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The binary asteroid 22 Kalliope: Linus orbit determination on the basis of speckle interferometric observations

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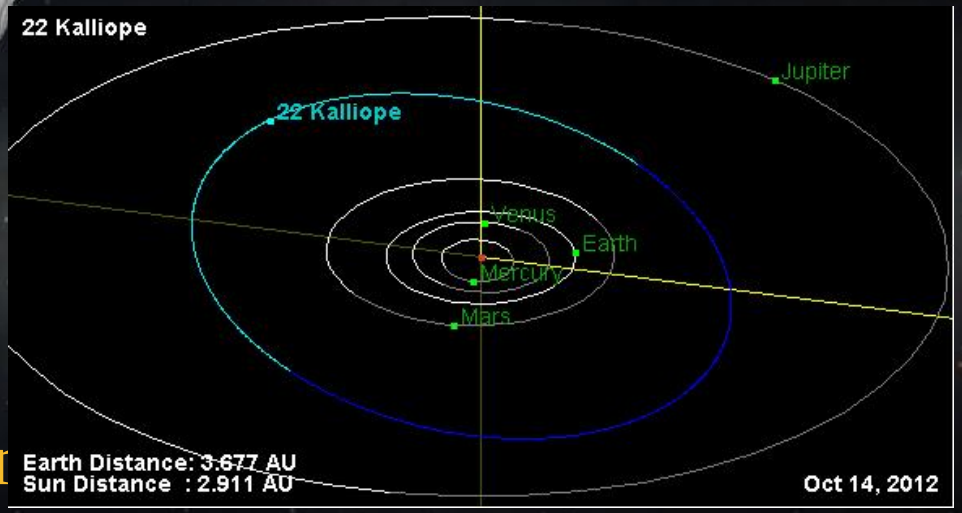
Binary asteroid 22 Kalliope

22 Kalliope - M-type asteroid from the Main asteroid belt discovered by J. R. Hind on November 16, 1852 in the Bishop' Observatory (UK). At the 29 August 2001 y. Michael E. Brown and Jean-Luc Margot discovered satellite of 22 Kalliope with the use Keck-II telescope and Adaptive Optic. This satellite was named Linus in honor Lin, the son of Kalliope.



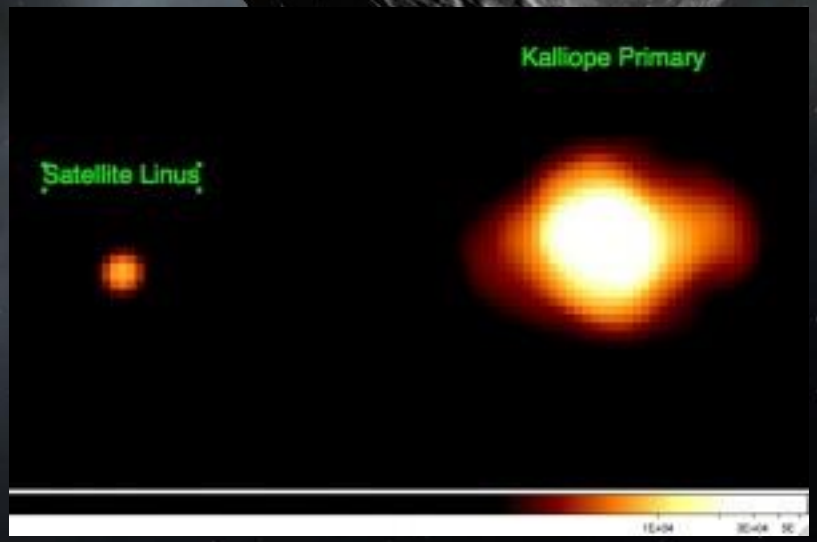
Main parameters:

