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Light Curve Analysis of a Recently Discovered Eclipsing Binary Star:

KAO-EGYPT J214258.21+440520.2

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DATE

Abstract

- New CCD light curves in V, Rc, and Ic bands
- Observations: September 27-28, 2016, using 1.88m telescope at Kottamia Astronomical Observatory, Egypt
- Analysis with Binary Maker 3.0 and PHOEBE
- Key Findings:
  - Semi-detached binary system
  - Orbital period: P = 0.617898 days
  - Mass ratio: q = 0.5491
  - Primary: G2 type (5830 K), Secondary: K3 type (4820 K)

Introduction

- System identified as Beta Lyrae—type eclipsing binary
- Multiple designations:
  - 2MASS J21425823+4405199
  - ASASSN-V J214258.14+440520.3
  - Gaia DR3 1973745009637804032
- Discovered during photometric monitoring of NOVA Cyg 1978 field
- Periodic variability with 0.617898 days period

Observations

- Telescope: 1.88m reflector at Kottamia Astronomical Observatory, Egypt
- Camera: EEV CCD 42-40 (2048×2048 pixels), liquid nitrogen cooled
- Filters: V, Rc, Ic
- Observatory Coordinates:
  - Latitude: 29°56'2.43" N
  - Longitude: 31°49'40.10" E
  - Elevation: 467 meters above sea level

Observed Stars

Table: Equatorial Coordinates

Star	UCAC4 ID	R.A.	Dec.
Variable (V1)	671-102525	21 42 58.234	+44 05 19.74
Comparison (C)	671-102430	21 42 40.450	+44 01 52.88
Check (K)	671-102408	21 42 37.652	+44 04 42.68

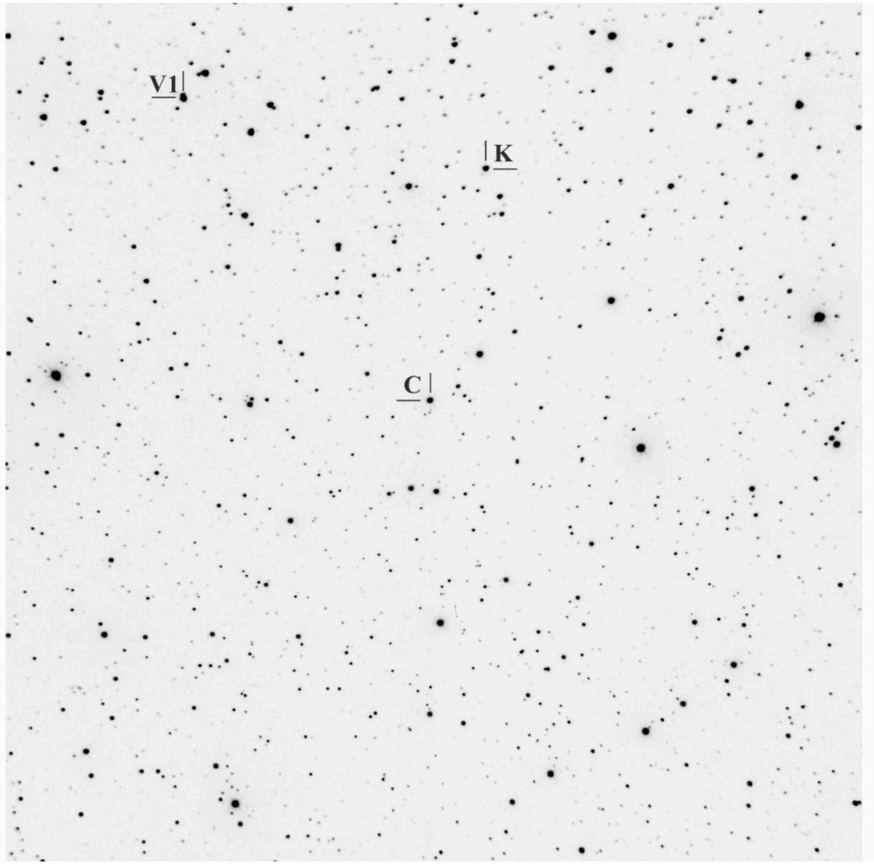

Fig. 1. *Finding chart showing the positions of the newly discovered variable star (V1), the comparison star (C), and the check star (K).*

