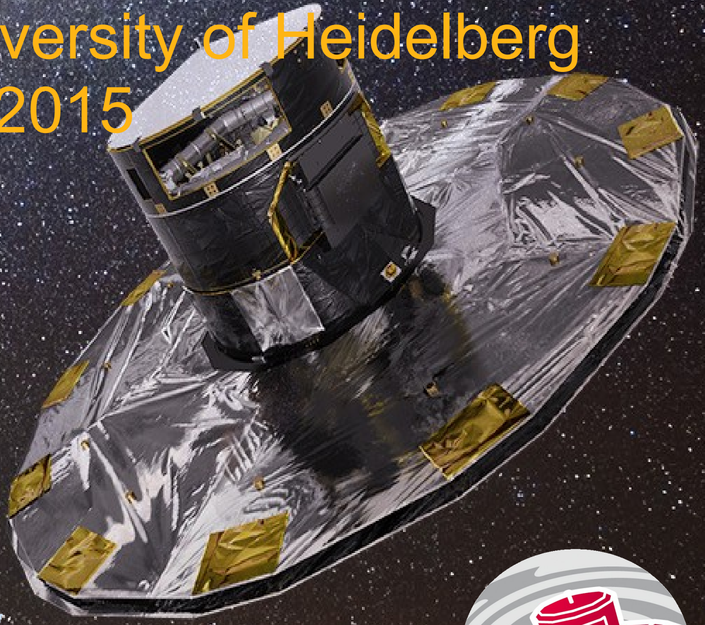
GAIA - the Bright and Near Future for Galactic and Stellar Science

Martin Altmann
Centre for Astrophysics of the University of Heidelberg
Oxford, 24th July 2015
(archival version)



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Gaia – the promise

- 1+ billion stars to 20.7^{th} magnitude, 1% of MW stars
- Full 5 parameter astrometric data for $>10^9$ stars
  - Between 10 and 900 µas precision for parallaxes, positions and proper motions!
- Multi colour (spectro)photometry of 10^9 stars
- High resol. spectroscopy for 10^8 stars to 17^{th} mag
  - Radial velocities, abundances, rotation velocities for the brighter objects.

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Gaia – the promise

- Calibration of the cosmic distance ladder
- Kinematics of the components of the Milky Way and its satellites
- Solar system objects (NEOs and PHOs)
- Fundamental physics (gravitational constant)
- Kinematics/Dynamics of star clusters
- Transient objects
- positions of 1 million QSOs/AGNs

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Gaia – the promise

- Gaia will revolutionise our understanding of the Galaxy and galaxies in general!
- Enhanced by follow up studies (Gaia ESO Survey) and existing large surveys (SDSS, PanSTARRS, RAVE, 2MASS, MUSYC), Gaia data will even give more insights
- For astrometry of faint objects (Brown & White Dwarfs, M-stars), Gaia will provide an excellent reference frame
-

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Gaia – the promise

Gaia vs. Hipparcos:

Gaia: no input list, all objects 3 mag*<G<20 mag included,

Hipparcos: Input list for objects <7.3 mag

Stellar distances to	10 %:	150 million (HIP: 21000)
	1 %:	20 million (HIP: 100 ?)
	0.1 %:	1 million (HIP: none)
Variable stars:		50 million (HIP: 8000)
Astrometric binaries:		100 million (HIP: 3000)
with orbits:		100 000 (HIP: 235)

*: for <3 mag, special programme

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Gaia – the promise

Gaia vs. today

Direct stellar masses to 1%: > 10 000 (up to now a few dozen ?)

Quasars, galaxies: 500 000, a few dozen million

White dwarfs: 200 000 (up to now 2 000)

Brown dwarfs: 50 000 ? (up to now a few dozen ?)

Planetary systems: 50 000 (up to now 1500 or so)

Supernovae: 10 000 (up to now a few thousand)

Minor planets: 500 000 ? (up to now 200 000)

General relativity to 10^{-6} ? (up to now $50x10^{-6}$, or $10x10^{-6}$)

Complete stellar counts, precise stellar counts, all-sky inventory

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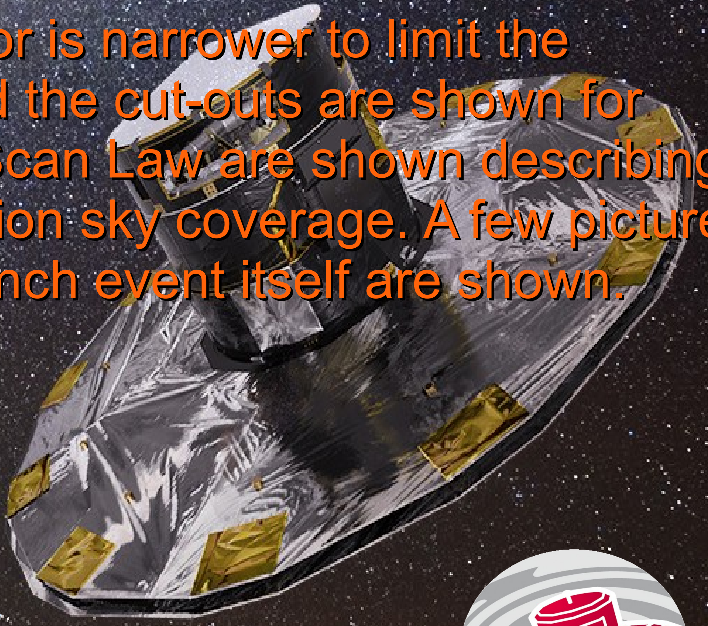
Gaia – the space-craft

The following slides/pages show images (both photos and graphics) of key components of Gaia, such as the optical assembly, one of the main mirrors or the CCD-array in the focal plane. This should give an impression of how Gaia works. The representation of the focal plane shows how a star drifts across the optical plane in order to be identified either as a source coming through FOV1 or FOV2 in one of the two sky mapper arrays, which is then, if above a certain threshold assigned an aperture which is then sent back to Earth. It then transverses the Astrometric array and then the two photometric (actually spectrophotometric) arrays (BP and RP), finally stars in a narrower field will be recorded by the spectral array (RVS, this detector is narrower to limit the required band width). Typical simulated data and the cut-outs are shown for each data type. Finally the orbit and (Nominal) Scan Law are shown describing the buildup of sky coverage and the end of mission sky coverage. A few pictures of the satellite in its pre-launch state and the launch event itself are shown.

(page inserted for “archival version”).



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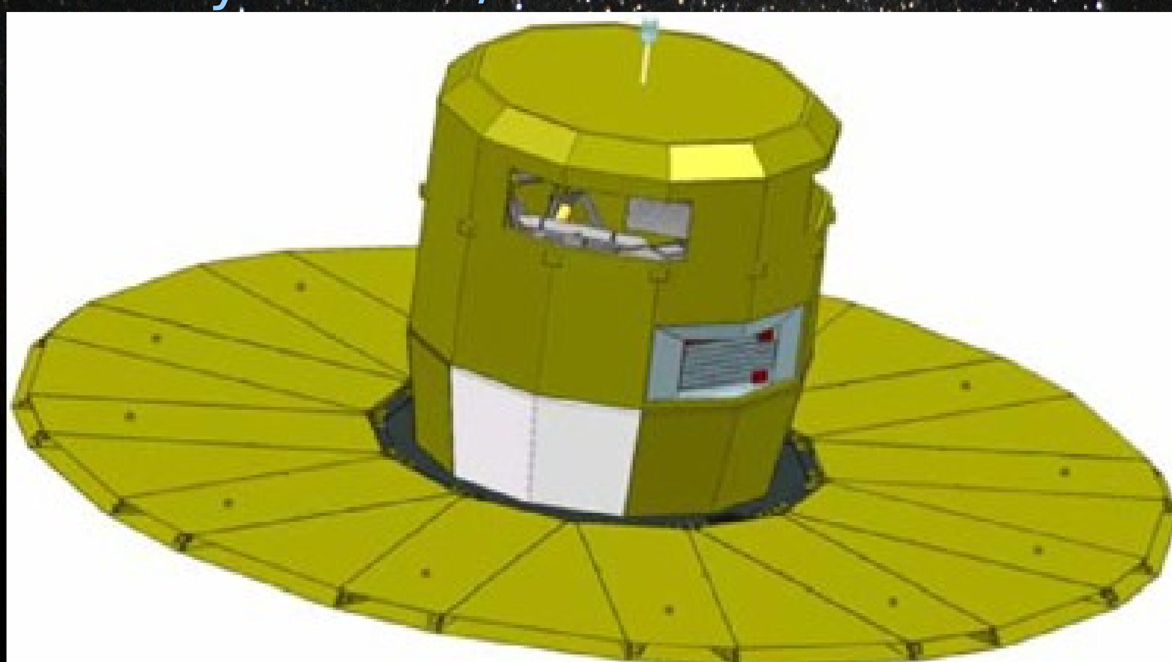
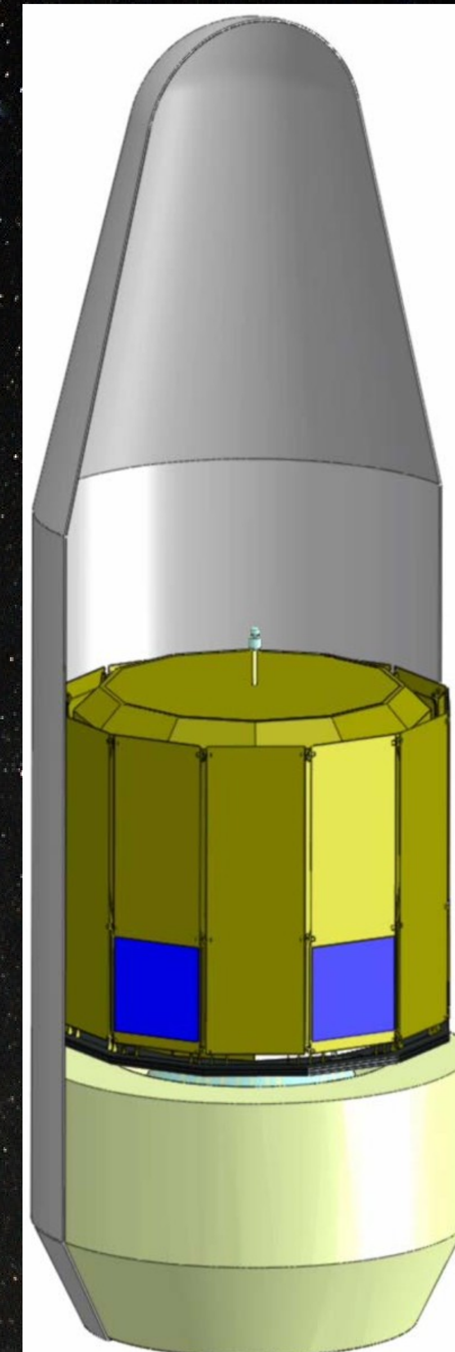
Gaia: the spacecraft

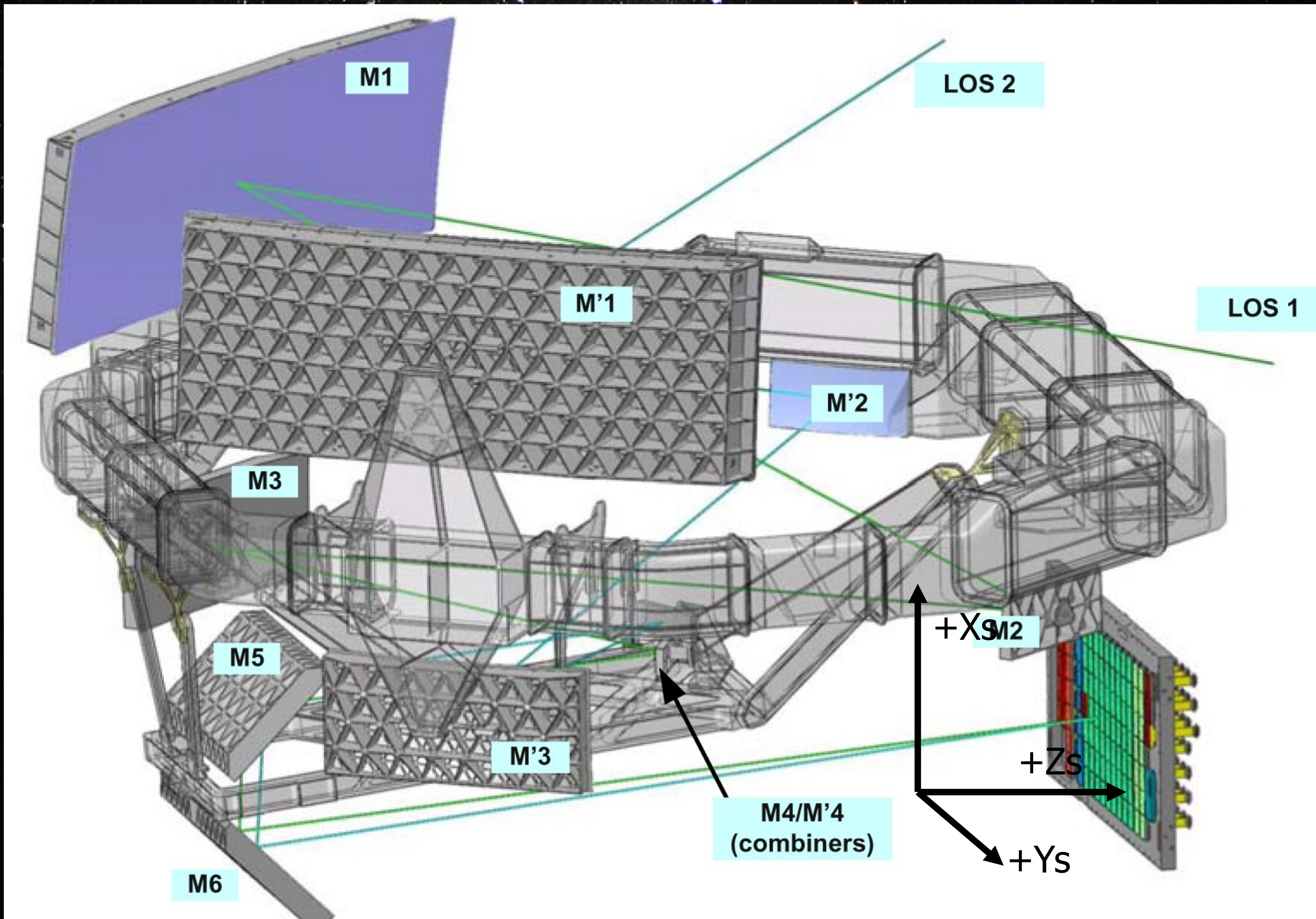
Some technical data:

Diameter: 3 m / 11 m
Height: 3 m
Mass: 1.2 bzw. 1.4 to
Power: 600 plus 500 W
Telemetry: 3-8 Mb/s

