}(f)$
- Simulated critical levels $Q_z^{\star} < \gamma = 0.001 \Rightarrow$ Reject $H_0$ $P_1 = 2.^{d}85$ ($Q_z^{\star} = 0.000094$) $P_2 = 1.^{d}54$ ($Q_z^{\star} = 0.00059$)
- Peak at $64.^{d}8$ replaced by $1.^{d}54$
- Unreal period $1.^{d}54$ caused by $P_0 = 1.^{d}0$ window and $2.^{d}85$
- GGG at $D = 1$ removed $\Rightarrow$ $2.^{d}85$ significance increased $Q_z^{\star} = 0.00014 \rightarrow 0.000094$




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

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

## Period analysis results

- Many peaks in $z(f)$

**(a)** Normalized $z_{\rm n}(f)$
$\Rightarrow$ Many peaks vanished
$\Rightarrow$ **Reliable statistics** $(Q_{\rm z}^{\star})$

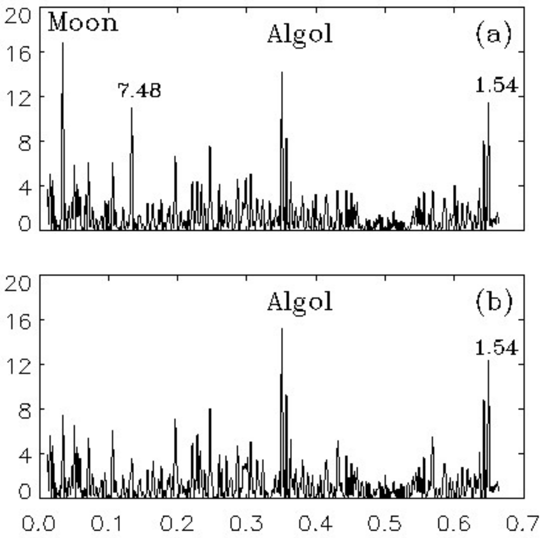
- Best periods in **G**
  29.6 days = **The Moon**
  2.85 days = **Algol?**

- 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

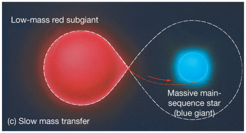
- Results for **G** do not depend on
  – Placing of seasons
  – Chosen day division
  – Removing/Not removing some days

- 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 ($m_{\mathrm{B}} = 2.81 M_\odot$) more massive than Algol A ($m_{\mathrm{A}} = 2.50 M_\odot$)
- Algol B evolved to a giant $\Rightarrow$ Filled its Roche lobe $\Rightarrow$ **Mass Transfer (MT)** to Algol A $\Rightarrow$ Algol A became more massive $\Rightarrow$ **Now**: $m_{\mathrm{A}} = 3.7 M_\odot$ ja $m_{\mathrm{B}} = 0.8 M_\odot$






- MT from less to more massive companion should increase $P_{\mathrm{orb}}$ (Kwee 1958)

  $$\dot{P}_{\mathrm{orb}} / P_{\mathrm{orb}} = -[3\, \dot{m}_{\mathrm{B}}\, (m_{\mathrm{A}} - m_{\mathrm{B}})] / (m_{\mathrm{A}} m_{\mathrm{B}})$$

  $\dot{P}_{\mathrm{orb}} =$ Rate of $P_{\mathrm{orb}}$ change

  $m_{\mathrm{A}}$ and $m_{\mathrm{B}} =$ Masses of gainer and loser

  $\dot{m}_{\mathrm{B}} =$ MT rate
- **Test**: $P_{\mathrm{orb}}$ was $2.^{\mathrm{d}}850$ in 1224 B.C and has increased to $2.^{\mathrm{d}}867328$ today $\Rightarrow$ constant $\dot{P}_{\mathrm{orb}}$ gives $\dot{m}_{\mathrm{B}} = -2.2 \times 10^{-7} M_\odot$ per year.
- "Best fitting" evolutionary model (Sarna 1993) predicted $\dot{m}_{\mathrm{B}} = -2.9 \times 10^{-7} M_\odot$
- **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 $\Rightarrow$ Short MT bursts $\Rightarrow$ Explains low **observed** MT values $\Rightarrow$ 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 perturbes Algol A–B system orbital plane $\Rightarrow$ $i_1$ changes $\Rightarrow$ Eclipses may not always occur
- $\Psi = 95^{\circ} \pm 3^{\circ}$ (Csizmadia et al. 2009) $\Rightarrow$ $P_{i_1}$=25 000 years
- $\Psi = 86^{\circ} \pm 5^{\circ}$ (Zavala et al. 2010) $\Rightarrow$ $P_{i_1}$=31 000 years
- Lower $P_{i_1}$ limits were 14 000 and 16 000 years $\Rightarrow$ **Eclipses: Yes or No in Ancient Egypt?**

- **After submitting our paper**: $\Psi = 90.^{\circ}2 \pm 0^{\circ}.32$ (Baron et al. 2012) $\Rightarrow$ **Eclipses in Ancient Egypt similar to those observed now** $\Rightarrow$ **We predicted this!**

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

$[a_1] = [a_2] = {}'' / 1000$,
$[i_1] = [i_2] = [\Omega_1] = [\Omega_2] = {}^{\circ}$,
$[e_1] = [e_2] =$ dimensionless
$[P_1] = [P_2] = \mathrm{d}$
$[m_A] = [m_B] = [m_C] = M_{\odot}$

- **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

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

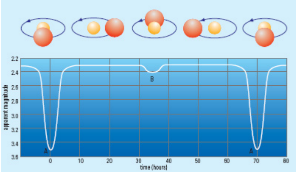
# Modern history of variable stars

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

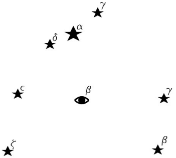
- **1638**: **Holwarda** (1618–1651) ⇒ **Mira** disappears and reappears in 11 months
- **Mira** expands and contracts ⇒ **Variability**
- **1667**: **Montanari** (1633–1687) discovered **2nd periodic variable star** **Algol** ($\beta$ Per)
- Montanari did not notice **Algol**'s periodicity
- **Algol** 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 $10^{\mathrm{h}}$ primary eclipses
- **Naked eye**: Detects $0.^{\mathrm{m}}1$ differences of close-by stars
- **Ideal comparison star**: Variable becomes at least $0.^{\mathrm{m}}1$ brighter and at least $0.^{\mathrm{m}}1$ dimmer $\Rightarrow$ Algol has six!