Ephemeris & Light Curves

- Epoch of Primary Minimum: HJD 2457660.4129 ± 0.0012
- Orbital Period: 0.617898 ± 0.00272 days

Ephemeris:

HJD (Min. I) = 2457660.4129 + 0.617898 × E

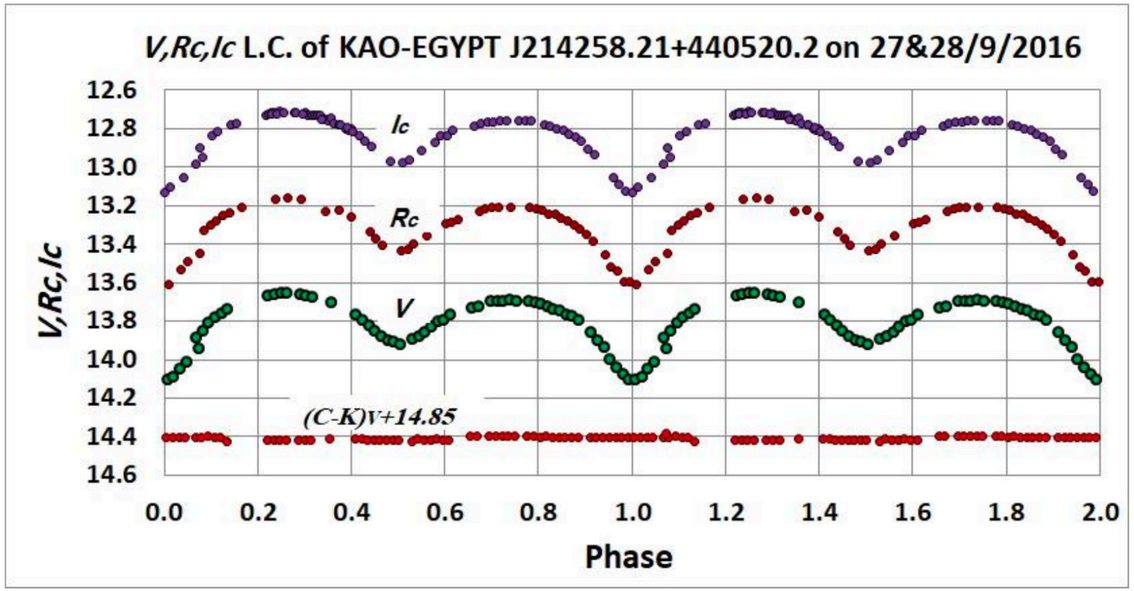

Fig. 2. *Phased light curve of the newly discovered variable star KAO-EGYPT J214258.21+440520.2 (V1) in the V, Rc, Ic filters, plotted alongside the differential magnitude [(C–K) + 14.7]*

Light Curve Modeling

Binary Maker 3.0 Analysis:

- No spectroscopic radial velocity data available
- Used parameters from similar systems in CALEB database
- Iterative fitting to match V-band data
- Temperature estimation using (V-R) color index
  - (V-R) = 0.48978 → $T_{eff} \approx 5830$ K
- Primary temperature fixed at 5830 K
- Secondary temperature adjusted iteratively

Mass Ratio Determination

q-search Method (Deb et al. 2010):

- Tested mass ratios from q = 0.10 to 1.00
- Calculated sum of squared residuals for each model
- Minimum residuals at q = 0.549
- Adopted photometric mass ratio: q = 0.5491

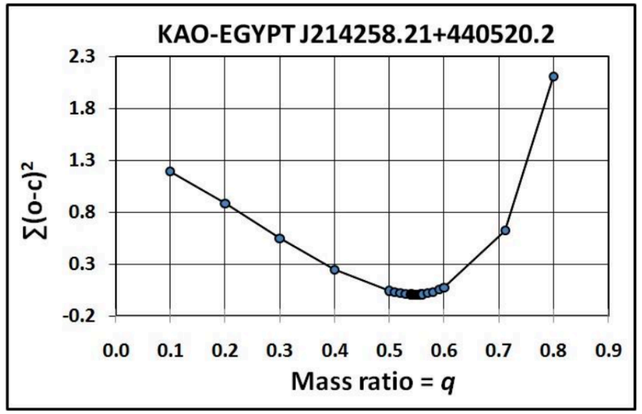

Fig. 3. *The q-search diagram for the eclipsing binary system V1, showing the variation of the sum of squared residuals with different assumed mass ratios (q). The minimum value corresponds to the most probable photometric mass ratio*

