Probing micro-arcsecond astrometry with NACO

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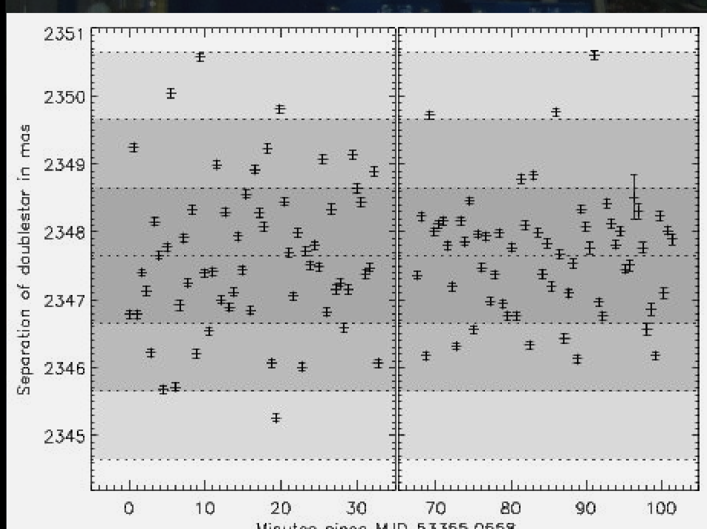
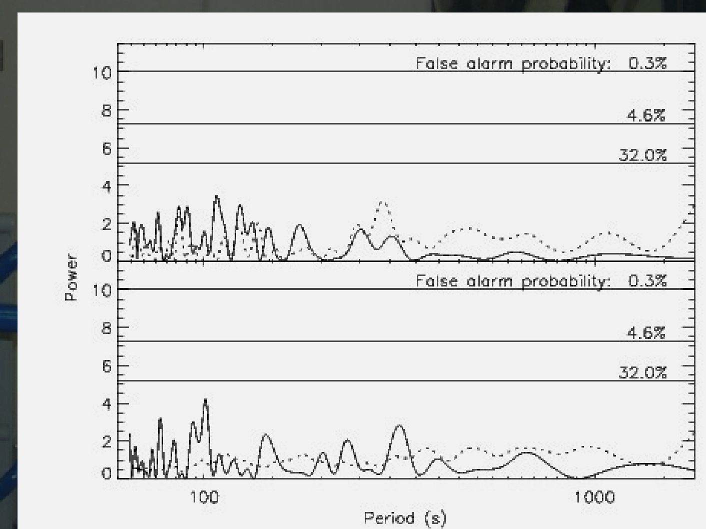
(1) AIU Jena, (2) ESO Garching





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I. Motivation – the hunt for extrasolar planets

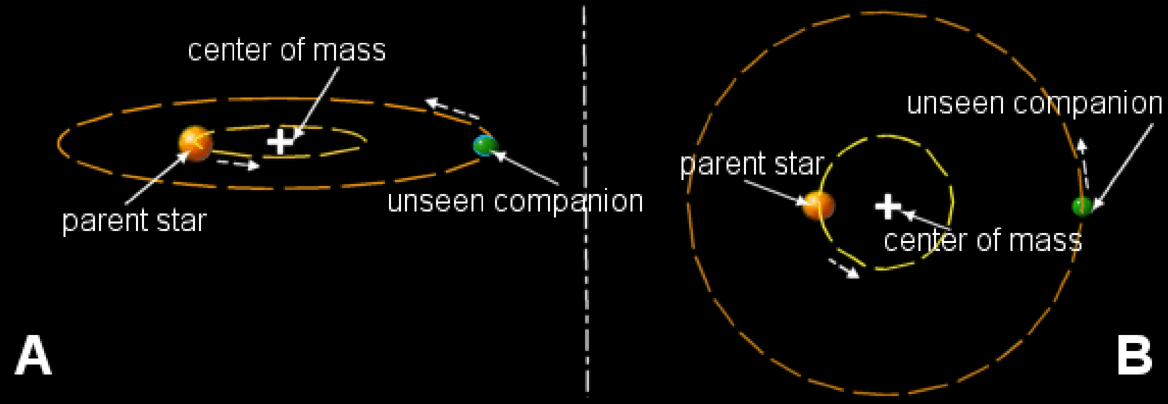
II. Achievements and limits of ground based non-AO astrometry

III. Concept and first results for relative narrow-field AO-assisted astrometry

IV. Implications for the NACO calibration plan – wishful thinking ?

1. Motivation: The hunt for extrasolar planets

Most successful method today: Radial-velocity (RV) measurement



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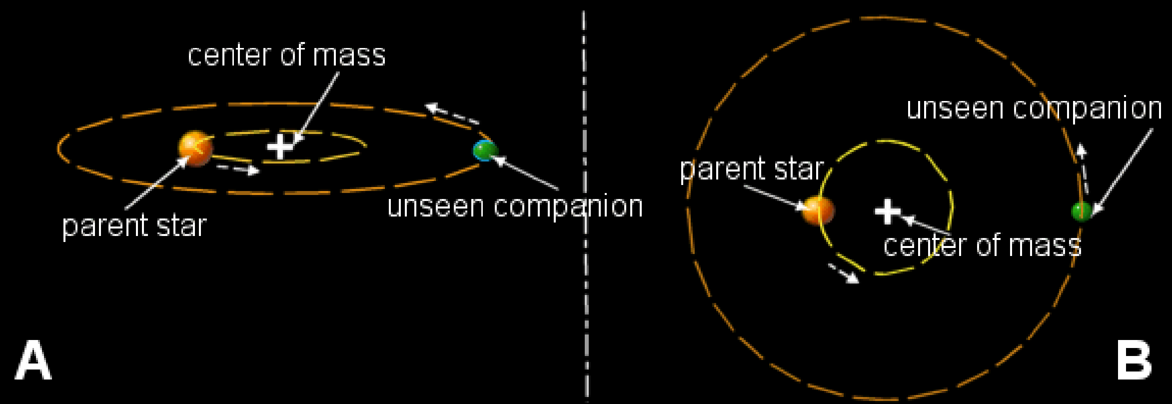

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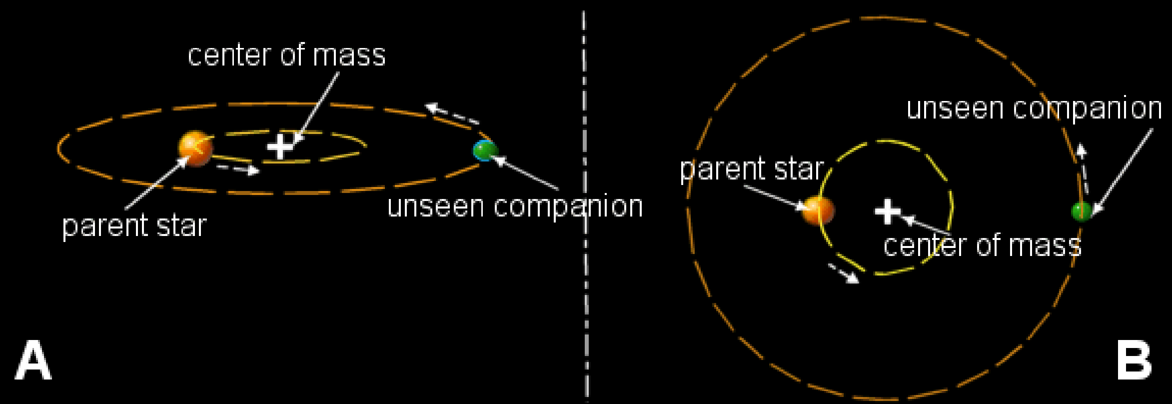

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(2) Limited sensitivity by inclination angle, stellar activity (spectral type, youth etc.) and binarity of the host star

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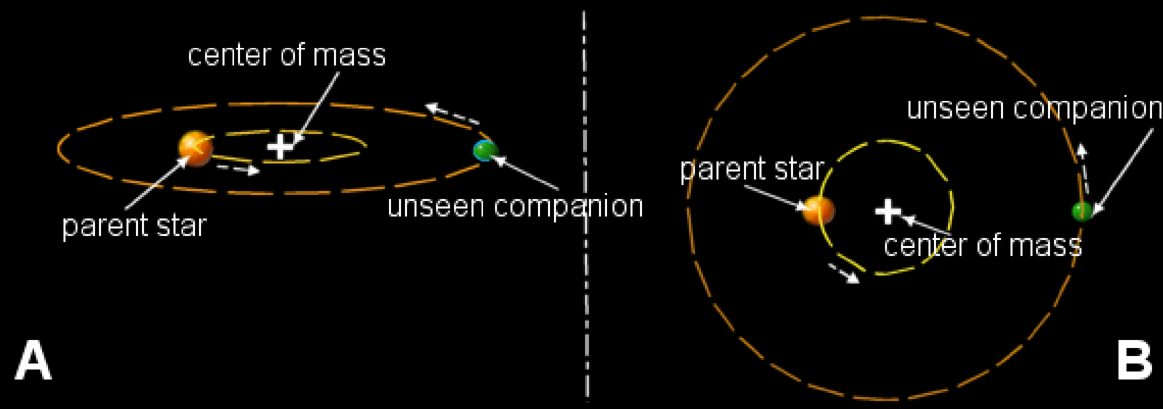
Radial-velocity (RV) measurement AND astrometry