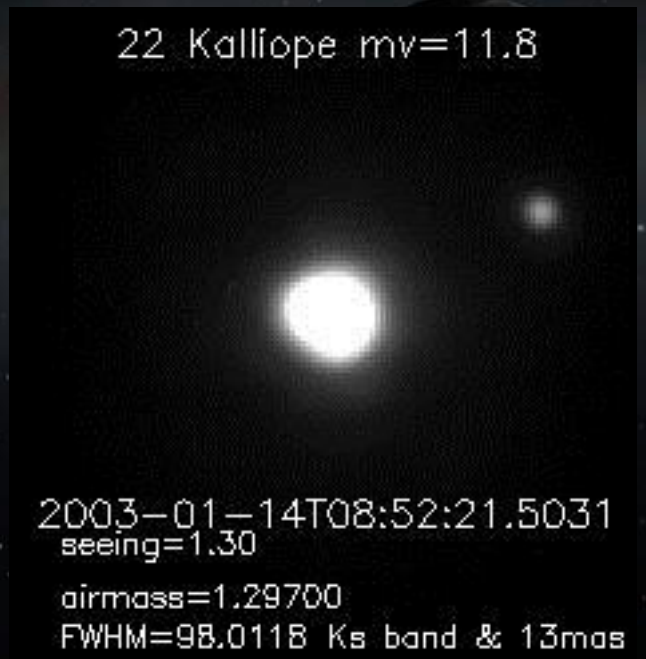
Diameter of Kalliope ≈ 167 km

Diameter of Linus ≈ 28 km

Investigation of binary and multiple asteroids

- Adaptive optic
- Photometry
- Radar Observations
- IR-observations
- Speckle interferomery



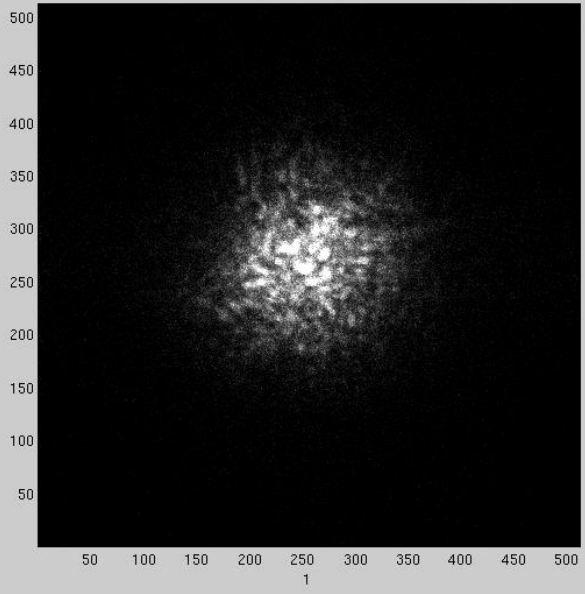


Speckle-interferometry of 22 Kalliope asteroid with the 6-meter BTA telescope (SAO)

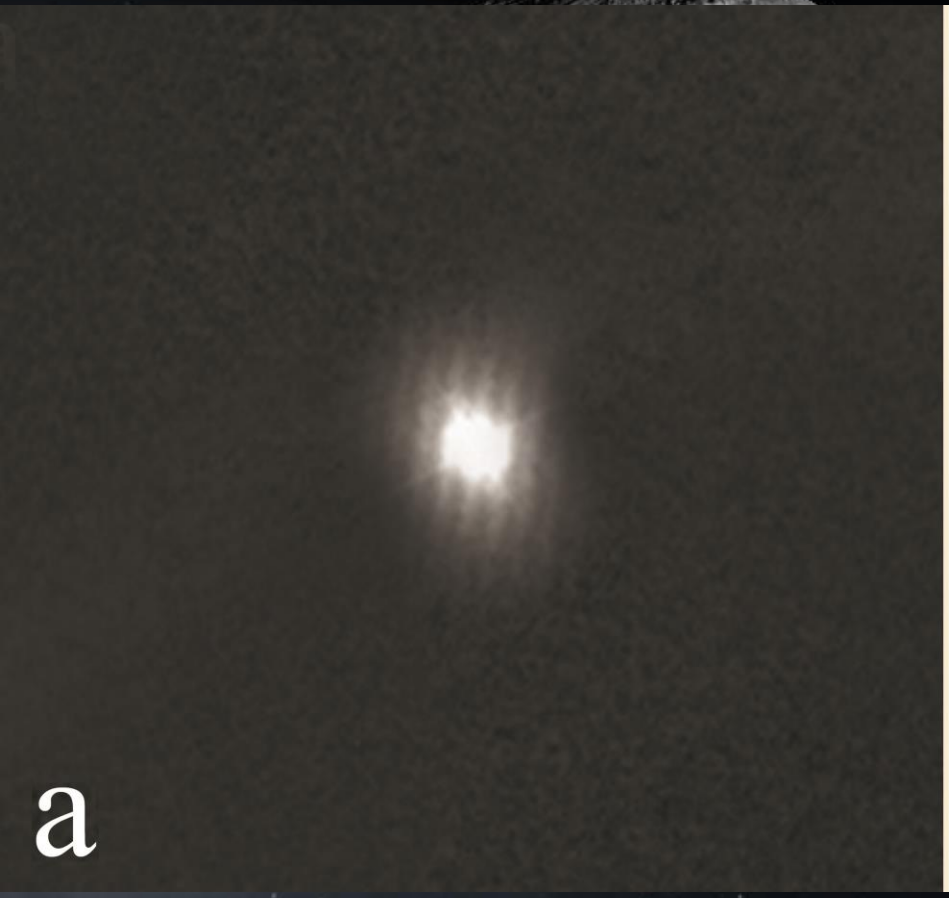
The observations were carried out at the period from December, 10 till December, 16 of 2011 y.
During this period we processed 9 accurate positions of Linus orbiting around the main component of 22 Kalliope