PHOEBE Analysis

PHOEBE Package (Version 0.31a):

- Adopted semi-detached binary model
- Parameters:
  - Albedos: A1 = A2 = 0.5
  - Gravity darkening: g1 = g2 = 0.32
  - Limb darkening: Linear cosine law (Van Hamme 1993)
- Adjusted parameters: i, T2, Ω1, Ω2, q, L1, L2

Photometric Solution Results

Key Parameters:

- Secondary temperature: 4820.64 ± 79.10 K
- Orbital inclination: 74.002° ± 0.531
- Mass ratio: 0.5491
- Fillout factors: Primary ≈ -0.0026, Secondary ≈ -0.116
- Luminosity ratios:
  - V-band: L1/(L1+L2) = 0.8755
  - Rc-band: L1/(L1+L2) = 0.8606
  - Ic-band: L1/(L1+L2) = 0.8426

System Configuration

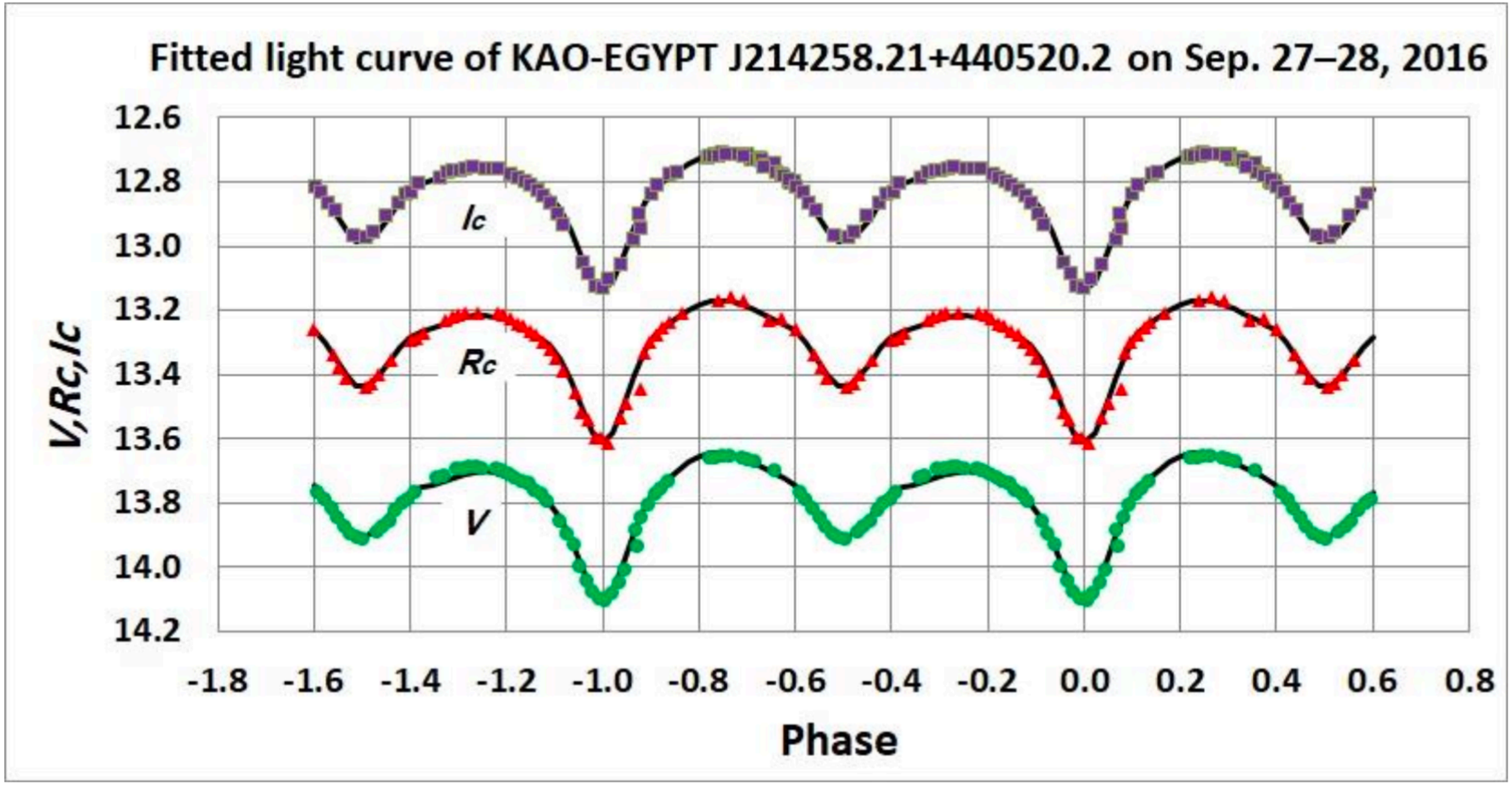

Fig. 4. *Observed light curves of KAO-EGYPT J214258.21+440520.2 in the V, Rc, and Ic bands (dots), shown together with the best-fitting synthetic curves (solid lines) obtained from the PHOEBE model*