Possible solution: Astrometric measurement of the 'wobble' in the two other directions on the sky

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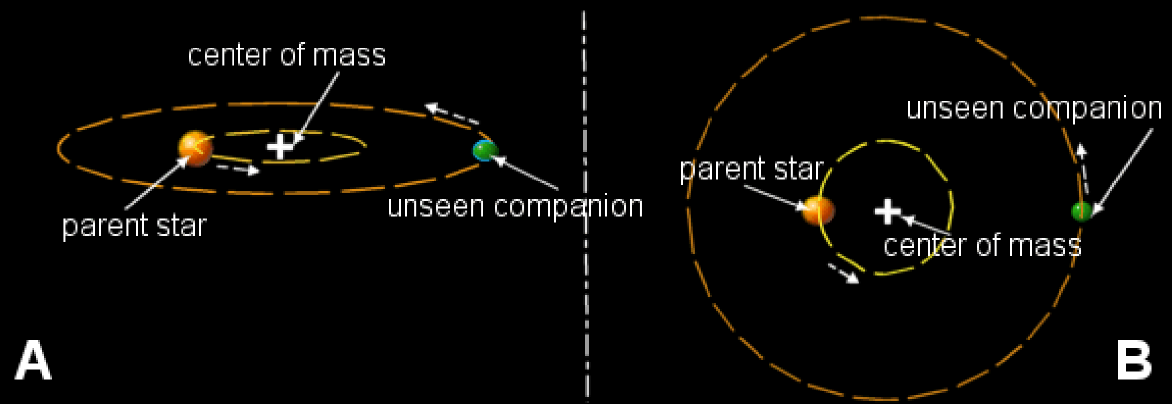

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Limitation: Achievable astrometric precision

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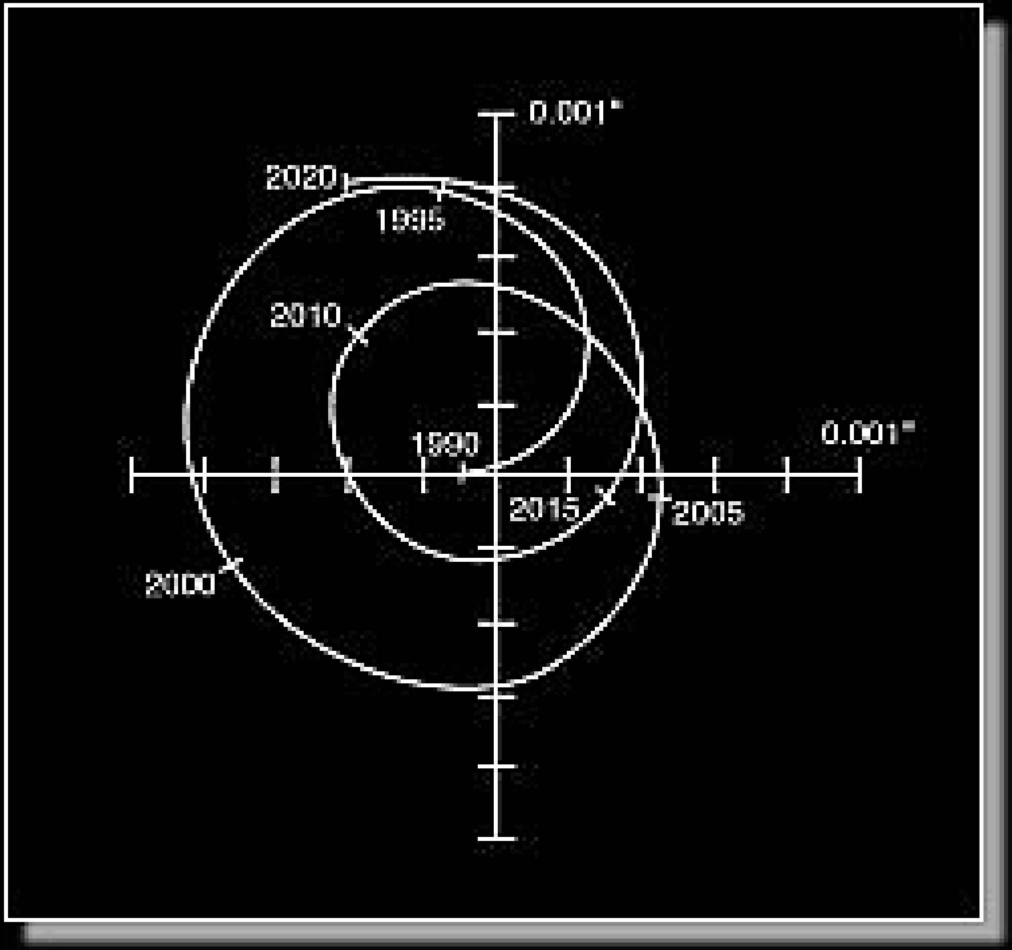
Expected order of magnitude of astrometric displacement:

Example: sun seen from 10 pc ▷

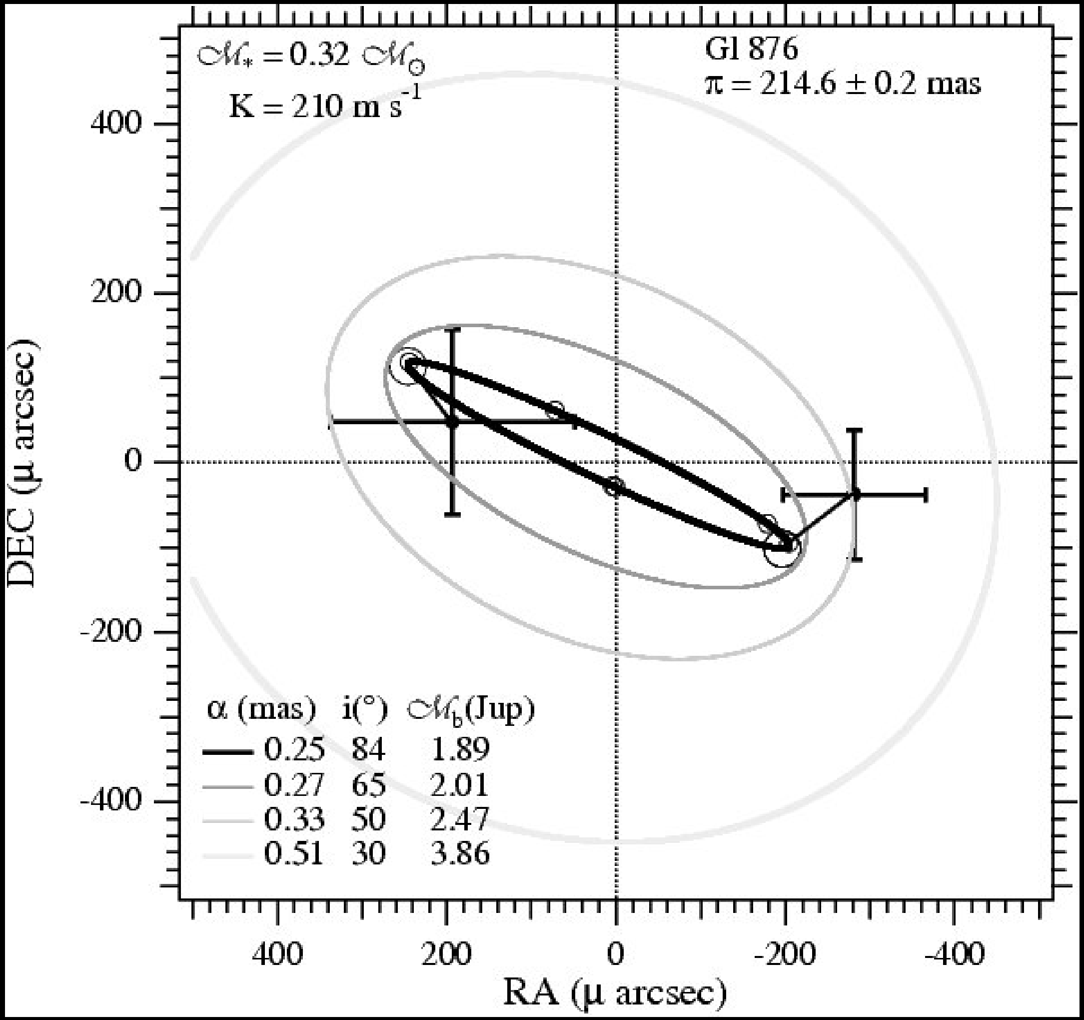


Most RV planet candidates have smaller separation (> ~ 50% of all known planet candidates have orbits of < ~ 1AU)

small astrometric signal

1. Motivation: The hunt for extrasolar planets

First successful demonstration by HST FGS (Benedict et al.)



