Conjunctions and microlensing events in α Centauri

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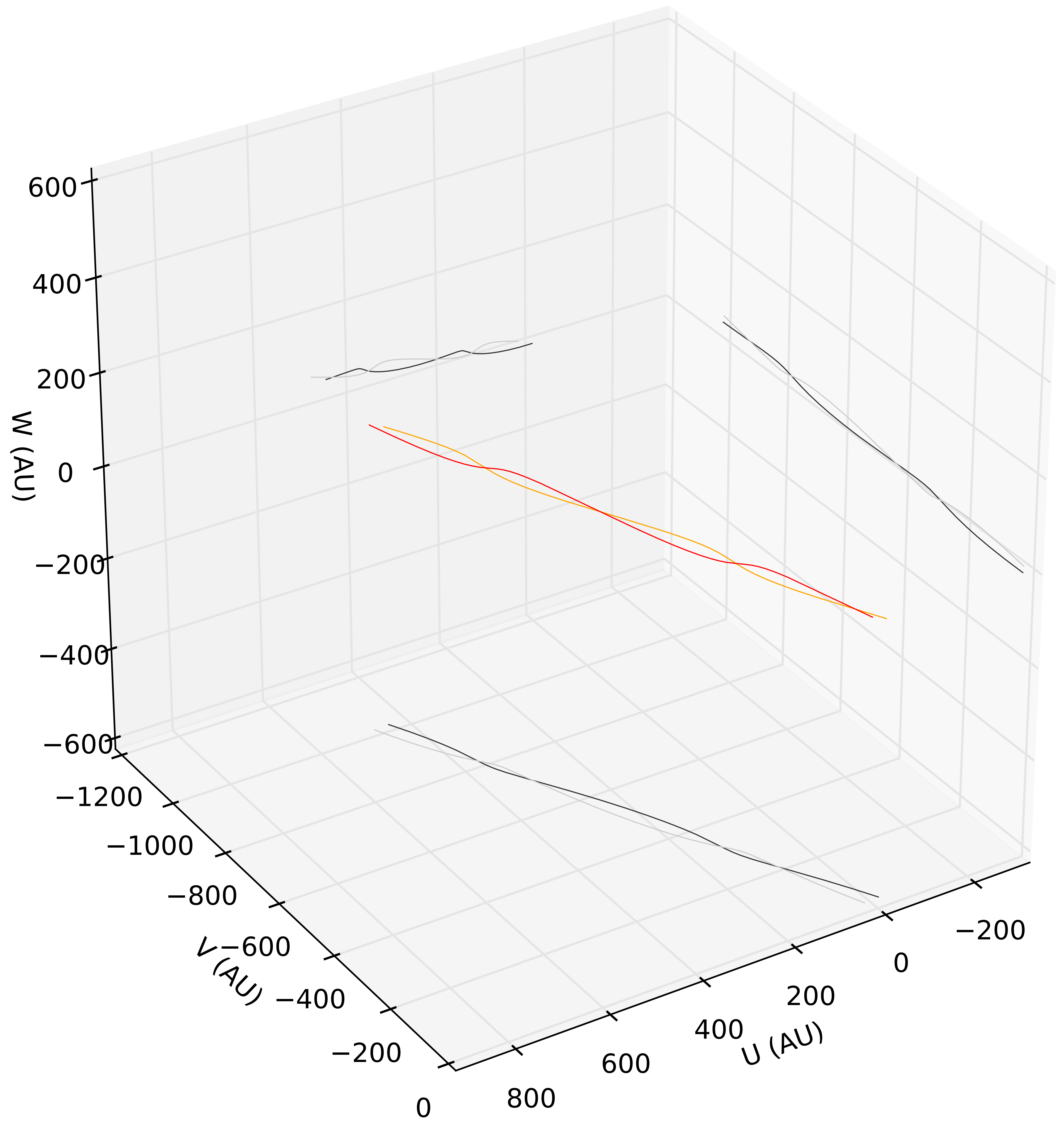
Photo: ESO/B. Tafreshi (twanight.org)/Digitized Sky Survey 2

Where is α Cen ?

Image: ESO/S. Brunier

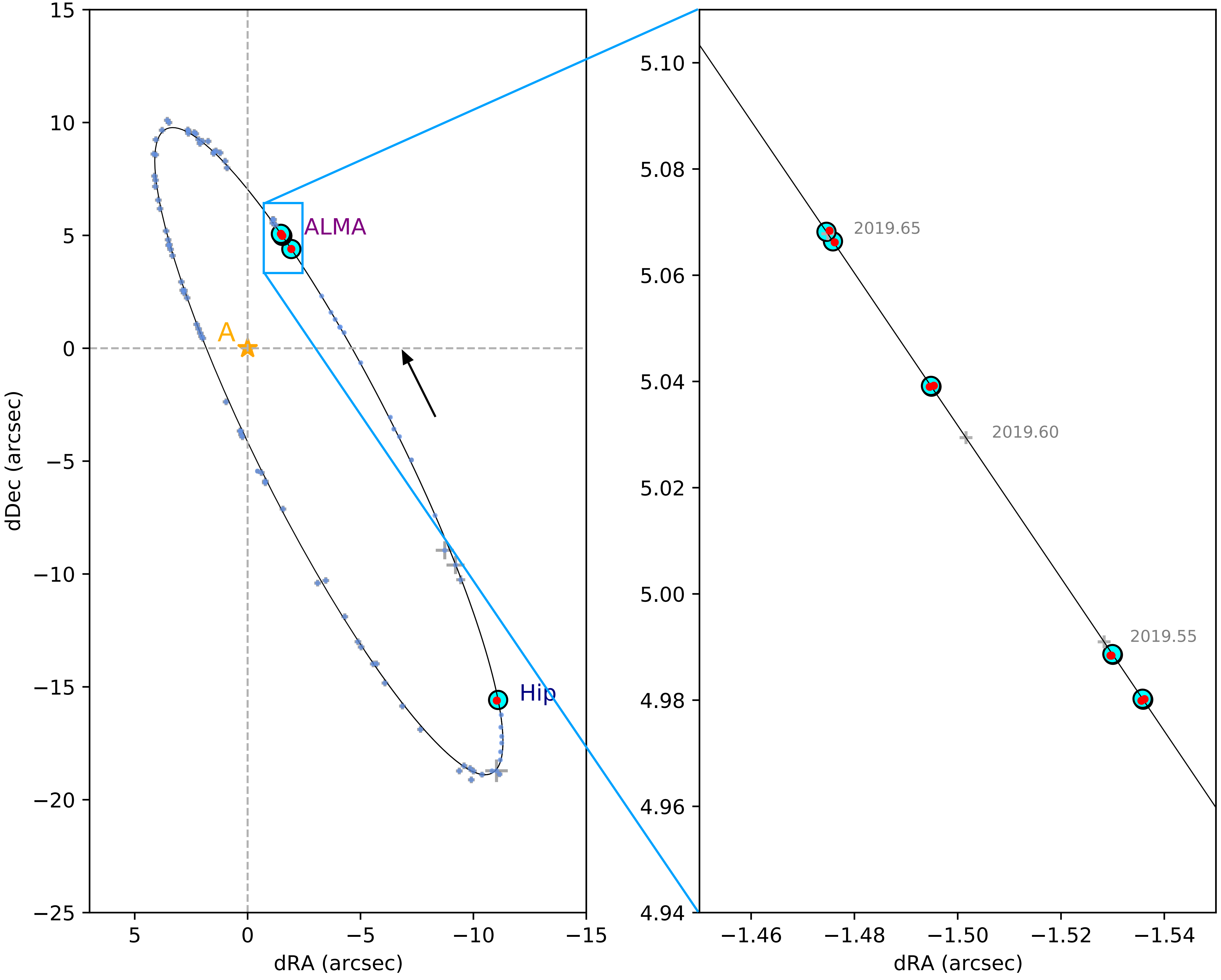
Sky trajectory of α Cen AB



- Accurate orbital parameters, orbital parallax and barycentric proper motion
- The apparent motion of α Cen is relatively complex: proper motion + orbital motion + parallactic wobble + perspective effects

α Cen AB's orbit

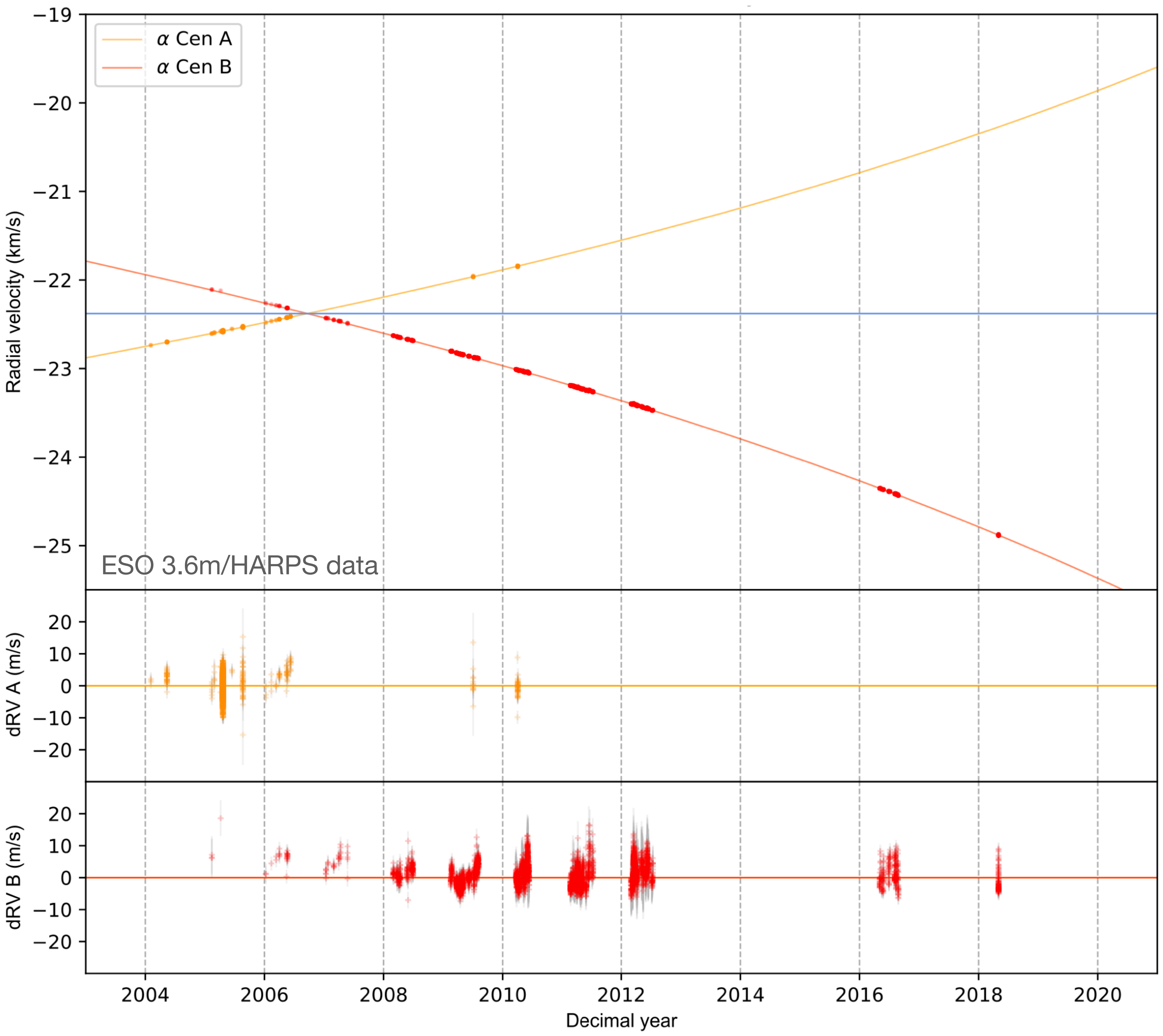
- The extreme brightness of the two stars is *not* an advantage to measure their positions
- Addition of high precision radial velocities (HARPS)
- Orbital fit provides high accuracy stellar masses (0.4%) and parallax (0.05%)



Kervella et al. (2016, A&A 594, A107)
Akeson et al. (2021, AJ, 162, 14)

Radial velocities of α Cen A & B

- Barycentric radial velocity = -22.4 km/s
- Final accuracy on AB barycenter velocity of **± 5 m/s**
- Orbital fit provides high accuracy stellar masses (0.4%) and parallax (0.05%)



Akeson et al. (2021, AJ, 162, 14)