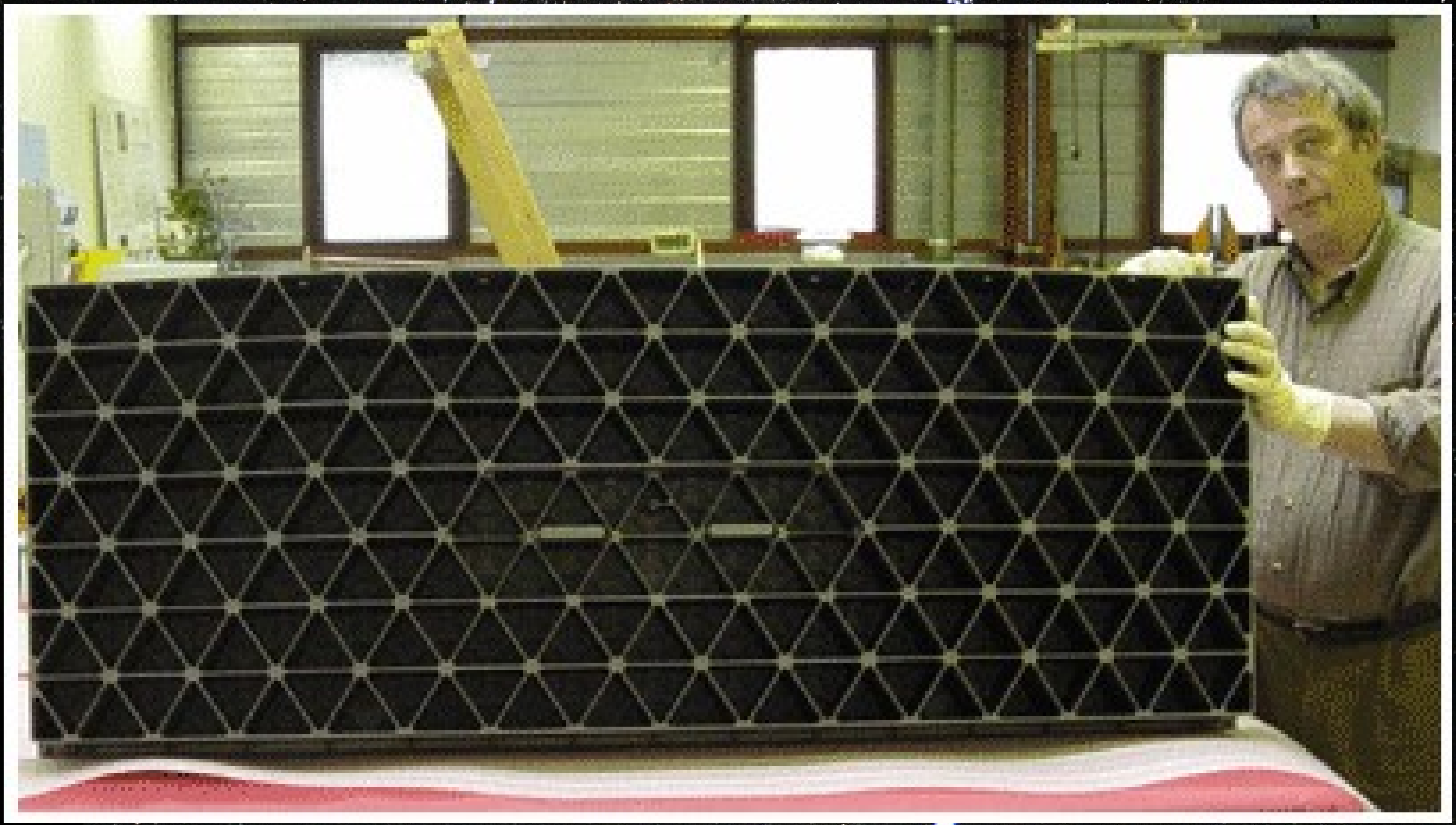




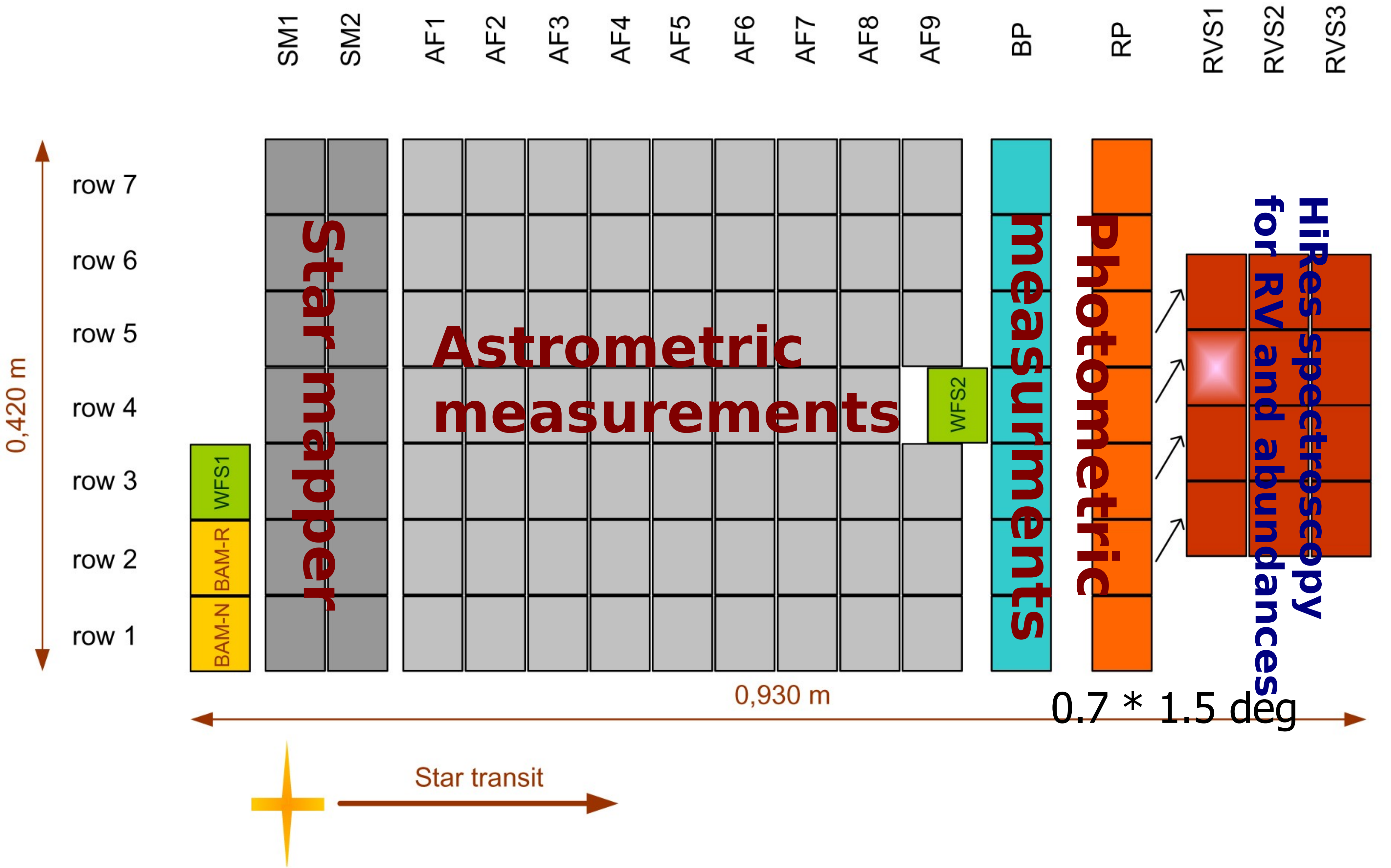
Gaia: the optical assembly



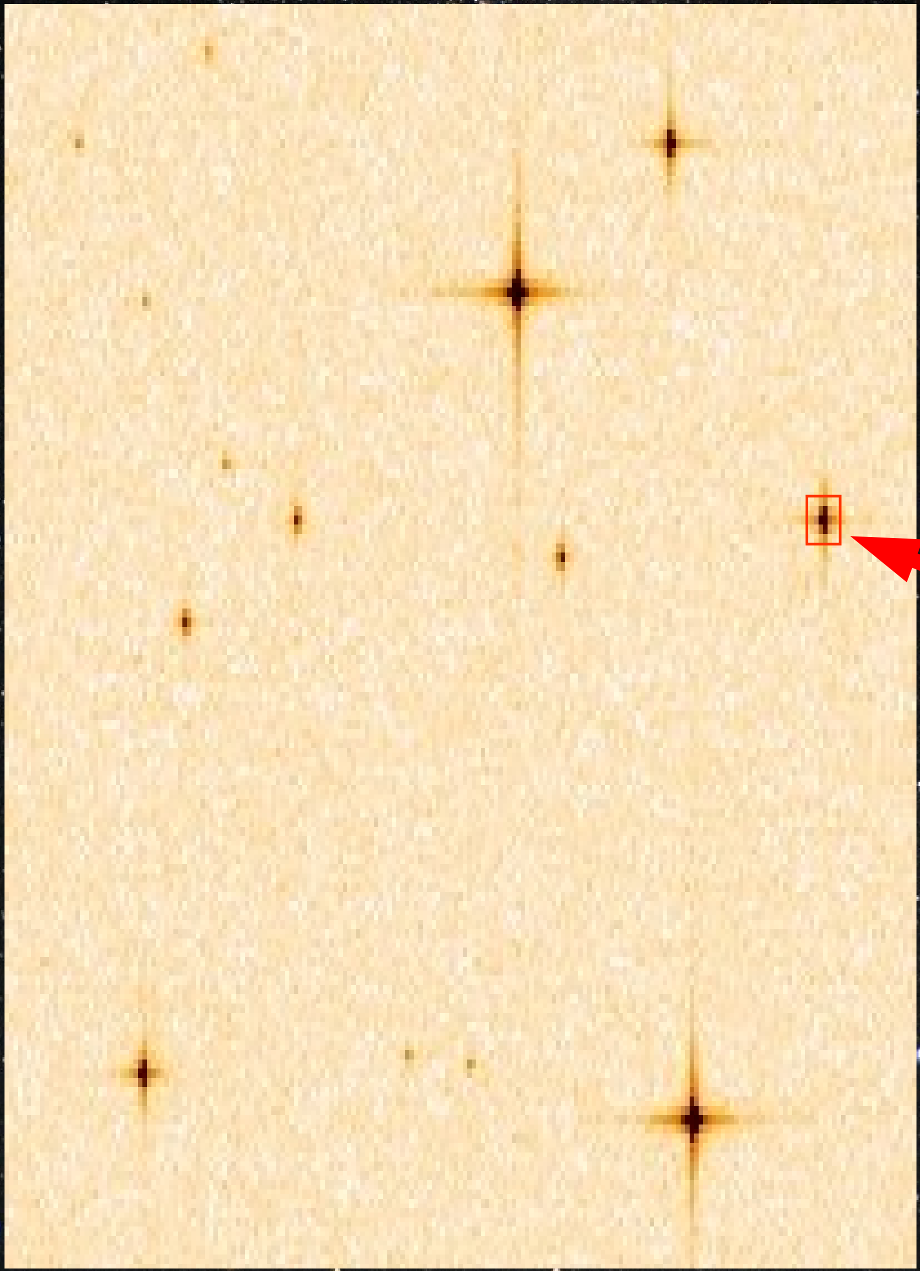
Gaia: one of the main mirrors



Gaia: the focal plane

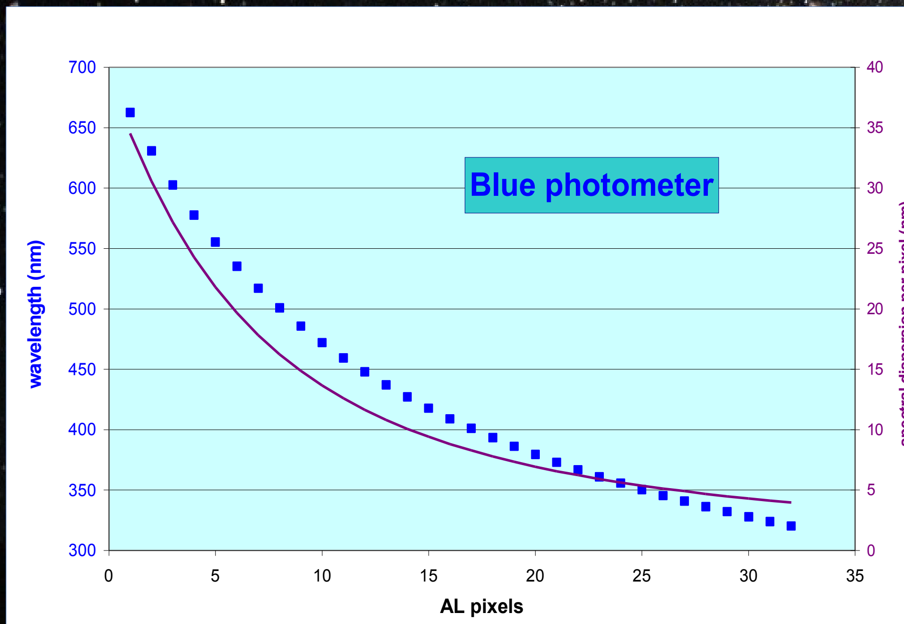


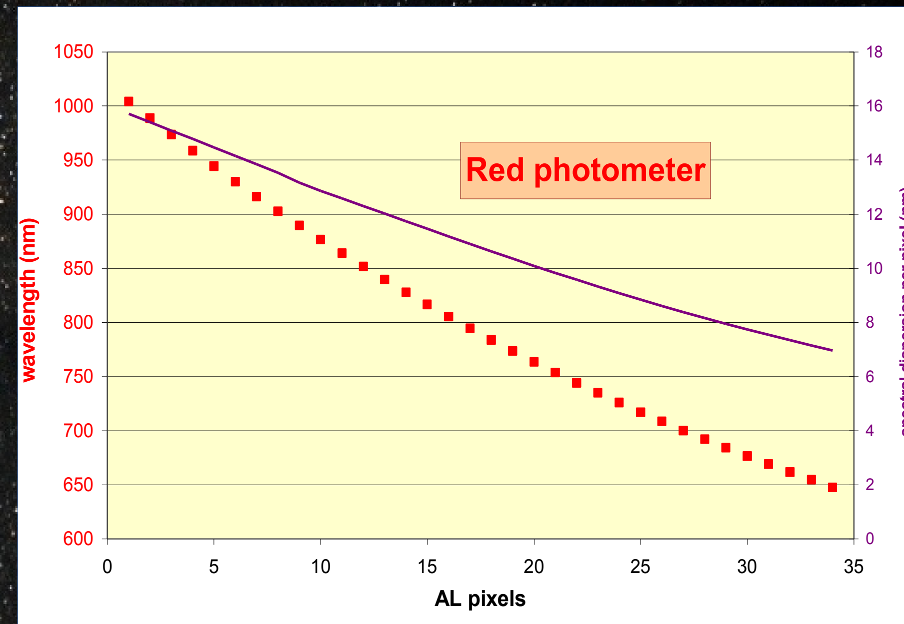
Gaia: Astrometric images

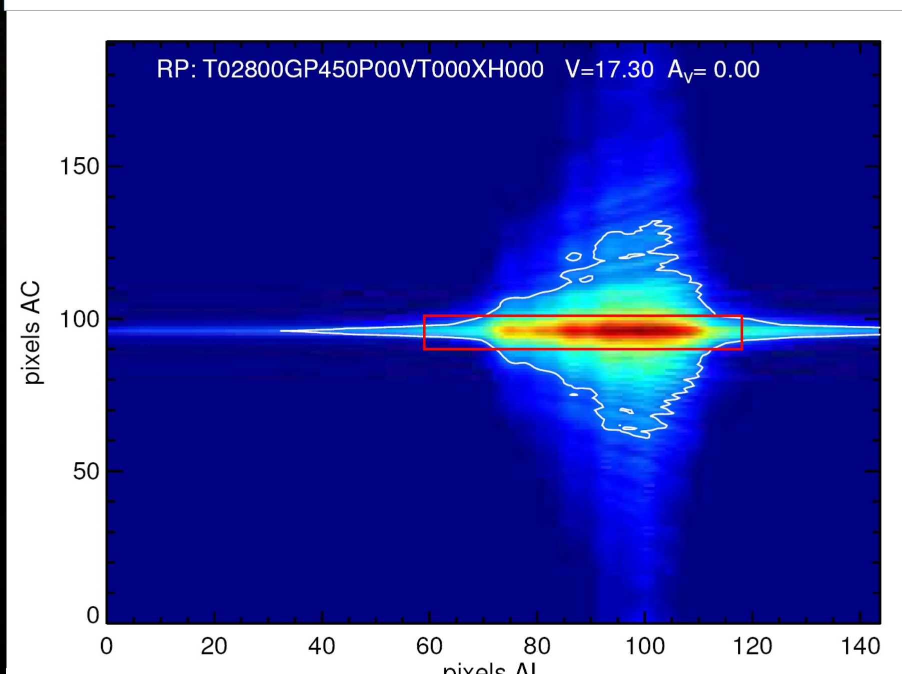


Red box: "window" = data sent to ground (for each detected and confirmed image)

Gaia: Photometry Measurement Concept



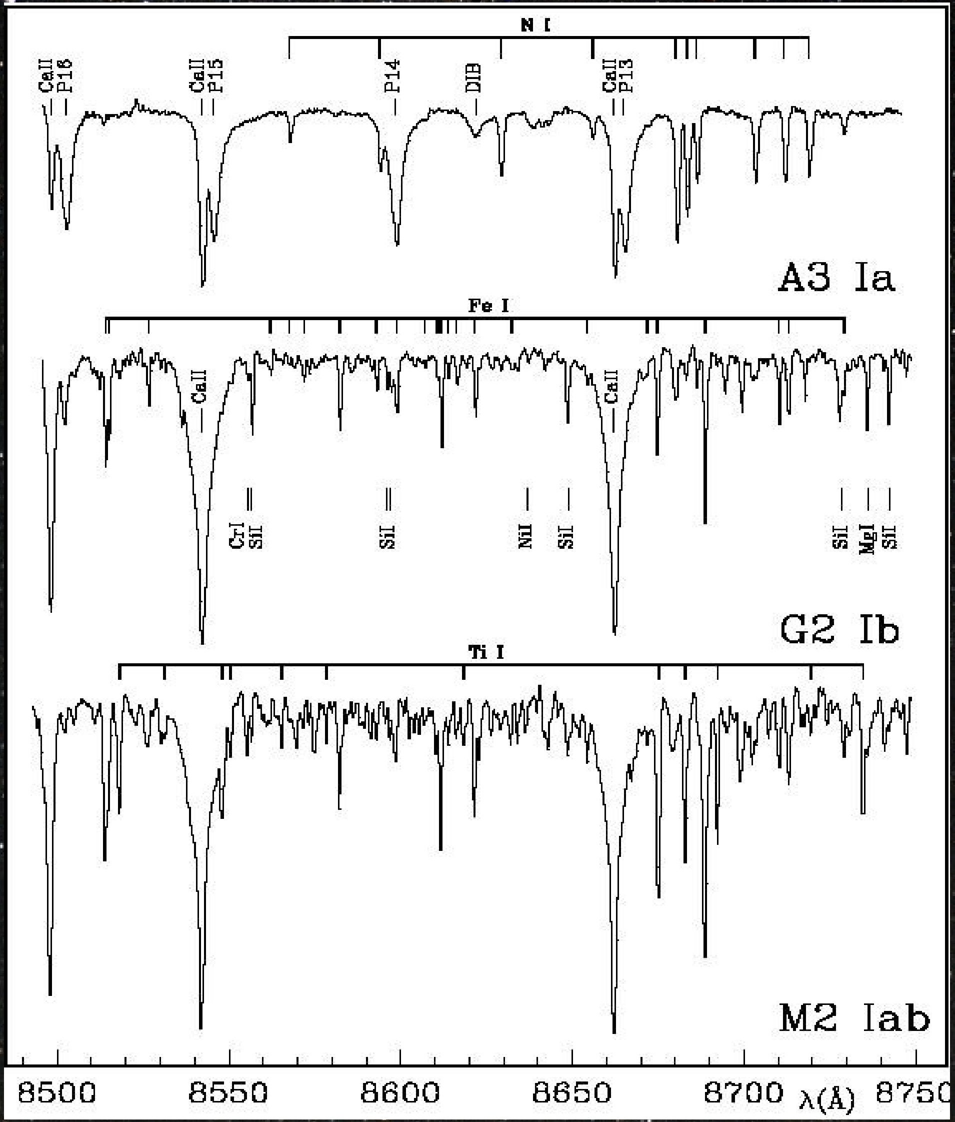




Figu

RP spectrum of M dwarf (V=17.3)
Red box: data sent to ground
White contour: sky-background level
Colour coding: signal intensity