II. Achievements and limits of 'classical' astrometry

Method:	One (or more) targets are observed in large field optical imaging. A set of stars surrounding the target(s) provides the astrometric reference frame.	
Benchmark:	Gatewood (1987)	~ 1 mas per night
	Han (1989)	~ 1 mas per hour (binary stars)
	Monet (1992)	~ 0.5 mas per night
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Limits:	(1) Differential chromatic refraction (~130 μas) (2) High stellar density for reference frame (3) High astrometric stability of reference frame (3) Excellent seeing conditions needed (< 0.6”)

III. Relative, narrow-field, AO-assisted astrometry

Concept: (1) Observation of a single target plus one reference object in a narrow field with an adaptive optics system in the near-infrared.

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(2) 'Beat down' the observational noise by high number of observations, as done for RV technique.

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Advantages: (1) DCR effect is ~200 times smaller in a NB filter at 2.2μm compared to an optical (e.g. R band) broad band filter.
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(3) Adaptive Optics + Active Optics of the VLT leave many degrees of freedom for the imager.
-> Platescale changes ?!
-> Instrumental stability has to be assured over many epochs with a suitable (but still independent) reference frame.

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First results: Imaging of *HD19994* and *HD19063*

Properties of HD19994 AB:

double star (F8V + M3V) Ks = 4 + 7 mag
separation: ~2.5”
HD19994 A has a RV exoplanet candidate of $m \sin(i) = 1.68\ M_{Jup}$ in a 1.42 AU orbit with an orbital period: 535.7 days

Expected astrometric signal: > 130 μas

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Properties of HD19063 AB

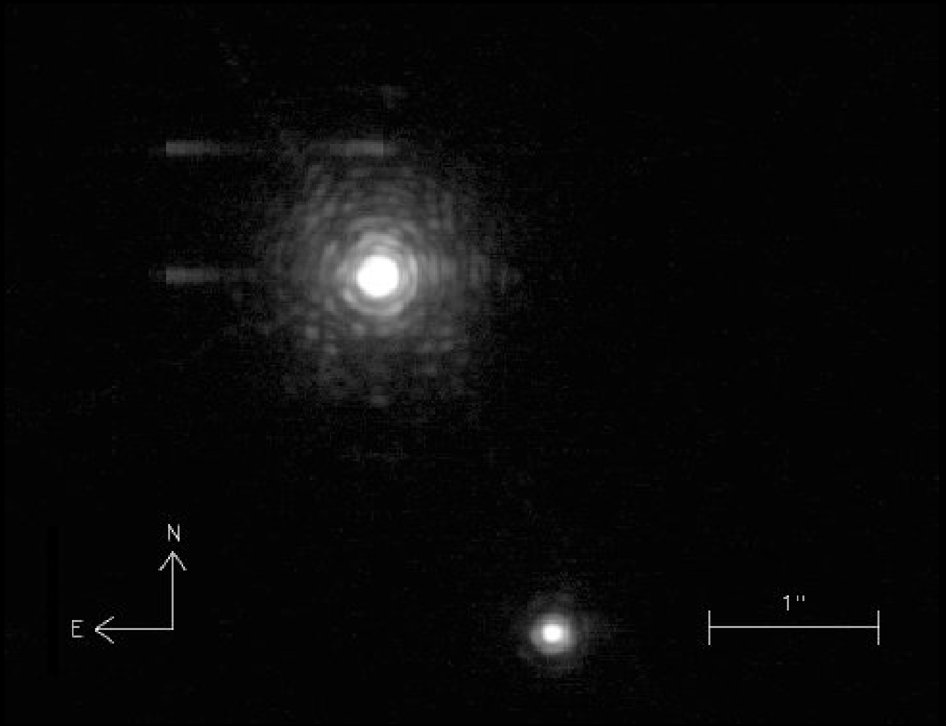
double star (F8V + K?V), Ks = 6 + 8 mag
separation: ~0.7”
no RV exoplanet candidate (but only upper limit on RV amplitude)

No astrometric signal expected

III. Relative, narrow-field, AO-assisted astrometry

First successful observation campaign with NACO in 12/2004

Specs: S13 camera (full frame)
NB_2.17 μm
DoubleCorr readout
t_{exp} = MinDIT (0.3s)
Autojitter pattern
120 frames in 1 hour
(split into two time slots)



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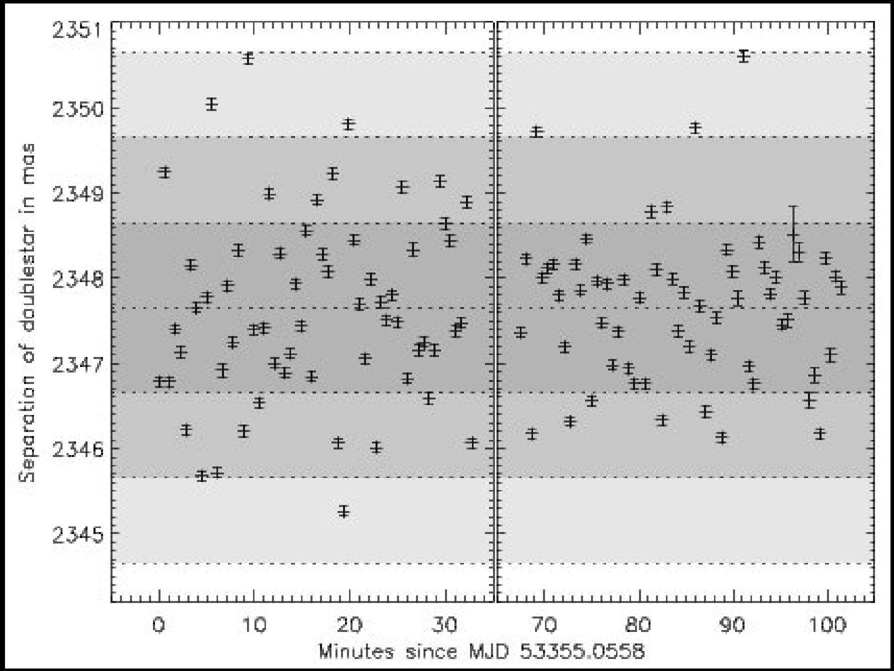