Roche Geometry

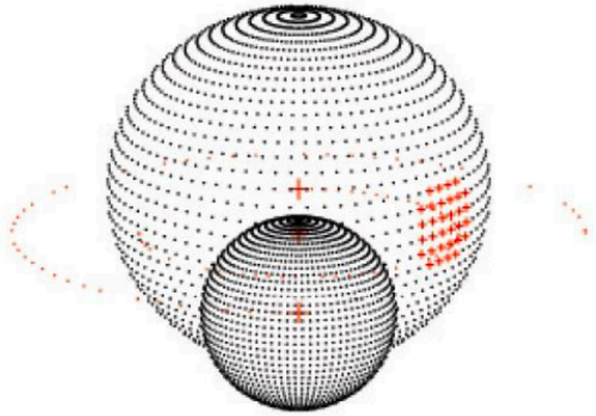

Fig. 5: Phase 0.0

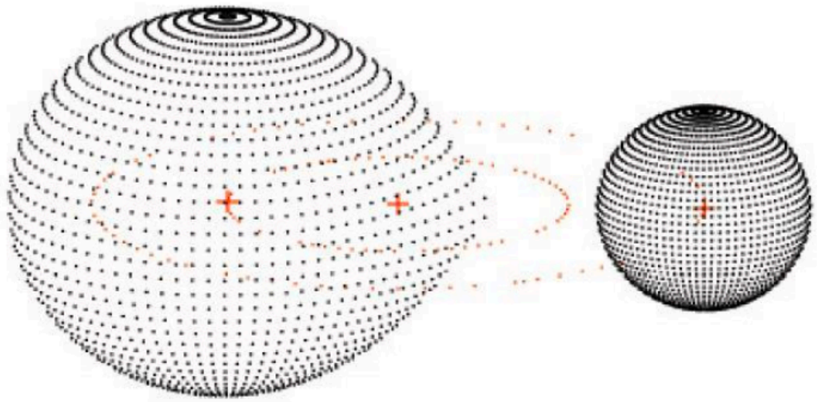

Fig. 6: Phase 0.25

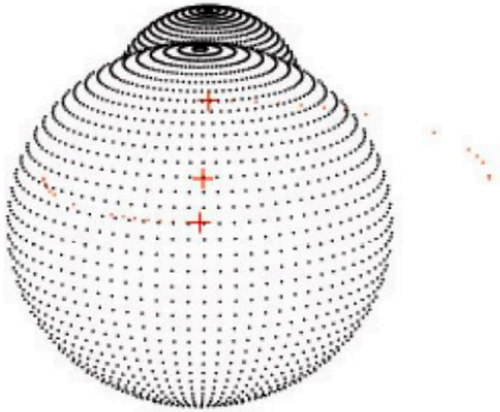

Fig. 7: Phase 0.50

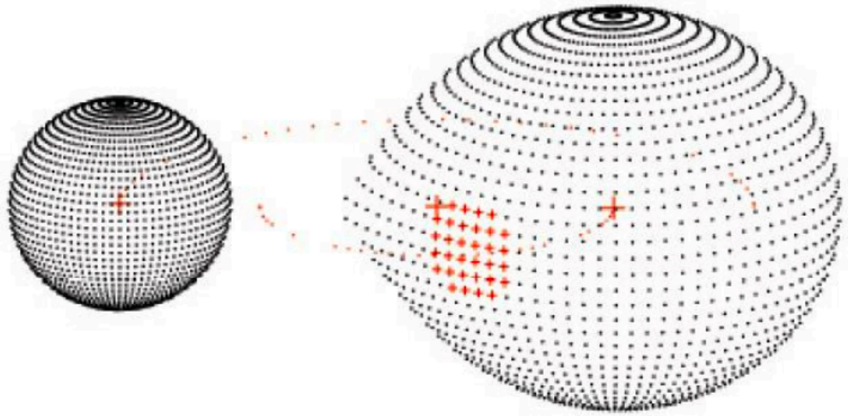

Fig. 8: Phase 0.75

Absolute Parameters

Using Harmanec (1988) empirical relations:

Parameter	Primary	Secondary
Mass ($M_\odot$)	1.106 ± 0.050	0.619 ± 0.125
Radius ($R_\odot$)	1.618 ± 0.092	0.957 ± 0.055
Luminosity ($L_\odot$)	2.711 ± 0.359	0.443 ± 0.063
Log g (cm/s^2)	4.072 ± 0.062	4.268 ± 0.101

Distance: ~1099 pc (~3585.5 light-years)

Evolutionary Status

Stellar Components:

- Primary: G2 type, 1.106 $M_\odot$, 1.618 $R_\odot$, 2.711 $L_\odot$
- Secondary: K3 type, 0.619 $M_\odot$, 0.957 $R_\odot$, 0.443 $L_\odot$

Evolutionary Status:

- Both components near Terminal Age Main Sequence (TAMS)
- Estimated age: ~7.6 billion years
- Semi-detached configuration
- Primary fills its Roche lobe