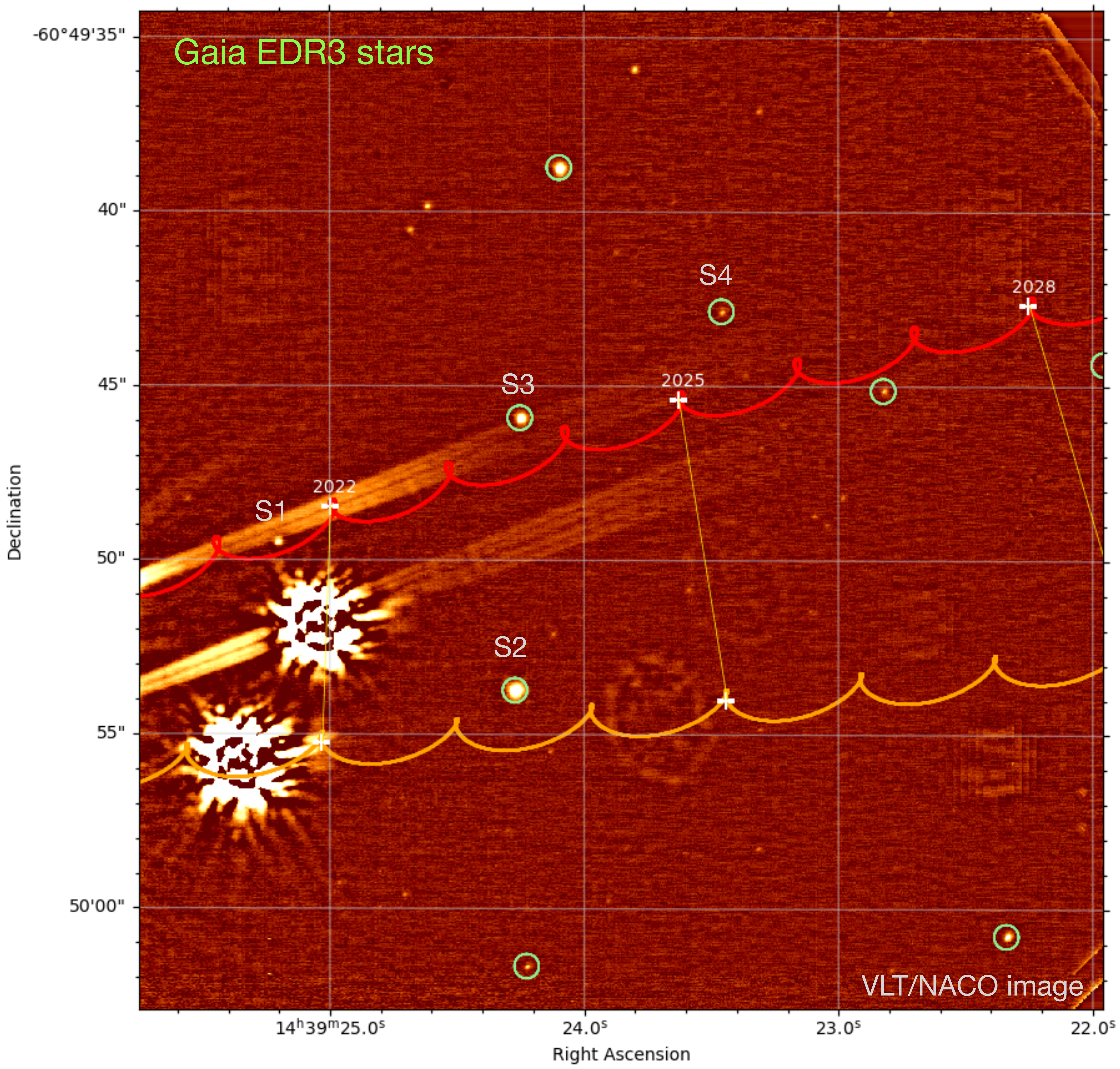
The apparent trajectory of α Centauri AB

- Combination of fast **proper motion, orbital motion** (80 years period) and *large* **parallactic wobble**

Stellar conjunctions

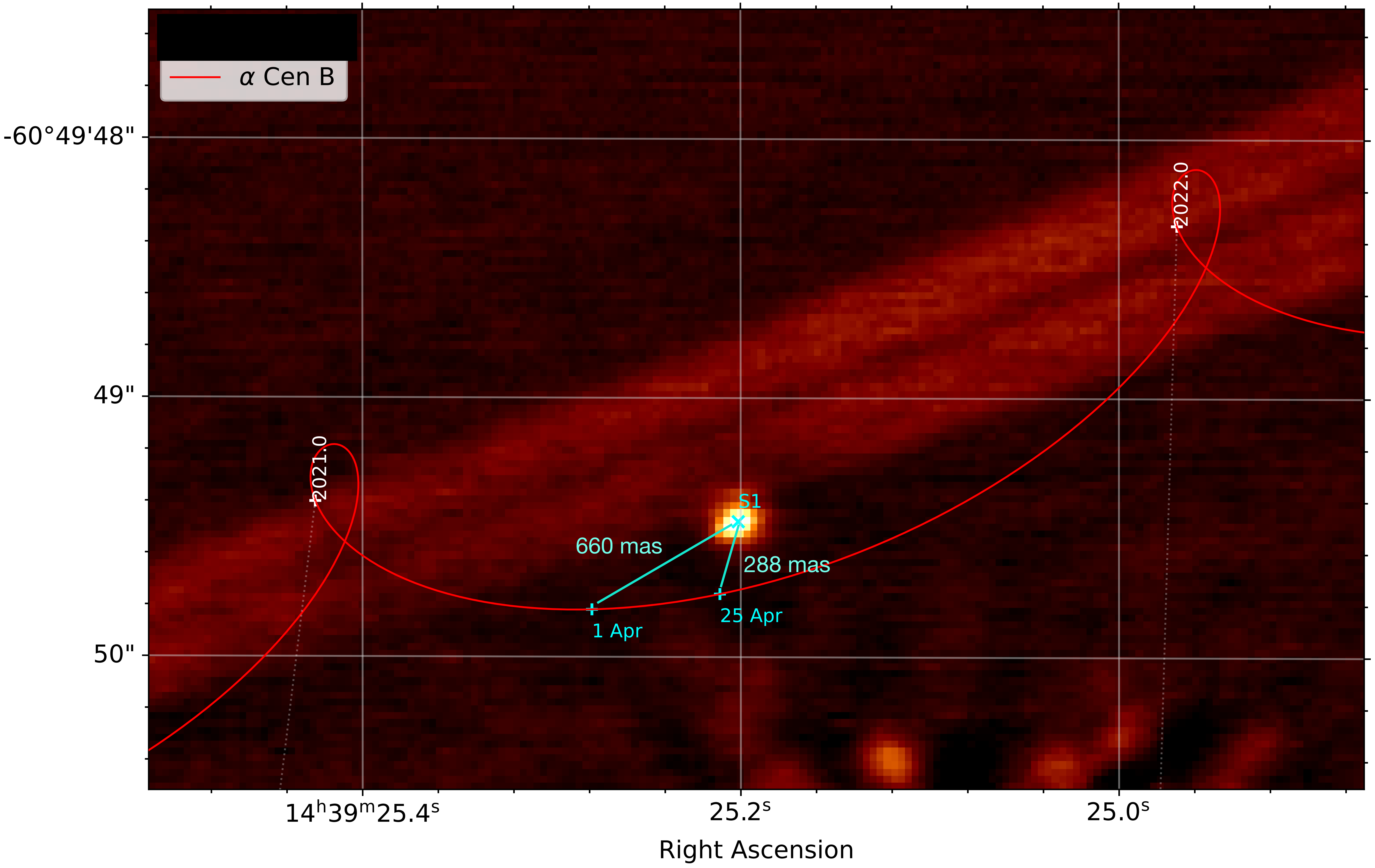
Astrometry of stellar conjunctions

- **Objectives**: anchor AB to the *Gaia* celestial frame and measure gravitational lensing events
- Position measured with ~ 50 µas accuracy from differential astrometry between S stars and α Cen AB with the VLTI/GRAVITY interferometer
- Goal to estimate the **proper motion vector** of the barycenter of α Cen AB to ± 20 µas/year (± 12 cm/s)



α Cen B-S1 conjunction in 2021

- Observation of B-S1 obtained with GRAVITY on 2 April 2021 @ 660 mas (0.9 au projected)
- High B-S1 contrast of **14 mag** in the K band (that is, a factor ~300 000)
- Second observation obtained on 25 April 2021 @ 288 mas (0.4 au).
- Expected gravitational lensing displacement of S1 ~**20 mas**
- Data analysis in progress

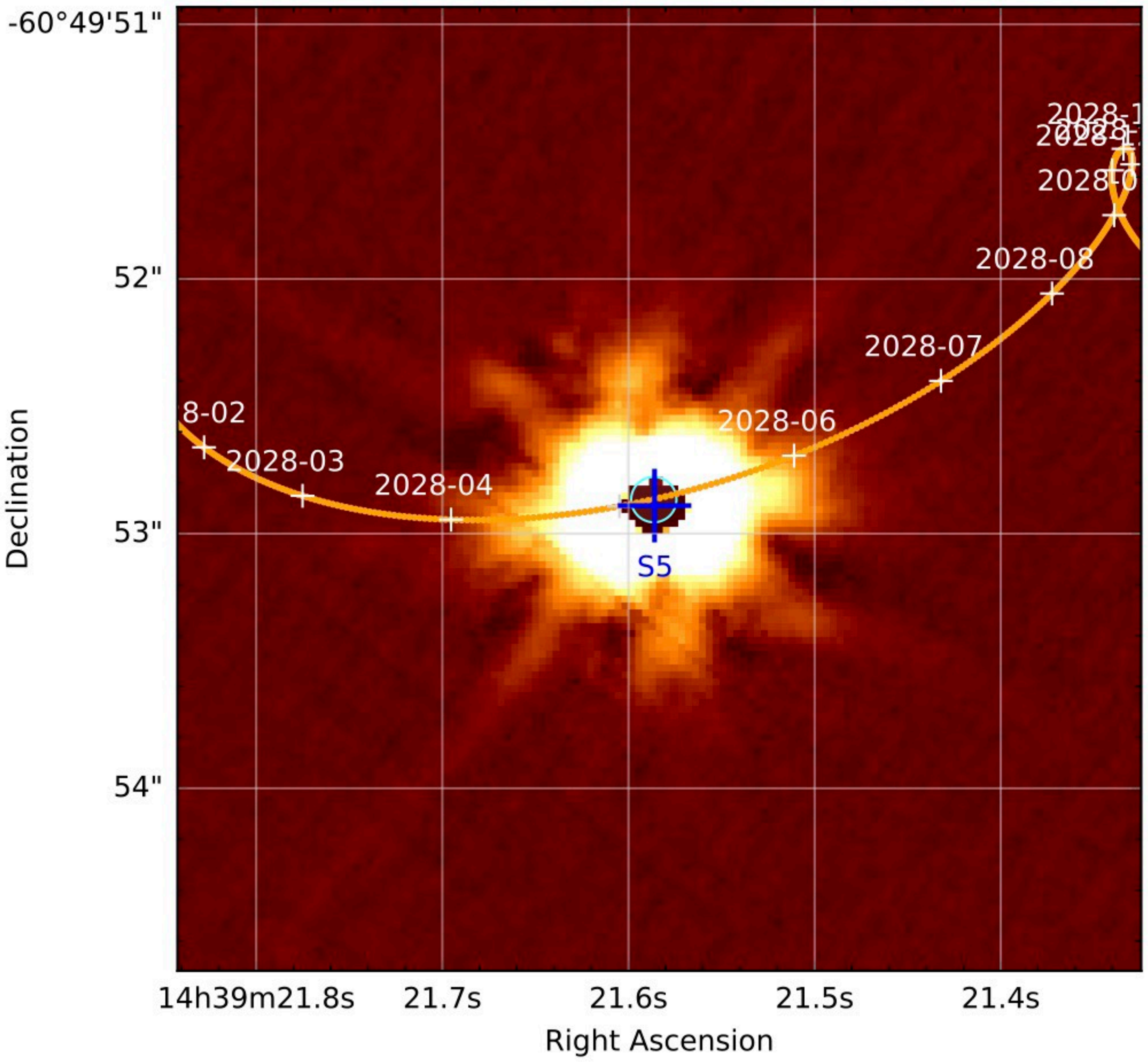


α Cen A-S5 conjunction

- In **April 2028**, α Cen A will approach star S5 within < 0.1"