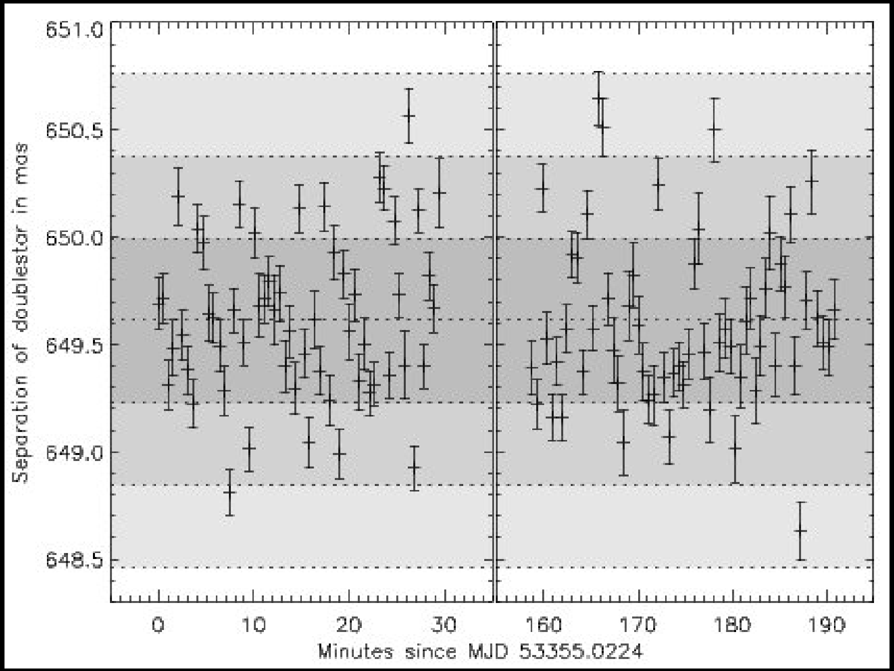

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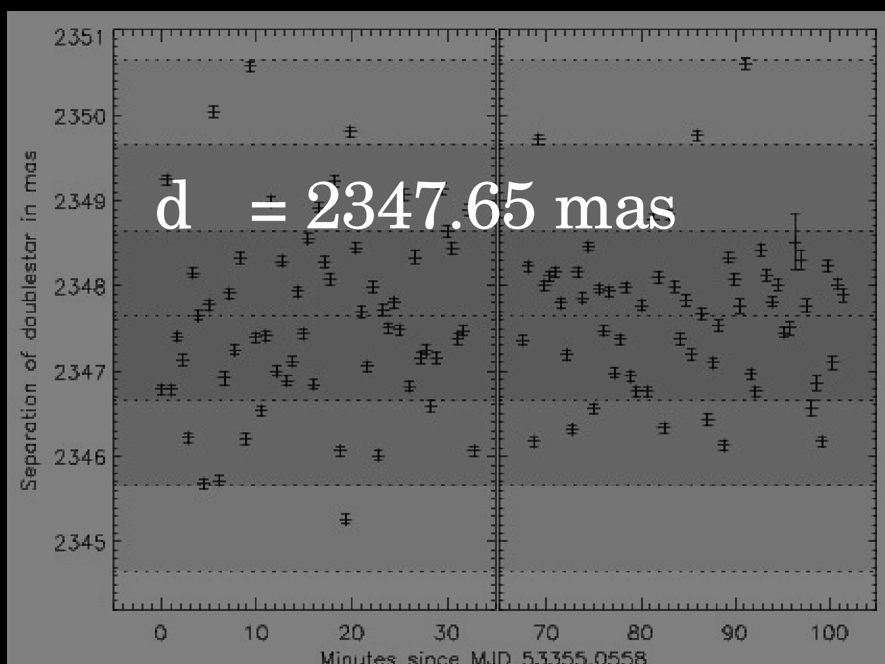

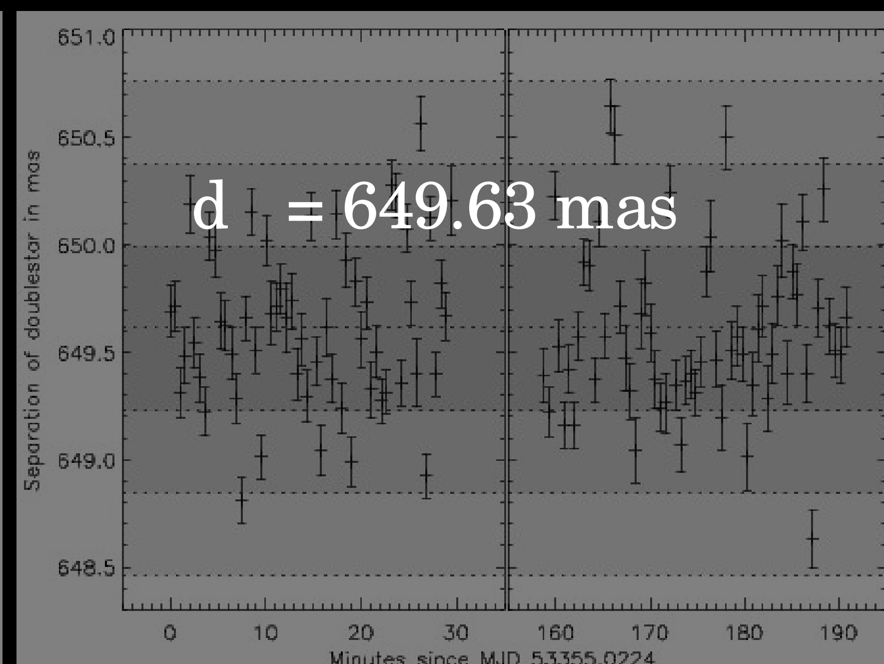

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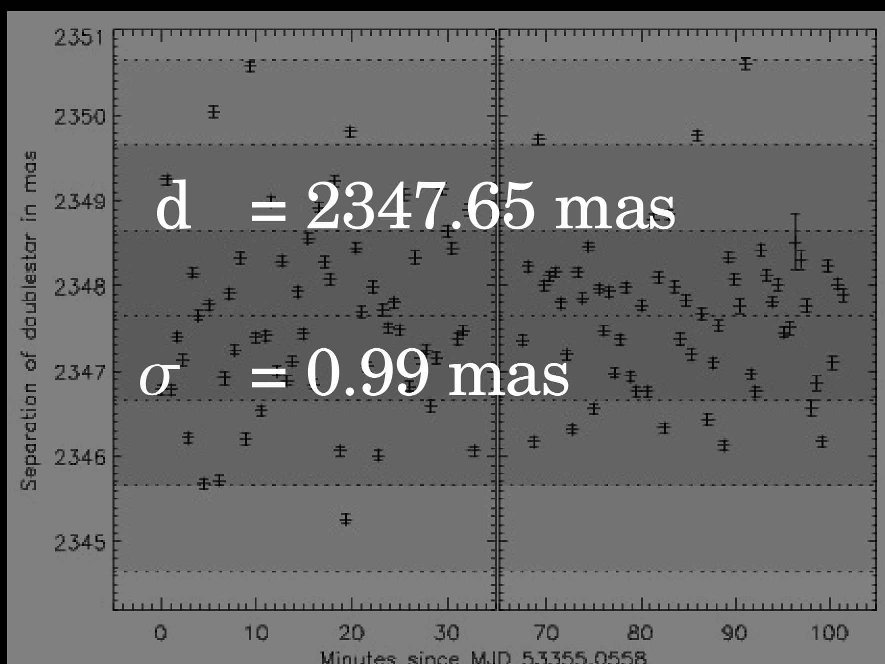

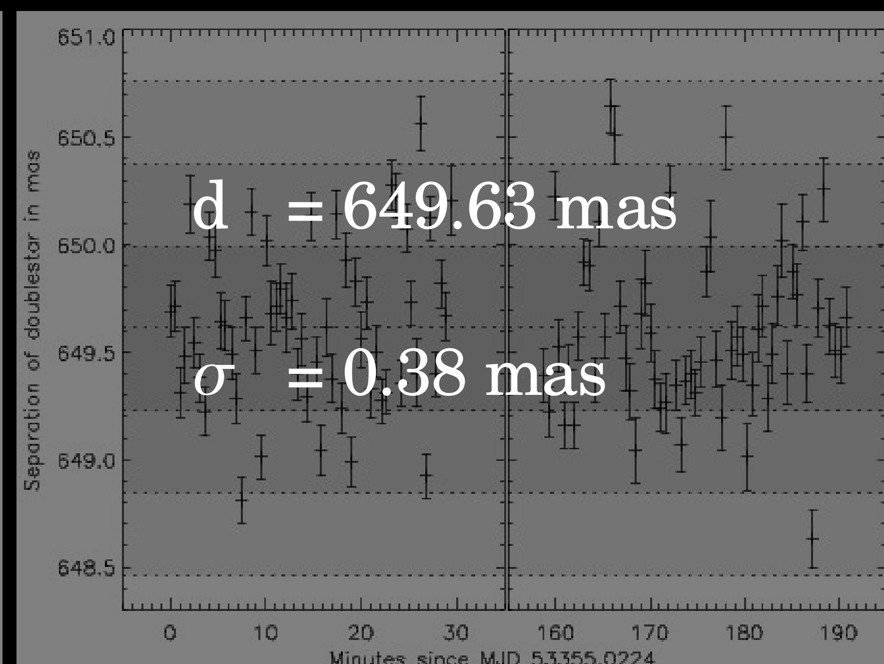

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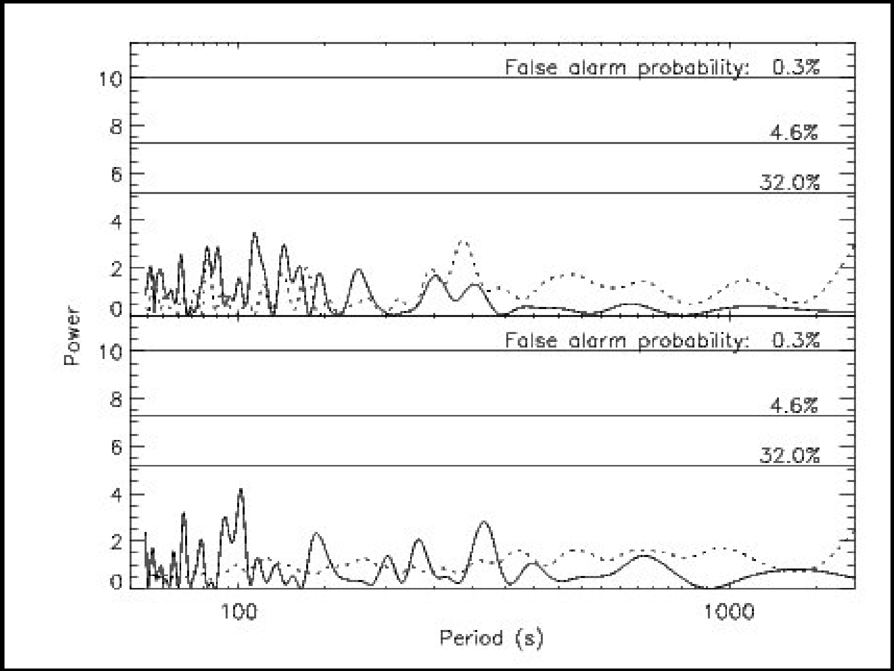