| Algol | 2.1 | 1.3 | | |
|---|---|---|---|---|
| Star | $m$ | $\Delta m$ | Goes below | Stays below |
| $\alpha$ Per | 1.8 | – | Never | Never |
| $\gamma$ And | 2.3 | – | in 2 hours | for 6 hours |
| $\zeta$ Per | 2.8 | – | in 3 hours | for 4 hours |
| $\epsilon$ Per | 2.9 | 0.1 | in 3 hours | for 4 hours |
| $\gamma$ Per | 2.9 | – | in 3 hours | for 4 hours |
| $\beta$ Tri | 3.0 | – | in 3 hours | for 4 hours |
| $\delta$ Per | 3.0 | – | in 3 hours | for 4 hours |

- **Goodricke** made notes $\Rightarrow$ Determined mid eclipse epochs $\Rightarrow$ These occured at multiples of 2.867 days

## 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 $\Rightarrow$ **No!**
- **the Moon** has $P = 29.6 \Rightarrow$ **Yes, it is in CC!**
- Some variable **stars** $\Rightarrow$ **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 $6^{\mathrm{m}}$
- **Naked eye**: Limit magnitude difference $0.^{\mathrm{m}}1$

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

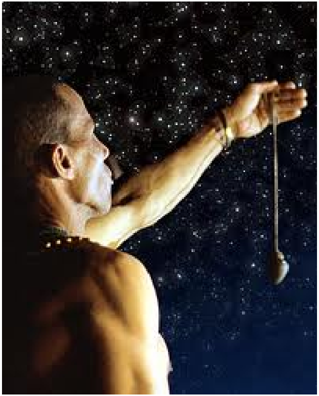
$C_2$: *Period known and fulfils* $1.^{\mathrm{d}}5 \leq P \leq 90^{\mathrm{d}} \Rightarrow$ **13 candidates**

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

$C_4$: *Variability could be predicted* $\Rightarrow$ **7 candidates**

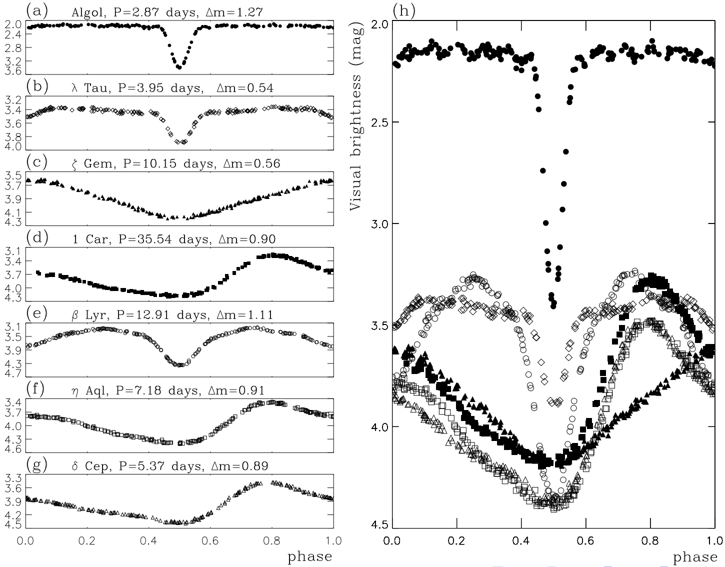
**4 cepheids**: $\zeta$ Gem, l Car, $\eta$ Aql and $\delta$ Cep

**3 eclipsing binaries**: Algol, $\lambda$ Tau and $\beta$ Lyr



**(h)** Same magnitude scale: **Algol** brightest ($m_{\max} = 2.2$)

**Algol** has largest amplitude ($\Delta m = 1.27$)

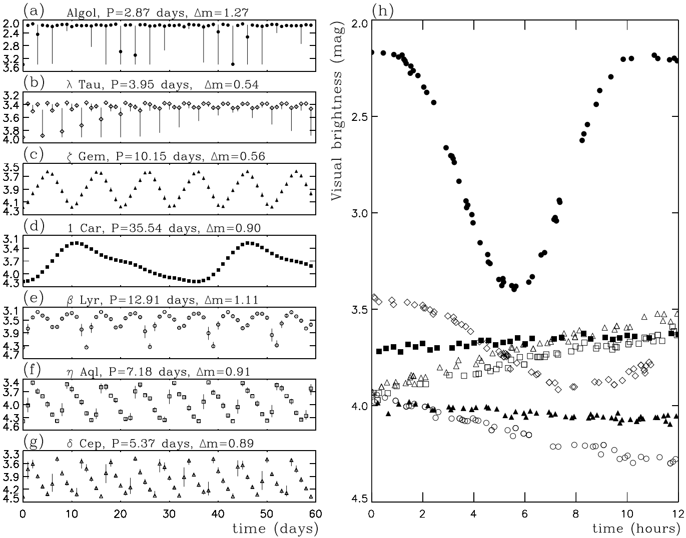


$C_5$: *Variability can be detected during a single night*

- **(a–g)** 12 hours long nights $\Rightarrow$ Vertical lines show nightly variability
- $\zeta$ **Gem** and **l 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