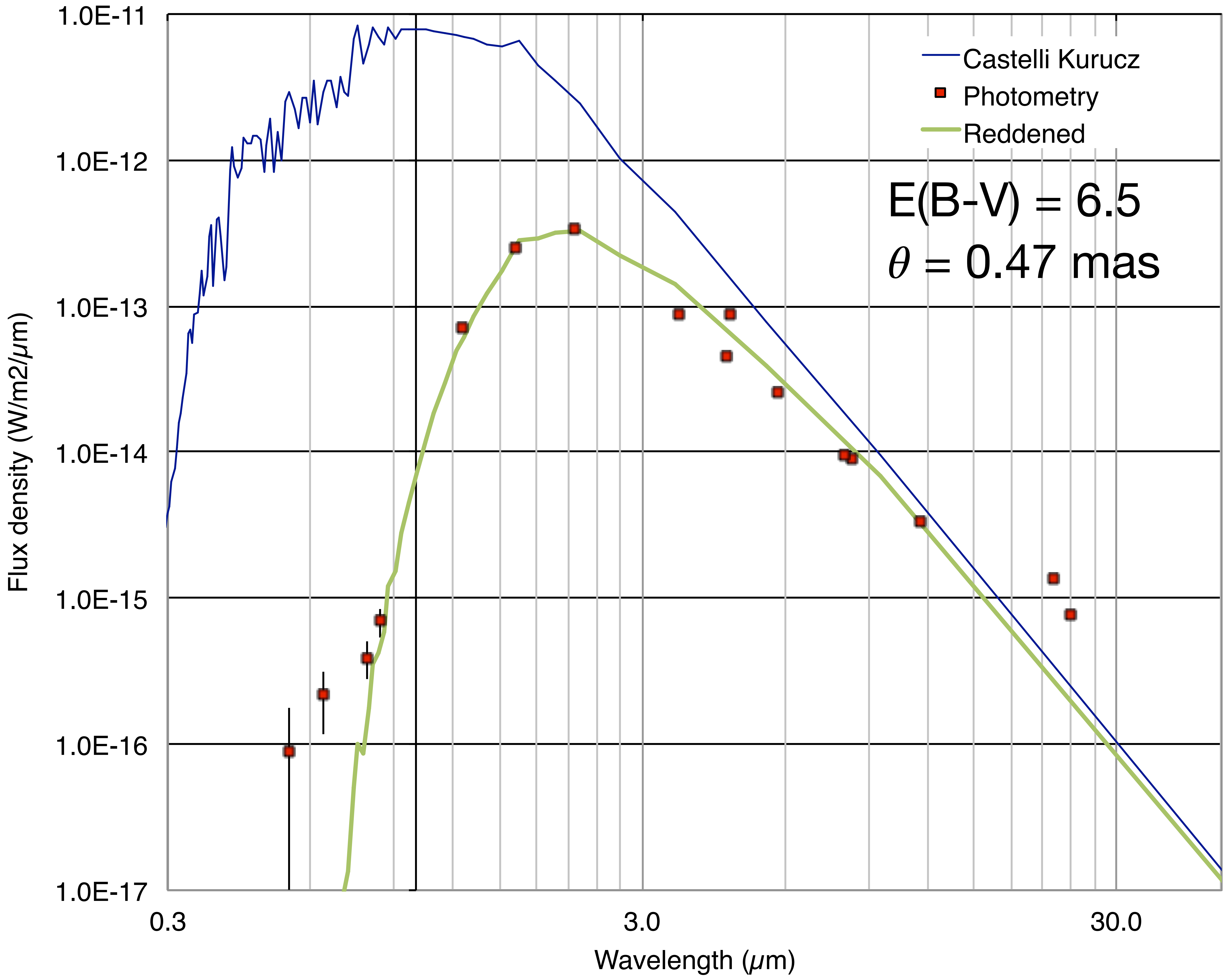
- S5 is faint in the visible, but bright in the infrared, **mK_s = 7.76 (contrast ~5000 with A)**

- About 1/2 probability that S5 **enters the Einstein ring** of α Cen A



Kervella et al. (2016, A&A 594, A107)

Nature of source S5



Band	$\lambda_0[\mu m]$	Mag.	Flux[a]	Ref.[b]
		STAR S5		
Bessel V	0.54	21.53 ± 0.95	0.9 ± 0.9	K07
Bessel R	0.64	20.00 ± 0.41	2.2 ± 1.0	K07
Bessel I	0.79	18.66 ± 0.27	3.9 ± 1.1	K07
Bessel Z	0.84	18.00 ± 0.22	6.9 ± 1.6	K07
2MASS J	1.25	11.60 ± 0.03	717 ± 20	K07
2MASS H	1.62	9.125 ± 0.027	2540 ± 64	G15
2MASS K_s	2.16	7.756 ± 0.024	3380 ± 76	G15
IRAC 3.6	3.6	7.161 ± 0.058	888 ± 49	G15
IRAC 4.5	4.5	6.912 ± 0.052	458 ± 22	G15
WISE W2	4.6	6.089 ± 0.025	886 ± 21	G15
IRAC 5.8	5.8	6.500 ± 0.027	258 ± 6.4	G15
IRAC 8.0	8.0	6.257 ± 0.027	94.5 ± 2.5	G15
MSX6C A	8.28	6.05 ± 0.06	89.4 ± 4.7	E03
WISE W3	11.6	5.725 ± 0.017	33.4 ± 0.5	G15
WISE W4	22.1	3.924 ± 0.029	13.7 ± 0.4	G15
MIPS 24	24	4.22 ± 0.02	7.8 ± 0.2	G15

Kervella et al. A&A 594, A107 (2016)

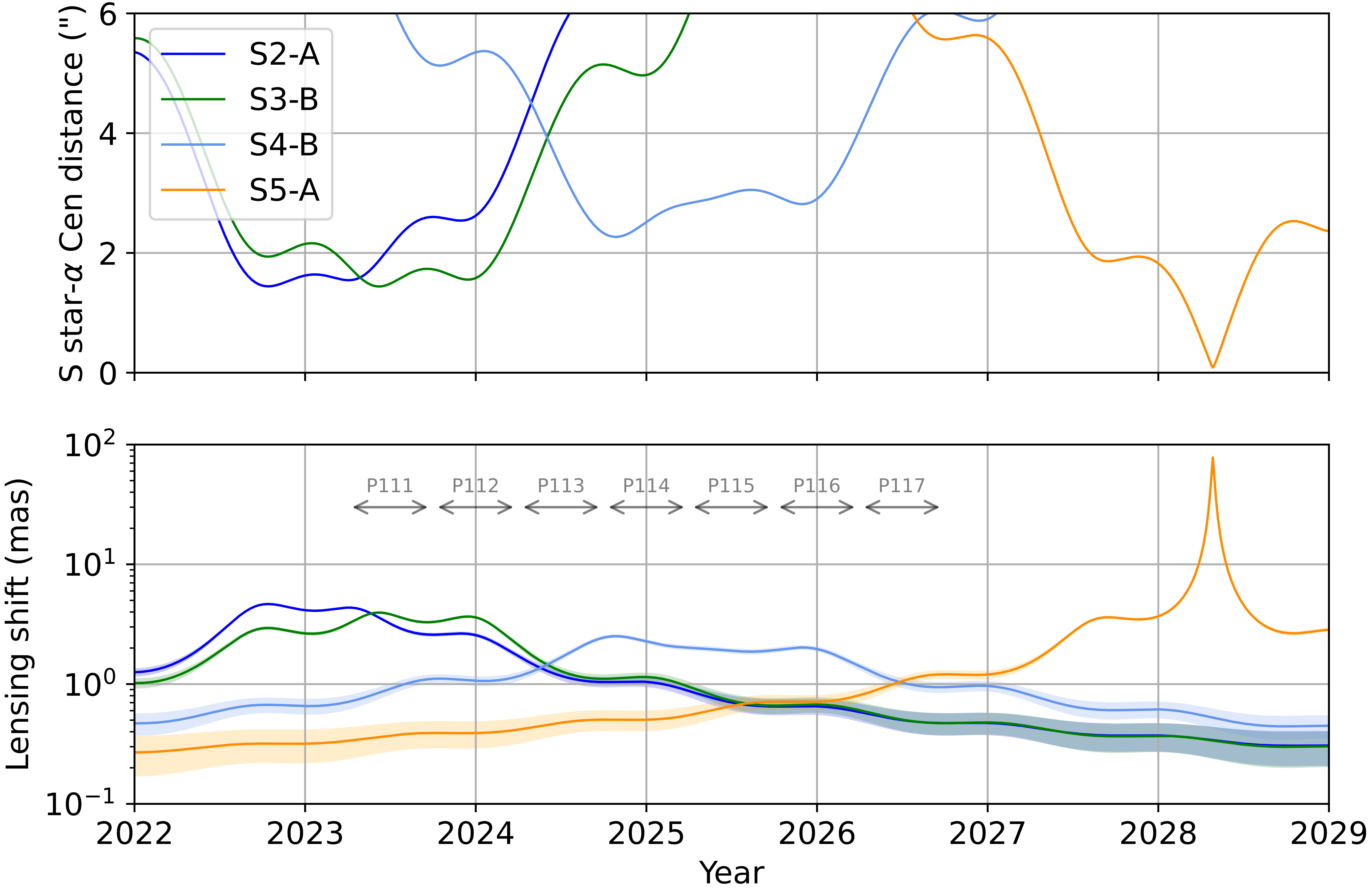
A-S5 conjunction 2028

$$\theta_{\mathrm{E}} = \sqrt{\frac{4\,GM}{c^2 d_\pi}}$$

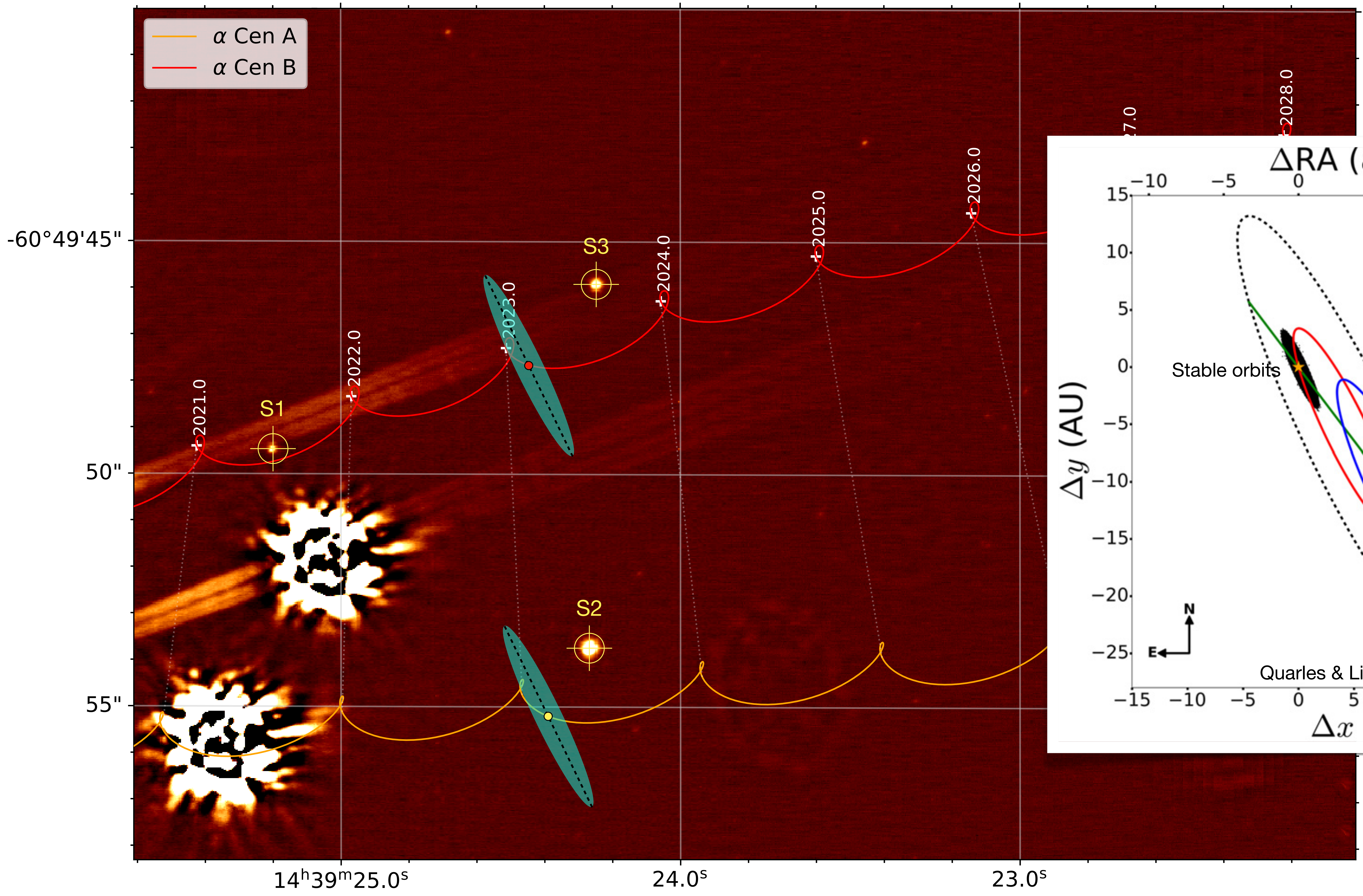
$$\theta_{\pm} = 0.5\left[u \pm \sqrt{u^2 + 4}\right]\theta_{\mathrm{E}}$$