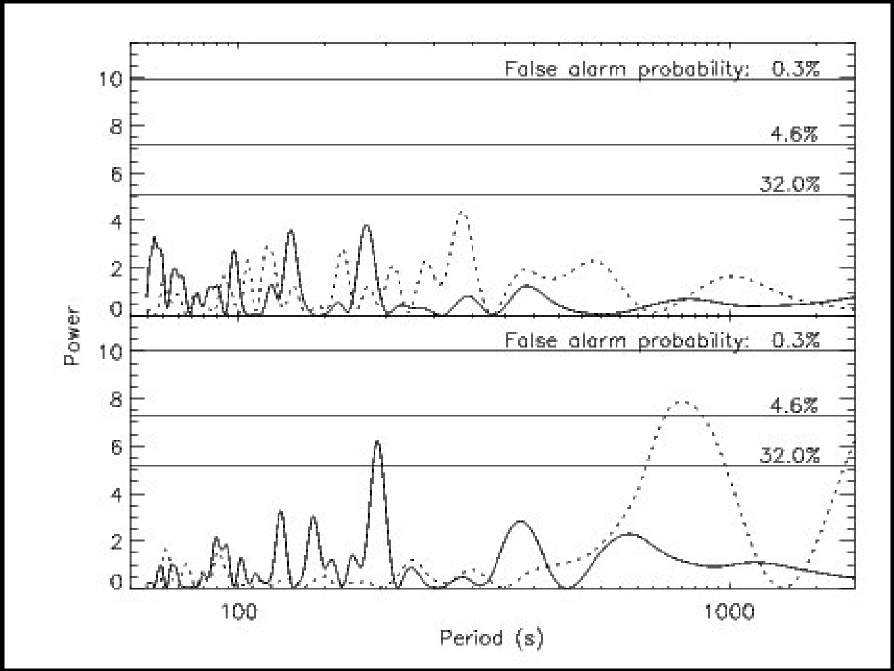

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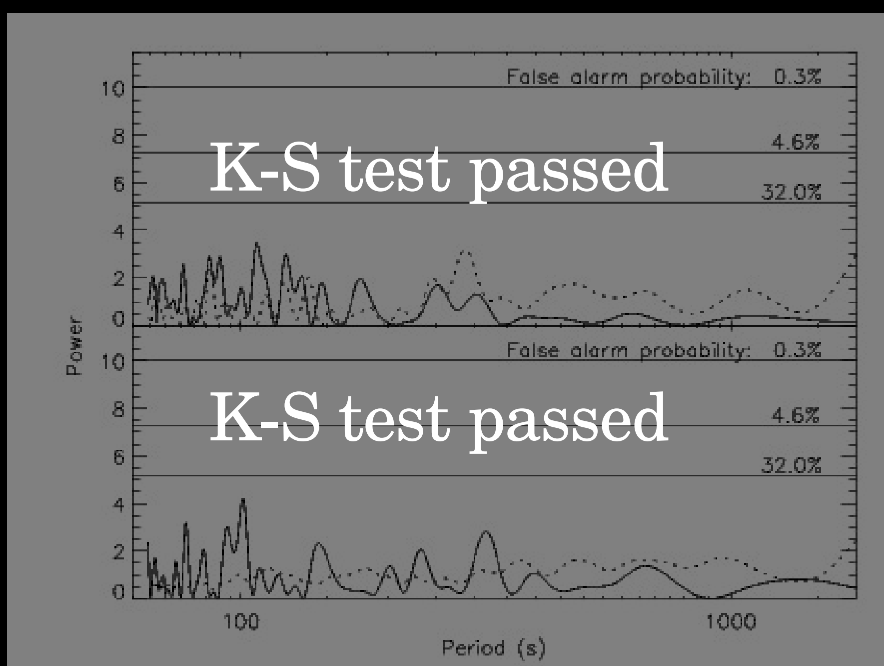

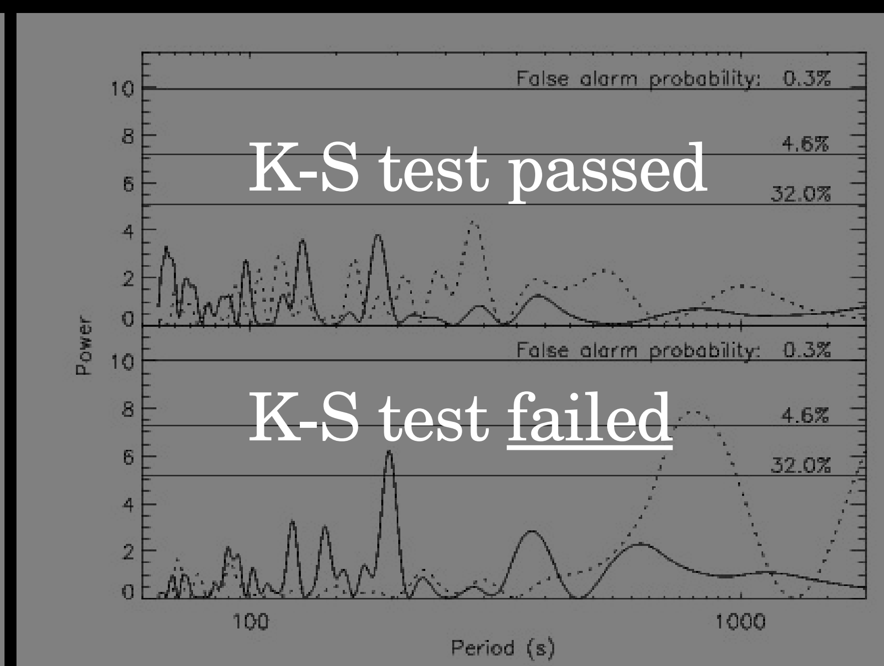

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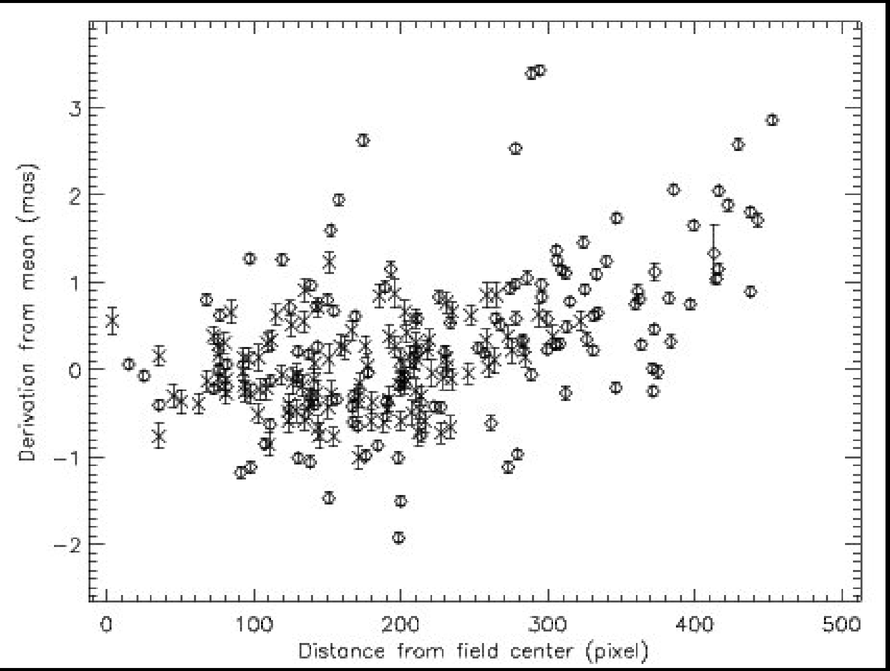
Results: *Field distortions!*



