Observability of light deflection induced by Jupiter's quadrupole

The GAREQ system

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Collaborators

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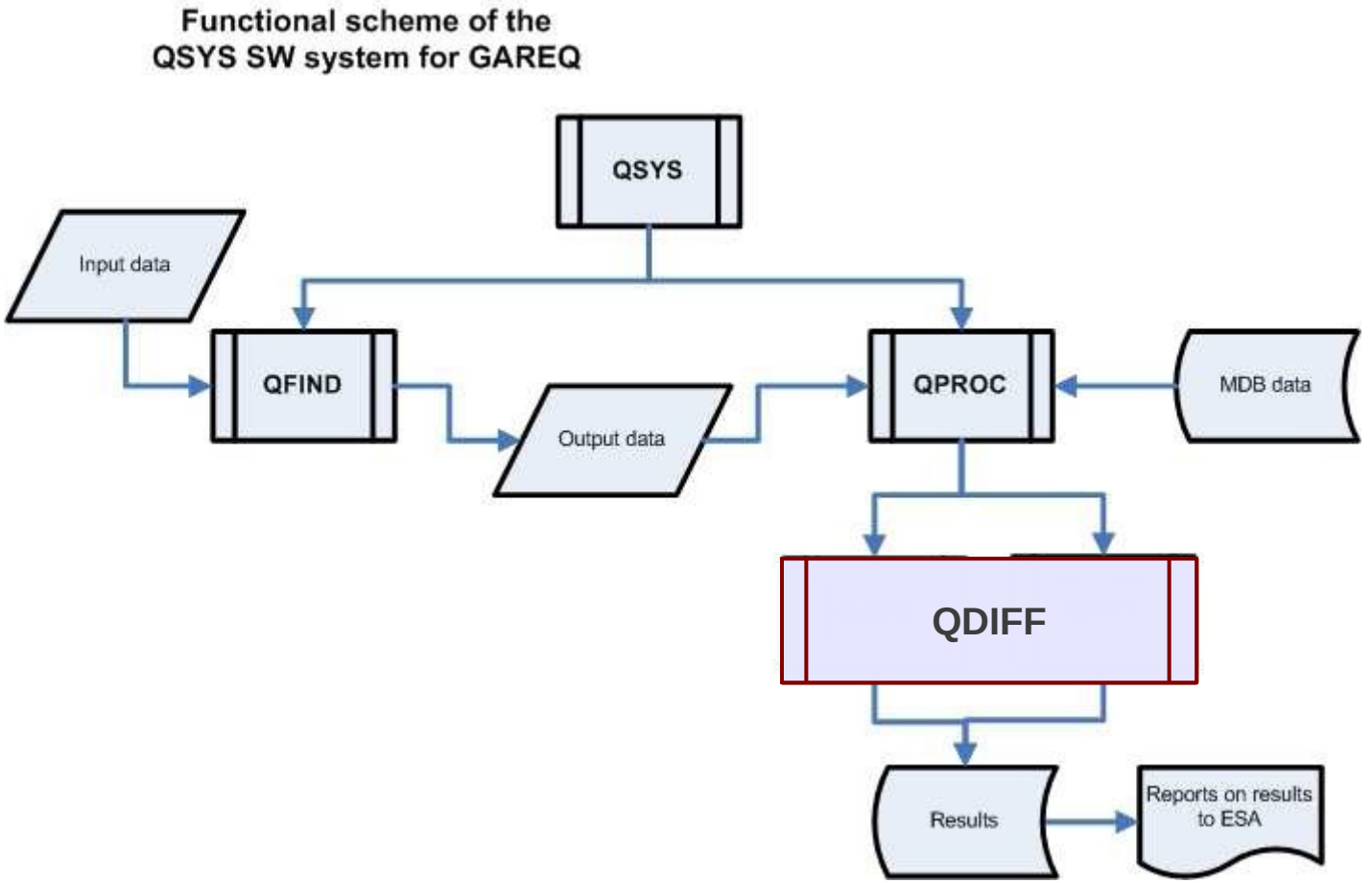
- DPCT: R. Messineo (ALTEC)
- International: F. Mignard (OCA, Nice), S. Klioner (U. Dresden), J. de Bruine (ESTEC), L. Lindegren (Lund Univ.), D. Hobbs (Lund Univ.)

What? Why?

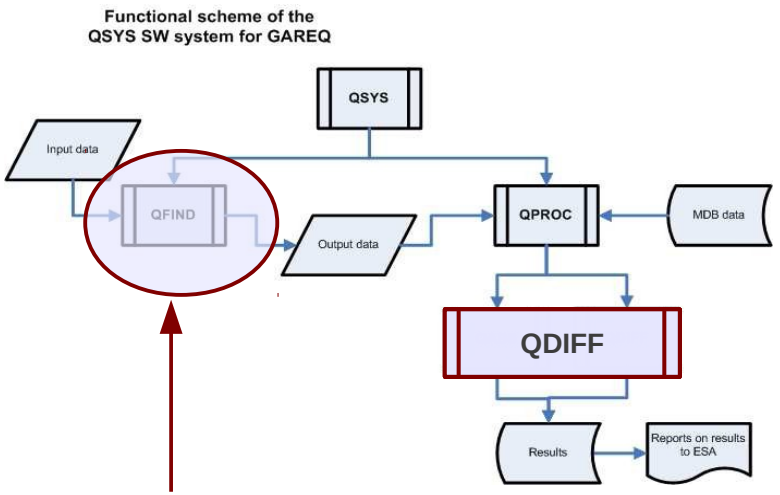
- **What?** GAREQ is a fully portable software system to be implemented and run at DPCT (ALTEC)
- **Why?**
  - Optimize the initial scanning law mission parameters.
  - Measure differential quadrupole effects to provide absolute standards throughout the mission.
  - To possibly perform first-time measurements of the light deflection due to Jupiter's quadrupole moment.