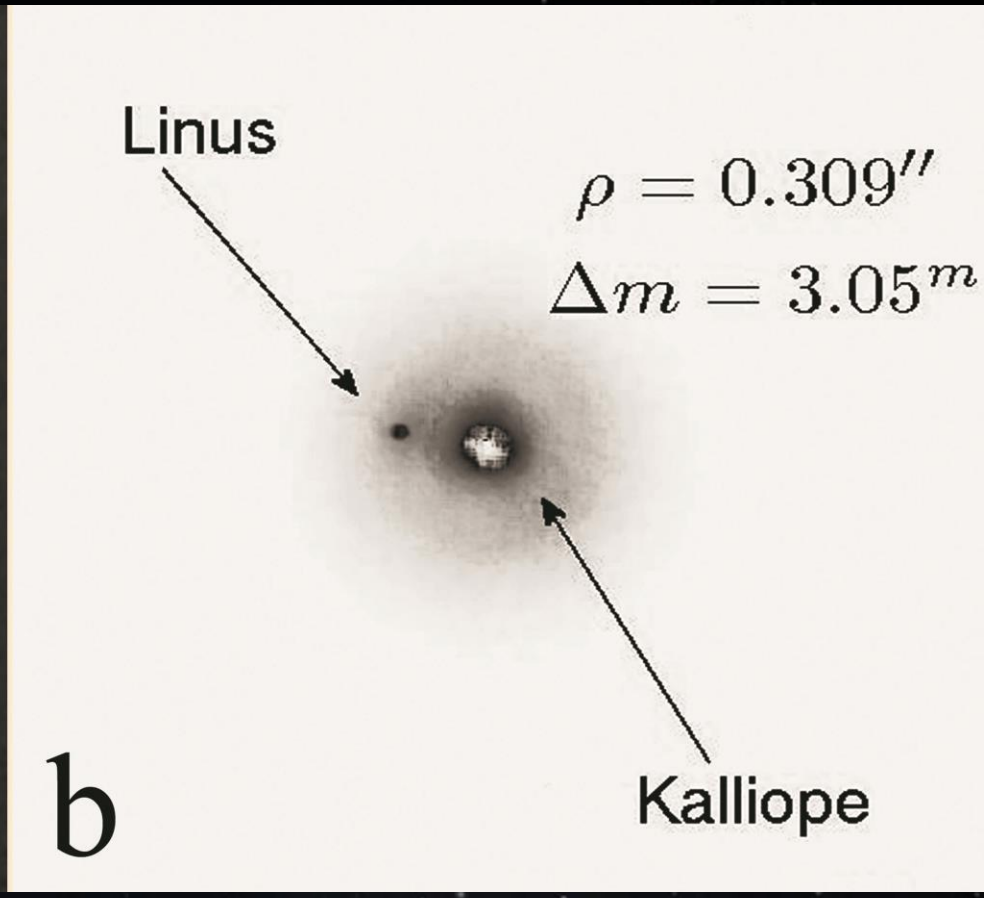
Table 1. The Linus observational data: separation, positional angle, magnitude difference, their errors.