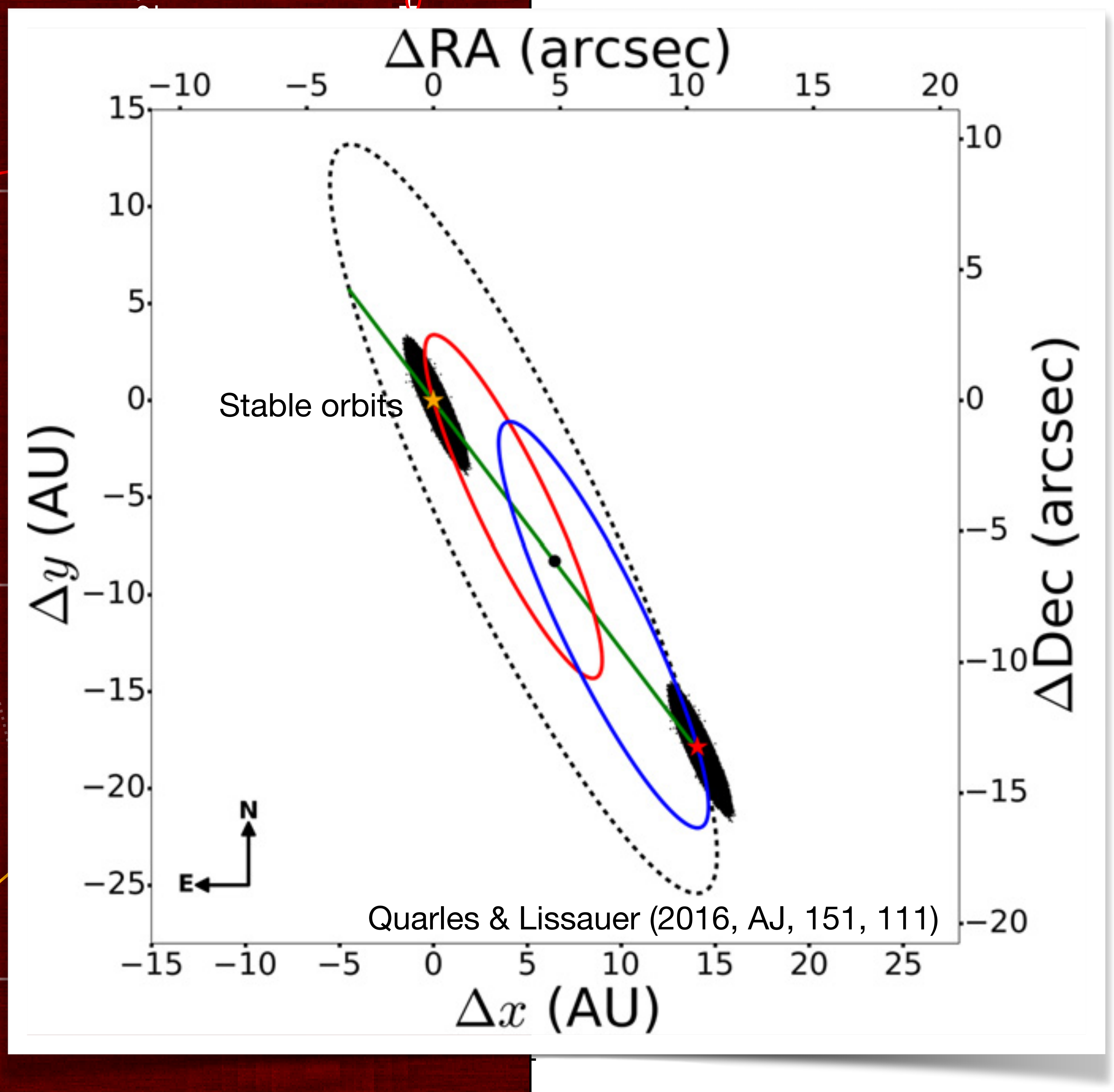
$$u = \rho_{\min}/\theta_{\mathrm{E}}$$

Gravitational deflection

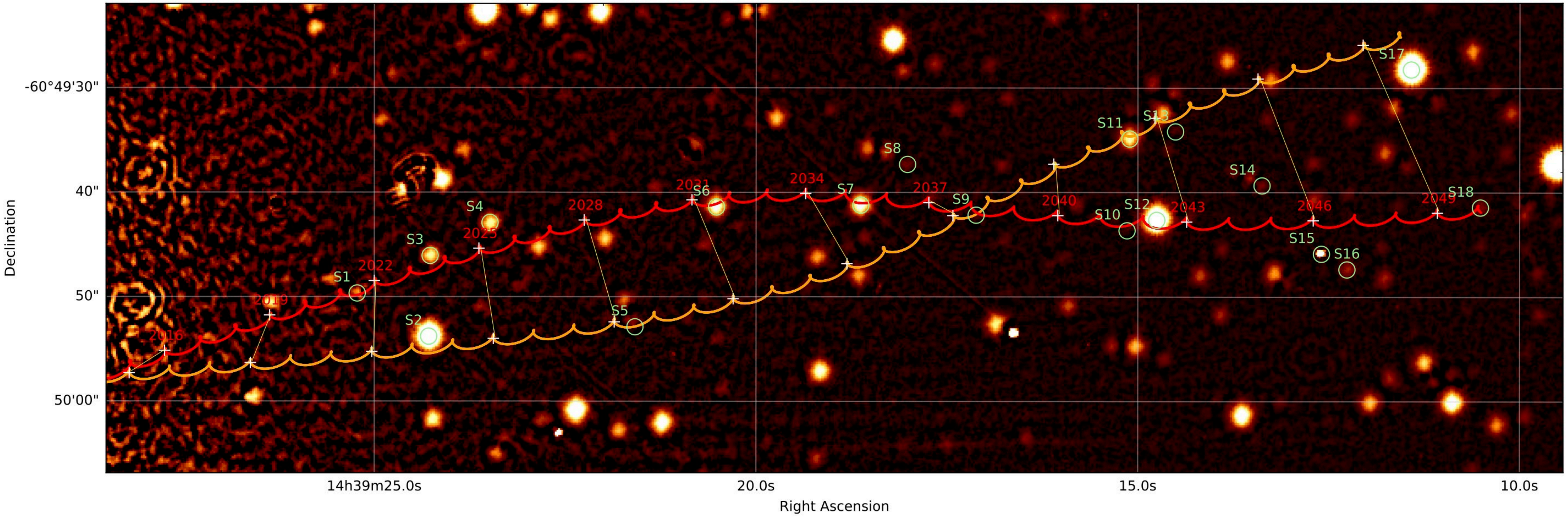


Planets from astrometric lensing





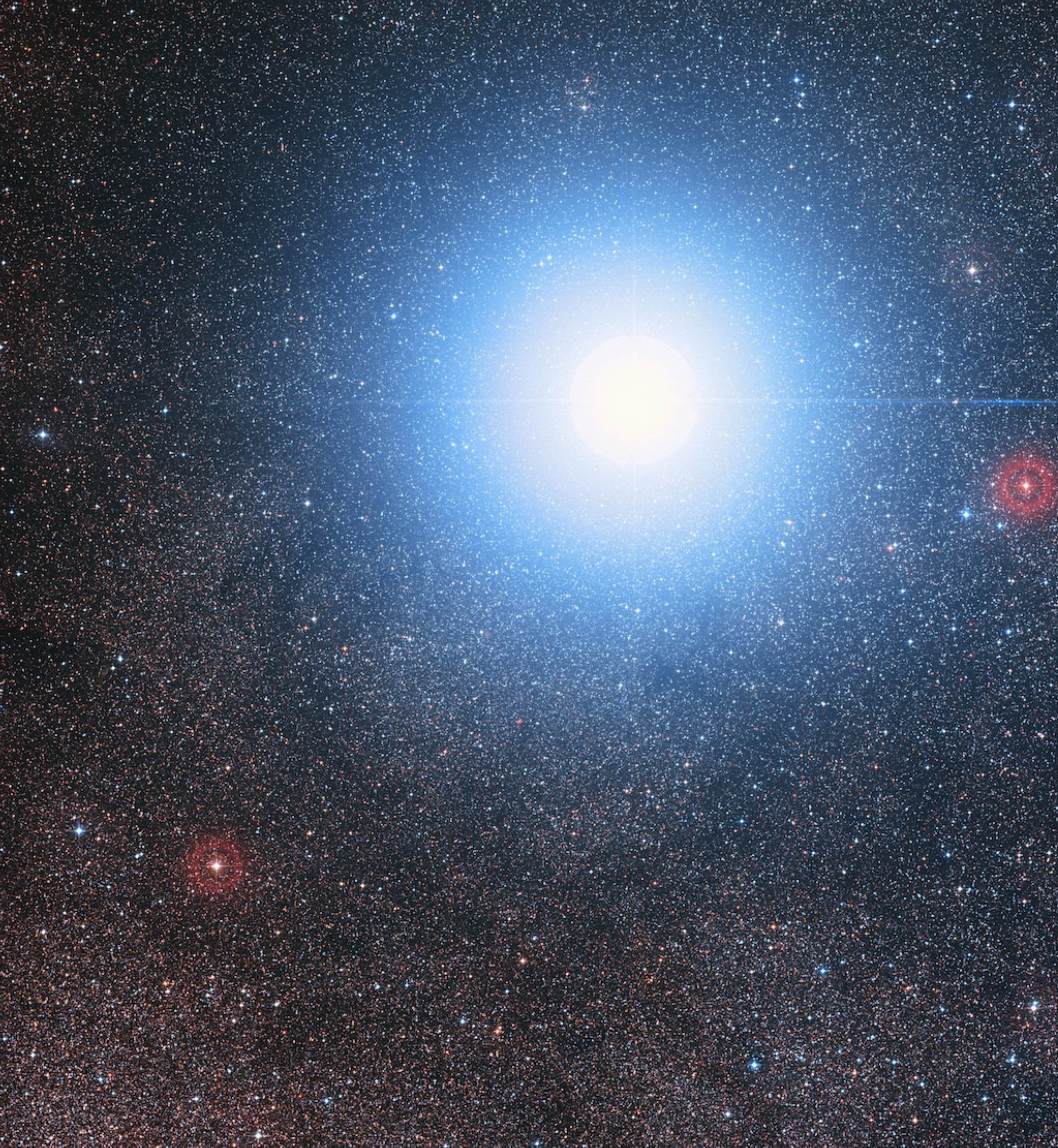
Opportunities in the coming years



★[a]	$\rho_{\min}[''] $	Date[b]	#[c]	K07[d]	m_V	ΔV	m_I	ΔI	m_K	ΔK	RA	Dec	Epoch	μ_α[e]	μ_δ[d]	σ_μ[d]
B	0.205 ± 0.177	2021-05-03	S1	1266	$20.0_{0.5}$	18.7	$17.6_{0.2}$	17.2	$13.58_{0.17}$	14.2	14:39:25.224	−60:49:49.67	2009.152	−5	−12	12
A	1.643 ± 0.112	2023-04-27	S2	1184	$15.7_{0.2}$	15.7	$13.3_{0.2}$	13.9	$11.14_{0.03}$	12.6	14:39:24.283	−60:49:53.80	2016.236	+2	−2	5
B	1.354 ± 0.186	2023-12-12	S3	1181	$19.7_{0.3}$	18.4	$16.0_{0.2}$	15.6	$12.89_{0.11}$	13.5	14:39:24.264	−60:49:46.03	2009.152	+1	−4	11
B	2.433 ± 0.119	2024-10-26	S4	1113	$17.5_{0.2}$	16.2	$15.9_{0.2}$	15.5	–	–	14:39:23.485	−60:49:42.91	2016.236	+6	+8	5
A	0.015 ± 0.135	2028-05-06	S5	0951	$21.5_{0.9}$	21.5	$18.7_{0.3}$	19.3	$7.76_{0.02}$	9.3	14:39:21.586	−60:49:52.89	2016.236	−5	−5	5
B	0.269 ± 0.277	2031-05-25	S6	0856	$16.9_{0.2}$	15.6	$15.4_{0.2}$	14.9	–	–	14:39:20.518	−60:49:41.41	2009.152	−6	−1	11

- With GRAVITY, we measure the differential position of α Cen A and B and the background S stars to 50-100 µas.
- Potential for very accurate parallax and proper motion, as well as gravitational mass determinations of A and B

Kervella et al. A&A 594, A107 (2016)