Evolutionary Diagrams

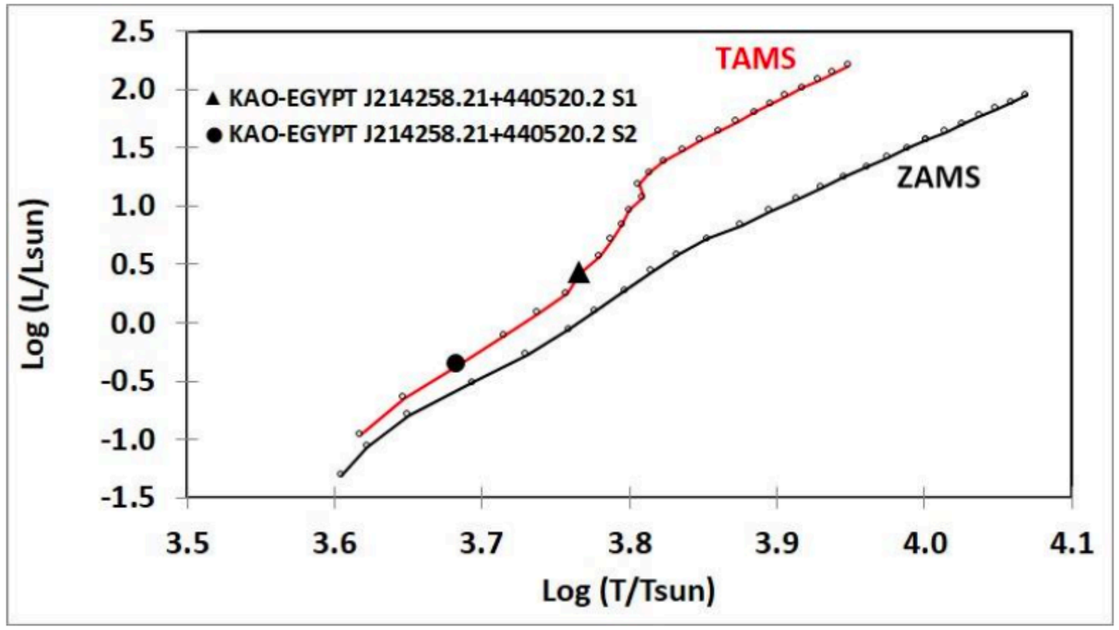

Fig. 10: Log T-Log L diagram

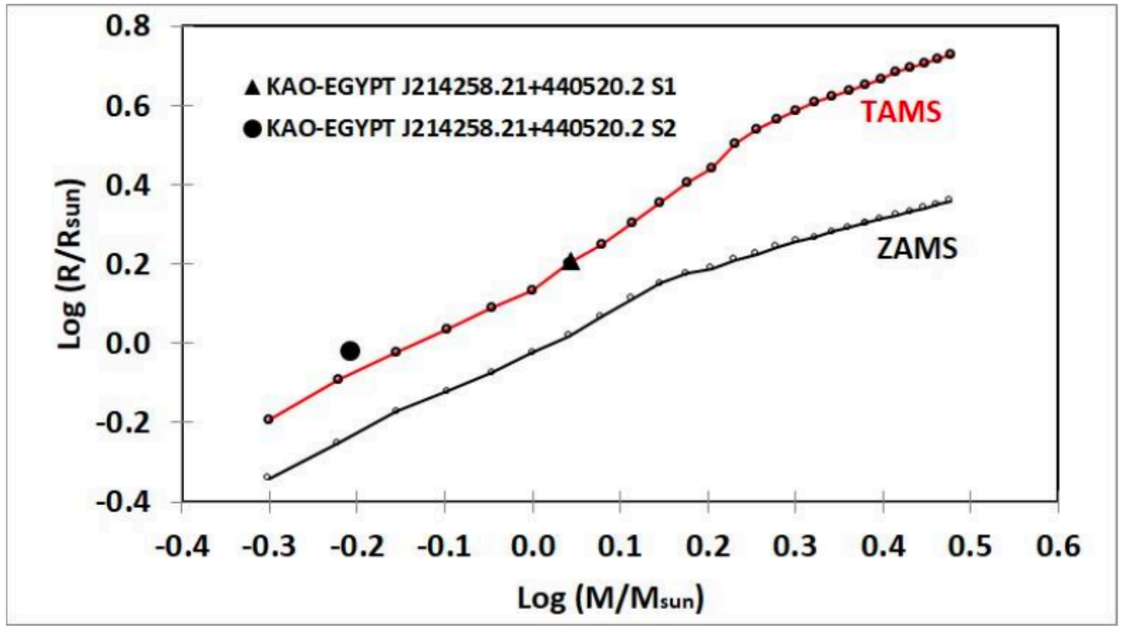

Fig. 11: Log M-Log R diagram

Evolutionary Diagrams

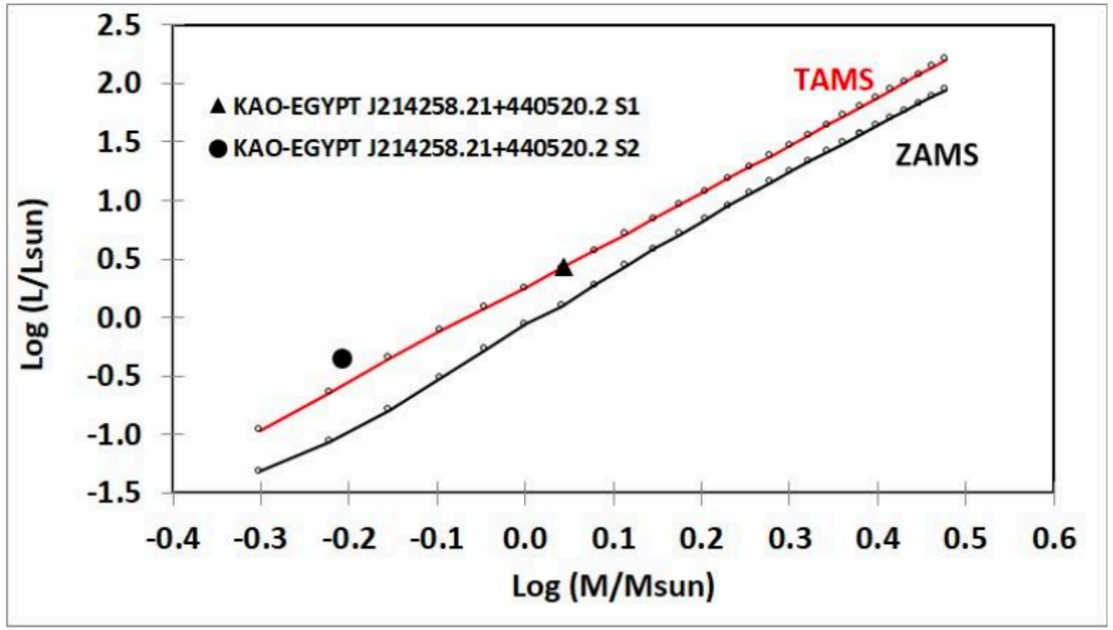

Fig. 12: Log M-Log L diagram

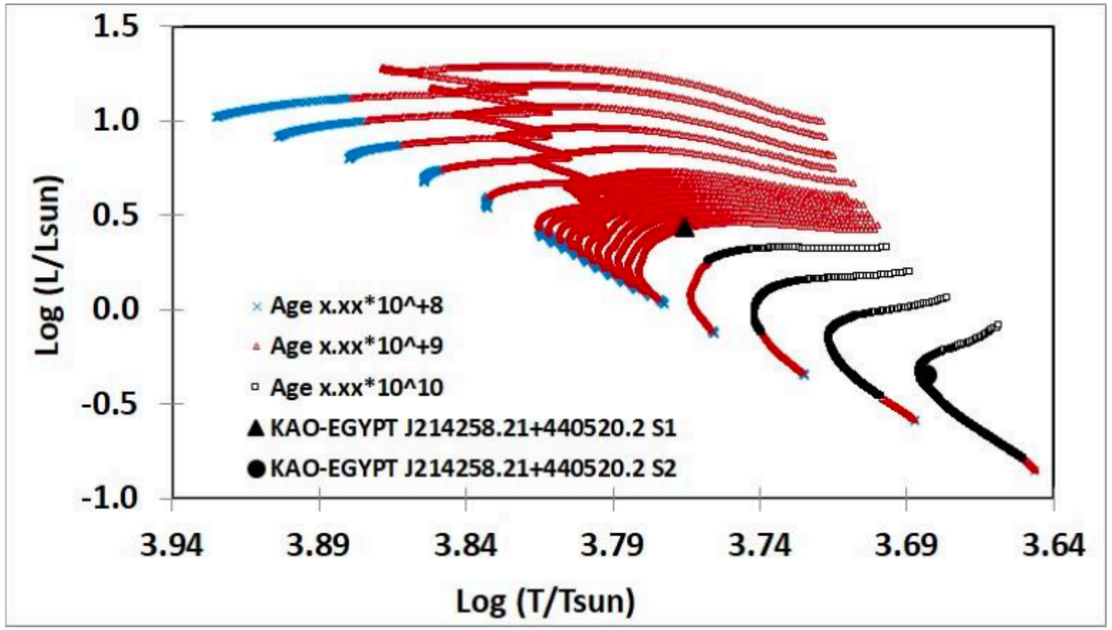

Fig. 13: Log T-Log L isochrones diagram

Conclusions

- First comprehensive analysis of KAO-EGYPT J214258.21+440520.2
- Semi-detached Beta Lyrae -type binary system
- Orbital period: 0.617898 days, Mass ratio: 0.5491
- Primary: G2 type (5830 K), Secondary: K3 type (4820 K)
- Evolved system (~7.6 Gyr) with primary near TAMS
- Distance: ~1099 parsecs

Limitations & Future Work

Limitations:

- No radial velocity data → uncertain mass ratio and absolute parameters
- Reliance on photometric methods only

Future Work:

More detailed analysis using PHOEBE 2 (already started)

- High-resolution studies for tidal effects
- Chemical composition analysis
- Verification of mass transfer processes

Thank You

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