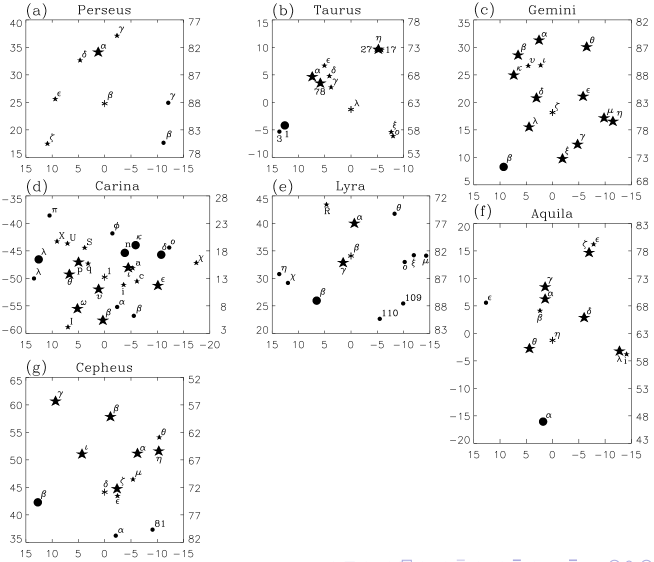
  $\lambda$ **Tau's** 14 hours eclipse $\Rightarrow$ Never observable during a single night



- **If** not in a single night $\Rightarrow$ **Then** during several nights? $\Rightarrow$ Observations recorded **(Mira)**

$C_6$: *Variability changes the constellation pattern*

- All close objects
- Brighter stars: ★, ●
- Comparison stars: ⋆, •
- Other variable stars
- Altitude $\equiv$ Extinction
- Light curve period
- **Last candidates**: **Algol**, $\lambda$ **Tau**, perhaps $\beta$ **Lyr**
- $C_1, \ldots, C_6$ **true** $\Rightarrow$ **Variabilty discovered** $\Rightarrow$ **Problem: Period still unknown!**



$C_7$: *Period of variability could be discovered by Ancient Egyptians*

- We assumed $0.^{m}1$ accuracy ( **Hipparcos**, 190-125 B.C: accuracy $1.^{m}0$, **Ptolemy**, 100-125 A.D: accuracy $0.^{m}4 - 1.^{m}0$)
- **Differential photometry** with suitable comparison stars $\Rightarrow$ **Time series** of irregularly spaced data $m(t_1), m(t_2), \ldots \Rightarrow$ Cartesian coordinate system or Modern time series analysis $\Rightarrow$ **Discovery** of $\zeta$ **Gem**, **l Car**, $\eta$ **Aql**, $\delta$ **Cep** or $\beta$ **Lyr** periods $\Rightarrow$ **Impossible!**
- **Recording eclipse epochs** $\Rightarrow$ **Series of time points** $t_1, t_2, \ldots \Rightarrow$ Multiples of some number $P \Rightarrow$ **Discovery** of $\lambda$ **Tau** and **Algol** periods $\Rightarrow$ **Possible!**

$C_8$: *History of modern astronomy: Variability and periodicity was discovered first*

**Algol**: **2nd**, Montanari, 1669; Goodricke 1783

$\lambda$ **Tau**: **18th**, Baxendell, 1848

- $C_1 - C_8 \Rightarrow$ **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** $2.^{d}850$ in 1224 B.C.
5. Period has **increased** to $2.^{d}867$
6. Increase **observed** for **the first time**, 230 years after discovery
7. Increase gives an MT rate **estimate**
8. **Eclipses** observed in Ancient Egypt $\Leftrightarrow$ 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 = **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) $\Rightarrow$ 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: Identication of SW dates** and **Transformation of SW dates into series of time points**
- 28 SWs: 'Abydos', 'Busiris', 'Earth', 'Enemy', 'Ennead', 'Eye', 'Fire', 'Flame', 'Followers', 'Heart', 'Heaven', 'Heliopolis', 'Horus', 'Lion', 'Majesty', 'Man', 'Nut', 'Nun', 'Onnophris', 'Osiris', 'Re', 'Rebel', 'Sakhmet', 'Seth', 'Shu', 'Sobek', 'Thoth' and 'Wedjat'

## 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?**

- **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

  $n_{\mathrm{G}}$ = Number of **GGG** dates in CC **containing some particular SW**

  $n_{\mathrm{S}}$ = Number of **SSS** dates in CC **containing some particular SW**

  $N_{\mathrm{G}} = 177$ = Number of all days in CC with **GGG** prognonis

  $N_{\mathrm{S}} = 105$ = 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)

  $t_{\mathrm{i}} = N_{\mathrm{E}} - 1 + a_{\mathrm{i}}$

  $N_{\mathrm{E}} = 30(M-1) + D$ = "Egyptian day"

  $a_{\mathrm{i}}$ = **3** 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 $a_{\mathrm{i}}$ all these samples ($n = 6 \times 564 = 3384$) is $m_{\mathrm{t}} = 0.33$

  ⇒ Suitable time point for an SW

  $t_{\mathrm{i}} = t_{\mathrm{i}}(D, M) = N_{\mathrm{E}} - 1 + m_{\mathrm{t}}$
- Time points of **old** study **"synchronized"** with time points of **new** study ⇒ **"Synchronized"** phases for **old** and **new** time points connected to the $P_{\mathrm{Algol}} = 2.^{\mathrm{d}}85$ and $P_{\mathrm{Moon}} = 29.^{\mathrm{d}}6$ signals

# Method

- **Period:** $P$
- **Phases:** $\phi_i = \mathrm{FRAC}[(t_i - t_0)/P]$
- **Phase angles:** $\Theta_i = 360^o\ \phi_i$
- **Unit vectors:** $\mathbf{r}_i = [\cos\Theta_i, \sin\Theta_i]$
- **Sum vector:** $\mathbf{R} = \sum_{i=1}^{n} \mathbf{r}_i$
- **Rayleigh test statistic:** $z = |\mathbf{R}|^2/n$
- **Critical level:** $Q_z = 1 - (1 - e^{-z})^m$
- **Angle of R:** $\Theta_R = \mathrm{atan}(R_y/R_x)$, where
  $R_x = \sum_{i=1}^{n} \cos\Theta_i$
  $R_y = \sum_{i=1}^{n} \sin\Theta_i$
- **Phase of R:** $\phi_R = \Theta_R/(360^o)$
- Mutual $\mathbf{r}_i$ directions, length $|\mathbf{R}|$ and $z$ value are **invariant** for any **constant shift** of $t_i$, $t_0$, or $m_t$
- **Zero epoch ephemeris:** $t_E = t_0 + P\phi_R$