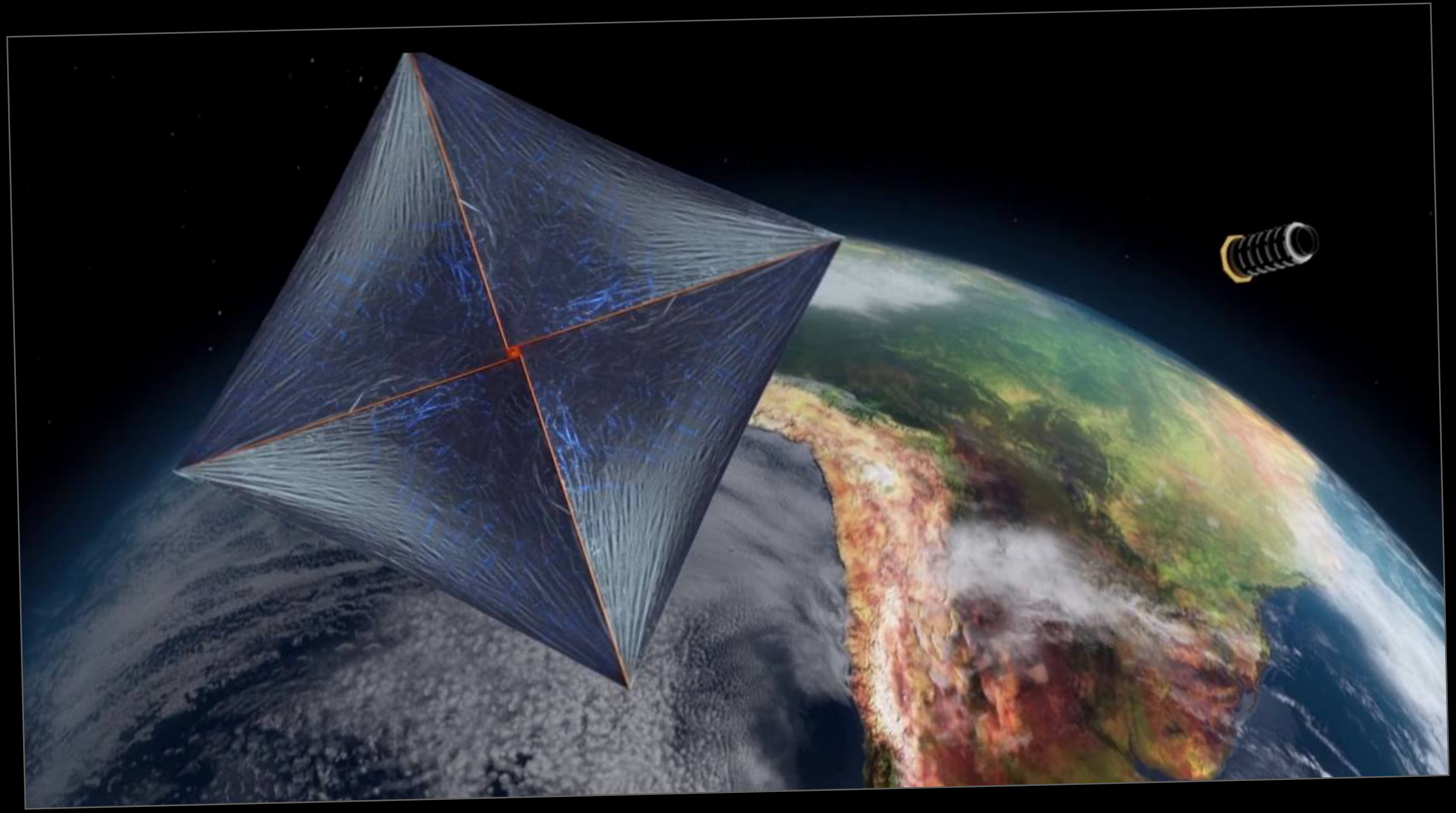


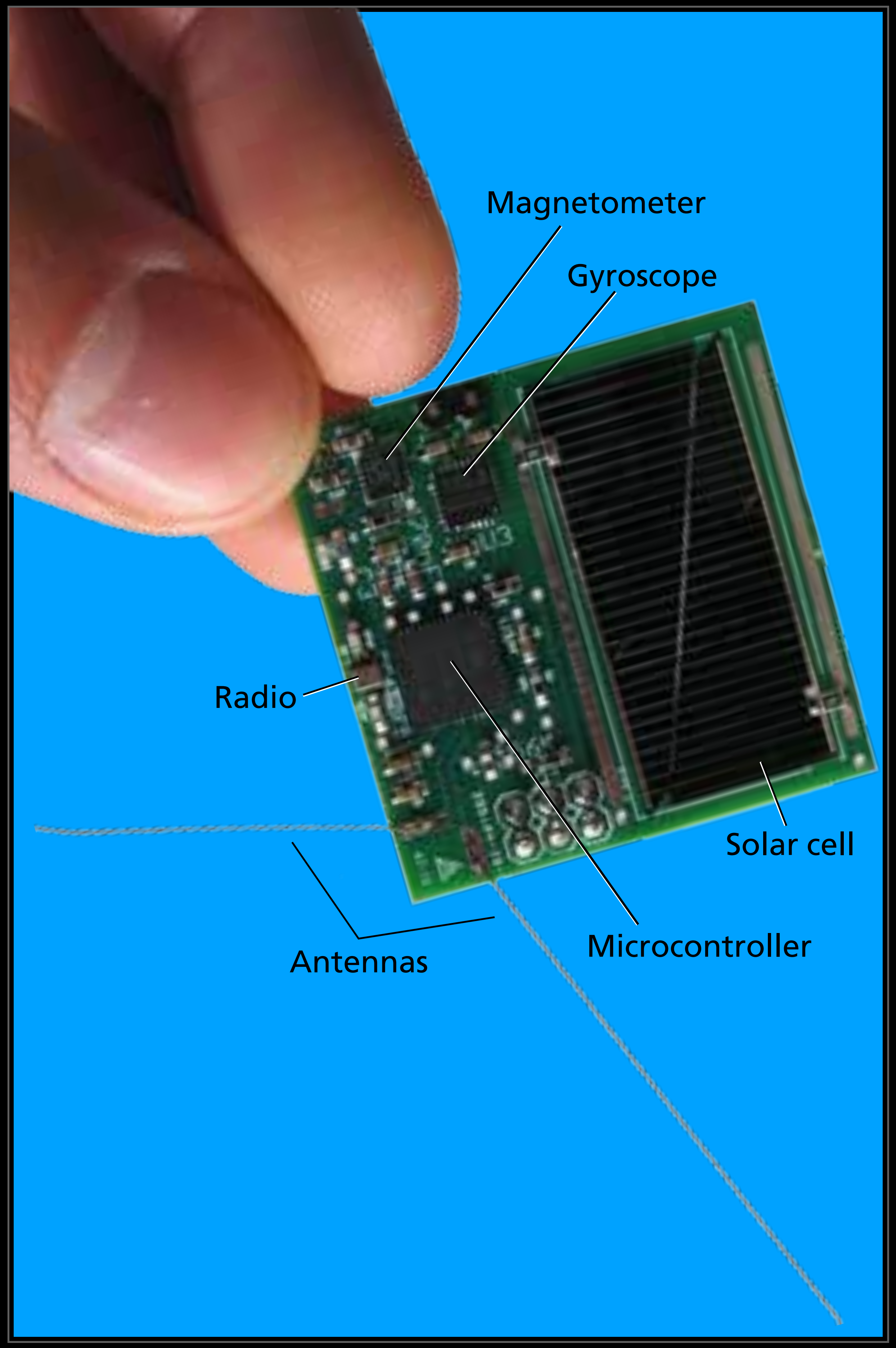
Summary

- **Objective #1:** determine the gravitational mass of Alpha Cen A and B, particularly A to ~0.1% with S5 event
- **Objective #2:** search for gravitational signature of planets from astrometric shift due to secondary lensing
- **Objective #3:** measure the parallax and proper motion of the pair with very high accuracy

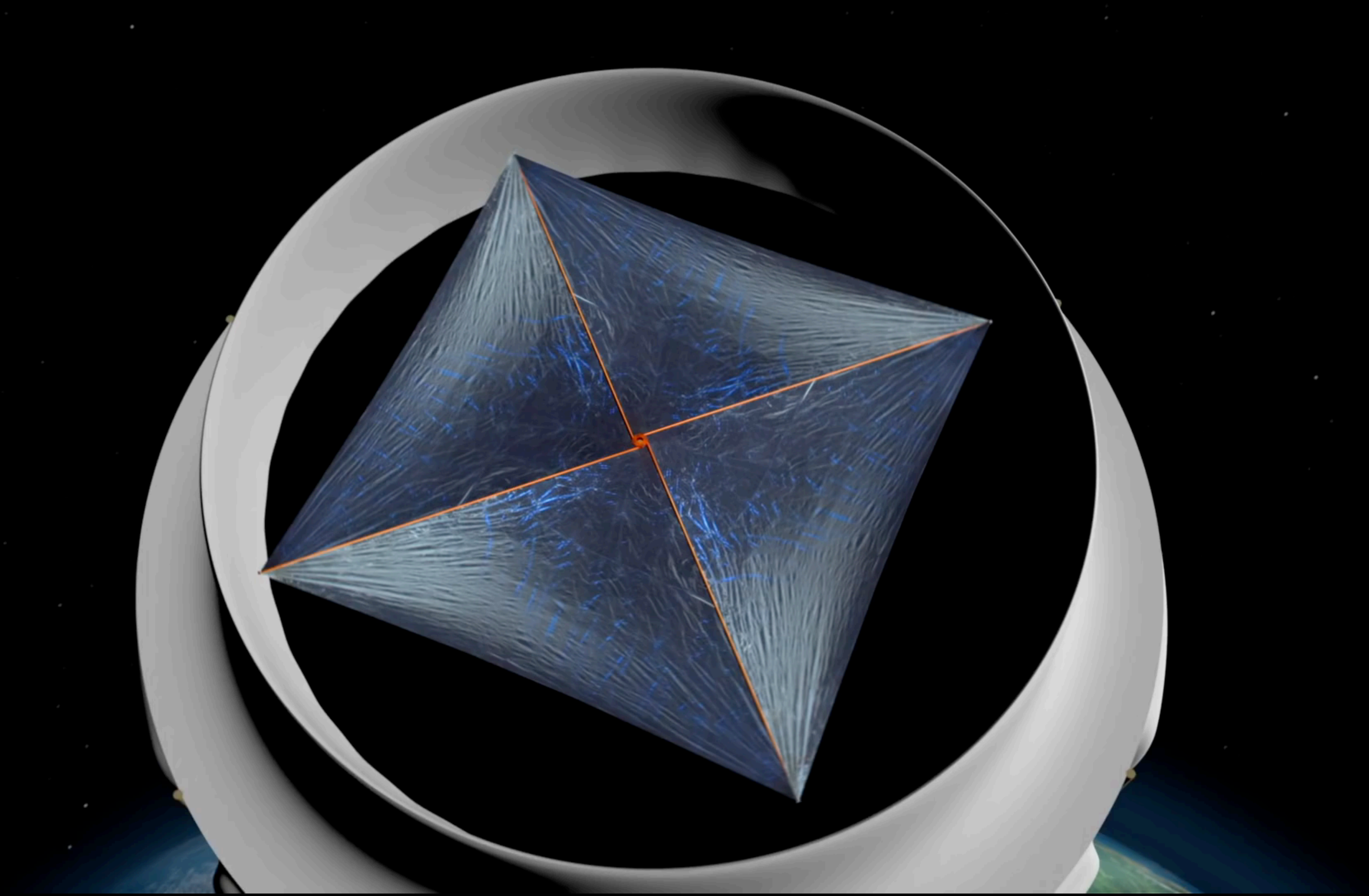
An interstellar probe ?