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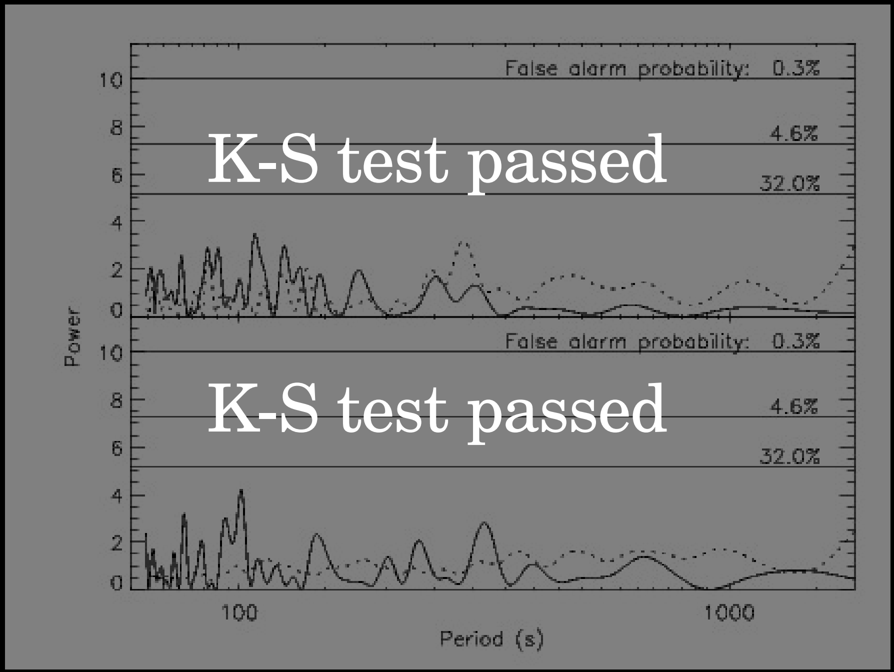

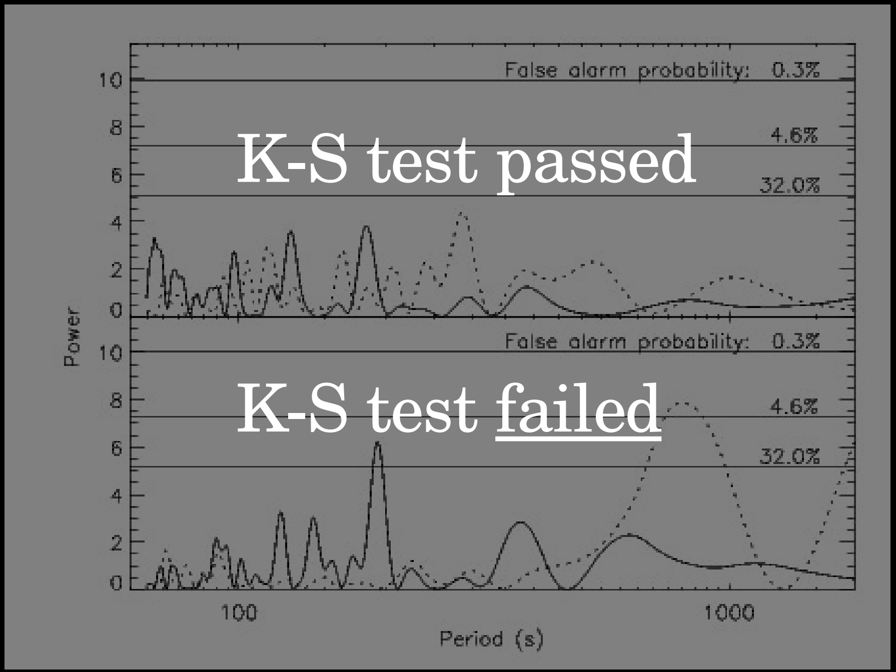

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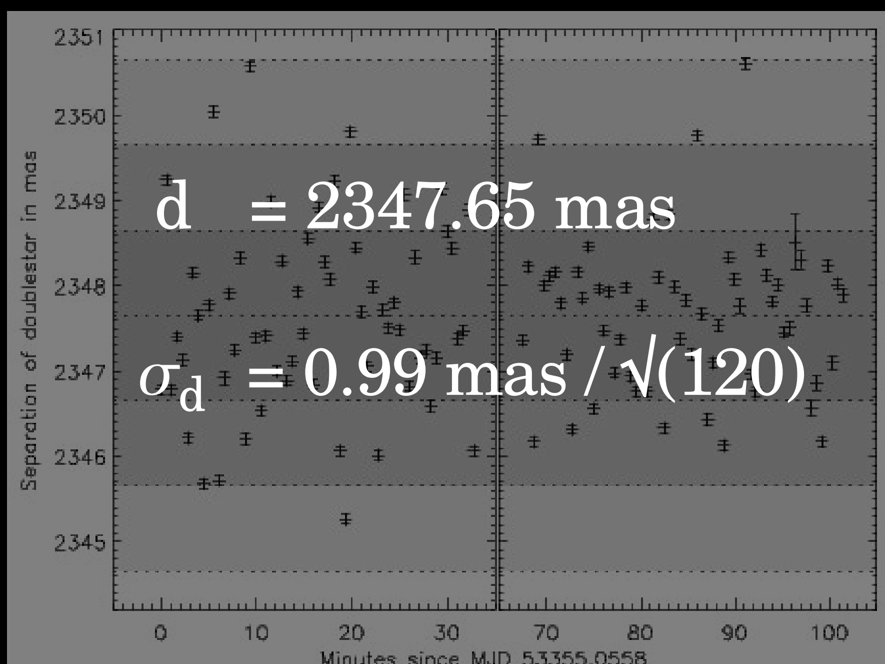