The GAREQ setup

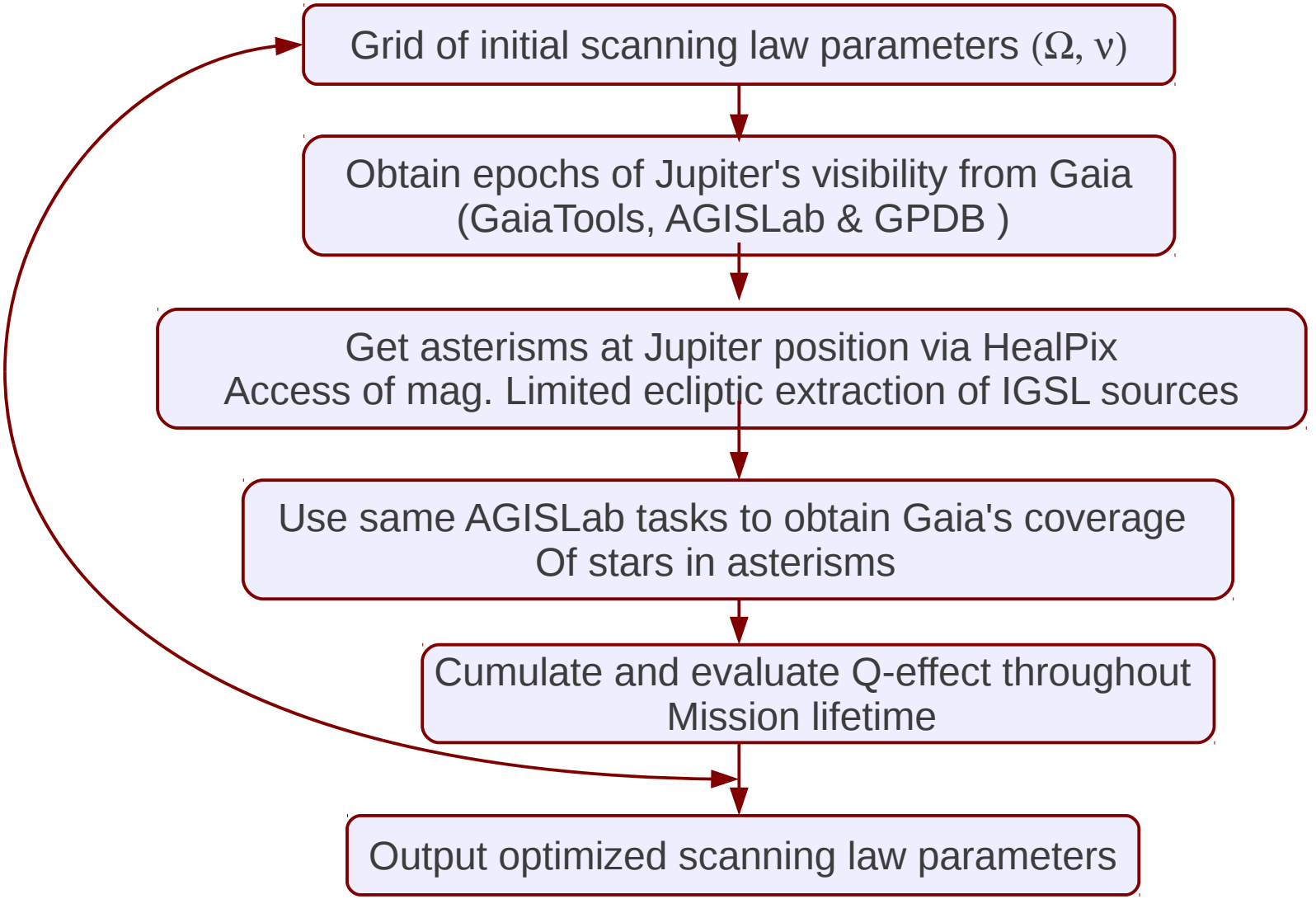


LiveLink technical note UA-003

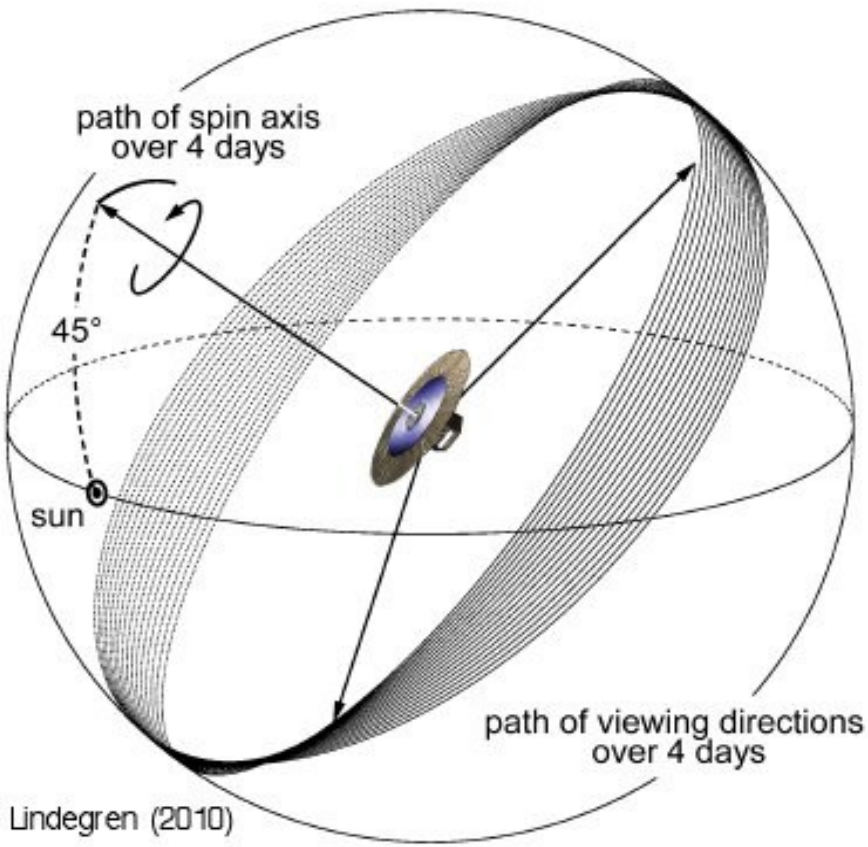
Optimizing the Initial Scanning Law mission parameters: Ω_0 ν_0