- Project *Breakthrough Starshot*



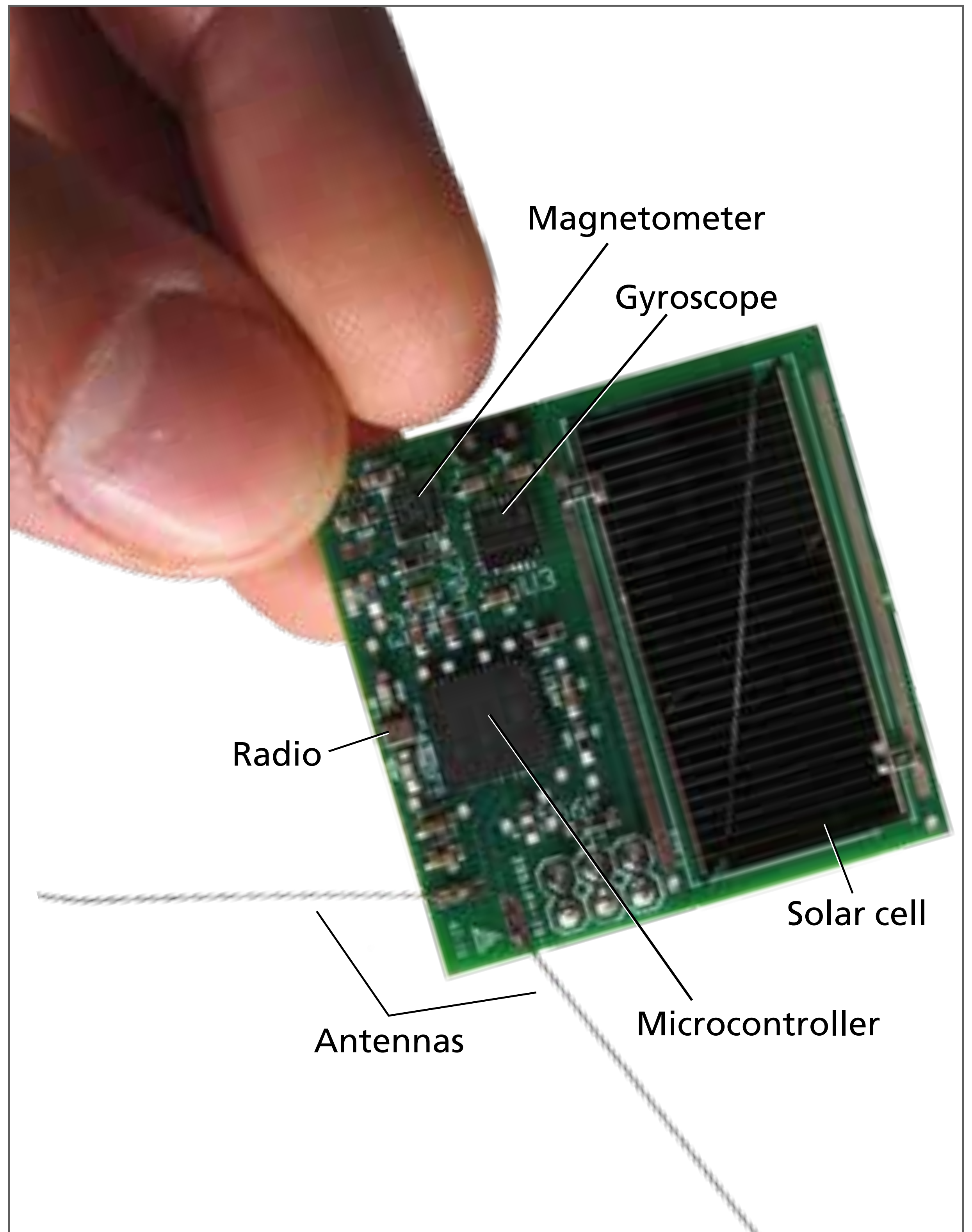


Breakthrough Starshot



Technological challenges

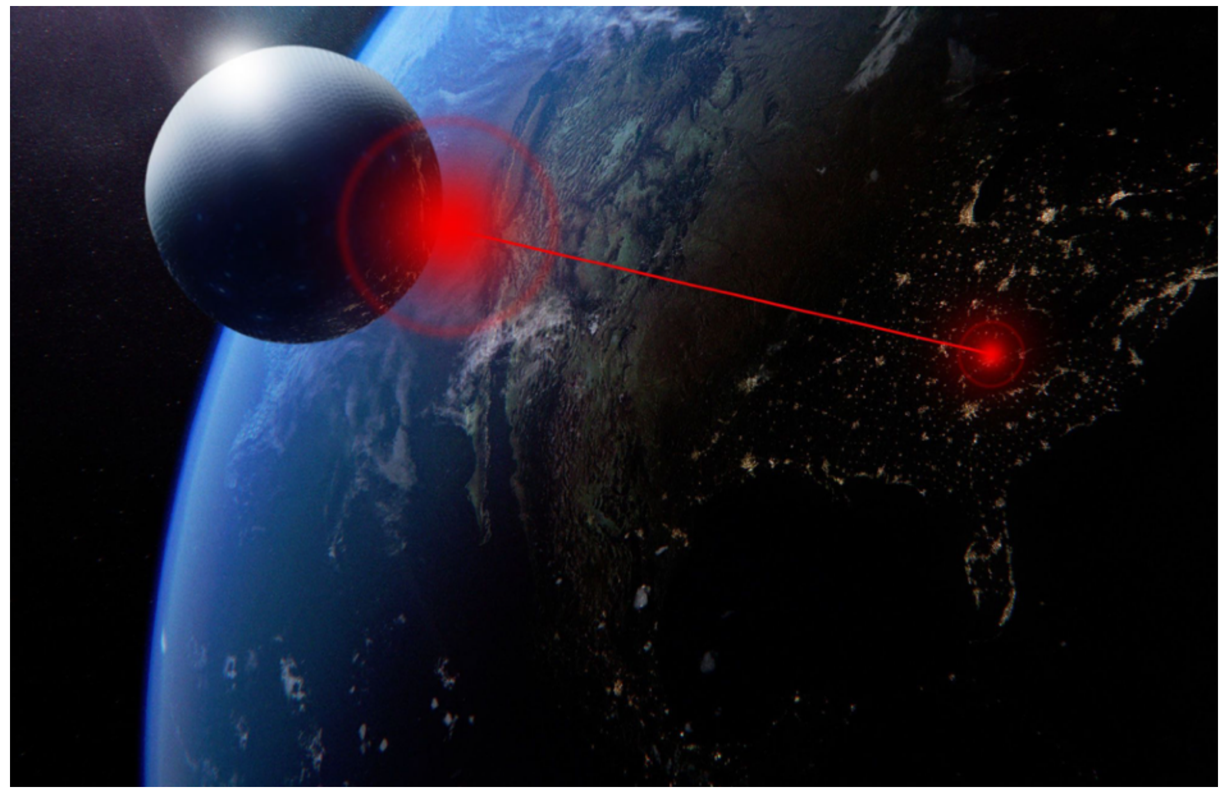
http://breakthroughinitiatives.org/challenges/3



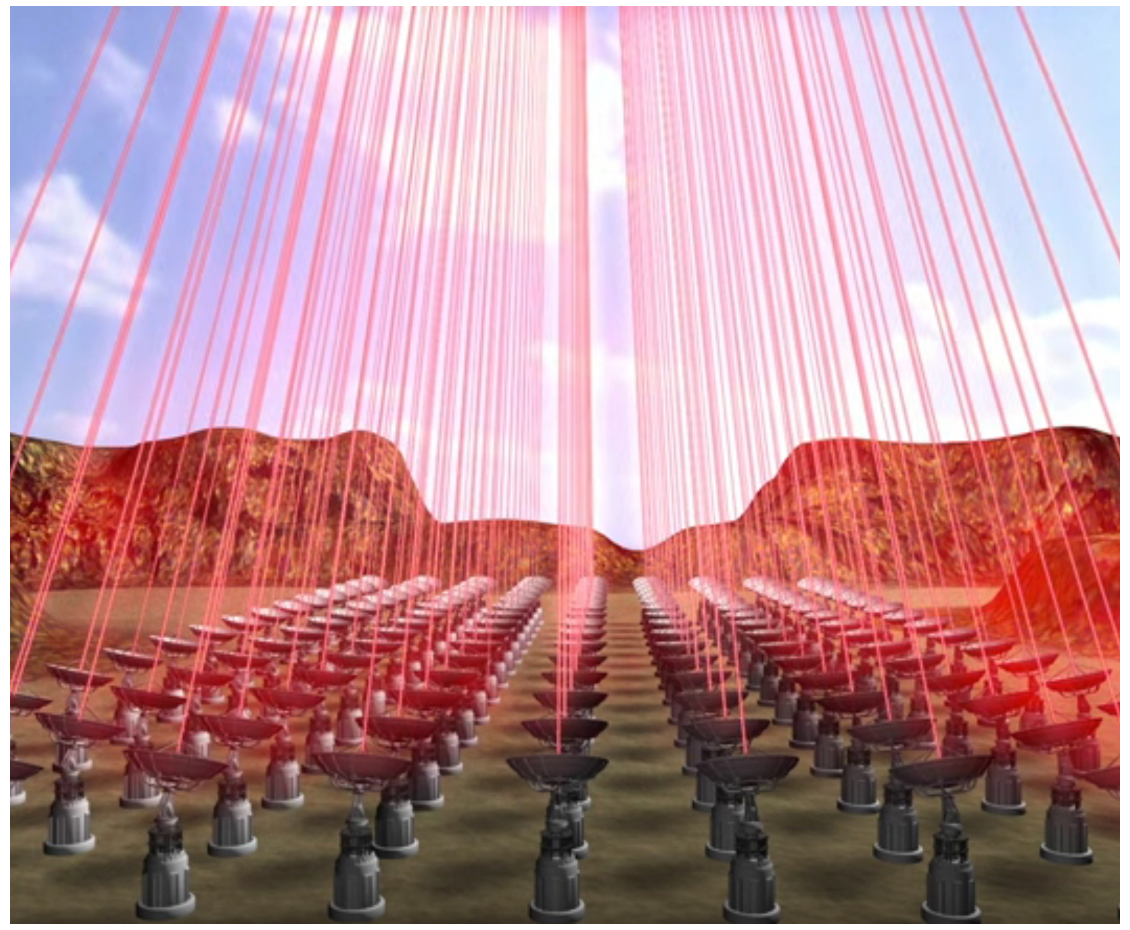
***Sprite* nano-satellites**
4 grams, in orbit July 2017
Cornell University