**1.** $\Rightarrow$ **Shift epoch** $t_0$ of $\phi_i$ to **zero epoch** $t_E$
$\Rightarrow$ Sum vector $\mathbf{R}$ points to $\Theta = \Theta_R = 0^o$
$\Rightarrow$ $\mathbf{r}_i$ with $-90^o < \Theta_i < 90^o$ strengthen $P$ signal
$\Rightarrow$ Other $\mathbf{r}_i$ weaken $P$ signal

**3.** **"Impact"** of any subsample $\mathbf{t}^*$ on $P$ signal
$z_x = (R_x/|R_x|)(R_x^2/n)$
**Note:** $R_x$ computed only for $n = n^*$ values $\mathbf{t}^*$

**3a.** $z_x > 0 \equiv \mathbf{t}^*$ strengthen $P$ signal

**3b.** $z_x < 0 \equiv \mathbf{t}^*$ weaken $P$ signal

**3c.** $z_x \approx 0 \equiv \mathbf{t}^*$ represent noise

**4.** **Old** data samples **SSTP=1,3,5,7,9,11** had
$t_E = 0.53 \pm 0.09$ for $P_A = 2.^d85$
$t_E = 3.50 \pm 0.09$ for $P_M = 29.^d6$
$\Rightarrow$ This gave two ephemerides

$$t_0 = t_E = 0.53, \quad P = P_A = 2.85(\mathrm{Algol}) \qquad (1)$$

$$t_0 = t_E = 3.50, \quad P = P_M = 29.6(\mathrm{Moon}) \qquad (2)$$

**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** $\mathbf{r}_i$ are $\mathbf{g}_i$ and $\mathbf{s}_i$

**7.** **Identification:** For example, SW with **GGG** *"Connected to the $P_A = 2.^d85$ signal"*
$\equiv z_x \geq 1.0$ and $Q_z \leq 0.2$ with Eq. 1

- $Q_z$ = Probability for concentration of **all** $n_G$ and $n_S$ directions of $\mathbf{g}_i$ and $\mathbf{s}_i$ of each SW
- Many $Q_z$ estimates based on **small** samples ($n_G$ or $n_S$) are **unreliable**

## Binomial distribution probability

- $\mathbf{g}_i$ and $\mathbf{s}_i$ of any SW are subsamples of *all* $\mathbf{g}_i$ ($N_G = 177$) and $\mathbf{s}_i$ ($N_S = 105$)

1. Choose direction $\Theta_R$ of $\mathbf{R}$ for some SW
2. Identify $n_1$ directions of $\mathbf{g}_i$ or $\mathbf{s}_i$ 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 $\Theta_R \Rightarrow$ **Concentration** probability
- $Q_B$ estimates based on large samples ($N_G = 177$ or $N_S = 105$) are **reliable**
- **Drawing lottery balls**

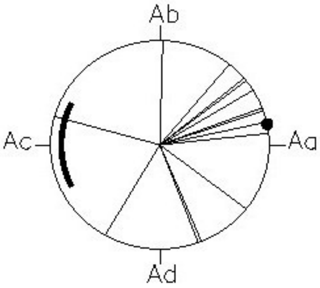
## Finding 'Horus'

- Of all SWs, **'Horus'** has largest $z_x$ with ephemeris of Eq. 1
  $\Rightarrow$ Most probable SW connected to Algol
- **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
- **Meaning of Eq 1: G** prognoses connected to $P_{\rm Algol} = 2.^{\rm d}85$ concentrated around epochs
  $Aa = 0.53 + i\, P_{\rm Algol}$,
  where $i = 0, 1, 2, \ldots, 126$ in 360 days of CC
- **Same meaning: What** happened at regular $2.^{\rm d}85$ intervals on 0.53, 3.38, ... and 359.63
- **Rounds** after first Aa moment at 0.53
  $K = (t - 0.53)/P_{\rm Algol} = (t - 0.53)/2.85$
  $\Rightarrow$ Project to angles $\Theta = K \times 360^{\rm o}$ on unit circle
  $\Rightarrow$ Same locations on unit circle after full rounds
  $\Rightarrow$ Remove multiples of $360^{\rm o}$ (full rounds)
- **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

## **Appendix:** Text, Table & Figure

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

- **'Horus'**: 14 angles $\Theta = K \times 360^{\mathrm{o}}$
- **'Horus'**: $\Theta_{\mathrm{R}} = 11^{\mathrm{o}} \equiv$ 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 brigthest 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**$^{\mathrm{h}}$ primary eclipse

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

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

- SW with lucky **GGG** prognoses
  *"Connected to the $P_A = 2.^d85$ signal"*
  $\equiv z_x \geq 1.0$ and $Q_z < 0.2$ with Eq. 1

| SW | $n_G$ | $z_x$ | $Q_z$ | $Q_B$ |
|---|---|---|---|---|
| 'Horus' | 14 | +3.5 | 0.03 | 0.006 |
| 'Re' | 32 | +2.5 | 0.07 | |
| 'Wedjat' | 4 | +2.0 | 0.1 | |
| 'Followers' | 15 | +1.4 | 0.2 | |
| 'Sakhmet' | 4 | +1.3 | 0.06 | |
| 'Ennead' | 18 | +1.1 | 0.1 | 0.02 |

  - **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 $P_M = 29.^d6$ signal"*
  $\equiv z_x \geq 1.0$ and $Q_z < 0.2$ with Eq. 2

| SW | $n_G$ | $z_x$ | $Q_z$ | $Q_B$ |
|---|---|---|---|---|
| 'Earth' | 19 | +5.3 | 0.001 | |
| 'Heaven' | 19 | +3.4 | 0.03 | 0.002 |
| 'Busiris' | 4 | +3.0 | 0.05 | |
| 'Rebel' | 3 | +1.6 | 0.2 | |
| 'Thoth' | 10 | +1.3 | 0.1 | |
| 'Onnophris' | 7 | +1.0 | 0.1 | |