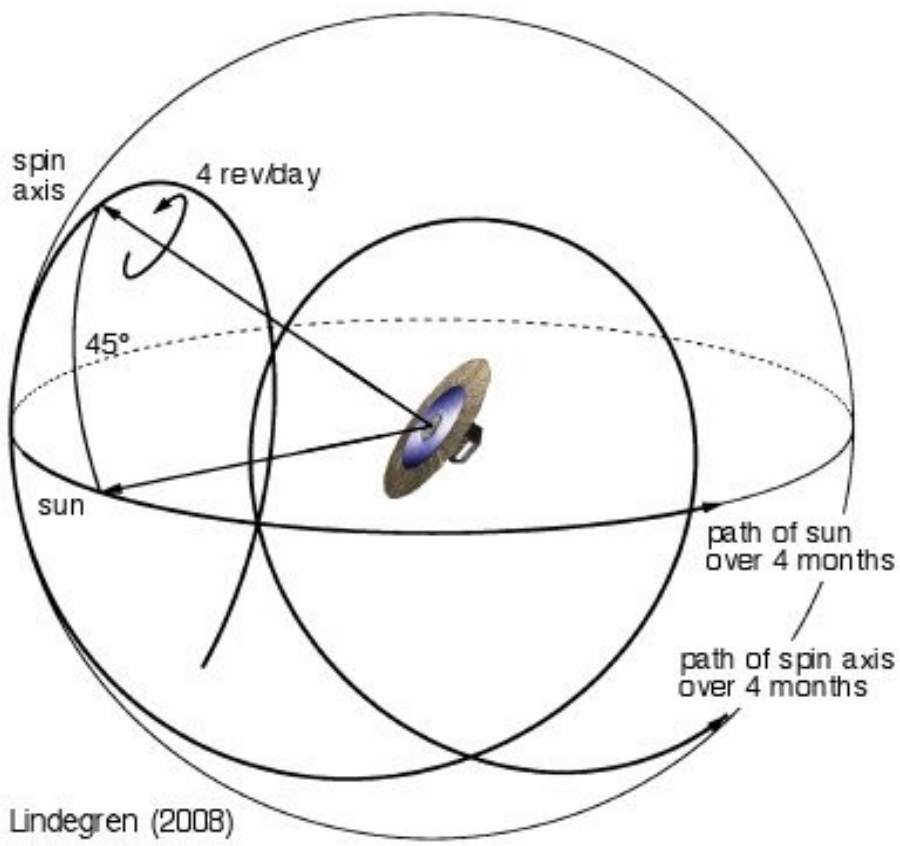


QFIND to obtain optimal observing scenario

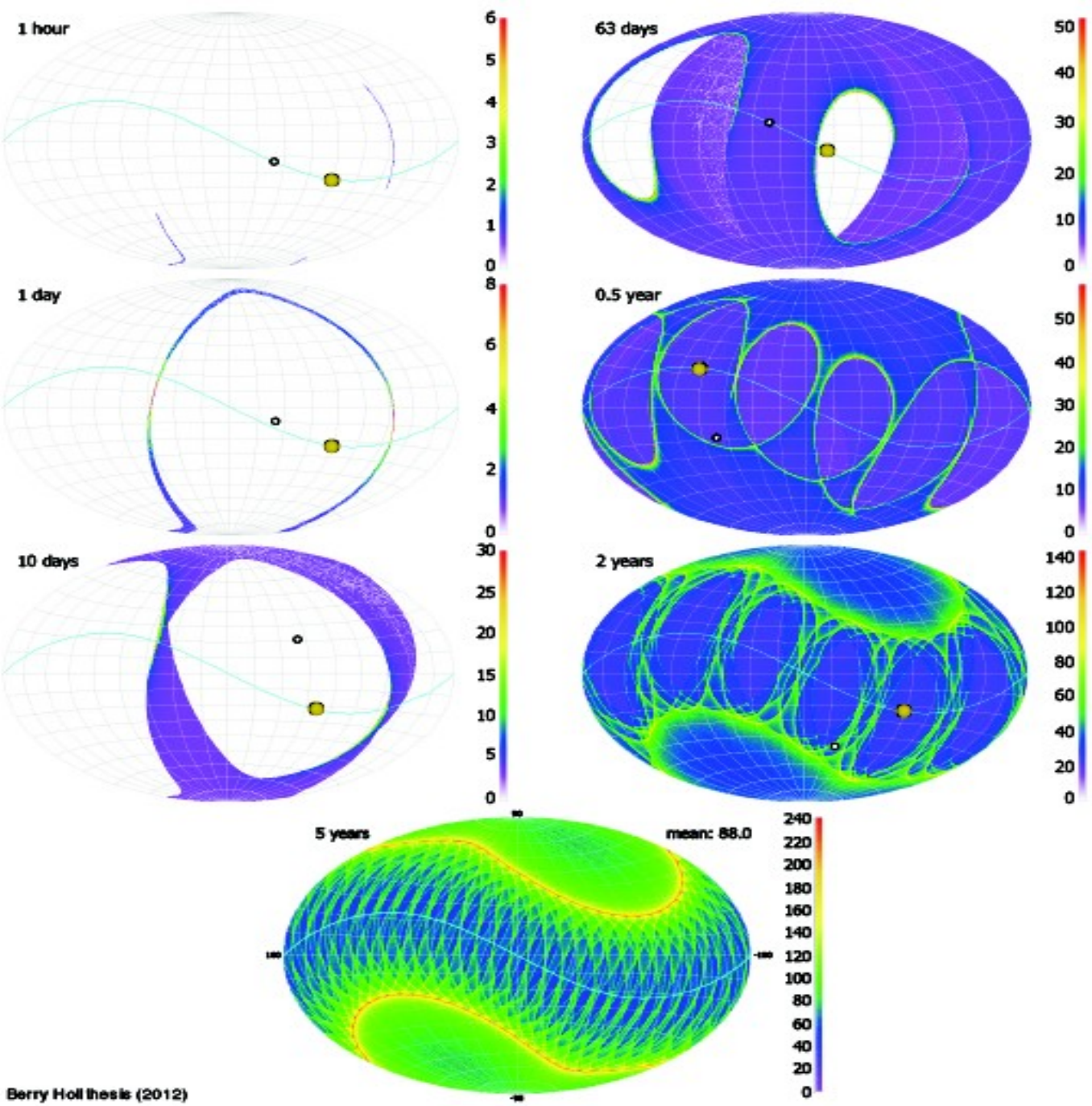


Gaia scanning law

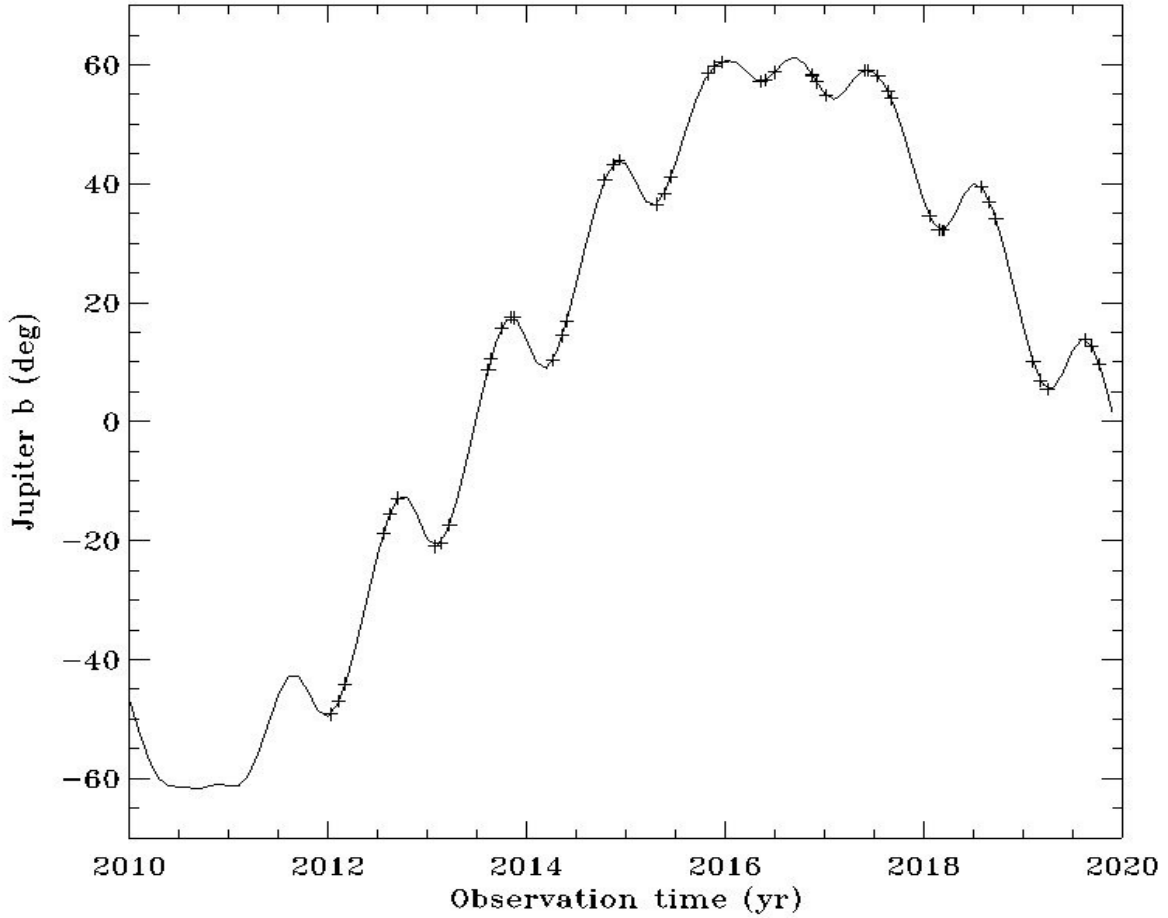




The scanning law (free) parameters are spin and precession (Omega and nu)

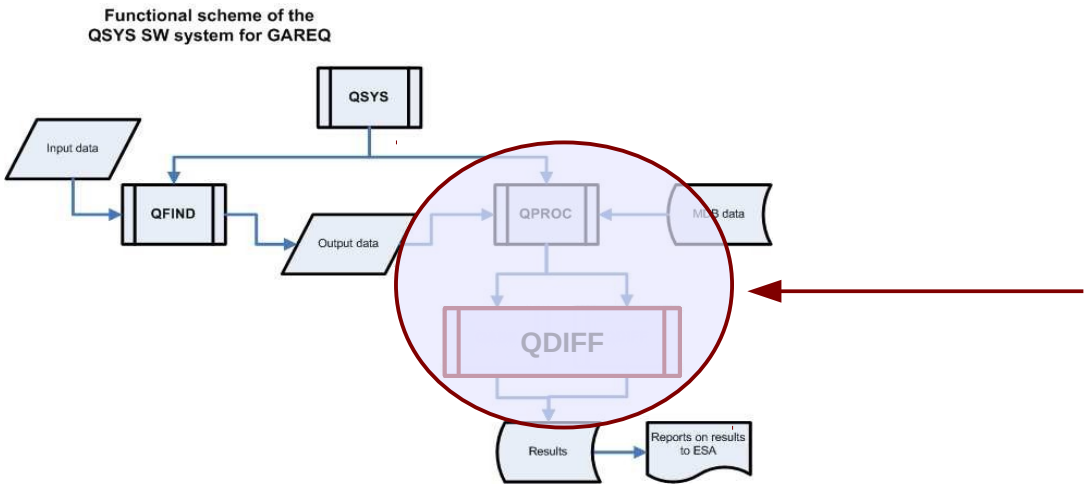

1 hour
63 days
1 day
0.5 year
10 days
2 years
5 years
mean: 88.0
Berry Holl thesis (2012)

Jupiter visibility from Gaia



Epochs of observation over 10 years for Gaia nominal scanning law

Measuring the Differential Quadrupole Effects



The Different modes of gravitational deflection

- The Monopolar deflection:
  - Associated with total mass and radial velocity of gravitating body.
  - Displaces apparent positions of stars radially away from origin of celestial coordinates of planet.
- The Dipolar deflection:
  - Due to translational mismatch of COM of planet and origin of planetary coordinates caused by inaccuracy of planetary ephemeris.
- The quadrupolar deflection:
  - caused by physical oblateness of planet

Kopeikin & Makarov 2007

Light deflection due to planets

	$\delta\Phi_{\rm pN}$	$\delta\Phi_Q$	$\delta\Phi_{\rm max}$
Sun	$1\farcs75$	$\sim 1\ \mu$as	(180°)
	μas	μas	
Mercury	83	–	$9'$
Venus	493	–	4.5°
Earth	574	0.6	178°
Moon	26	–	9°
Mars	116	0.2	$25'$
Jupiter	16280	239	$90^\circ/3'$
Saturn	5772	94	$18^\circ/51''$
Uranus	2081	25	$72'/6''$
Neptune	2535	9	$51'/3''$
Pluto	7	–	$8''$