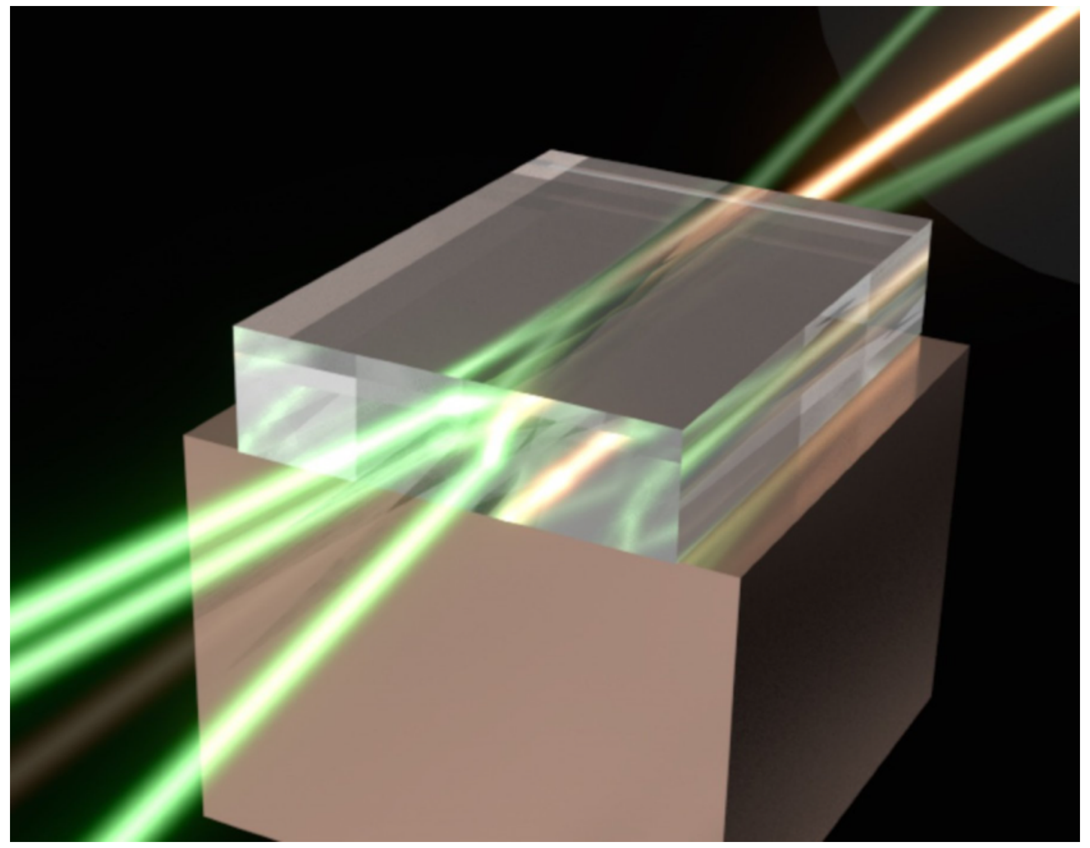
Starchip
60 000 g for 3'
300°C

LightSail 2 cubesat



Light sail
Absorbing less than
1/300 000 photons

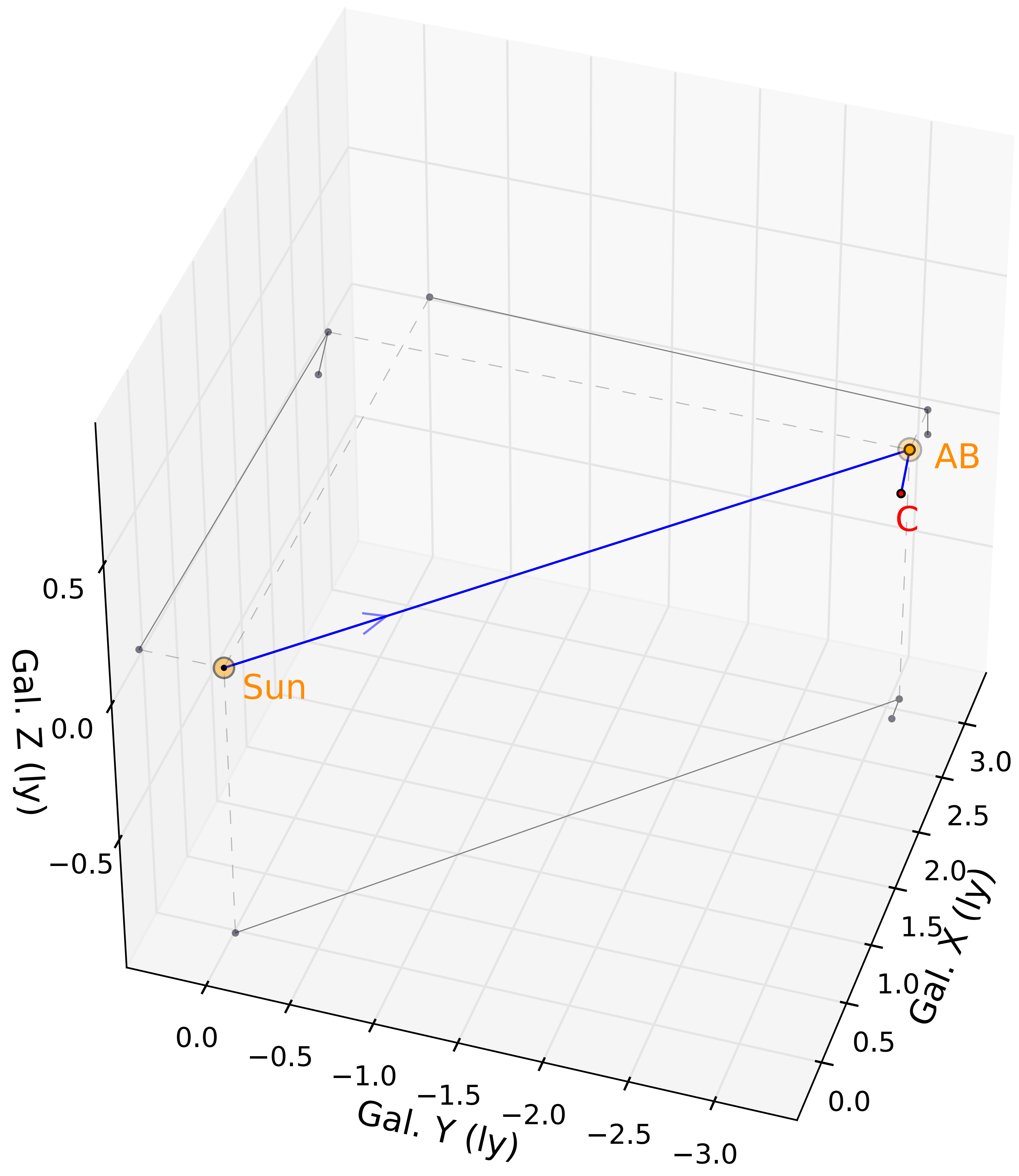


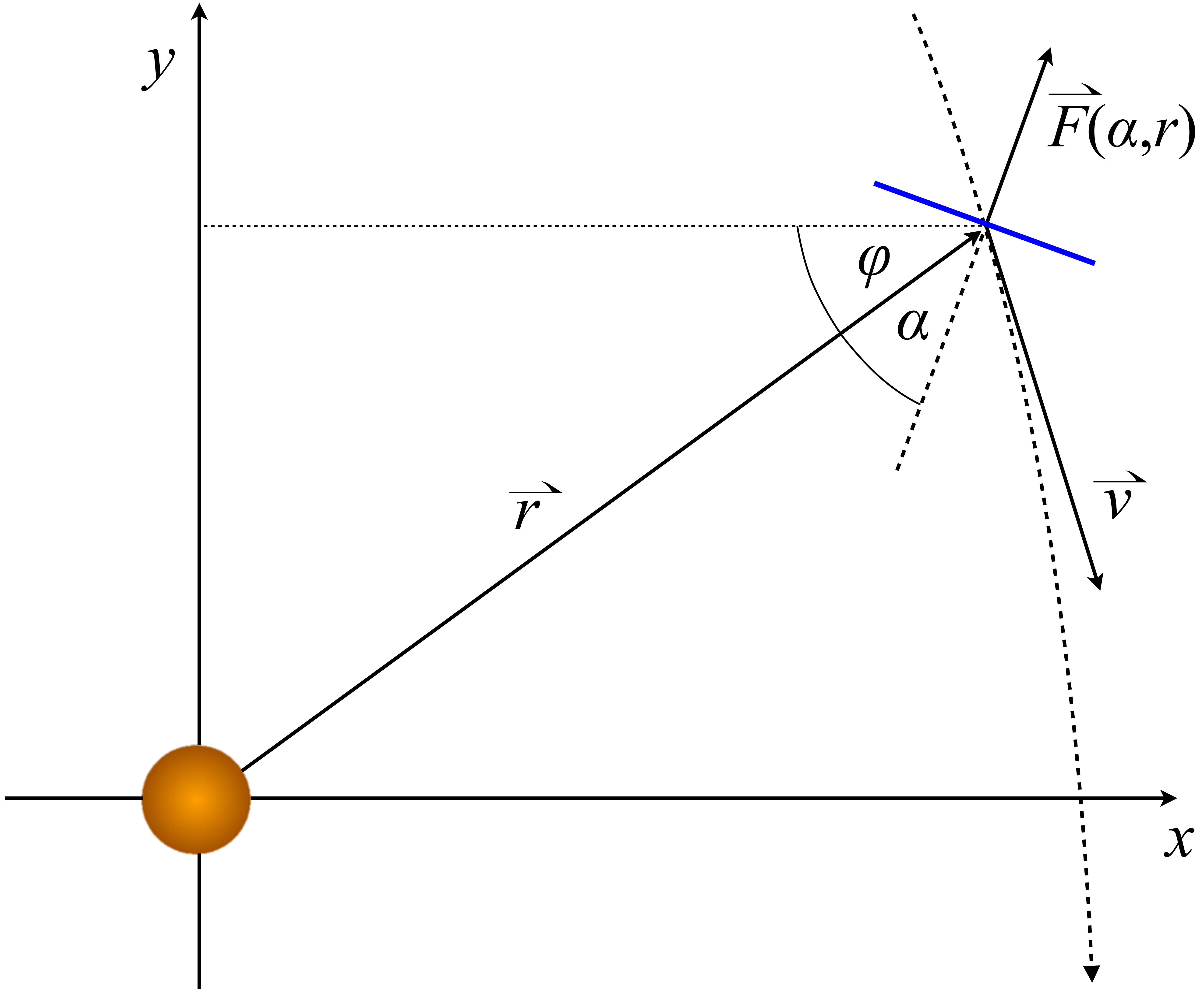


Light beamer
Combining focus of
individual laser beams
100 gigawatts

Interstellar trajectory

- A *serious* difficulty: pointing accuracy, astrometry of the three stars
- A *major* difficulty: how to slow down ?
- A possible solution: interstellar "pinball" of photo-gravitational velocity reduction
- Objective: orbital injection around Proxima b



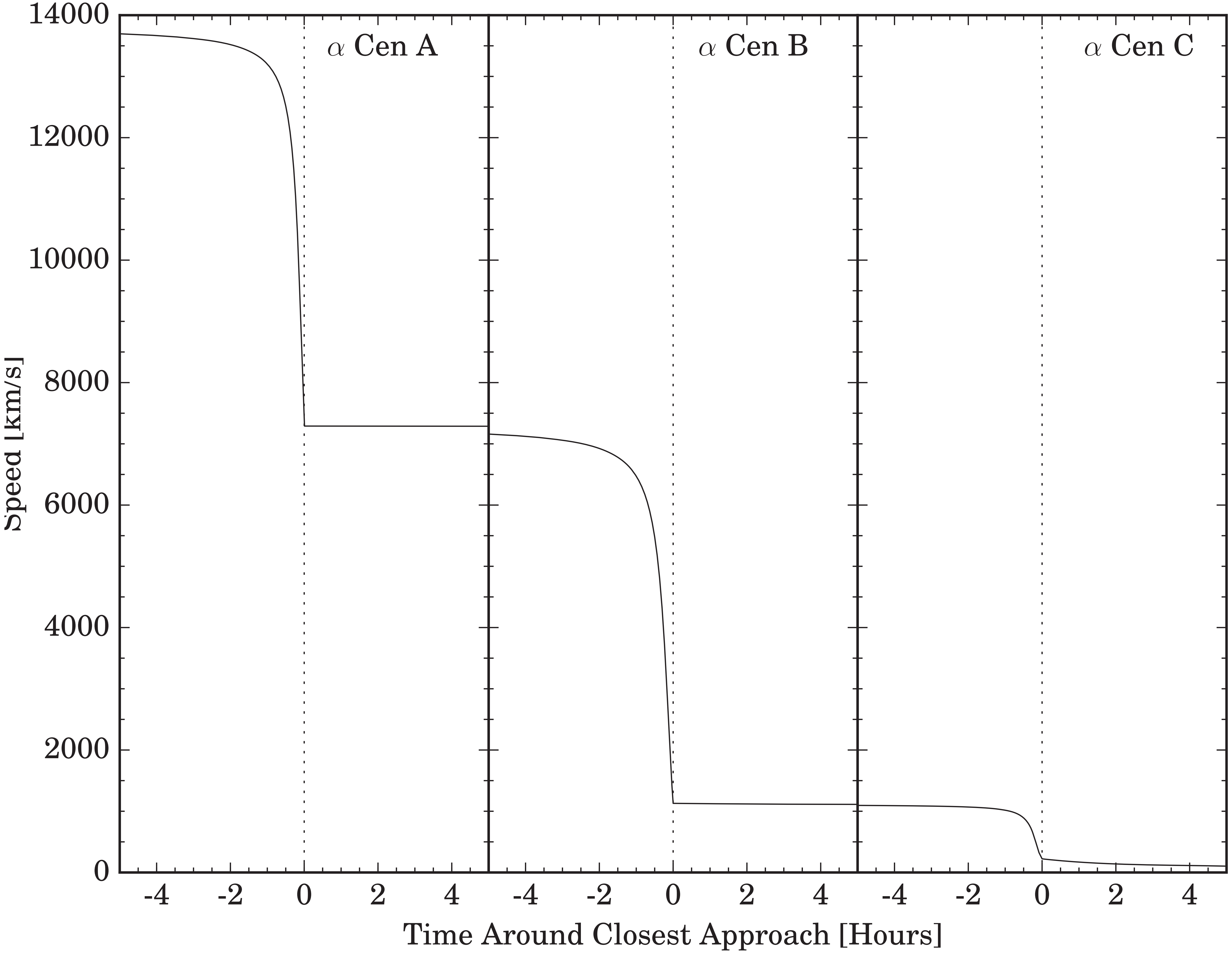


Geometry of a slingshot trajectory. The star is in the origin of the coordinate system. The trajectory of the solar sail, with instantaneous velocity v, is shown as a dotted curve in the x–y plane.