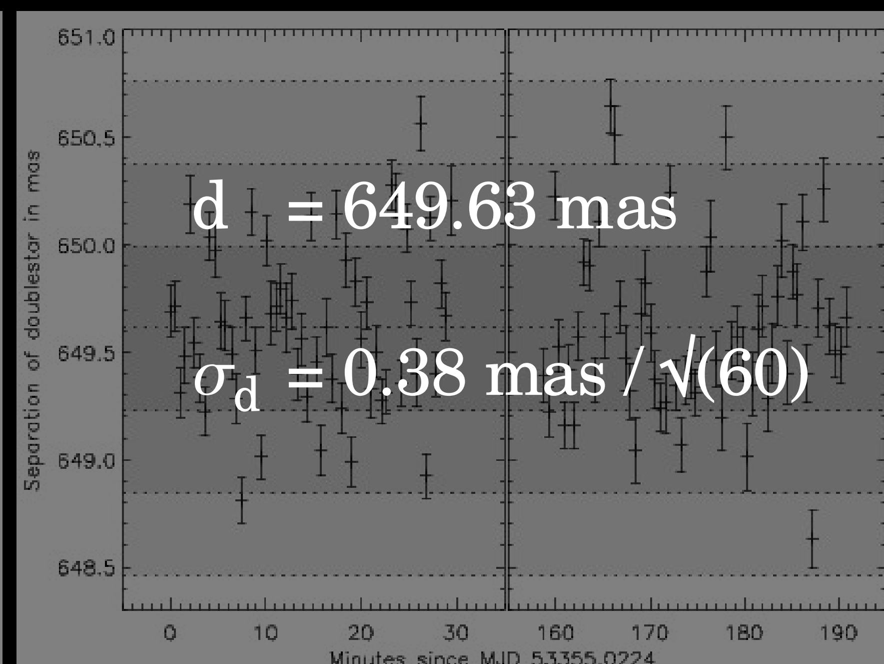

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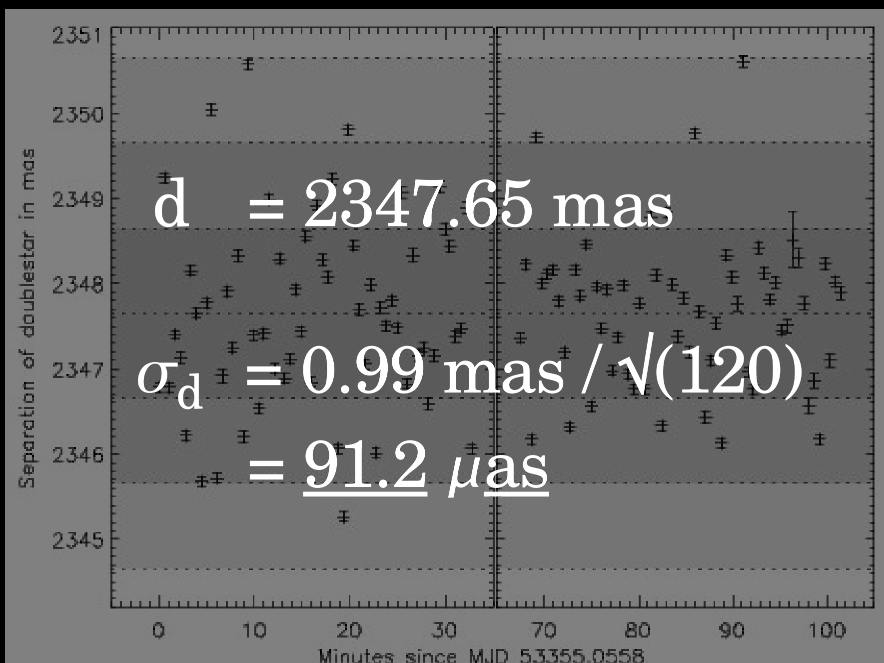
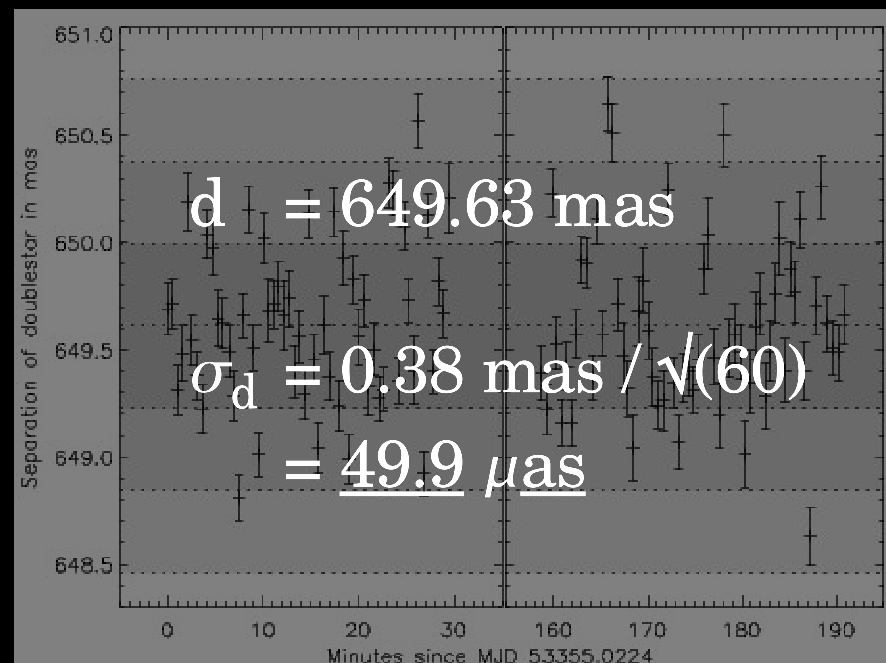


$d = 2347.65$ mas

$\sigma_d = 0.99$ mas / √(120)

= <u>91.2</u> μ<u>as</u>



$d = 649.63$ mas

$\sigma_d = 0.38$ mas / √(60)

= <u>49.9</u> μ<u>as</u>

III. Relative, narrow-field, AO-assisted astrometry

Absolute vs. relative astrometry
Accuracy vs. precision

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III. Relative, narrow-field, AO-assisted astrometry

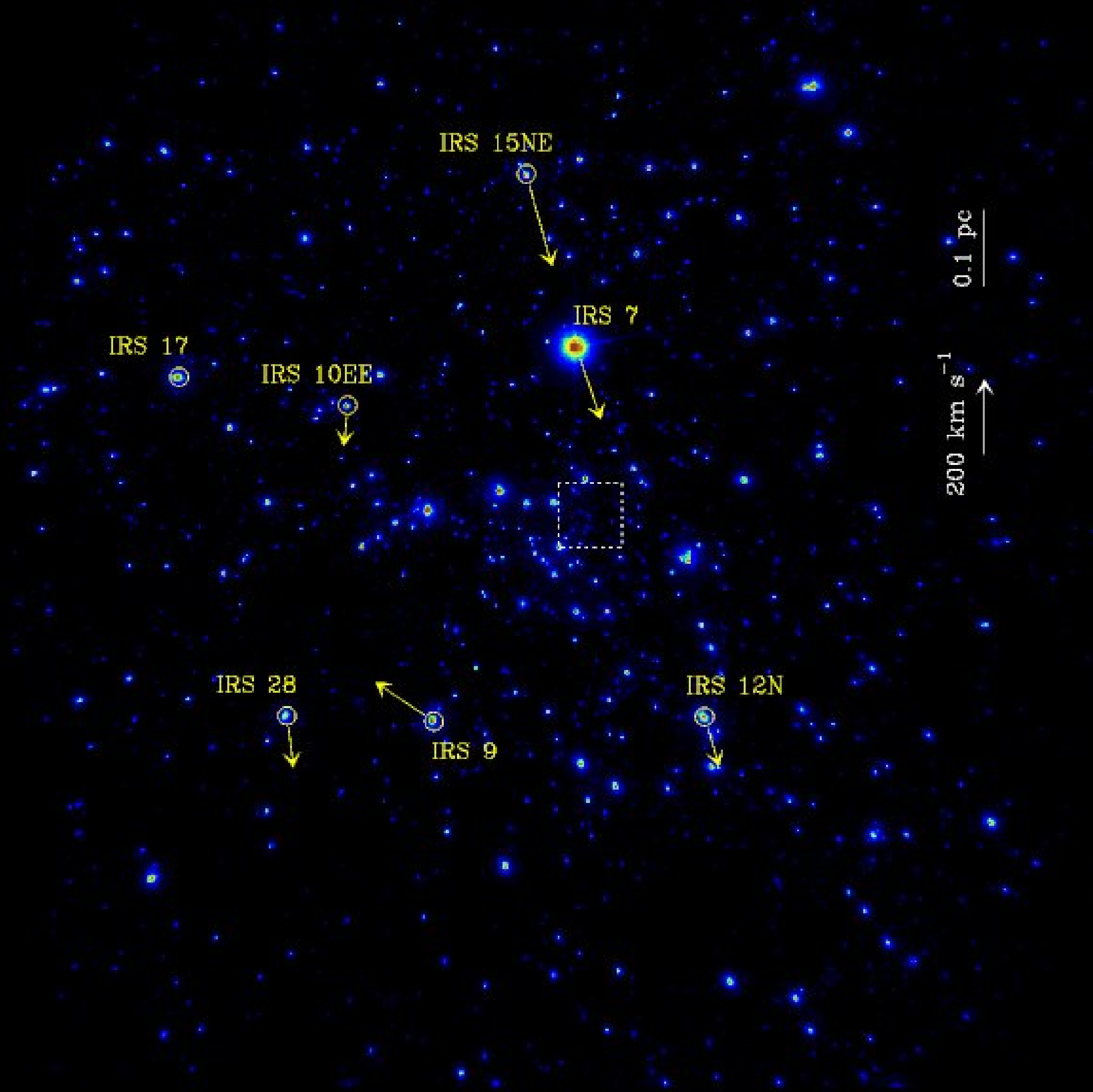
SiO masers in the Galactic center (Reid & Menten)

:

Not fitting into the FOV of the S13 camera

Positions known with precision << 1mas (VLBI measurements)

Uncertainties in PM sum up to >> 1mas



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So.... ???

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Relax on demands towards an (extreme) pixel scale calibration and concentrate on pixel scale stability

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Tough choice...