  - **These six SWs** connected to the **Moon**
  - 'Nut' $(z_x = -0.1)$

- $P_A$ and $P_A$ signals detected in lucky **G**
  $\Rightarrow$ No impact from unlucky **S**

- SW with unlucky **SSS** prognoses
  *"Connected to Algol"*
  $Q_z < 0.2$ with Eq. 1

| SW | $n_S$ | $z_x$ | $Q_z$ | $Q_B$ |
|---|---|---|---|---|
| 'Heart' | 5 | -3.1 | 0.03 | |
| 'Nun' | 3 | -0.8 | 0.06 | 0.003 |

- SW with unlucky **SSS** prognoses
  *"Connected to the Moon"*
  $Q_z < 0.2$ with Eq. 2

| SW | $n_S$ | $z_x$ | $Q_z$ | $Q_B$ |
|---|---|---|---|---|
| 'Seth' | 9 | -3.1 | 0.05 | |
| 'Osiris' | 4 | -2.0 | 0.05 | 0.02 |
| 'Abydos' | 2 | -0.8 | 0.1 | 0.02 |
| 'Lion' | 6 | -0.1 | 0.1 | 0.04 |
| 'Man' | 5 | +1.4 | 0.02 | 0.009 |
| 'Flame' | 4 | +3.6 | 0.03 | 0.003 |

- 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 $\sim$ 10 minutes $\Rightarrow$ Clarification:

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

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

– Values of $z$, $Q_{\text{z}}$, $z_{\text{x}}$ **shown only if** $Q_{\text{z}} \leq 0.2 \equiv$ At least weak periodicity

– **Notation:** Symbol ☠ $\equiv$ Nothing worth mentioning

– **Note:** Shift in times can be $\sigma_{\text{t}} \approx 0.5$ days $\Rightarrow$ Increasing order in $\Theta$ not precise

| | |
|---|---|
| **a**<br>$P_{\text{Algol}} = 2.^{\text{d}}85$<br>$n_{\text{G}} =$ **GGG** days<br>**Unit vectors** $\mathbf{g}_{\text{i}}$ | **c**<br>$P_{\text{Moon}} = 29.^{\text{d}}6$<br>$n_{\text{G}} =$ **GGG** days<br>**Unit vectors** $\mathbf{g}_{\text{i}}$ |
| **b**<br>$P_{\text{Algol}} = 2.^{\text{d}}85$<br>$n_{\text{S}} =$ **SSS** days<br>**Unit vectors** $\mathbf{s}_{\text{i}}$ | **d**<br>$P_{\text{Moon}} = 29.^{\text{d}}6$<br>$n_{\text{S}} =$ **SSS** days<br>**Unit vectors** $\mathbf{s}_{\text{i}}$ |

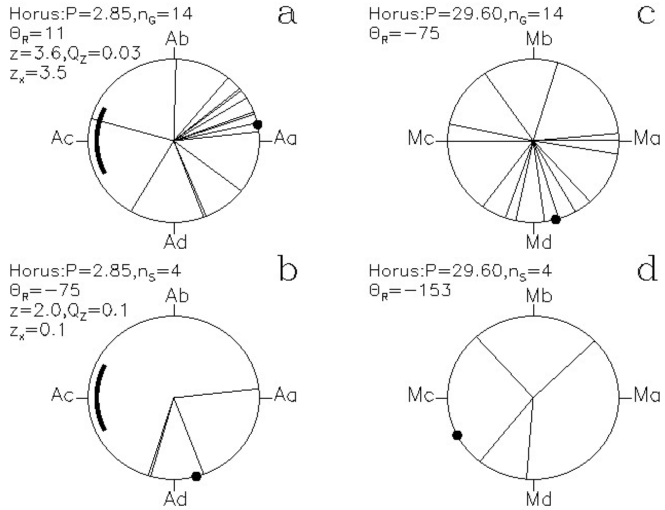
# 'Horus'

a **Strongest** connection to period $P_{\mathrm{Algol}} = 2.85$. 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 ☠




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

# 'Re'

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

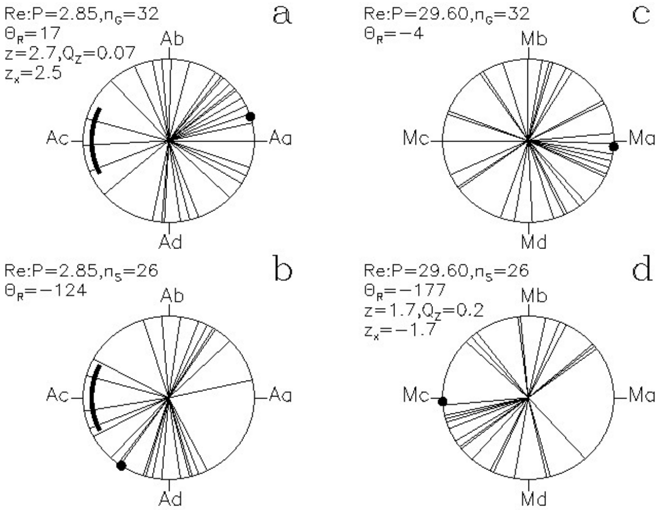
**b** No periodicity. Avoids Aa

**c** ☠

**d** Weak periodicity. Avoids Ma

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

...