Crosta & Mignard 2006

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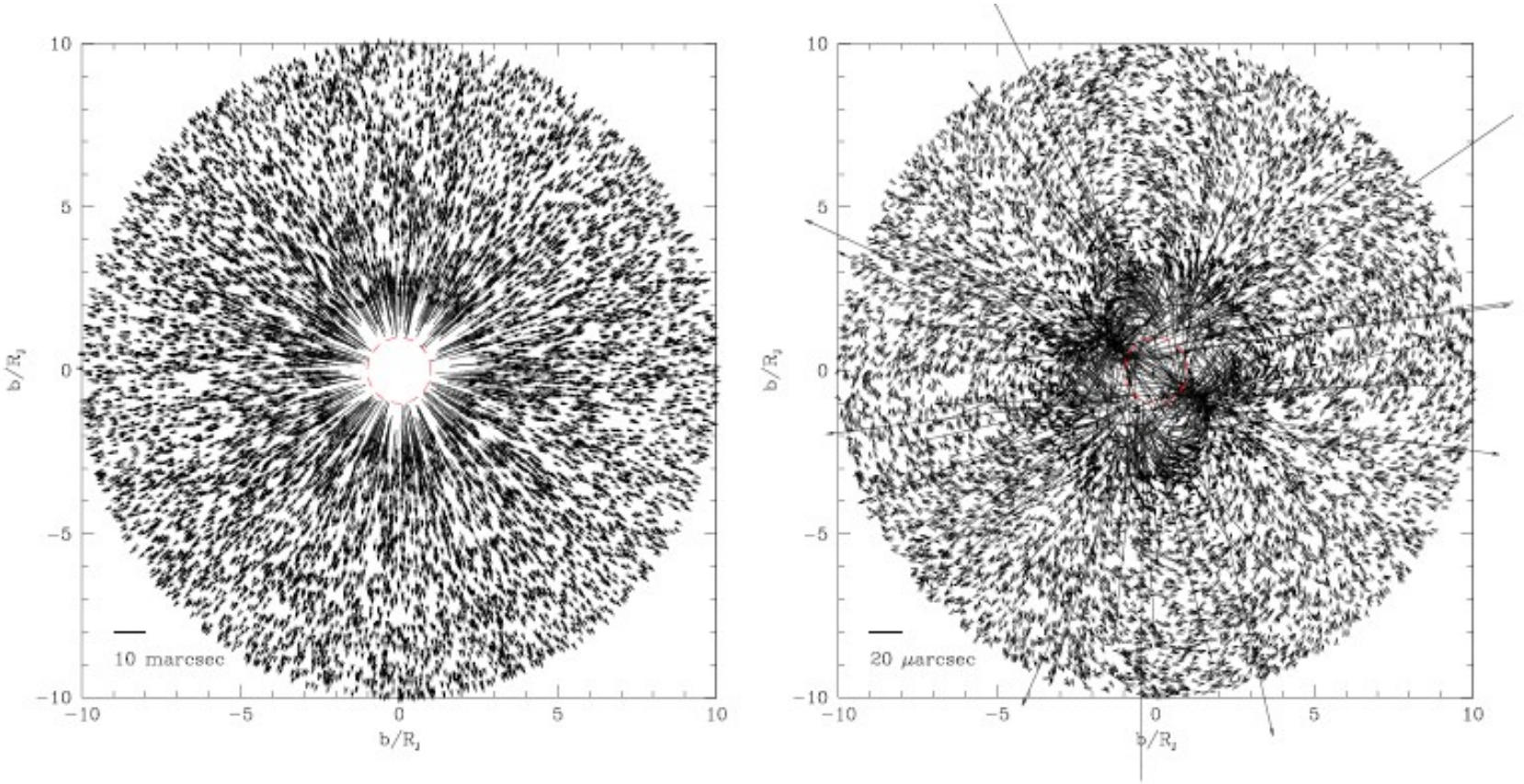
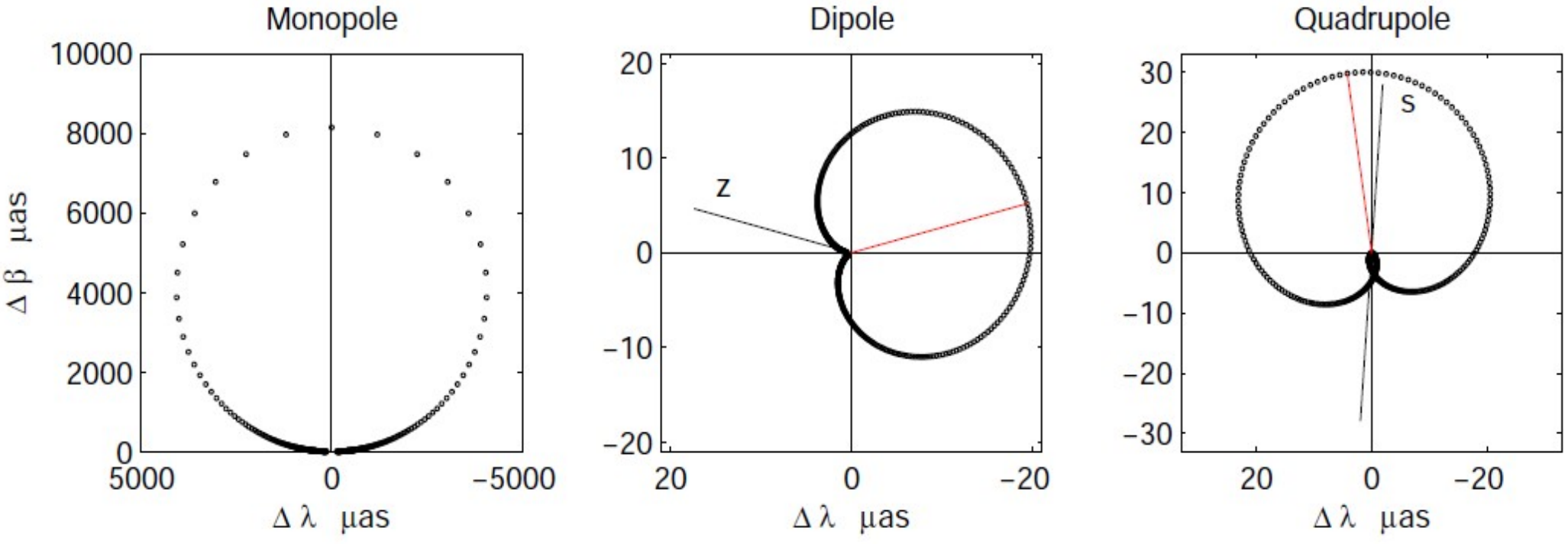
Gravitational field around Jupiter seen by Gaia