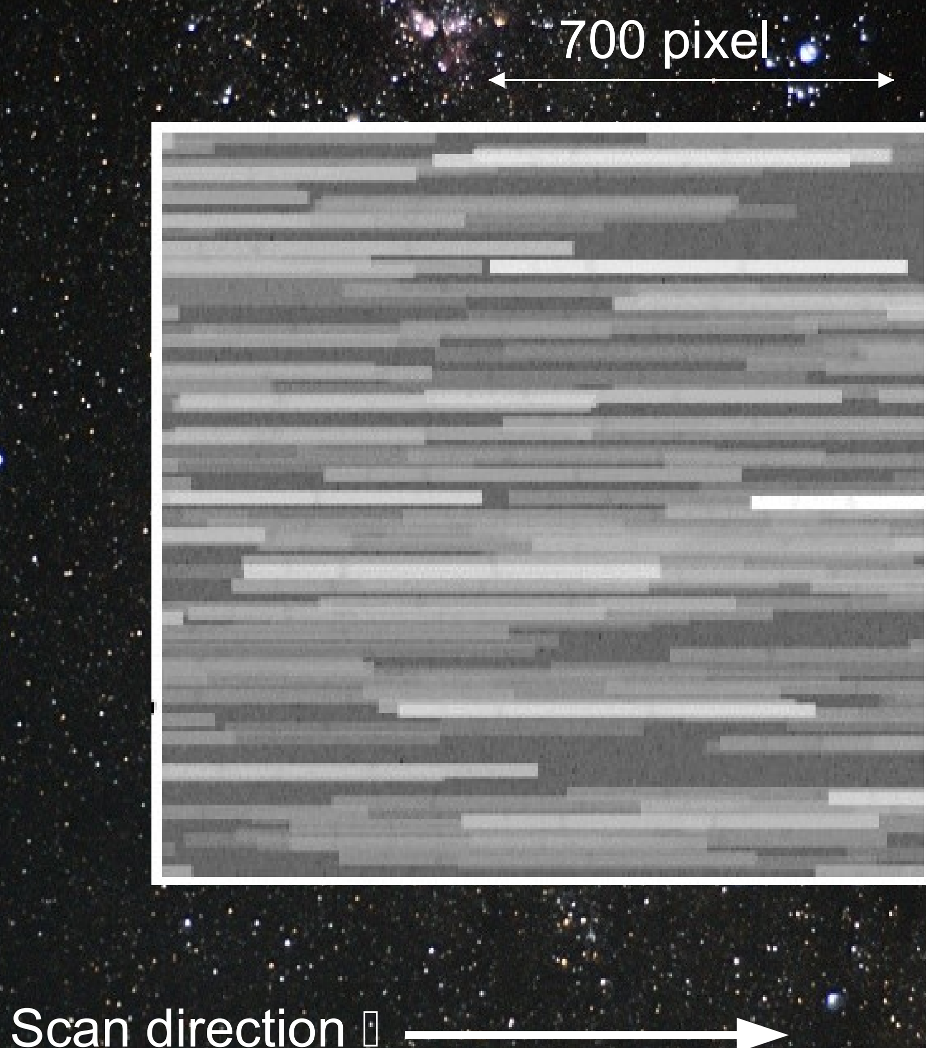
Ca II spectra



Stars of different spectral type and their spectra in the Gaia Spectral Window (847-874 nm). The main features are the Ca II tripplet andfor hotter stars the Paschen Hydrogen series. Whether the latter can be seen in a hot star, depends very much on the gravity of the star in question.

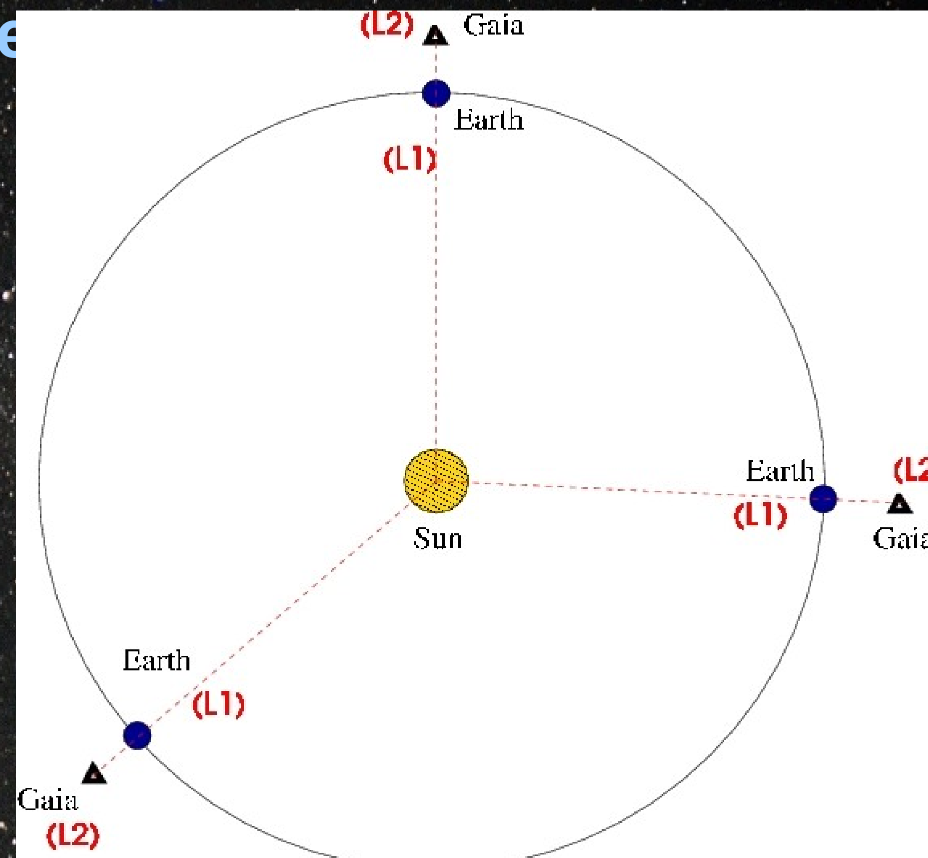
Effect of temperature: A to M stars

RVS spectra in a dense stellar field (schematic):



Gaia's Position near Earth-Sun Lagrange Point L2

Not exactly in L2, because permanent total eclipse there !



Choose an orbit near L2 which
- **avoids the Earth‘s shadow**
- **needs only minor orbital manoevering**

Sky Scanning Principle

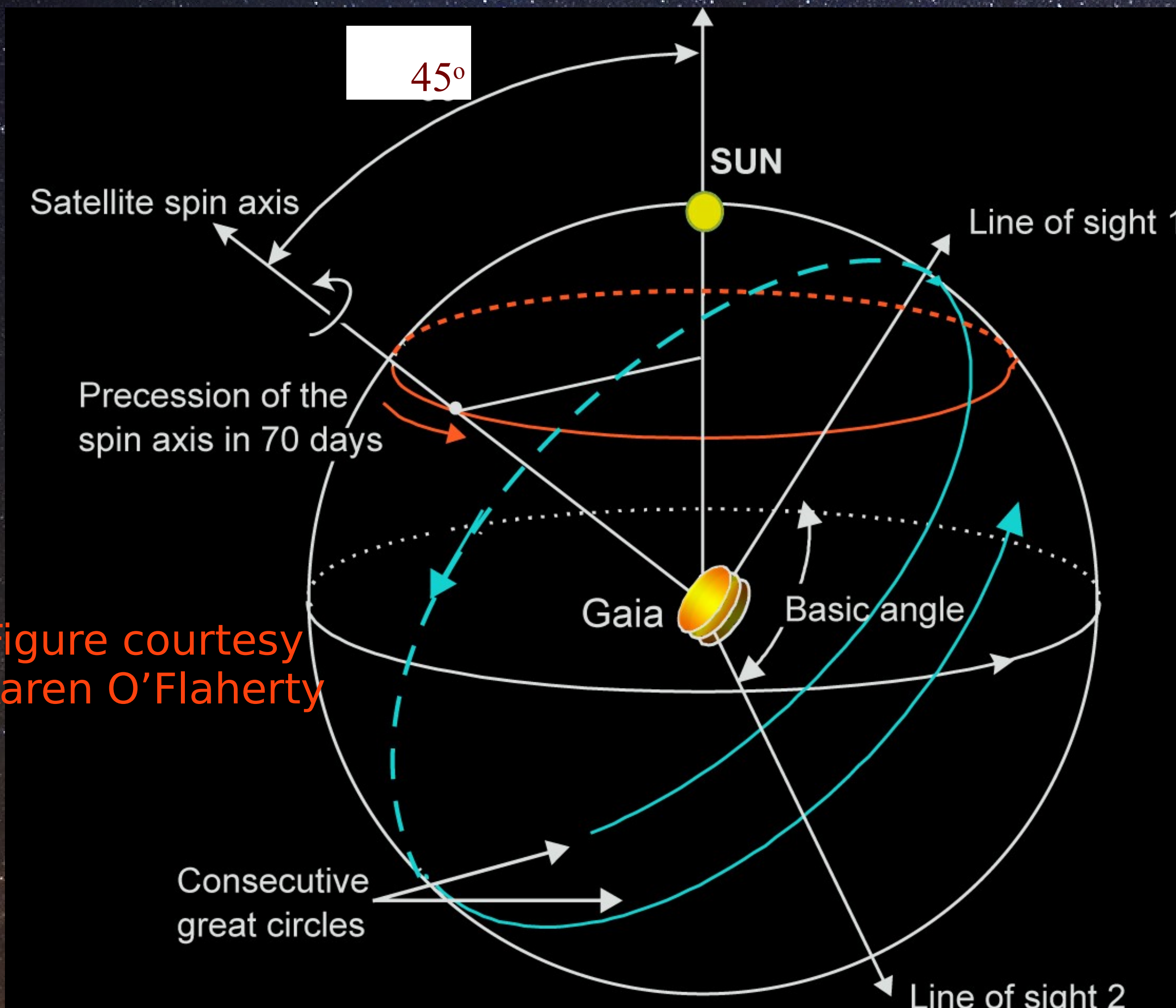
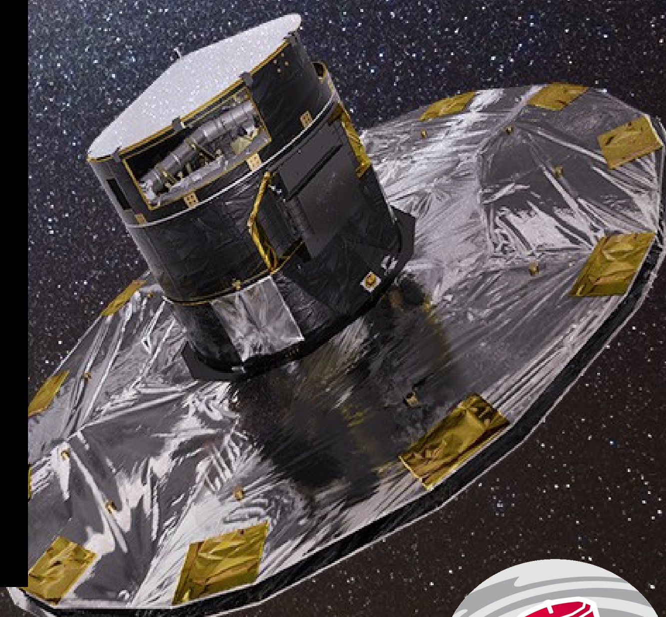


Figure courtesy
Karen O'Flaherty

Spin axis	45° to Sun
Scan rate:	60 arcsec/s
Spin period:	6 hours



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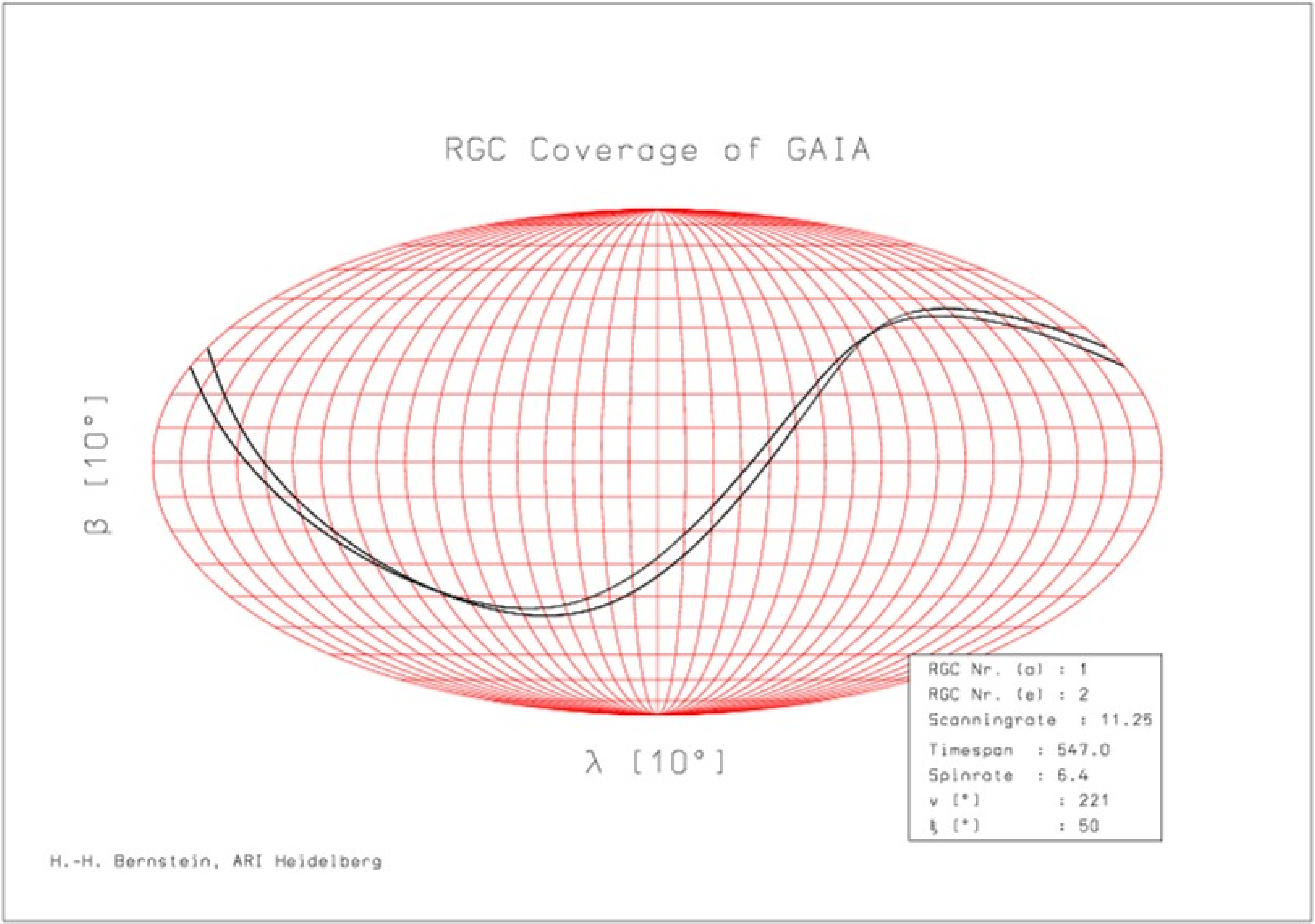
RGC Coverage of GAIA
β [10°]
λ [10°]
RGC Nr. (a) : 1
RGC Nr. (e) : 2
Scanningrate : 11.25
Timespan : 547.0
Spinrate : 6.4
ν [°] : 221
ξ [°] : 50
H.-H. Bernstein, ARI Heidelberg