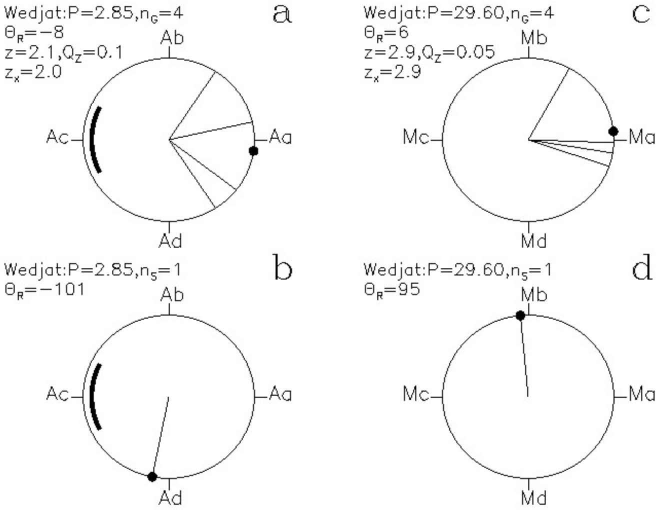
# 'Wedjat'

**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

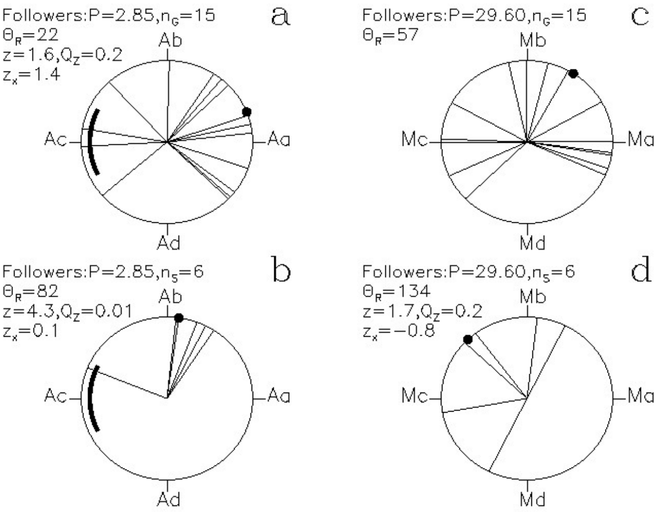
# 'Followers'

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

**b** **Before eclipse:**, not good! Concentration $Q_{\mathrm{B}} = 0.003$. **Pleaides** seem to **'follow'** very close to Algol as sky revolves

**c**

**d** Weak periodicity

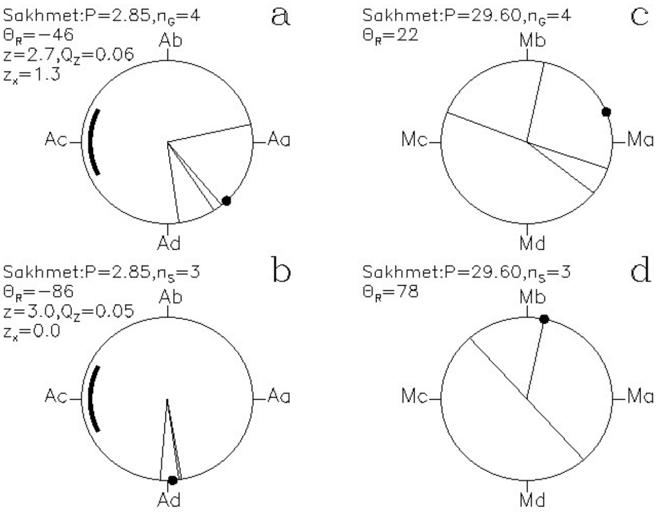


# ’Sakhmet’

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

b **After** eclipse, Anger: Not good! $Q_{\text{B}} = 0.0004$ 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:

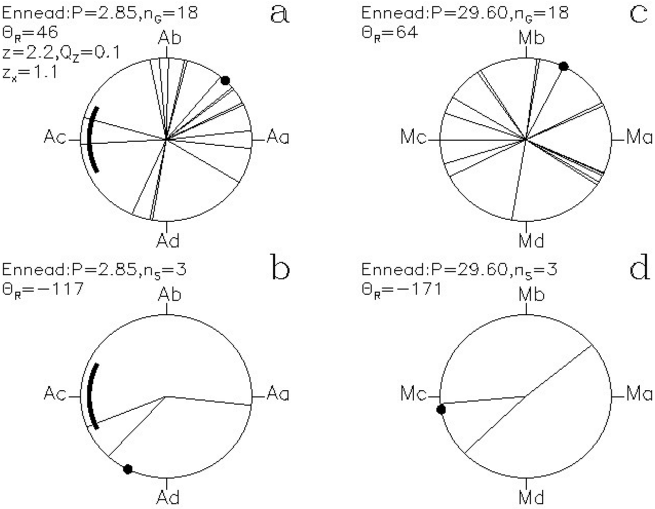


## 'Ennead'

a **6th strongest** connection to period $P_{\rm Algol} = 2.85$. Algol bright: good! $Q_{\rm B} = 0.02$

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

c & d ☠



## 'Earth'

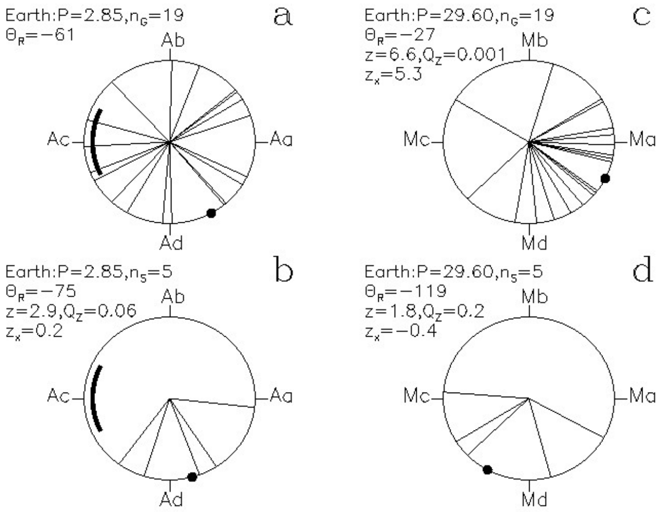
a ☠

b Weak periodicity. **After** Algol's eclipse: **'Sakhmet'**, **'Wedjat'**, ... ?