Monopole (left) and Quadrupole (right) stellar vector fields

Crosta & Mignard 2007

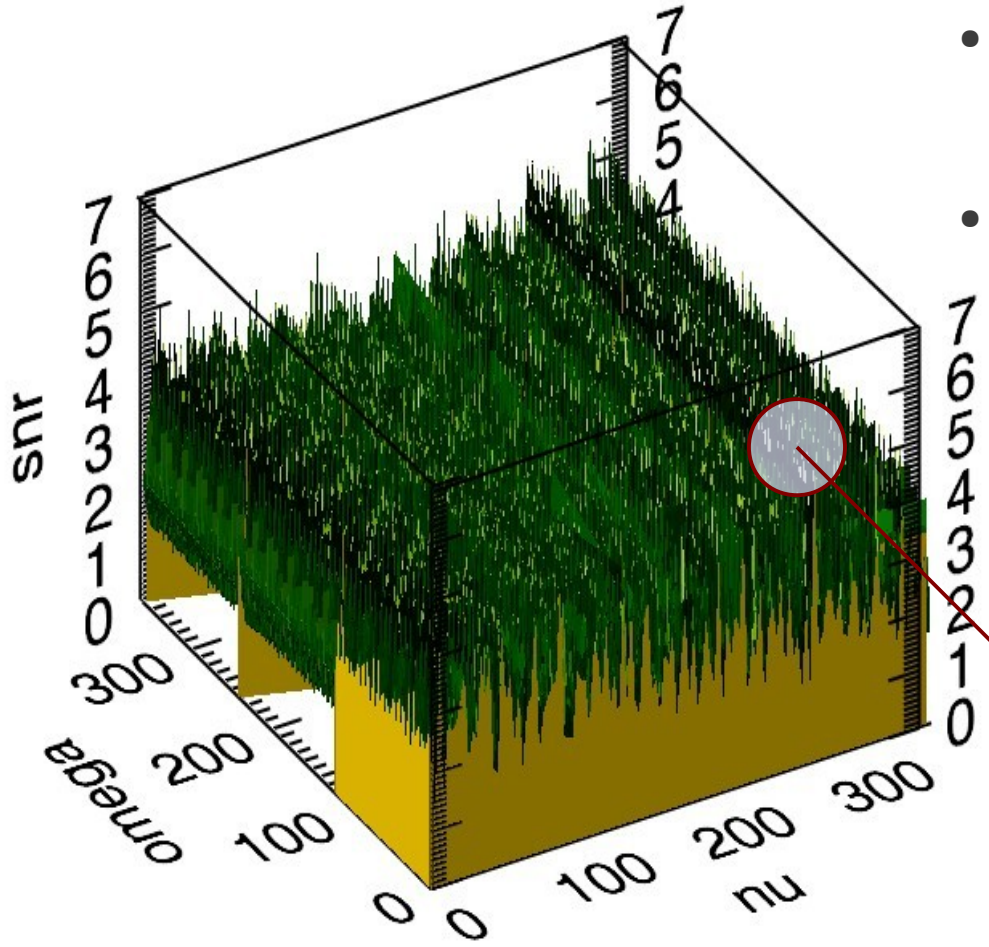
Deflection patterns



Kopeikin & Makarov 2007

The monopolar (circular), dipolar (cardiod), quadrupolar light deflection patterns in apparent Position of star (impact parameter = 40mas, time step = ~30 mins for monopole, ~3 mins for dipole and quadrupole).
The patterns depends on the gravitational model used, eg. no dipole term using time transfer functions (Le Poncin- Lafitte & Teyssandier 2008).