Date, time	ρ, mas	σ_ρ, mas	θ, deg	σ_θ, deg	Δm, mag	$\sigma_{\Delta m}$, mag	λ, nm
2011 December 10, $21^h\,59^m$	398	16	336.2	2.3	3.21	0.17	800
2011 December 11, $01^h\,14^m$	567	10	345.9	1.0	3.20	0.11	800
2011 December 12, $23^h\,42^m$	724	22	171.1	1.7	3.18	0.14	800
2011 December 13, $02^h\,36^m$	801	13	174.0	1.0	3.34	0.14	800
2011 December 13, $21^h\,26^m$	530	7	195.2	0.8	3.35	0.08	800
2011 December 15, $20^h\,52^m$	509	4	33.5	0.8	3.05	0.09	800
2011 December 16, $00^h\,49^m$	181	7	86.0	2.2	2.47	0.13	600
2011 December 16, $00^h\,54^m$	184	7	86.9	2.1	3.03	0.13	800
2011 December 16, $03^h\,27^m$	236	7	128.9	1.7	3.19	0.14	800



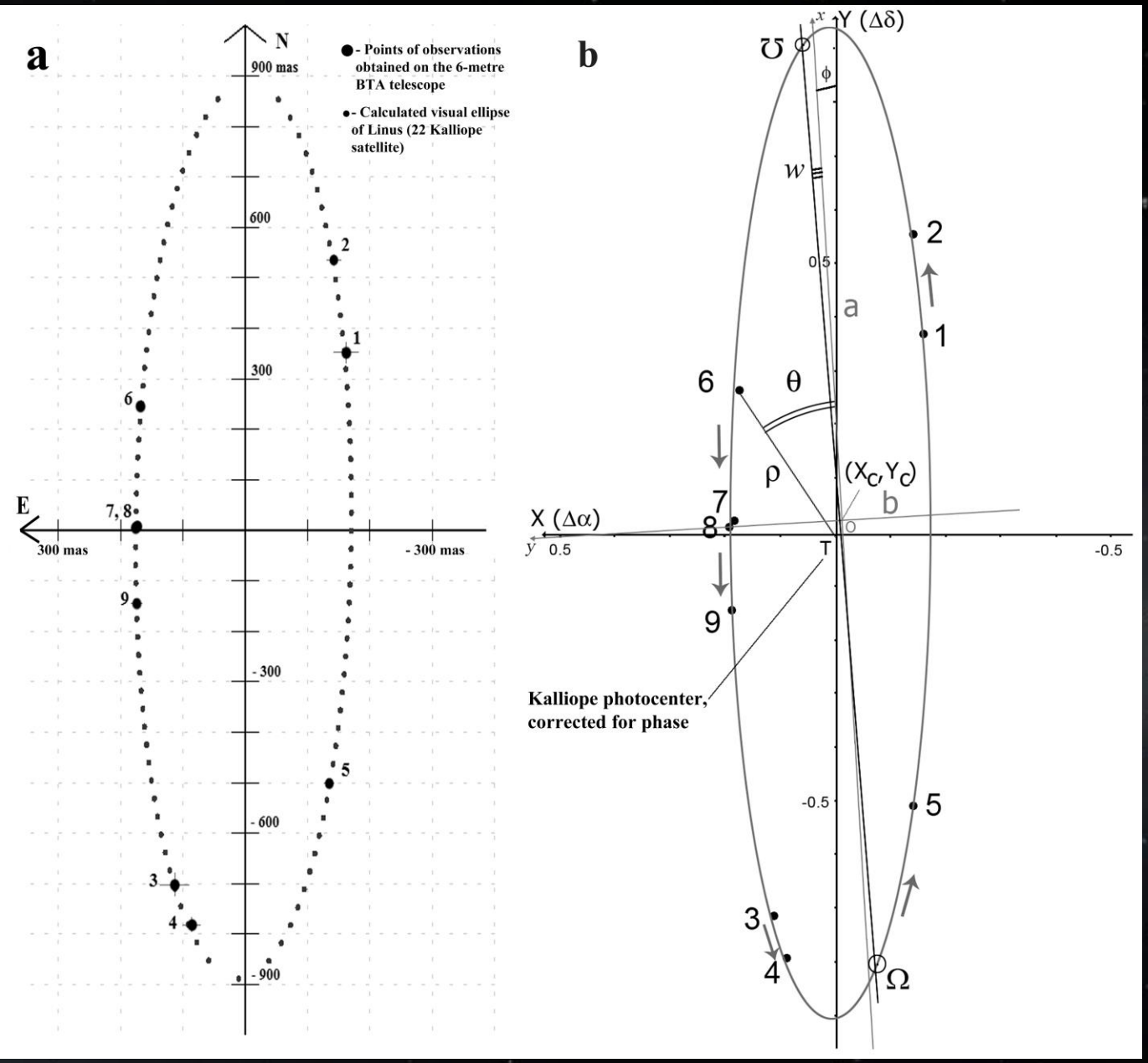
Speckle-interferometry of 22 Kalliope asteroid with the 6-meter BTA telescope (SAO)