c

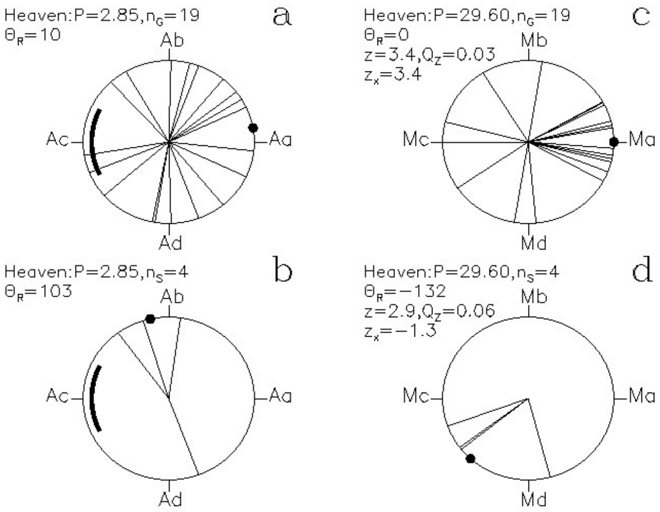
**Strongest** connection to period $P_{\mathrm{Moon}} = 29.6$. Good times on Earth at Ma = Full Moon

d Weak periodicity



## ' Heaven'

- a ☠
- b ☠
- c **2nd strongest** connection to period $P_{\rm Kuu} = 29.6$. Strong concentrar-tion $Q_{\rm B} = 0.002$. Good times in heaven at Ma = Full Moon
- d Weak periodicity. After Mc = New Moon



# ′Busiris′

Busiris is a site in Egypt and one of Osiris’ birthplaces

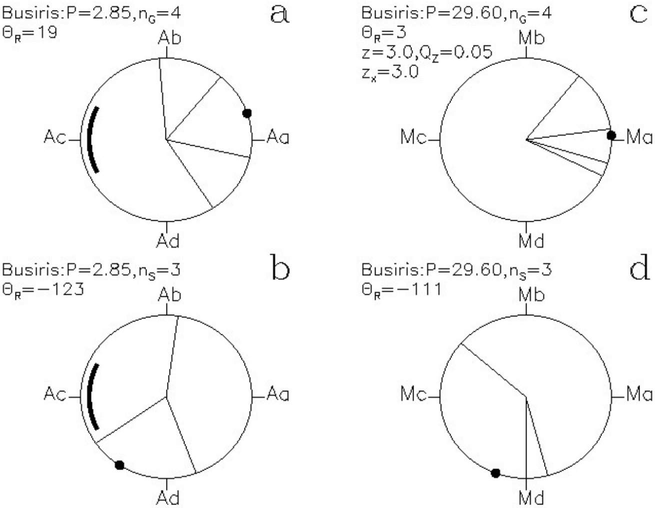
a ☠

b ☠

c

**3rd strongest** connection to period $P_{\rm Kuu} = 29.6$. Good time in Busiris at Ma = Full Moon

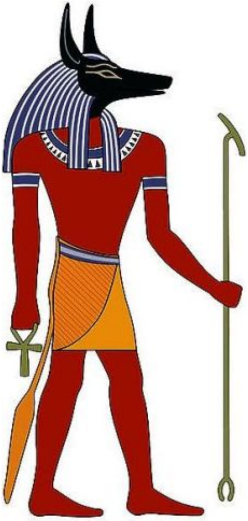
d ☠




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

- **Algol's 2.85 days signal** discovered **only in G** prognoses
  ⇒ Signal amplified **by GGG** prognoses of **'Horus'**, **'Re'**, **'Wedjat'**, **'Followers'**, **'Sakhmet'** **'Ennead'**
- **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
  ⇒ **SSS** prognoses of **'Heart'**, **'Nun'**, **'Seth'**, **'Osiris'**, **'Abydos'**, **'Lion'**, **'Man'** and **'Flame'** 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

**'Seth'** (@www.landofpyramids.org)



# 'Heart'

Connection to period $P_{\text{Algol}} = 2.85$

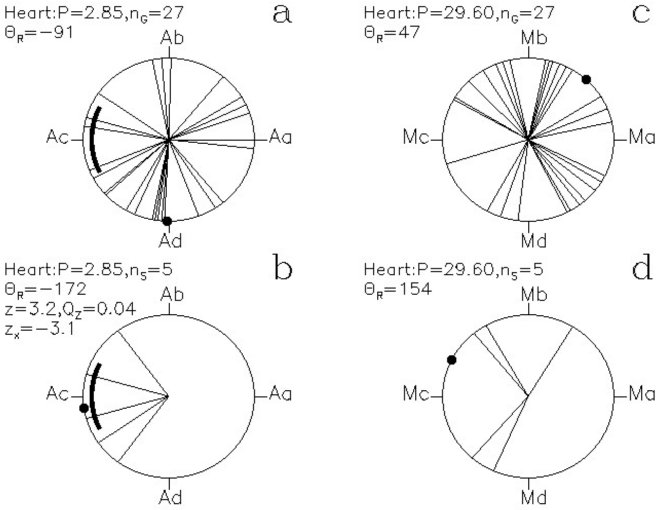
**Note:** This signal discovered in **G**, not in **S** prognoses

a ☠

b Periodicity. Bad times for **'Heart'** close to Ac = Algol's eclipse

c ☠

d ☠



# 'Seth'

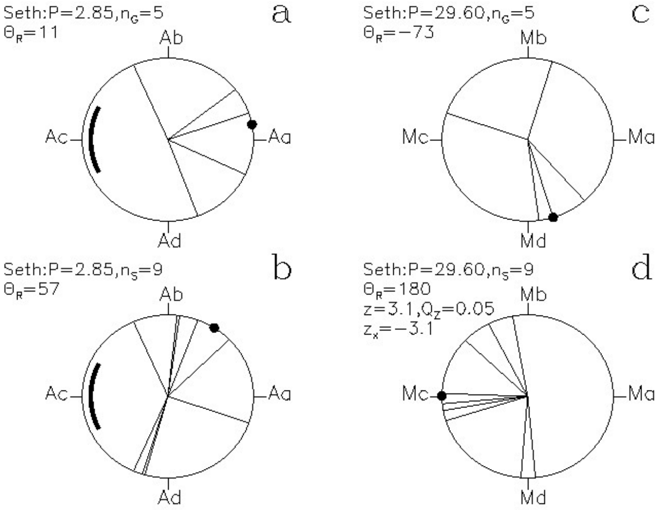
Connection to period $P_{\text{Moon}} = 29.6$
**Note:** This signal discovered in **G**, not in **S** prognoses

a ☠

b ☠

c ☠

d Periodicity. "See you on the dark side of the Moon."
Mc is **certainly** New Moon (Leitz).
$\Rightarrow$ Ma is **certainly** Full Moon.
**'Seth'** stops fighting with **'Horus'** between Md and Ma