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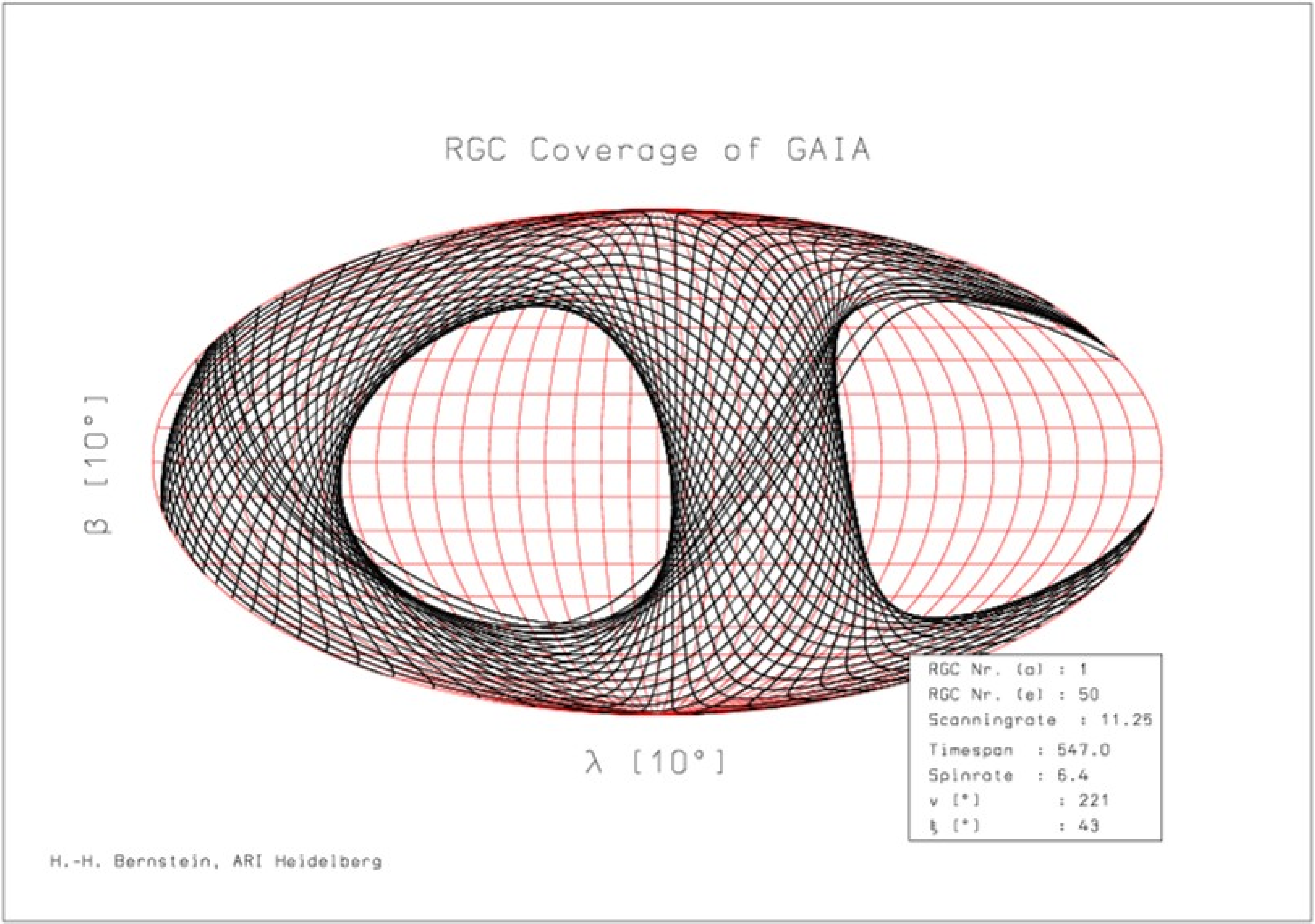
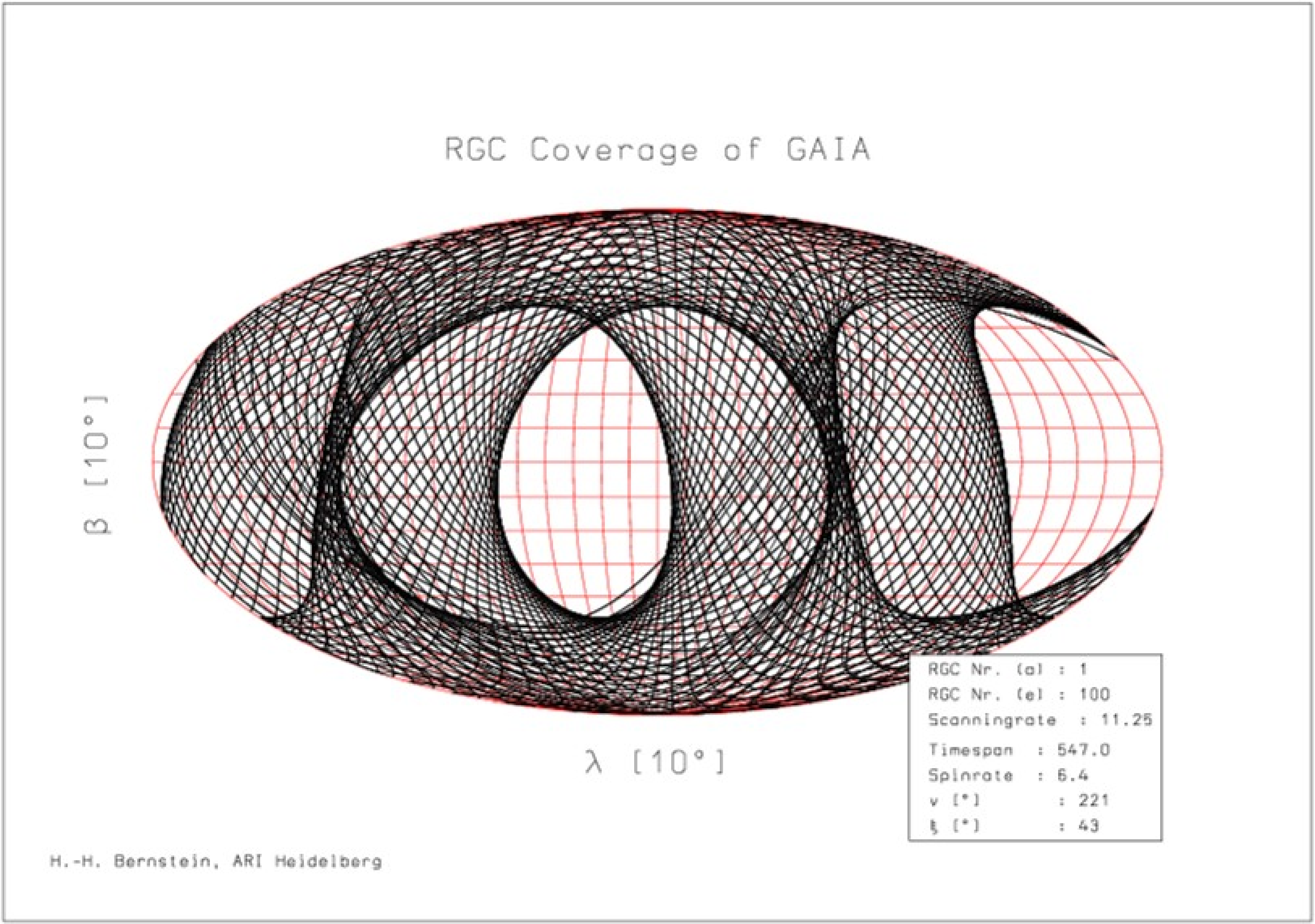

RGC Coverage of GAIA
β [10°]
λ [10°]
RGC Nr. (a) : 1
RGC Nr. (e) : 50
Scanningrate : 11.25
Timespan : 547.0
Spinrate : 6.4
ν [°] : 221
ξ [°] : 43
H.-H. Bernstein, ARI Heidelberg

DPAC


RGC Coverage of GAIA
β [10°]
λ [10°]
RGC Nr. (a) : 1
RGC Nr. (e) : 100
Scanningrate : 11.25
Timespan : 547.0
Spinrate : 6.4
ν [°] : 221
ξ [°] : 43
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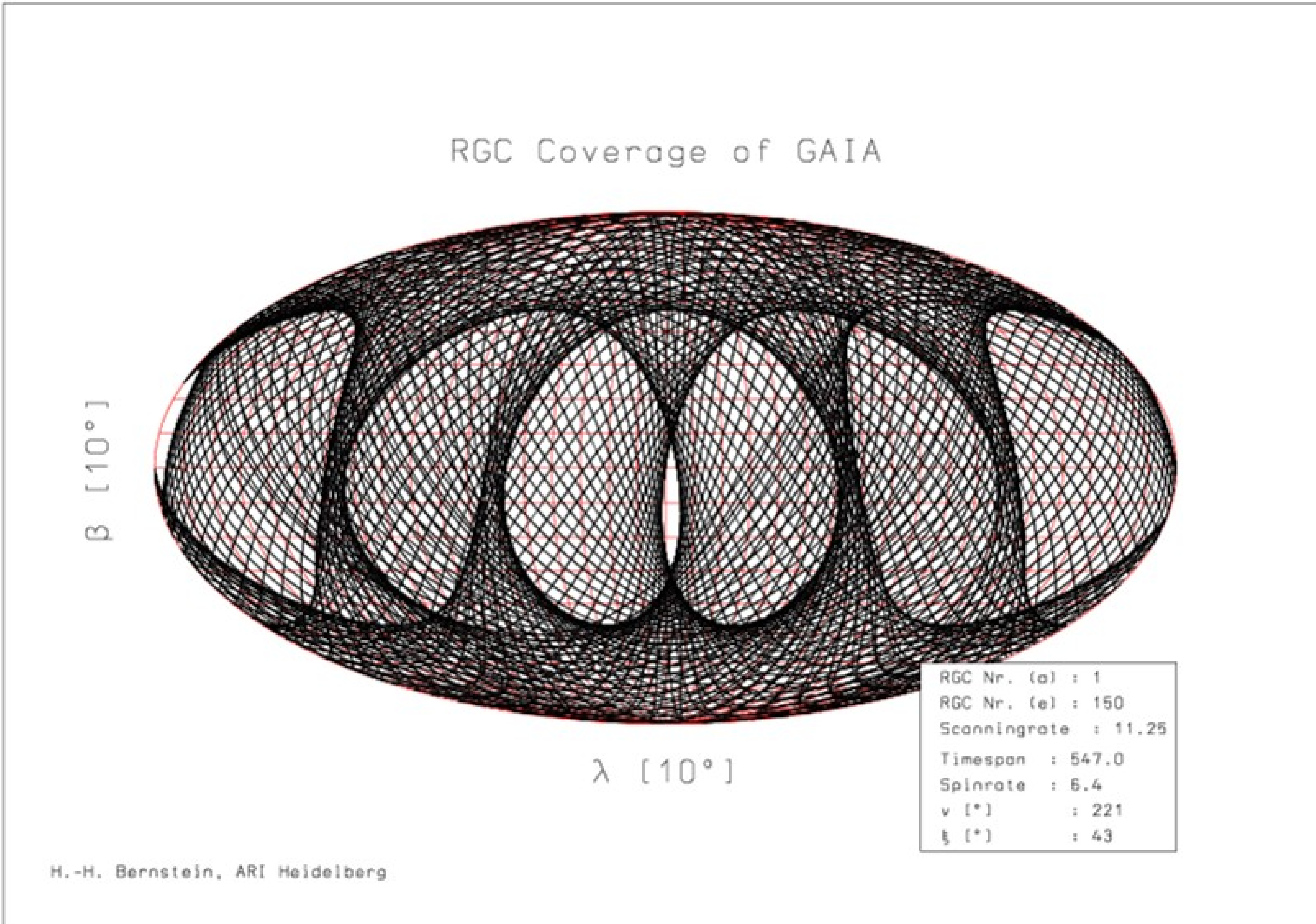
RGC Coverage of GAIA
β [10°]
λ [10°]
RGC Nr. (a) : 1
RGC Nr. (e) : 150
Scanningrate : 11.25
Timespan : 547.0
Spinrate : 6.4
ν [°] : 221
ξ [°] : 43
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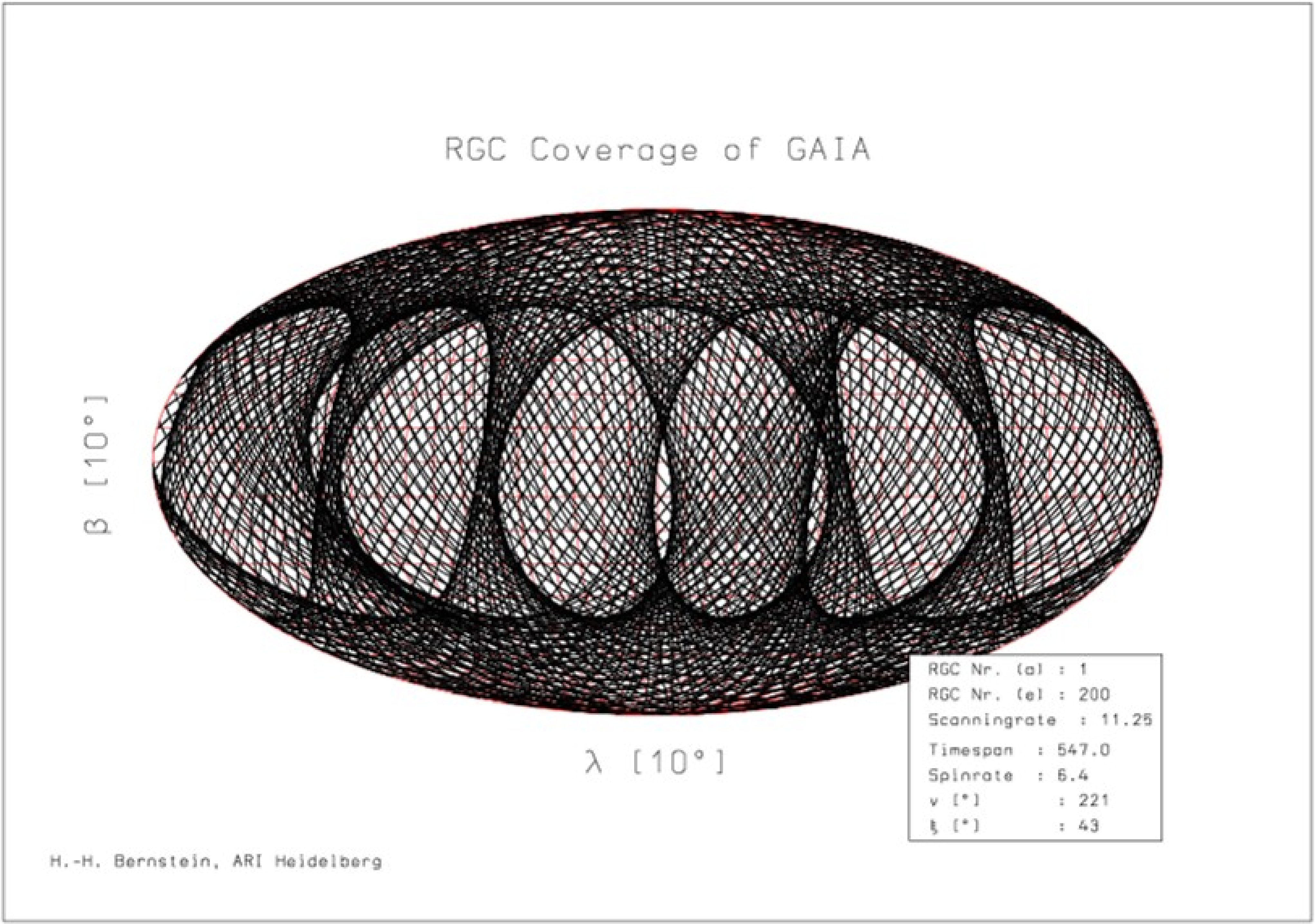
RGC Coverage of GAIA
β [10°]
λ [10°]
RGC Nr. (a) : 1
RGC Nr. (e) : 200
Scanningrate : 11.25
Timespan : 547.0
Spinrate : 6.4
ν [°] : 221
ξ [°] : 43
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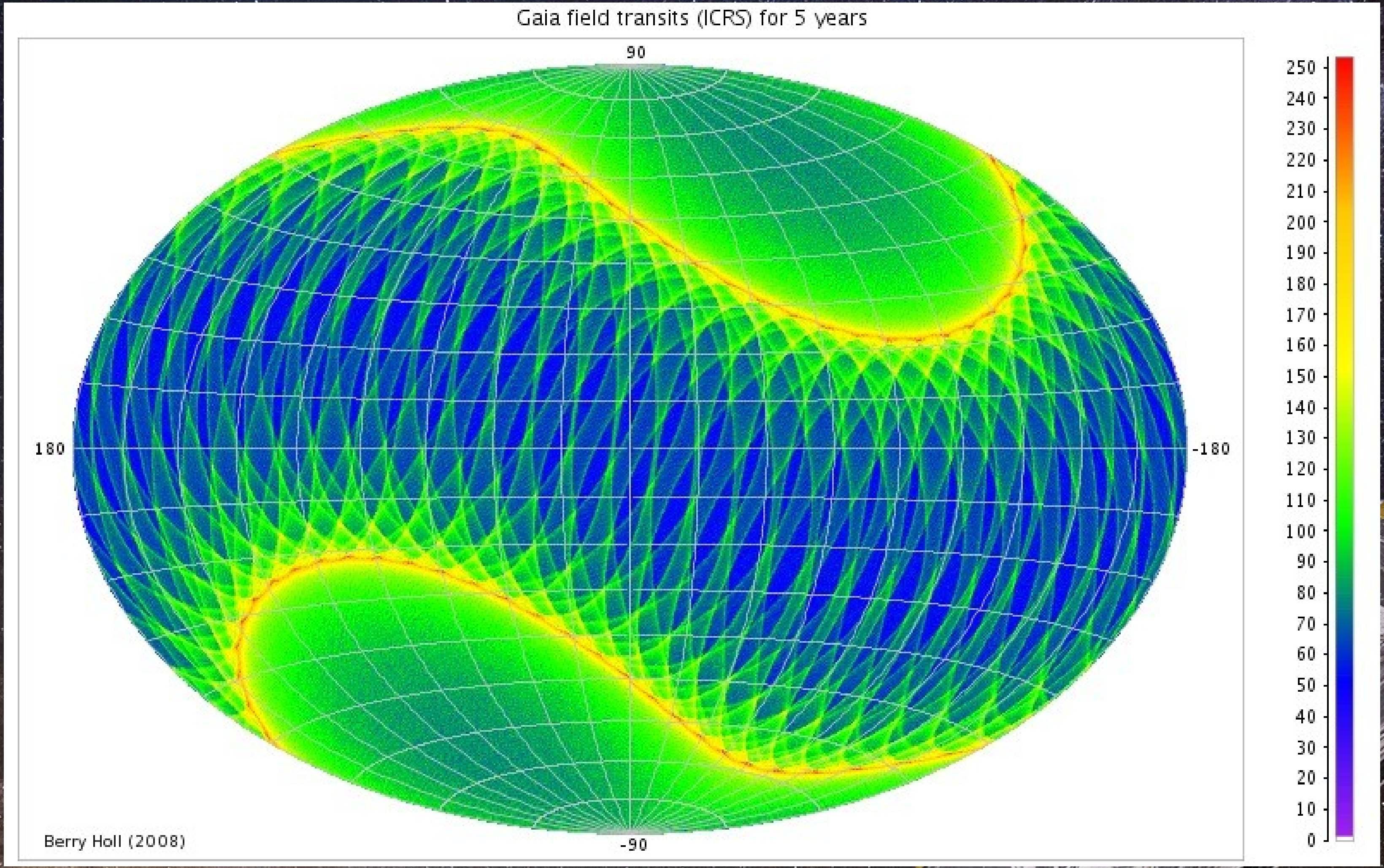
Gaia – end of mission sky coverage



Gaia – the first weeks

•19th December, 2013, 09:12 UTC, Gaia lifts off to start a new era in Galactic astronomy!