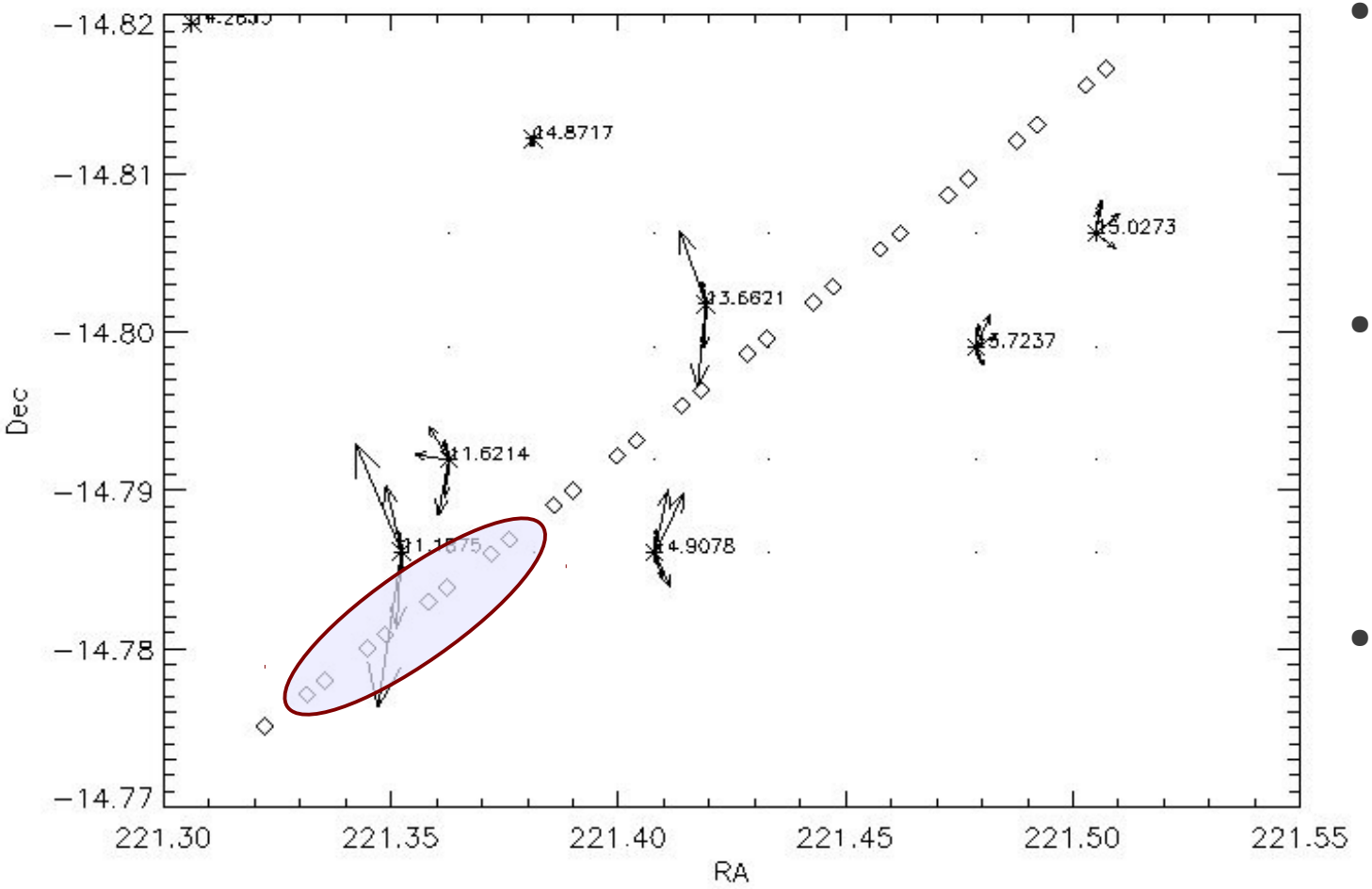
SNR per NSL



- Total SNR over 360x360 grid on nu and omega.
- Mission time = 2013.6 – 2018.6

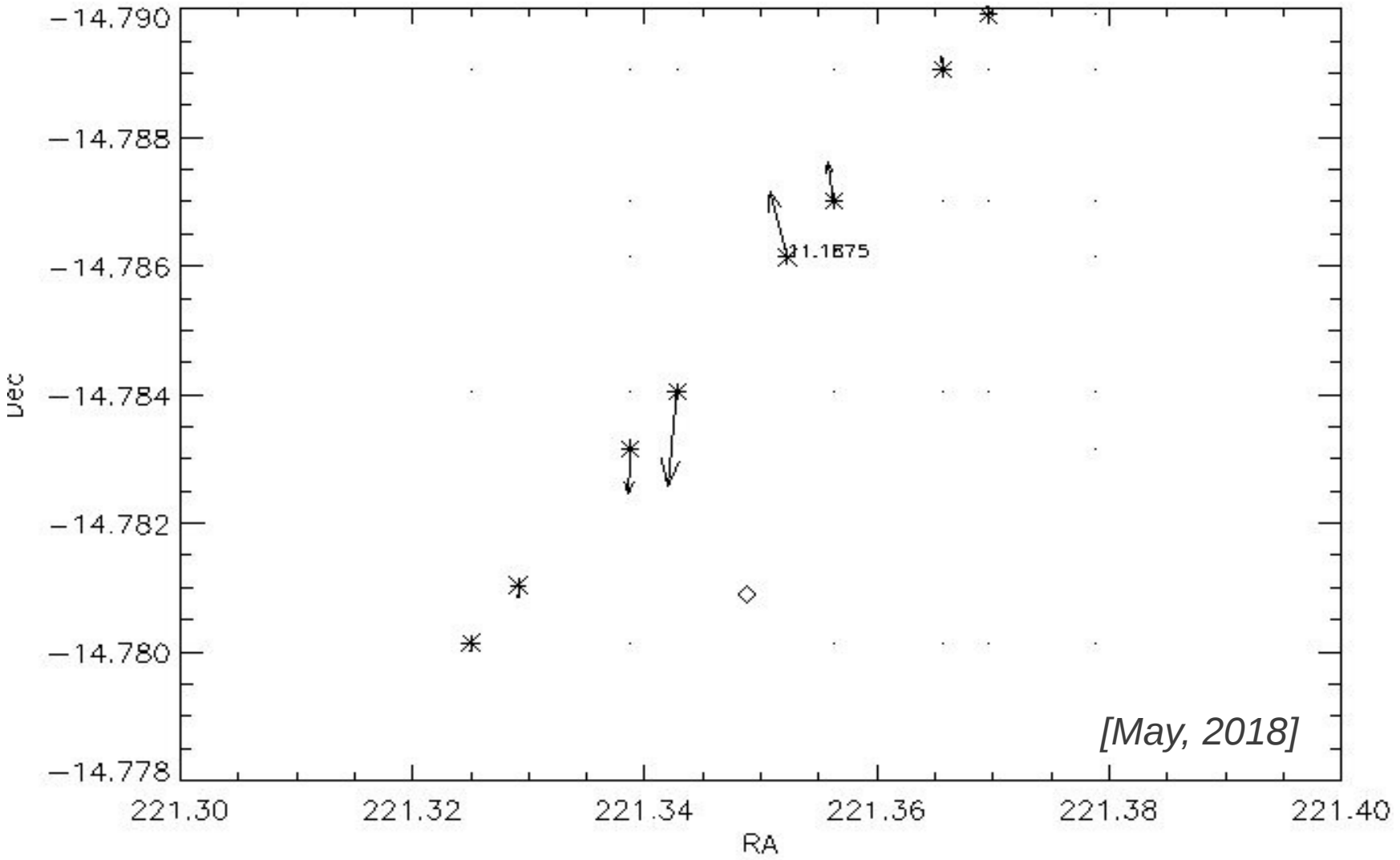
Max SNR at nu=276, omega=81

GAREQ-events for brightest star



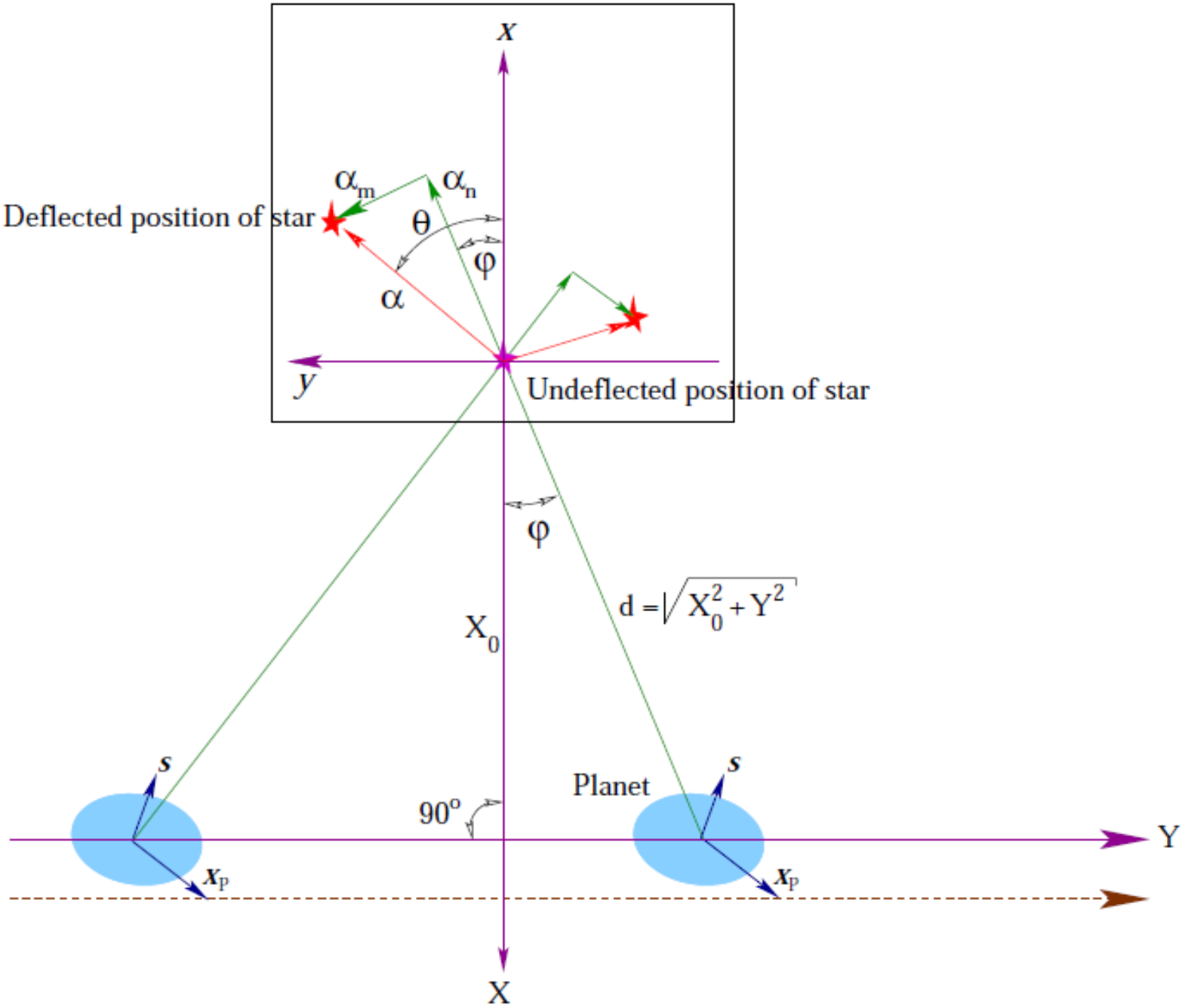
- Zoom onto brightest star events for max SNR.
- In best case, bright star can be seen 8 times within 5 Rjup.
- Arrows show the direction and magnitude of quadrupole effect.