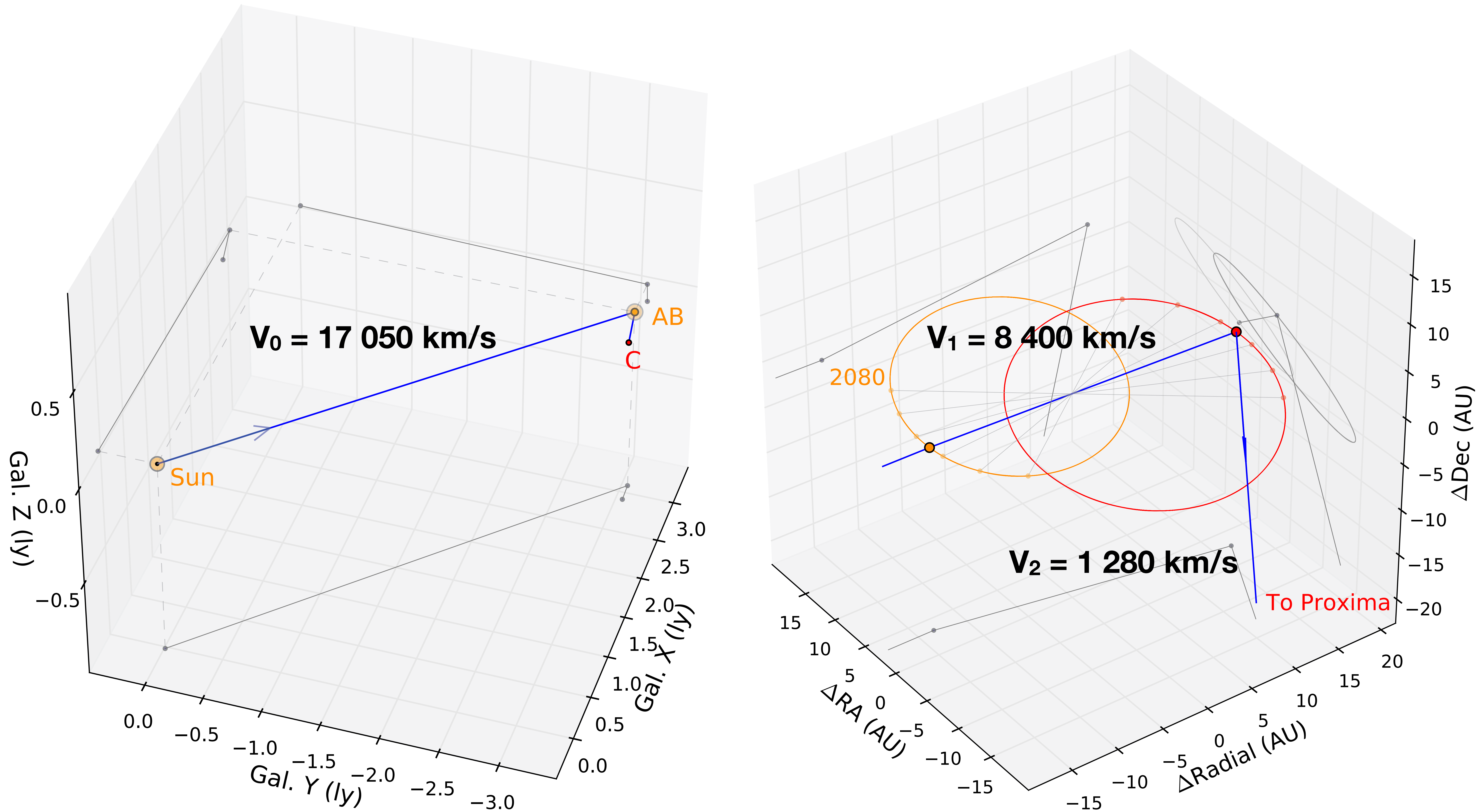
Heller & Hippke 2017, ApJL, 835, 32

Vmax = 13 800 km/s
travel ~ 100 years

Graphene sail

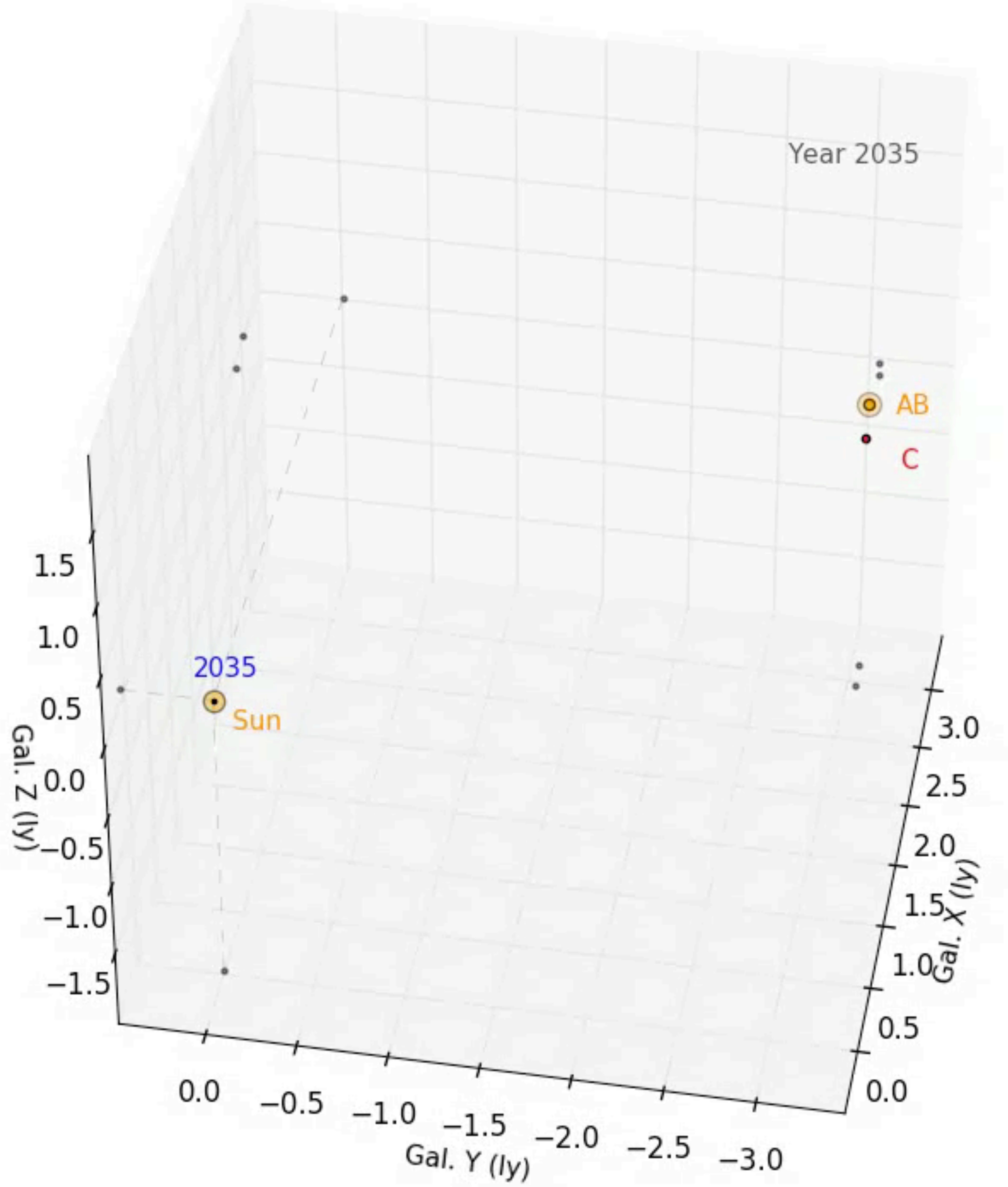


Heller & Hippke 2017, ApJL, 835, 32



Sun-AB = 75 years
AB-Proxima = 46 years

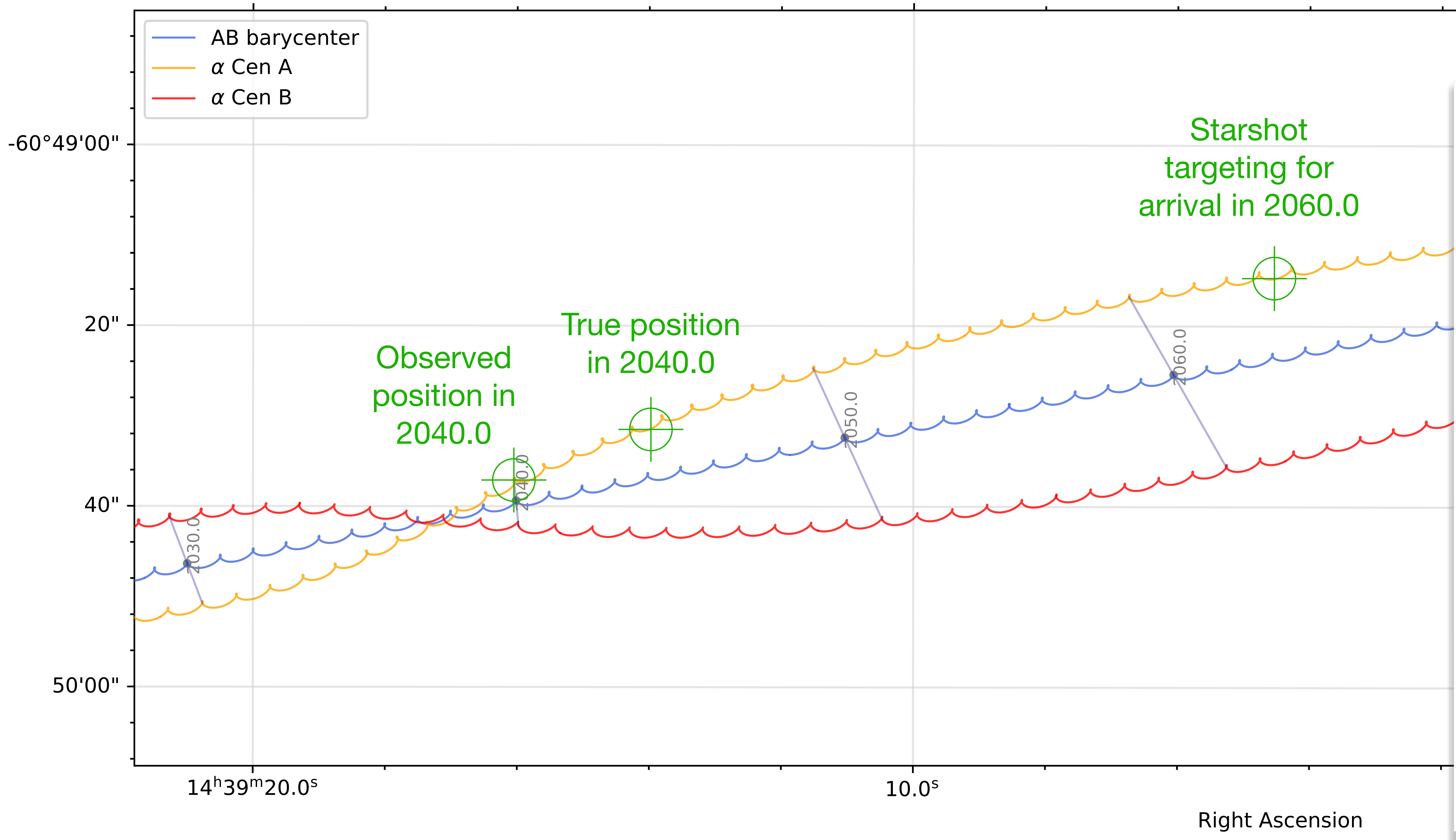
Heller, Hippke & Kervella 2017, AJ, 154, 115

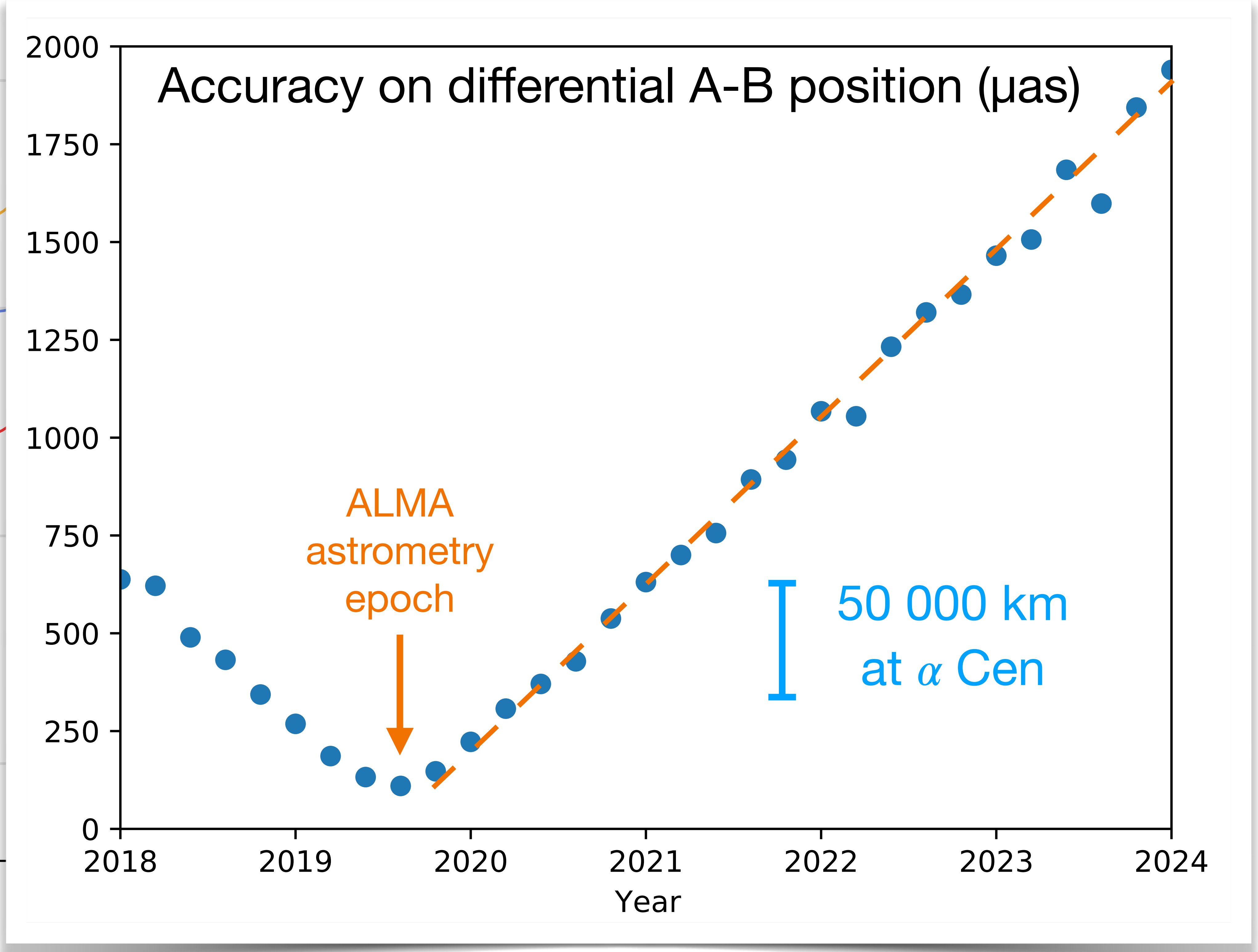


Year 2035
AB
C
2035
Sun
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Gal. Z (ly)
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
Gal. Y (ly)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Gal. X (ly)

Starshot navigation

Adopted flight time: 20 years
Adopted distance: 4.35 light years





- **Projected position, proper motion and distance** of the target star are critical for a successful rendez-vous
- **A very well known cruise velocity of the spacecraft** is also essential