Gaia – the first weeks

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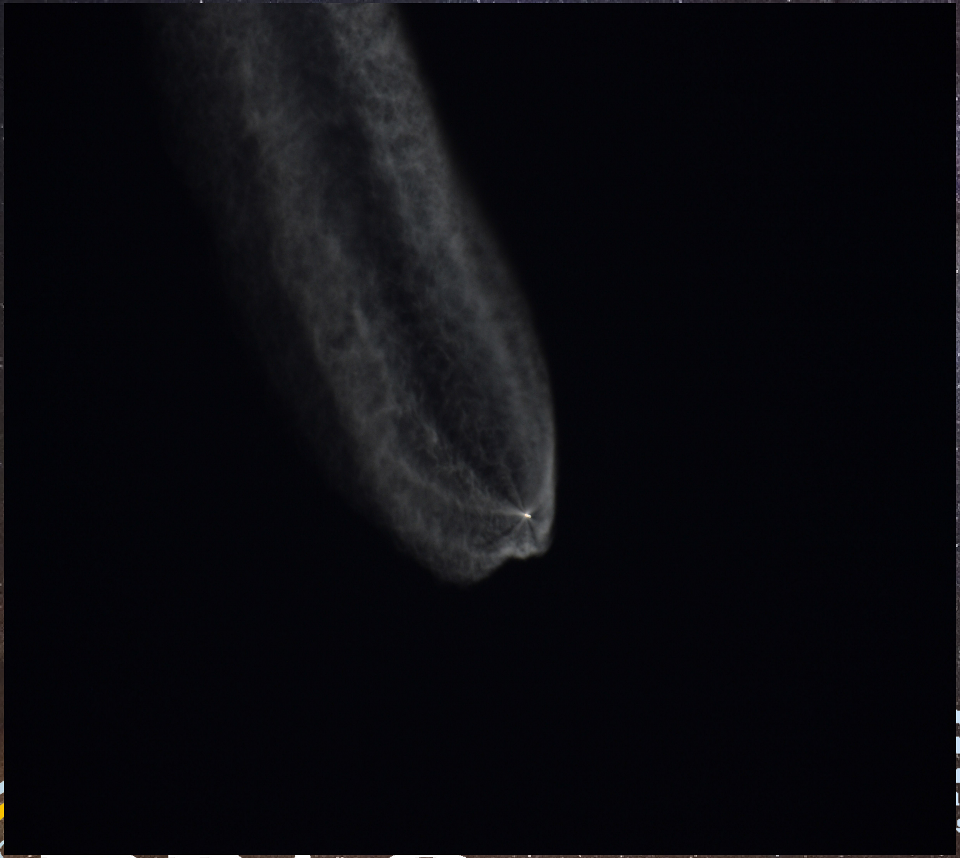
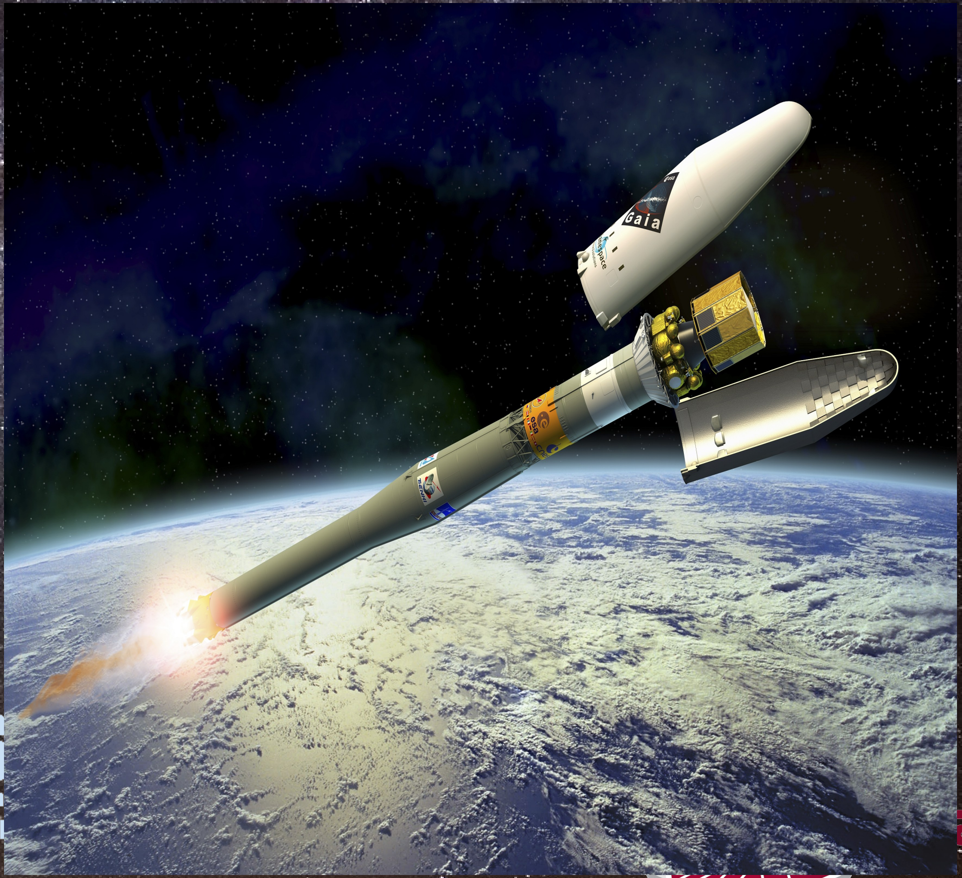


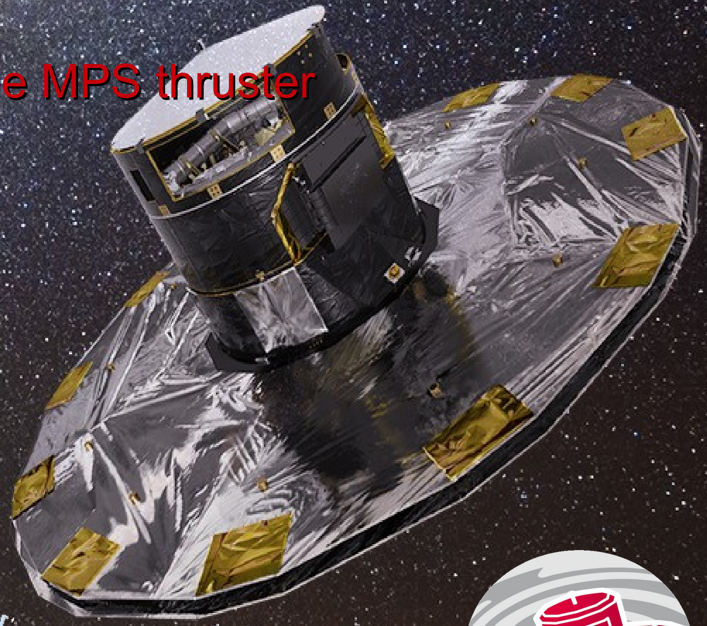


Gaia status

- All systems on board are working fine
  - All 102 CCDs and PEM units nominal sensitivity, readnoise, dark currents
  - Clean telescopes have nominal throughput
  - Target image quality and tiny focal-length difference achieved
  - ACS working extremely well (s/w and all hardware)
  - Power system, atomic clock, phased-array antenna, mass memory, …
  - Internal meteorology interferometer very precise (but …)

  - Sole functional defect: intermittent malfunction of one MPS thruster
    -> redundant system in use

- But there are also some nasty problems
  - Extended commissioning phase needed
  - Much more complicated calibration task
  - Some performance restrictions



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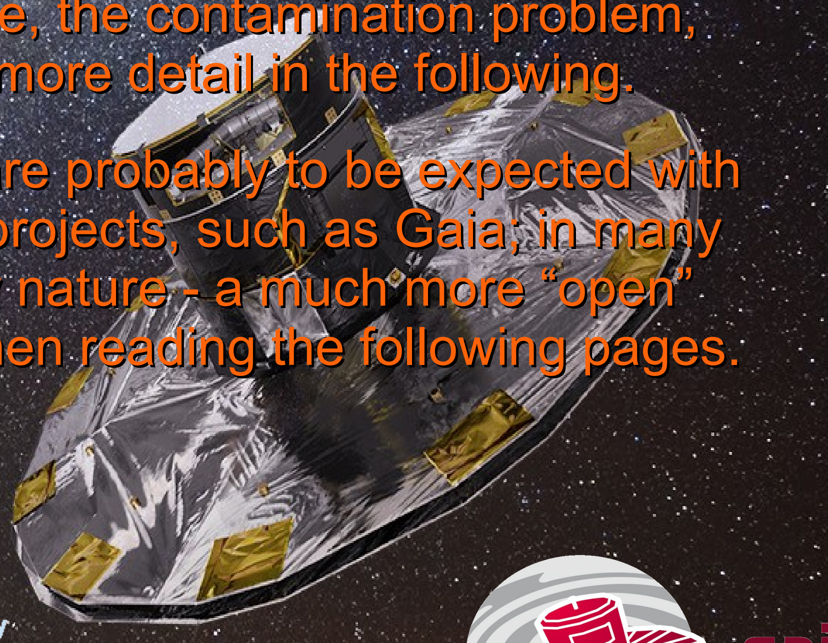
Gaia status - problems

While the launch went extremely well, and many components are functioning according to or even surpassing specifications, a number of pesky problems have turned up, which had an impact on the commissioning phase and might also affect operations. Fortunately none of them is a "show stealer" and the Gaia team is striving to keep the impact on the derived science data at a minimum. Certain data types, especially the high resolution spectrography will be slightly compromised, the main aim of the mission, namely the astrometry will be largely unaffected, just that the errors will increase slightly towards the fainter end.

The three main problems, i.e. the stray light issue, the contamination problem, and the Basic Angle Variations are described in more detail in the following.

As a conclusion, problems of a similar severity are probably to be expected with most satellite missions, especially cutting edge projects, such as Gaia; in many cases they are not made public, but Gaia is – by nature - a much more "open" mission than most – this is to be kept in mind when reading the following pages.

(page inserted for "archival version").



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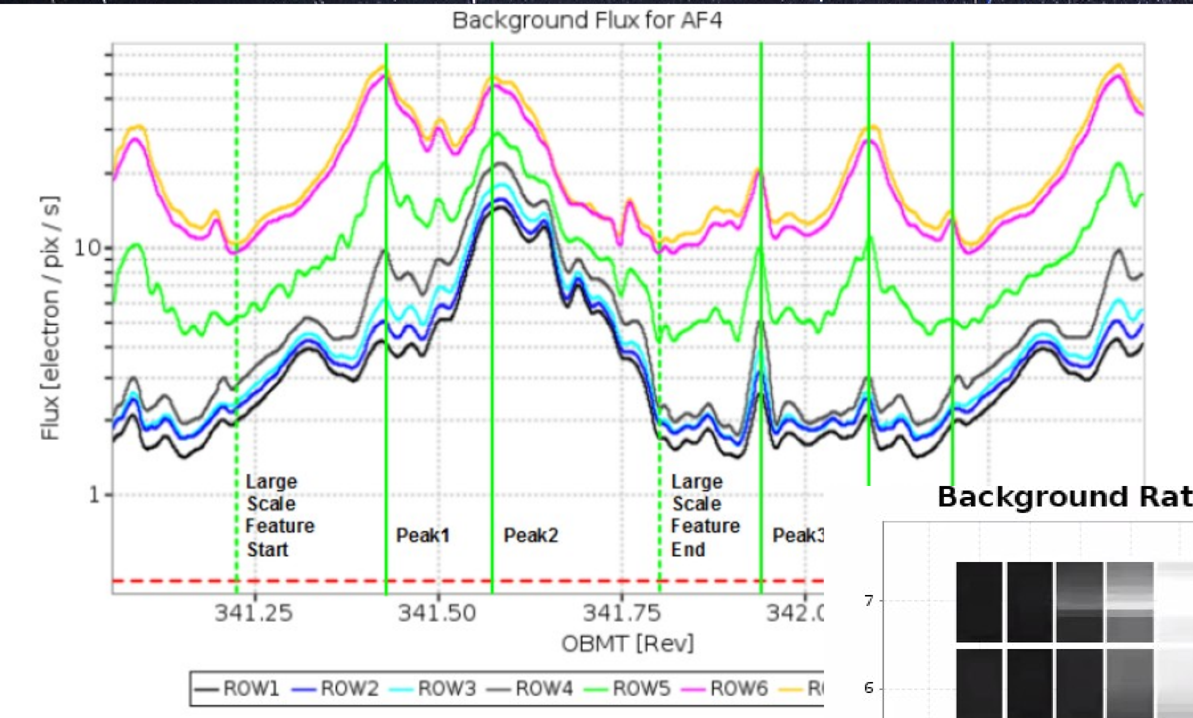
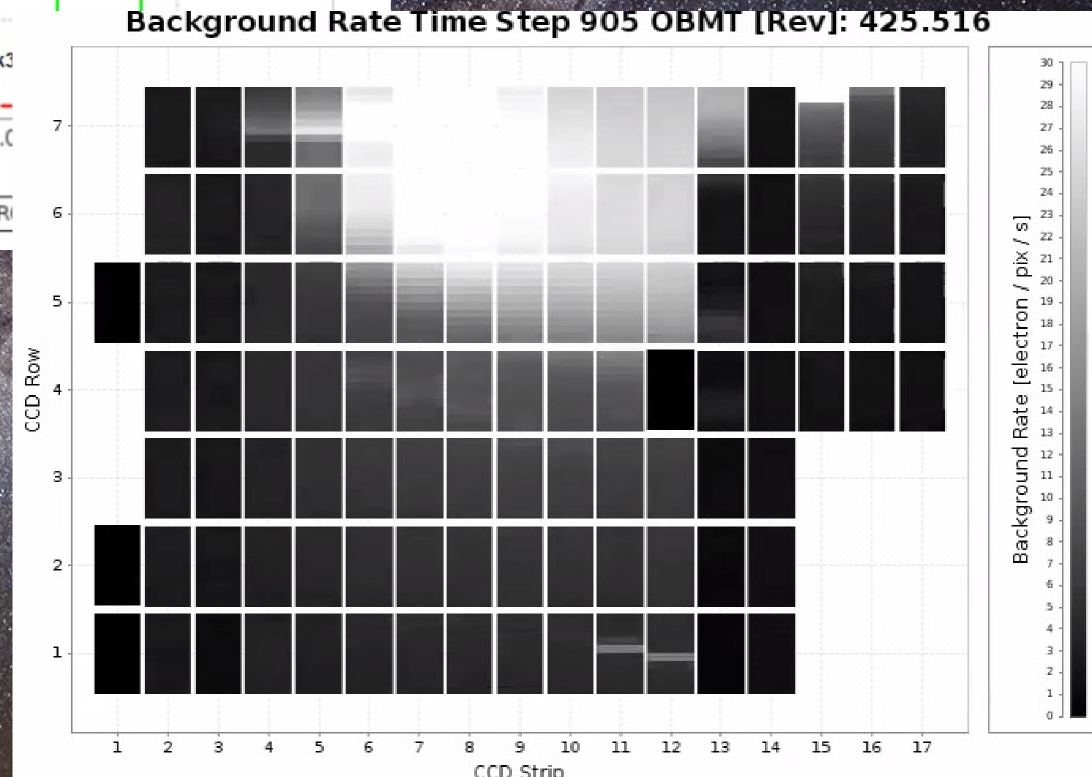
Gaia Status – Problems: 1. Excessive Straylight