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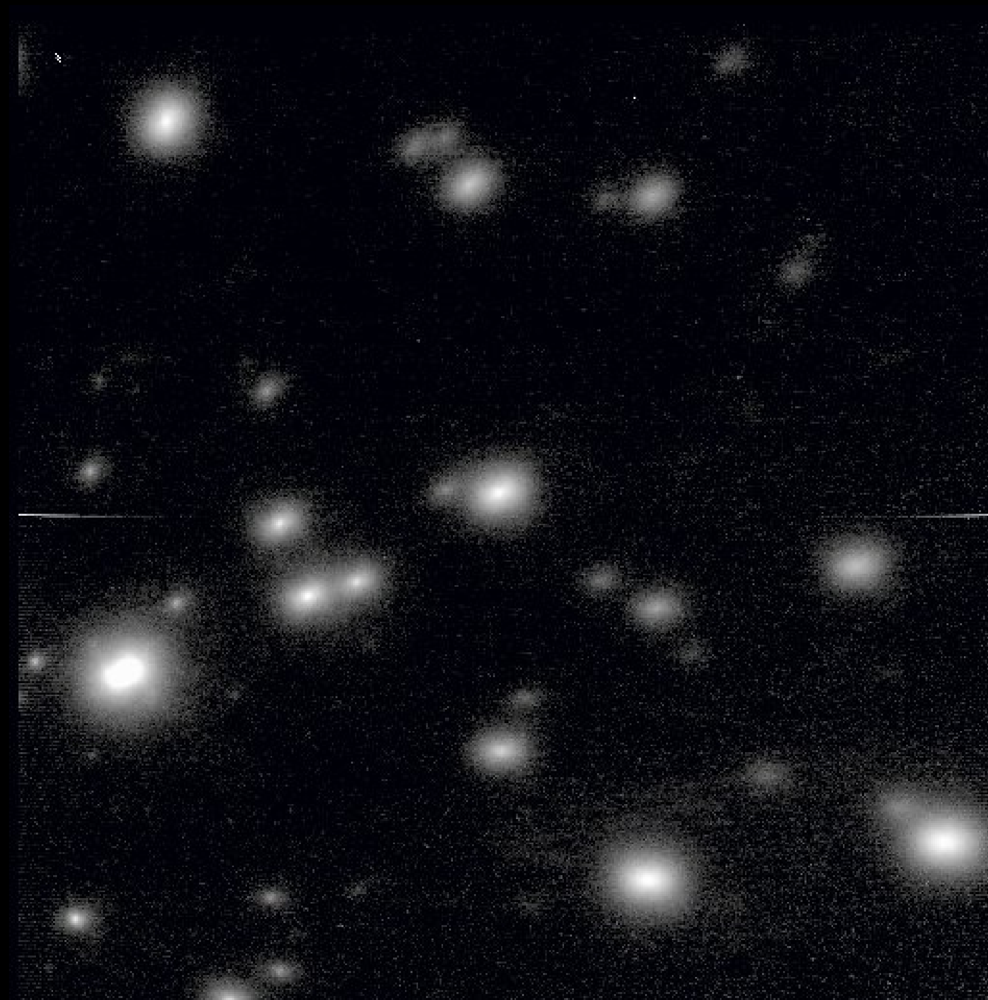
30s exposure time (NB filter)
180 (full) frames



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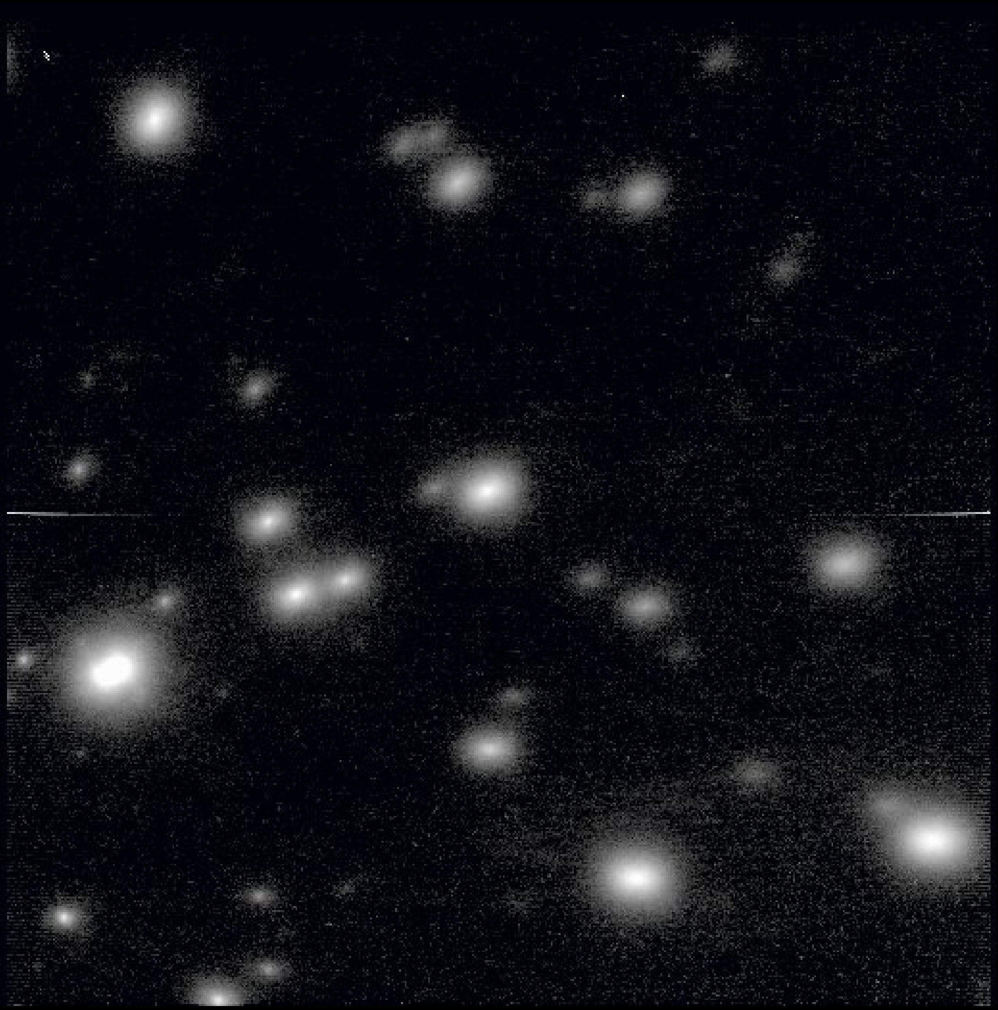

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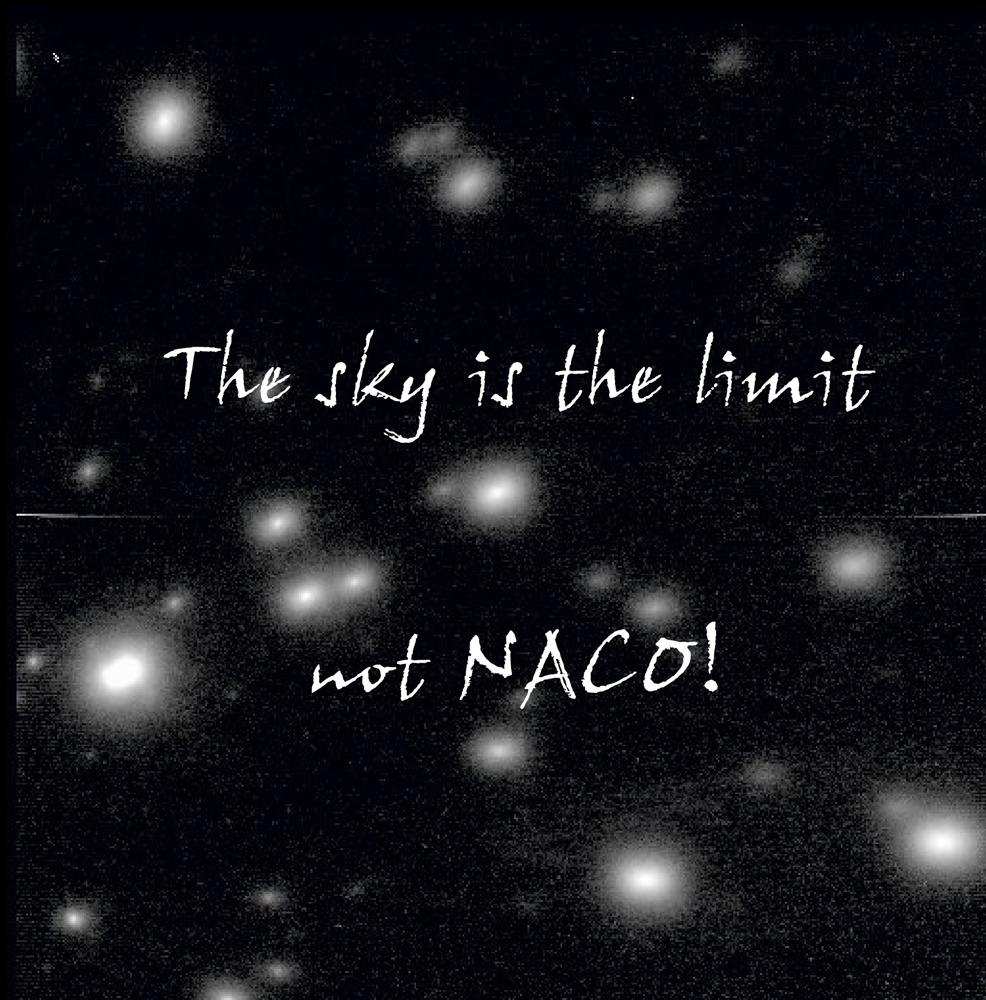

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Things to do on our side:

(1) Refined analysis of 180 images of 47Tuc

(2) Identify even more suitable regions

(3) Analyse 6000 (!) frames of HD19994 taken with NACO in Nov. 2006 within three hours using NACOs cube mode capabilities

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Missing NACO tests and calibrations:

(1) Analysis and monitoring of field distortions

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Wishful thinking ?