a) The example of power spectrum of the binary asteroid 22 Kalliope obtained with the use speckle interferometer at the 6-m BTA telescope. b) The reconstructed image of satellite Linus and its main component 22 Kalliope. Angular distance between the components and apparent magnitude differences are given.

Determination of a visible orbit of satellite Linus



For determination of visible orbit we applied Least squares method accounting 4 significant corrections to the observed positions:

1. correction for phase effect;
2. correction for geocentric distance change (scale);
3. correction to positional angle for change of local direction to celestial pole;
4. correction for change of inclination of Linus radius-vector to the picture plane.

Determination of a visible and true orbit of satellite Linus

Table 3. Initial data for direct geometrical method

Semi-major axis *a*	mas	907.2 ± 5
Semi-minor axis *b*	mas	176.7 ± 5
Positional angle of semi-major axis *a*	deg	0.5 ± 0.4
Distance between apparent ellipse centre and photocenter of 22 Kalliope	mas	2.5 ÷ 3.4
α — angle between the of semi-major axis *a* and direction toward photocenter of 22 Kalliope	deg	60 ÷ 100

For determination of the true ellipse of Linus orbit we used direct geometrical method, developed by A. A. Kiselev in Pulkovo Observatory

Table 4. The true ellipse parameters

Semi-major axis *A*	mas	907.3 ± 5
Semi-minor axis *B*	mas	907.2 ± 5
Eccentricity *E*		0.016 ± 0.004
Inclination *i*	deg	78.77 ± 0.1
w — angle between nodes line and *Ox* axis	deg	0.5 ± 0.1
Ω — ascending node positional angle (*w* + 180°)	deg	180.5 ± 0.1
Periastron longitude ω (from Ω)	deg	88.14 ± 3

An determination of a visible and true orbit of satellite Linus

Table 5. Linus orbital parameters in ecliptic coordinate system

Orbital parametres	Our results	P.Descamps et al, 2008	F. Vachier et al, 2012
Semi-major axis	$a = 907.3 \pm 5$ mas = 1109 ± 6 km	1099 ± 11 km	1082 ± 33 km
Semi-minor axis	$b = 907.2 \pm 5$ mas = 1109 ± 6 km		
Eccentricity	$e = 0.016 \pm 0.004$		0.0069 ± 0.03
Periastron longitude (in local astrocentric system)	$\omega = 88° \pm 3°$		
Periastron passage time	$T_p = 2011.94359 \pm 0.00002$ year		
Ecliptic coordinate of the orbital pole	$\beta = -11° \pm 2°$ $\lambda = 190° \pm 2°$	$\beta = -3° \pm 2°$ $\lambda = 197° \pm 2°$	
Ecliptic coordinate of the periastron	$\beta = -51° \pm 3°$ $\lambda = 295° \pm 3°$		
Longitude of the ascending node	$\lambda = 281° \pm 1°$	$284.5° \pm 2.0°$	$285.05° \pm 2.11°$
Inclination	$i = 101° \pm 1°$	$99.4° \pm 0.5°$	$94.18° \pm 1.92°$

Conclusion:

1. **We obtained instantaneous orbit of the 22 Kalliope satellite for the mean epoch of observation (2011 December 14, 00h 04m) using the speckle interferometry method for separating asteroid components and the direct geometric method for calculating of the true ellipse of an orbit.**

2. **We have obtained the full range of the elements of Linus orbit; furthermore, the orbital elements that were previously measured by other researches are in good agreement with the results of this research. However, slight differences might attest to the fact that Linus' orbit experiences moderate perturbations. The suggested methods of instant orbital calculation of asteroid satellites will allow monitoring changes in the measured orbits over the course of time.**


Thank You for attention!