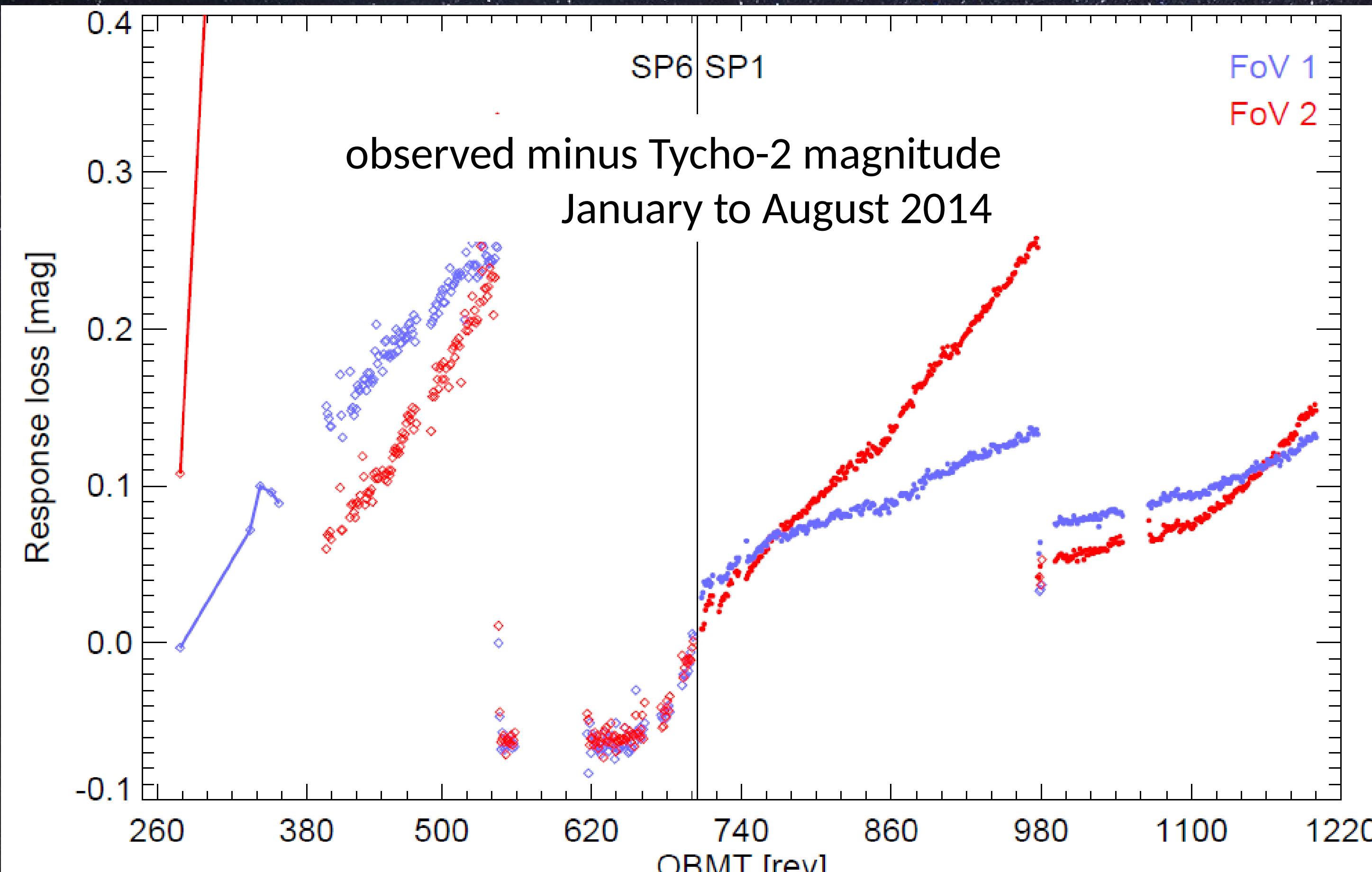


- Diffracted sunlight
- Milky Way
- Bright point objects

1. Sunshield
2. Insufficient baffling

Courtesy: U. Bastian

Gaia Status – Problems: 2. Contamination of the optics



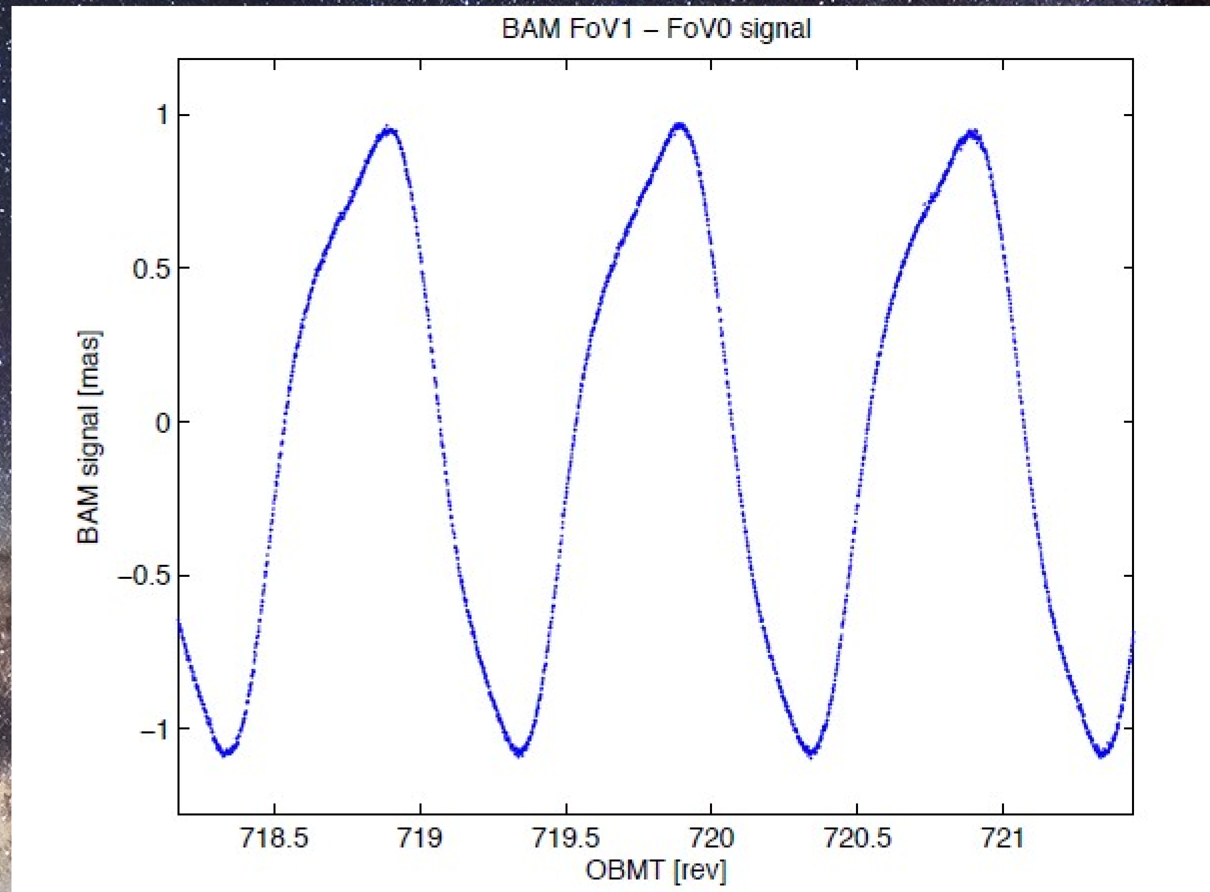
- **Five decontaminations done**
- **Interruptions of observations**
- **Disturbance of thermal state**
- **Contamination rate is decreasing**
- **Future evolution is unpredictable**

Courtesy: U. Bastian

Gaia Status – Problems: 3. Basic-angle oscillations

tied to the sun

very stable



1 mas = 5 10E-9 rad < 4 nm movement of the main-mirror edges ~ 10 Si atoms

(and even much less if it is a different mirror)

Noise: a dozen or so picometers !

Courtesy: U. Bastian

Gaia Status – Performance

Early astrometric precision assessment

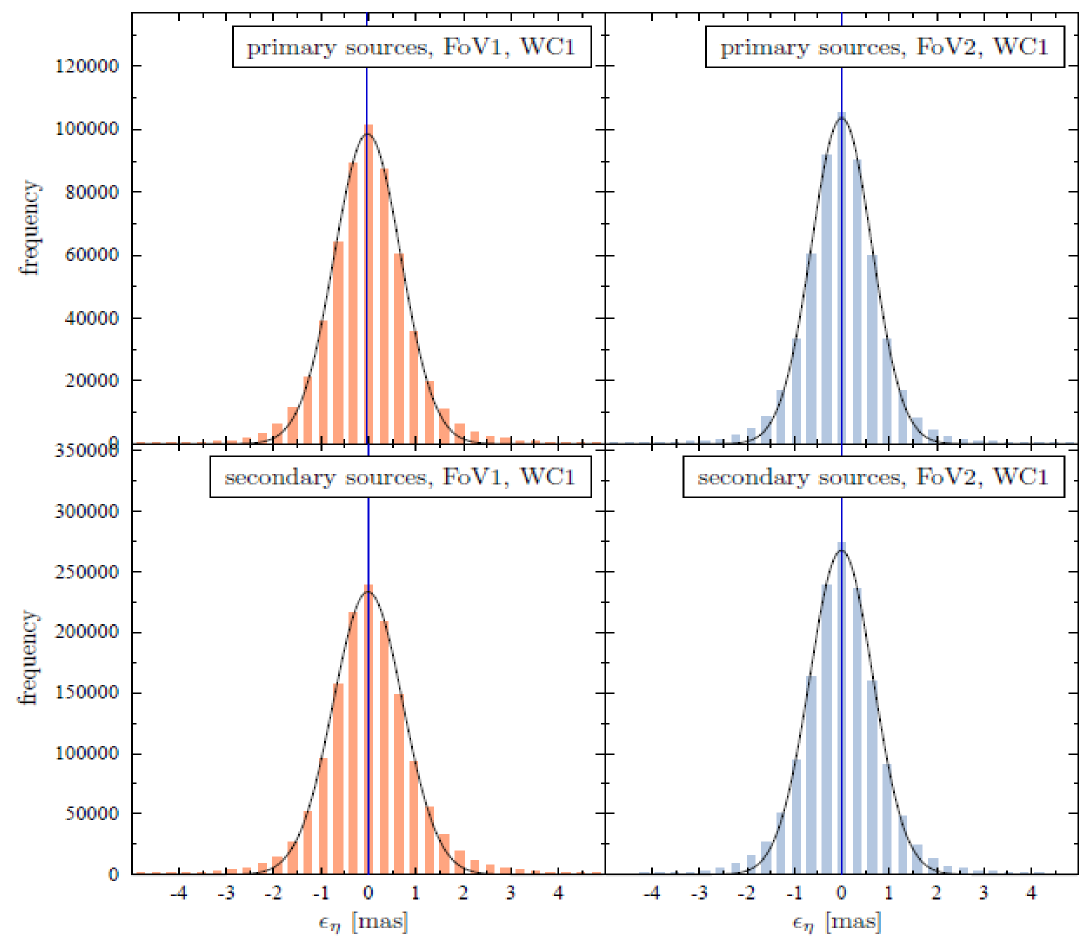


Figure courtesy First Look team

ODAS residuals:

0.6 mas at G=15 in June/July 2014

- Coarse attitude model
- Poor PSF calibration
- No source colours
- Imperfect straylight correction
-
- It was 2 mas in April/May 2014
- Target is 0.3 mas finally

Gaia's single-measurement noise better than Hipparcos' end-of-mission results

for 1000 times fainter stars and 10 000 times more stars.

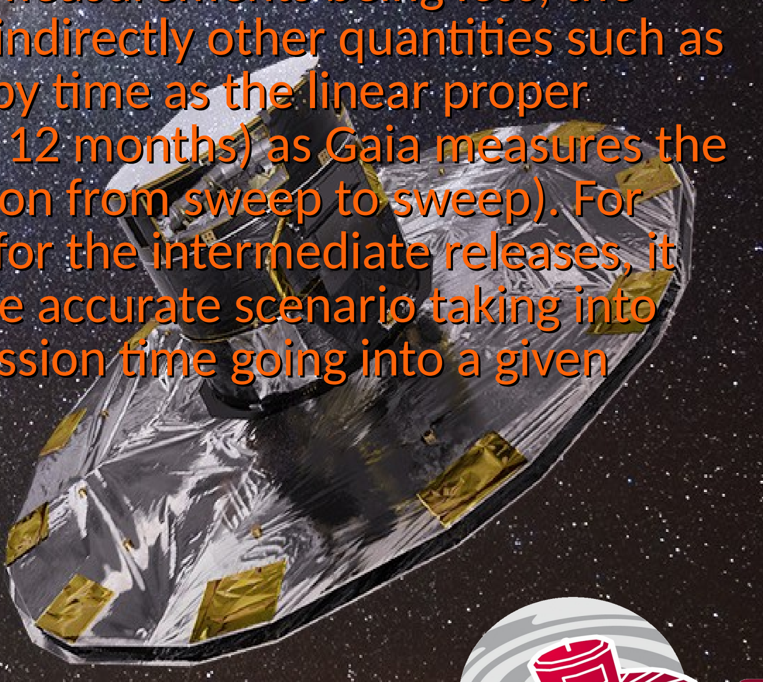
Very roughly reduced yet …

Courtesy: U. Bastian

Gaia - performance

The following pages give an overview of the expected precision at the end of the mission. The stated numerical values are based on the current (mid-2015) error model and can be subject to change as the Gaia team gets more and more insight into the complexity of the Gaia data. One needs to be aware of the extremely complex nature of such hyper-precise measurements, and even the best modeling cannot account for all issues. Nonetheless we are confident that these sophisticated predictions are reliable, and can sufficiently serve for previewing the Gaia performance. Obviously, the intermediate releases will have larger errors, with the number of measurements going into the solution being smaller, and the timespan of measurements being less, the latter directly affecting the proper motions, but also indirectly other quantities such as the parallaxes (who are per se not as much affected by time as the linear proper motoion, since the full parallax circle is completed in 12 months) as Gaia measures the combined motion (or actually the difference in position from sweep to sweep). For various reasons there is no prediction tool or model for the intermediate releases, it should however be possible to construct a reasonable accurate scenario taking into account the final performance and the fraction of mission time going into a given release.

(page inserted for "archival version").



Gaia - performance

As for the values given in this presentation, one should note that the values are simplified for reasons of clarity and usually the most pessimistic values have been used. This is especially justified in the terms of stellar colour, as the sdB/OB/O and other ***blue*** objects being the main topic of this conference are those with the highest errors. Moreover the errors of parallax and proper motion are somewhat different, with the proper motion error being generally lower than those of the parallax (Throughout this presentation these errors are assumed to be equal and equal to those of the parallax). Since the differences of these errors are a factor of 2 at most, the overall picture outlined in this presentation remains instructive. Also the size of the errors is dependent on the ecliptic latitude (β), as shown on the plots on page 37 (and in a more subtle but complicated way on the ecliptic longitude as is evident from the sky coverage plots). For a more quantitative assessment of the end of mission errors, please refer to:

http://www.cosmos.esa.int/web/gaia/science-performance

and the links therein, but also:

.http://www.rssd.esa.int/SYS/docs/ll_transfers/project=PUBDB&id=448635.pdf

(page inserted for "archival version").