Keeping Jupiter fixed...

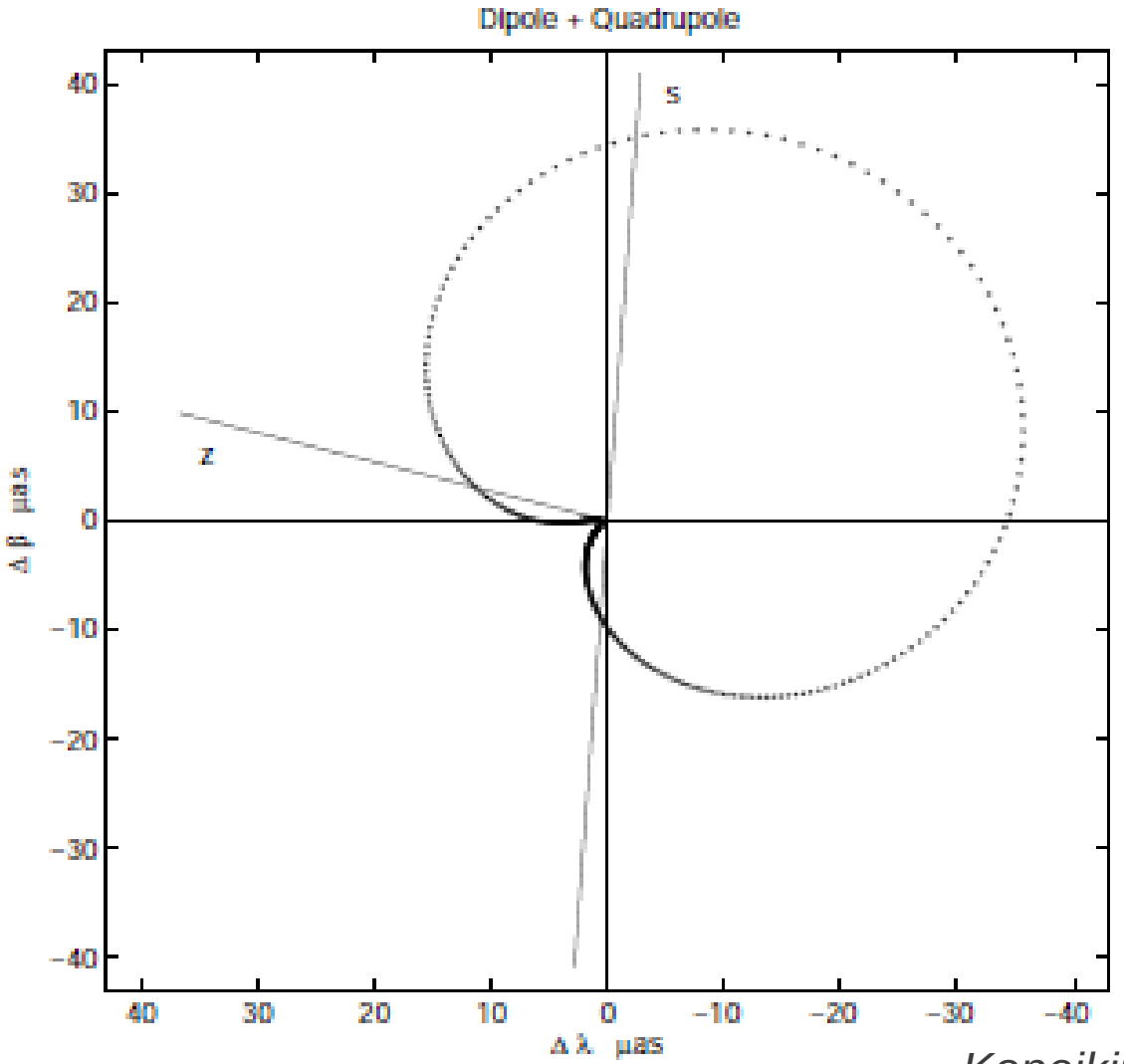


Timeline

- Launch - 3 months: REMAT to agree on the GAREQ Figure-of-Merit for optimizing the scanning-law initial conditions [GAREQ must be able to provide re-calculated mission parameters to ESOC throughout the mission.]
- GAREQ will perform the detection and analysis of several events throughout the mission potentially providing an absolute way to gauge satellite performance with time.
- GAREQ will possibly perform first-time measurements of the light deflection due to Jupiter's quadrupole moment since Einstein's prediction.


x
Deflected position of star
α_m
α_n
θ
φ
α
y
Undeflected position of star
φ
$d = \sqrt{X_0^2 + Y^2}$
X_0
s
Planet
s
90°
Y
x_p
x_p
X

Combined dipolar + quadrupolar deflection



Kopeikin & Makarov 2007