## 'Osiris'

Connection to period $P_{\mathrm{Moon}} = 29.6$

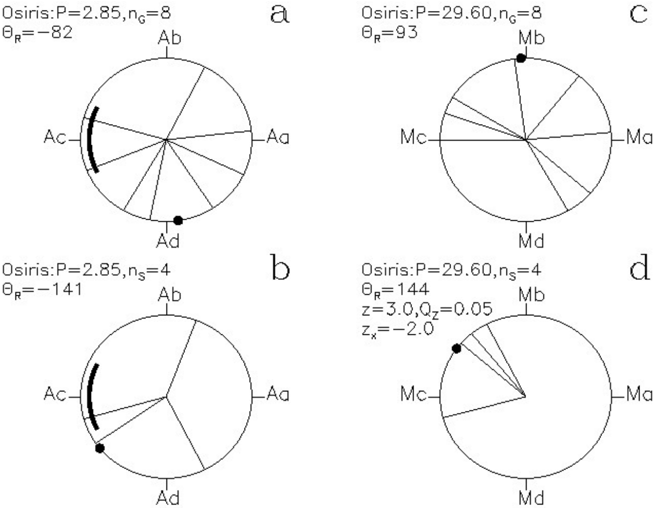
**Note:** This signal discovered in **G**, not in **S** prognoses

a

b

c

d Periodicity. Bad times close to Mc = New Moon. $Q_{\mathrm{B}} = 0.02$




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

## 'Man'

Connection to period $P_{\mathrm{Moon}} = 29.6$

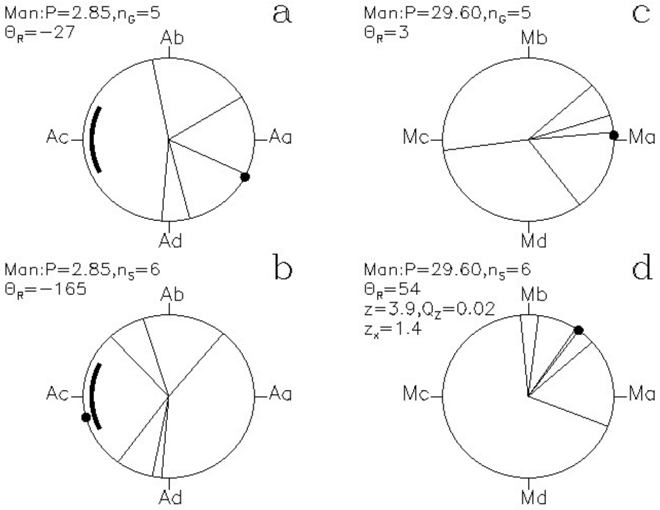
**Note:** This signal discovered in **G**, not in **S** prognoses

a

b

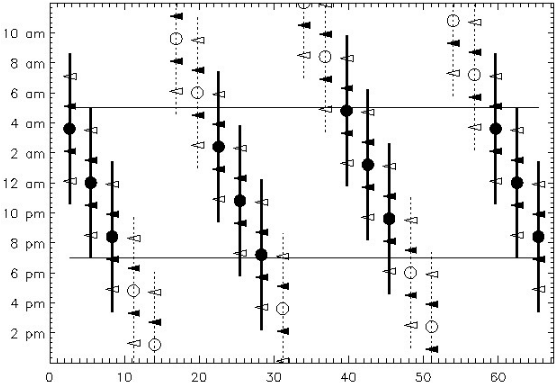
c

d Periodicity. Bad times after Ma = Full Moon. $Q_{\mathrm{B}} = 0.003$



# 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.

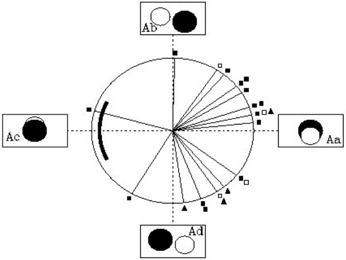
**LE2:** **Legend of Destruction of Mankind**: **'Re'** sends Eye of **'Horus'** ( **'Wedjat'** ) to punish mankind. **'Wedjat'** is transformed into the vengeful goddess **'Sakhmet'**. Other gods deceive **'Sakhmet'** to drinking human blood ("beer coloured red"). **'Sakhmet'** is pacified and mankind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

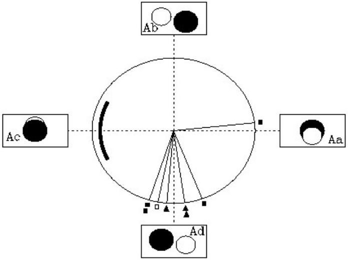
**Upper:** **GGG** **'Horus'** (■) **'Wedjat'** (□) **'Sakhmet '** (▲)

**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 $g_{\mathrm{i}}(7,9)$, where he *"smote him who rebelled"*, as in LE1 or LE2. The *"will is written"* for him in $g_{\mathrm{i}}(28,3)$ at the beginning of an eclipse – the only $\mathbf{g}_{\mathrm{i}}$ 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

## "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** $2.^{d}850$ in 1224 B.C.
5. Period has **increased** to $2.^{d}867$
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 nighly 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**