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Gaia - performance

Expected end-of-mission parallax standard errors

for solar-type stars:

V= 3...12 14 micro-arcsec

V= 15 24

V= 20 540

V= 21 ~900 new, being tried

End-of-mission photometric broad-band std errors [mmag]:

	B1V			G2V			M6V		
G [mag]	G	BP	RP	G	BP	RP	G	BP	RP
15	1	4	4	1	4	4	1	7	4
18	2	8	19	2	13	11	2	89	6
20	6	51	110	6	80	59	6	490	24

End-of-mission radial-velocity standard errors

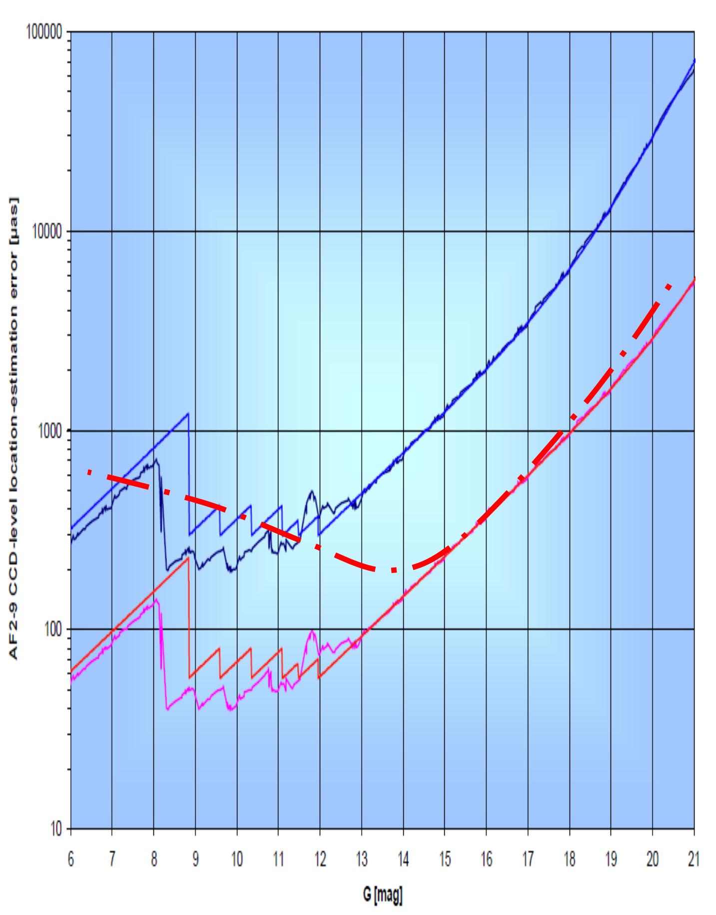
for solar-type stars:

G< 12.3 1 km/s

G= 15.5 15 km/s

G= 16.5 ---

Single-measurement precision;
red= along, blue = across scan



Courtesy: U. Bastian

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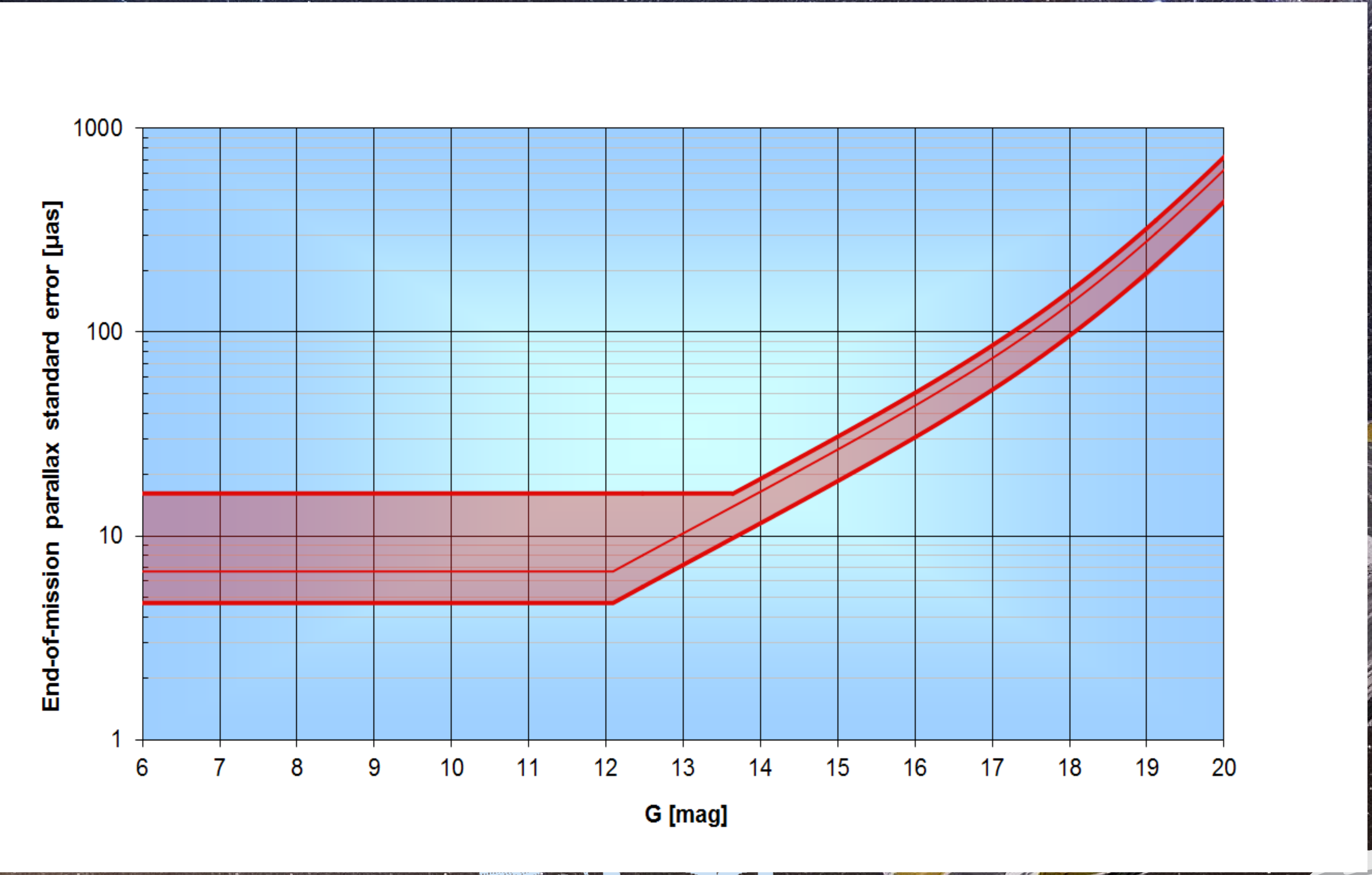
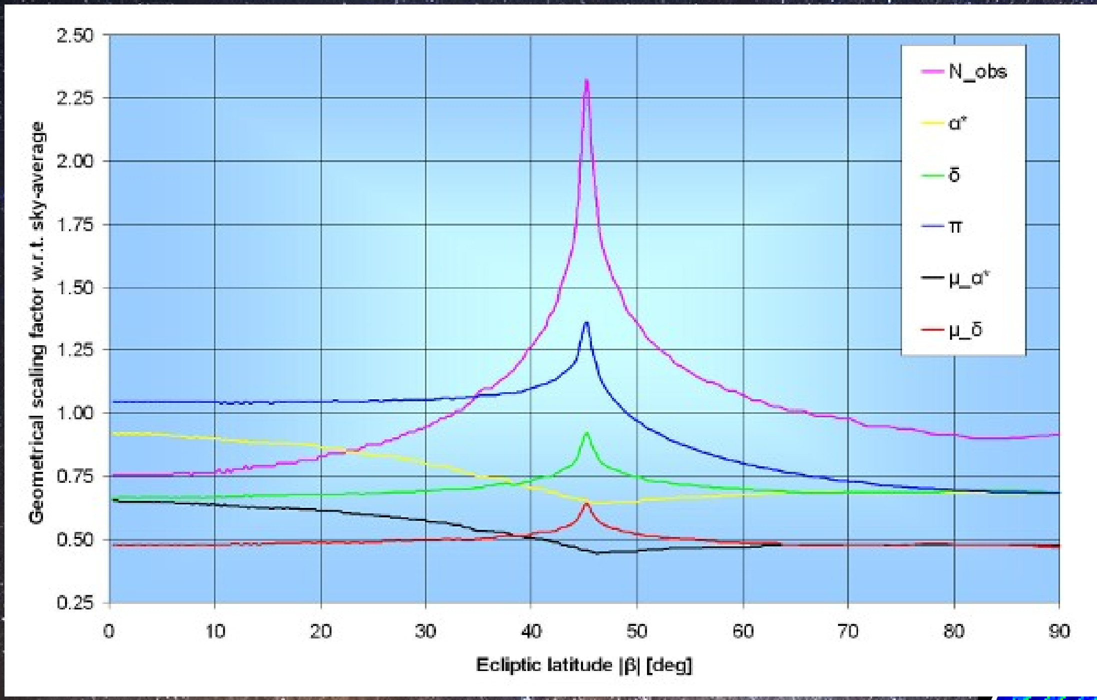
Gaia - performance

Astrometric (parallax) error in relation to object magnitude in a logarithmic representation (for blue objects, the upper curve should be used)

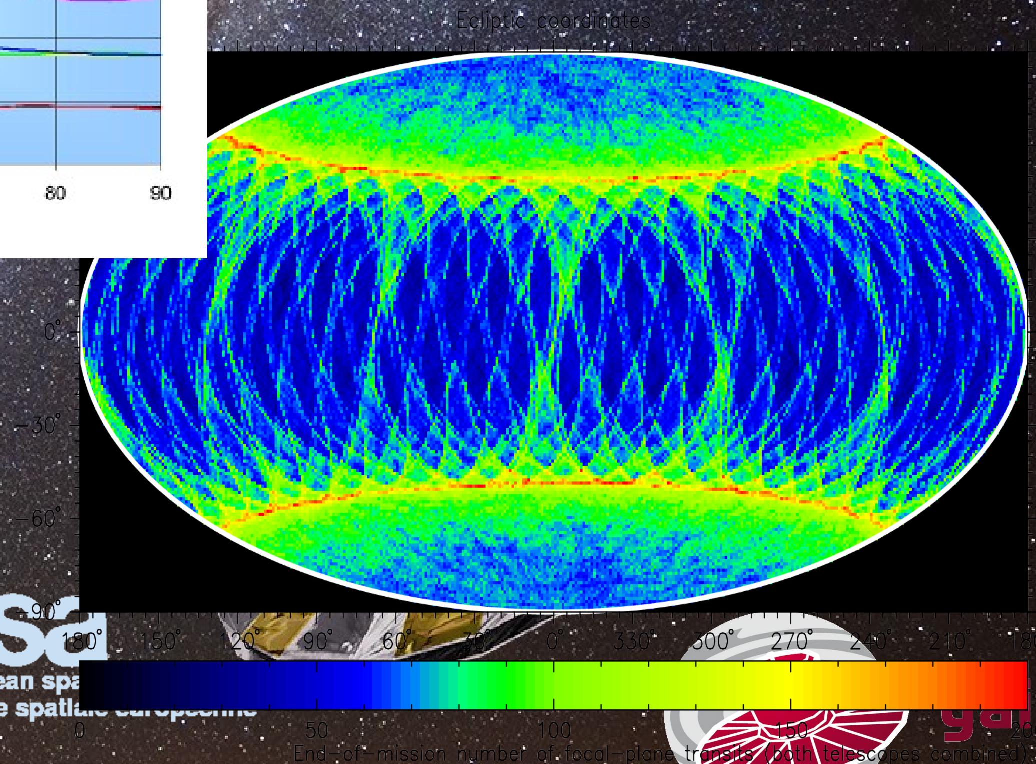


Gaia - performance



Dependency of the errors of Gaia astrometric measurements (normalised to the mean parallax error) of the elliptic latitude (β). The magenta curve shows the mean number of observations.

The sky coverage in elliptic coordinates, as in the celestial coordinates plot, blue areas have the fewest visits, green near the medium and red the highest number)



Gaia & sdB stars

- 10 bright sdB stars (HIP et al.):

Name	Vmag	μ_α	$\sigma\mu_\alpha$	μ_δ	$\sigma\mu_\delta$	π	$\sigma\pi$	$\sigma\pi/\pi$	$\pi/\sigma\pi$	Source
	Mag			mas/yr			mas			
HD127493	**10.08**	**-32.9**	**1.2**	**-18.2**	**1.1**	**5.43**	**1.21**	**0.22**	**4.49**	**HIP07**
HD149382	**8.94**	**-6.7**	**1.8**	**-4.2**	**1.8**	**13.53**	**1.15**	**0.08**	**11.77**	**HIP07**
HD205805	**10.18**	**+75.5**	**1.2**	**-10.0**	**0.9**	**3.75**	**1.68**	**0.45**	**2.23**	**HIP07**
HD188112	**10.22**	**+34.4**	**2.1**	**+21.6**	**1.4**	**13.64**	**1.71**	**0.12**	**7.98**	**HIP07**
CD -38 222	**10.26**	**+46.0**	**1.7**	**-6.5**	**1.1**	**2.09**	**1.52**	**0.73**	**1.38**	**HIP07**
HD4539	**10.29**	**+5.1**	**1.8**	**+25.2**	**1.4**	**2.22**	**2.17**	**0.98**	**1.02**	**HIP07**
Feige66	**10.59**	**+3.0**	**1.7**	**-26.0**	**1.3**	**6.15**	**1.62**	**0.26**	**3.80**	**HIP07**
HD171858	**9.85**	**-13.9**	**1.6**	**-22.7**	**1.6**	**----**	**----**	**----**	**----**	**TYC2**
SB707	**11.90**	**+85.8**	**3.2**	**-48.2**	**2.3**	**3.49**	**3.71**	**1.06**	**0.94**	**HIP07**
SB815	**11.00**	**-19.8**	**1.5**	**-7.5**	**1.8**	**4.56**	**1.72**	**0.38**	**2.65**	**HIP07**

HIP07 = van Leeuwen, F., 2007, A&A 474,655; TYC2 = Høg et al., 2000, A&A 355, 27

Gaia & sdB stars

- 10 bright sdB stars (HIP et al. with Gaia errors):

Name	Vmag	μ_α	$\sigma\mu_\alpha$	μ_δ	$\sigma\mu_\delta$	π	$\sigma\pi$	$\sigma\pi/\pi$	$\pi/\sigma\pi$	Source
	Mag	mas/yr				mas				
HD127493	10.08	-32.9	1.2	-18.2	1.1	5.43	0.016	0.003	339.38	HIP07
HD149382	8.94	-6.7	1.8	-4.2	1.8	13.53	0.016	0.001	845.62	HIP07
HD205805	10.18	+75.5	1.2	-10.0	0.9	3.75	0.016	0.004	234.38	HIP07
HD188112	10.22	+34.4	2.1	+21.6	1.4	13.64	0.016	0.001	852.50	HIP07
CD -38 222	10.26	+46.0	1.7	-6.5	1.1	2.09	0.016	0.008	130.62	HIP07
HD4539	10.29	+5.1	1.8	+25.2	1.4	2.22	0.016	0.007	138.75	HIP07
Feige66	10.59	+3.0	1.7	-26.0	1.3	6.15	0.016	0.003	384.38	HIP07
HD171858	9.85	-13.9	1.6	-22.7	1.6	----	0.016	----	----	TYC2
SB707	11.90	+85.8	3.2	-48.2	2.3	3.49	0.016	0.005	218.12	HIP07
SB815	11.00	-19.8	1.5	-7.5	1.8	4.56	0.016	0.004	285.00	HIP07

HIP07 = van Leeuwen, F., 2007, A&A 474,655; TYC2 = Høg et al., 2000, A&A 355, 27

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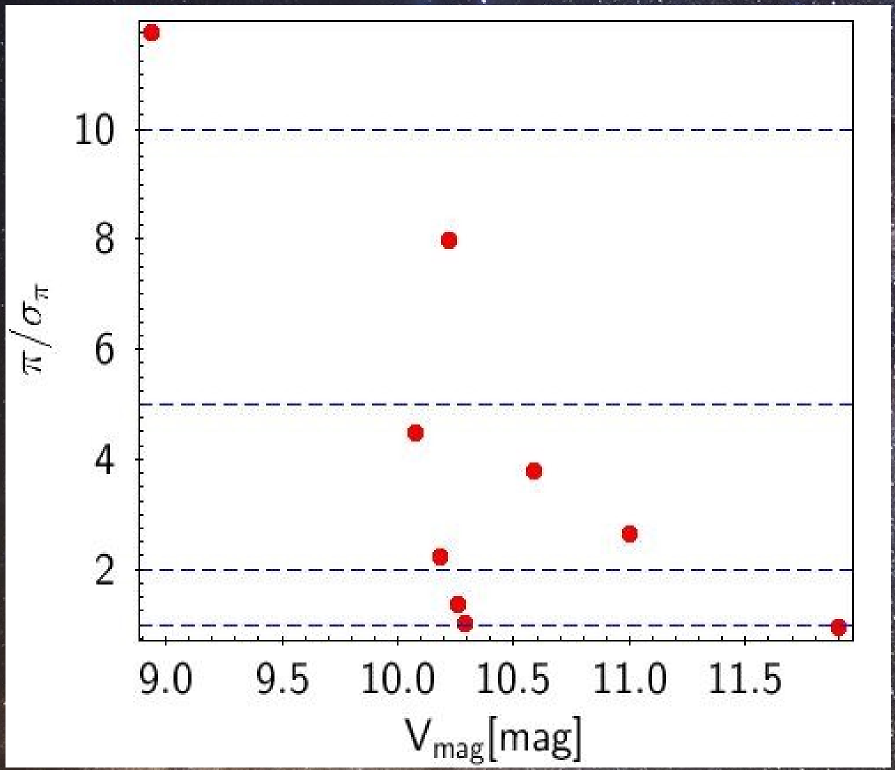
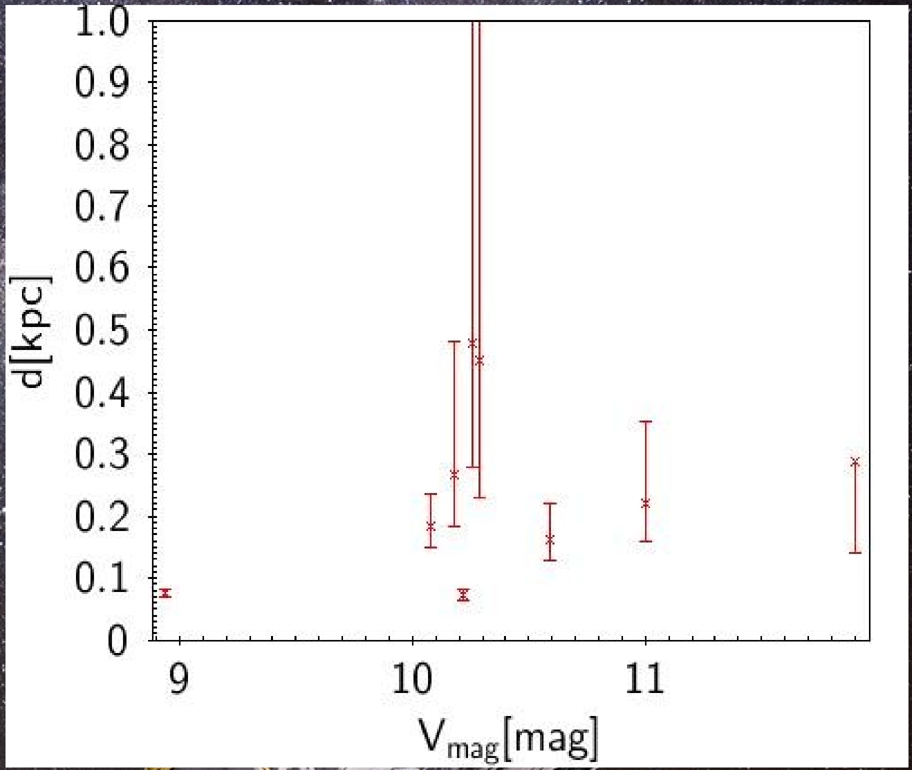
Gaia & sdB stars

- 10 bright sdB stars:





Gaia & sdB stars

- Parallaxes of a typical sdB star (M_G=5 mag):

d [pc]	G [mag]	π[μas]	σπ[μas]	σπ/π
100	10	10,000	16	0.0016
200	11.5	5,000	16	0.0032
500	13.5	2,000	16	0.0080
1000	15.0	1,000	28	0.0280
2000	16.5	500	60	0.3000
5000	18.5	200	200	1.0000
10000	20.0	100	500	5.0000

Gaia & sdB stars

- HIP&homegrown proper motion quality for a typical sdB star (M_G=5 mag):

d [pc]	G [mag]	σμ[μas/yr]	δv_{tan} [km/s]
100	10	1000	0.47 (2.4)
200	11.5	1500	1.4 (4.8)
500	13.5	2000	4.7 (12)
1 000	15.0	5000	12.0
2000	16.5	5000	48
5000	18.5	10000	240
10000	20.0	20000	1000

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Gaia & sdB stars

- Gaia Proper motion quality for a typical sdB star (M_G=5 mag):

d [pc]	G [mag]	σμ[μas/yr]	δv_{tan} [km/s]
100	10	16	0.008
200	11.5	16	0.015
500	13.5	16	0.031
1000	15.0	28	0.133
2000	16.5	60	0.570
5000	18.5	200	11.8
10000	20.0	500	23.7

Some examples

These examples, based on existing studies, are meant to demonstrate what is possible and what is not feasible with Gaia data. The different types of data derived by Gaia (or any other such mission as a matter of fact) have different limitations. For example, trigonometric parallaxes deteriorate quicker with distance than proper motions, as demonstrated on the tables on the previous viewgraphs. Therefore distances of objects at distances where the transversal motion is still derivable with great precision, need to be obtained through another method, e.g. using stellar models, which in turn can be very much enhanced in respect to the present situation by Gaia data, by fixing the distance of template stars sufficiently close enough to a much greater degrees of precision. Obviously this section cannot provide an “out of the can” solution for any given science approach or anything near it – it is merely meant to be an incentive for consideration of the potential of using Gaia data for Galactic and Stellar science – here focussing on sdB/HB and other blue stars (page inserted for “archival version”).

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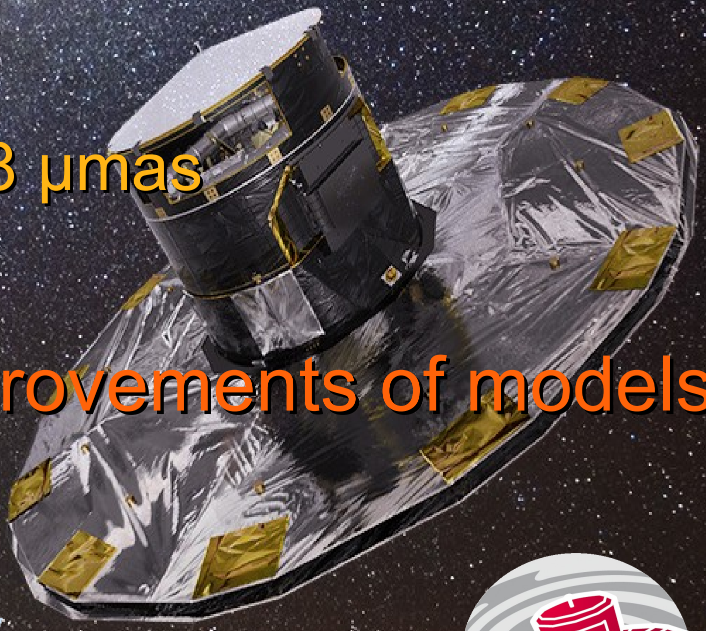
Some examples

- HD 271791 and its origin, see Heber et al. 2008
  - B2-3III HVS star
  - v_{rad}=441 km/s,
  - d=21±4 kpc
  - V=12.25 mag
  - Parallax of 21 kpc: 0.048 mas = 48 µmas
  - Error: 16 µmas → $d=21^{+10}_{-6}$ kpc

→ not better than before (but improvements of models, based on similar stars?)



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Some examples

- HD 271791 and its origin, see Heber et al. 2008
  - B2-3III HVS star
  - v_{rad}=441 km/s,
  - *d*=21±4 kpc
  - *V*=12.25 mag
  - Error of proper motions (Gaia): 16 µas/yr = 1.6 km/s
  - Before (3-5 mas/yr, based on scatter): 300-500 km/s

→ drastic improvement!

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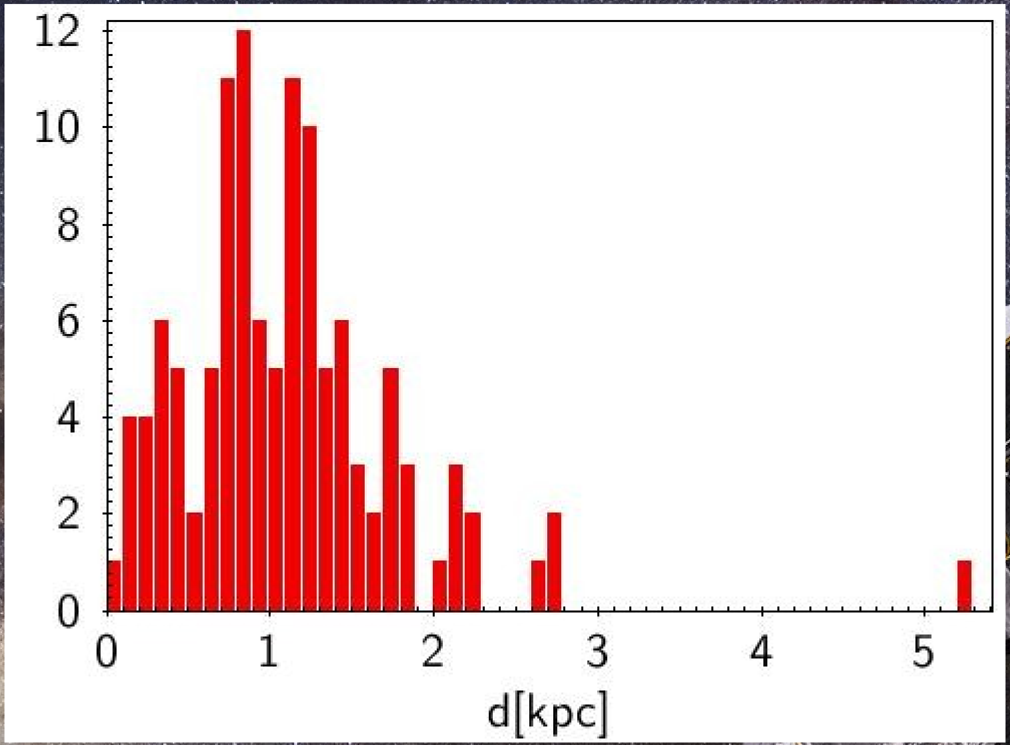
Some examples

- My old sdB/HBB sample (Altmann et al. 2004) and PhD thesis:
  - 114 sdB stars (V=8.9-17 mag) +a dozen or so HBB stars (8-17 mag) with HIP, Tyc2 and homegrown proper motions
  - SdB stars published in A&A 414, 181, HBB only in thesis (data too bad!)
  - Distances 80-2500 pc (sdB) 200-6000 pc (HBB)
  - Typical error of transversal velocity: 10-50 km/s (sdB), > 100km/s HBB

Some examples

- My old sdB/HBB sample (Altmann et al. 2004) and PhD thesis:



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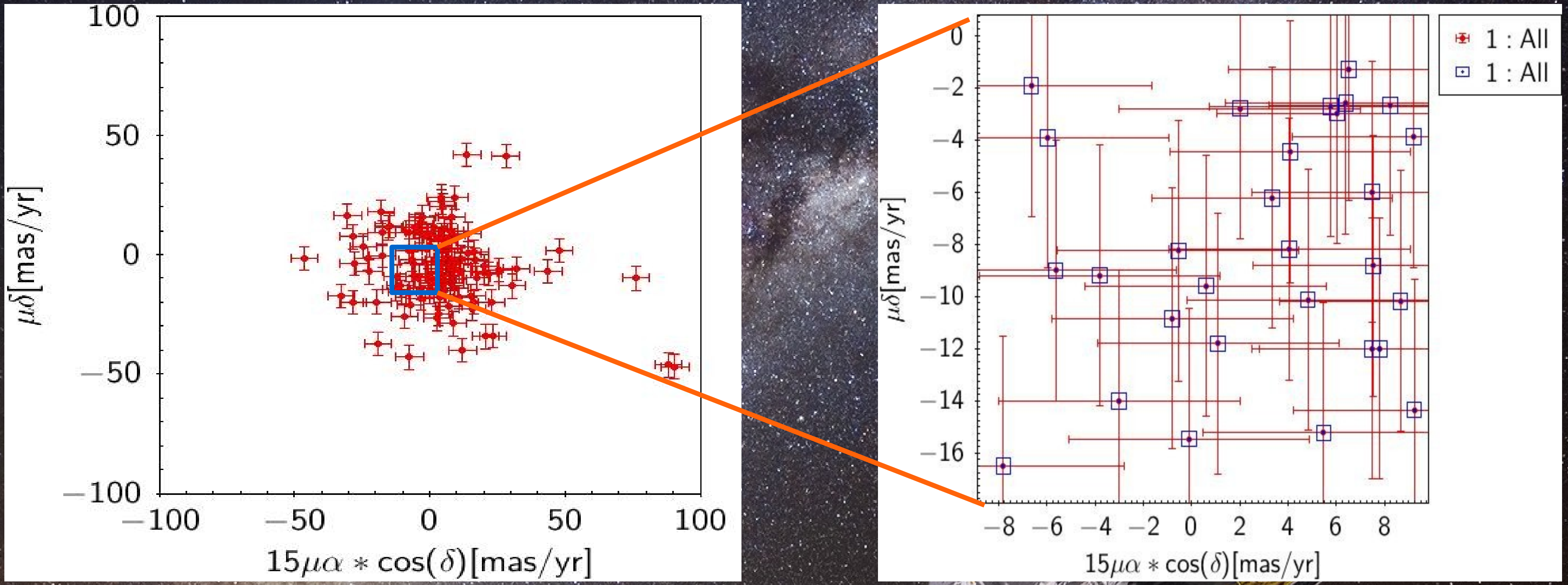
Some examples

- My old sdB/HBB sample (Altmann et al. 2004) and PhD thesis:



Red Symbols: proper motions and Errors from Altmann et al. (2004)/Altmann (2002), blue (right panel) Gaia errors

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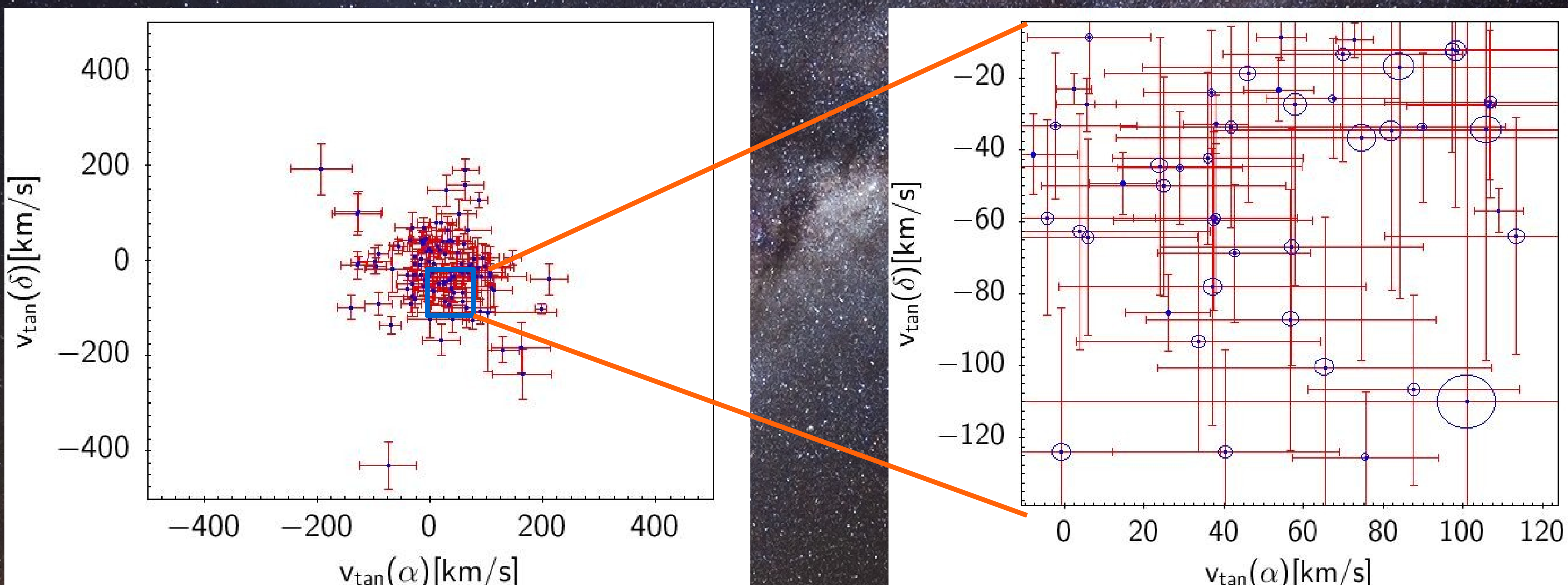
Some examples

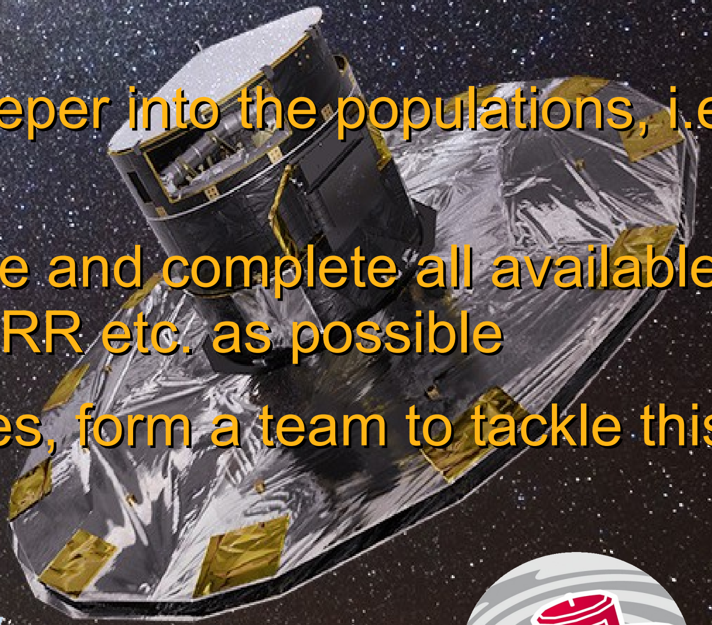
- My old sdB/HBB sample (Altmann et al. 2004) and PhD thesis:



Red symbols: Velocities and errors from Altmann et al. (2004)/Altmann (2002), blue symbols/circles: Gaia errors (Note: these errors are based on proper motion errors only, not on distance errors – total error may be larger)

Some examples

- My old sdB/HBB sample (Altmann et al. 2004) and PhD thesis:
  - From the astrometric side, results will be unambiguous (notwithstanding the overlap between Halo, Thick Disk and even Thin Disk!)
  - Larger, more precise samples will need refinement of diagnostic tools for quantitative analysis!
  - Gaia precision will enable us to look deeper into the populations, i.e. substructure
  - Until 2017 we need to collect, streamline and complete all available data on as many sdB/OB/O, HBB, HBA,RR etc. as possible
  - Proposal: for the benefit of all, join forces, form a team to tackle this!



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Some examples

- Planetary, BD or other companions to (sdB) stars :
  - A very important aspect for the understanding of the formation and nature of sdB-stars are close companions (see many talks during this meeting!)
  - Gaia will detect exoplanets and other unseen objects by the transversal displacements of the visible companion
  - These results will however probably not yet be released in the 1st 2 releases, but at a later stage!
  - Whether an object is detectable or not depends on the geometric configuration, mass ratio, etc., see e.g. Perryman et al. 2014 (ApJ 797, 14; arXiv:1411.1173v1)

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Some examples

- Planetary, BD or other companions to (sdB) stars :

  displacement: $\alpha_* = (M_p/M_*)(a_p/1\ \mathrm{AU})(d/1\ \mathrm{pc})^{-1}$ arcsec

  - Case 1: $M_*=0.5\ M_\odot$, $Mp=0.1\ M_\odot$, p=0.1 d
    - → $a_p=0.003$ AU
  - d=100 pc: $\alpha_p=6$ μas *undetectable!*

Some examples

- Planetary, BD or other companions to (sdB) stars :

  displacement: $\alpha_* = (M_p/M_*)(a_p/1\text{ AU})(d/1\text{ pc})^{-1}$ arcsec

- Case 2: $M_* = 0.5\ M_\odot$, $M_p = 1\ M_{Jup}$, a= 1 AU

- d=100 pc: $\alpha_* = 10$ µas <u>probably *undetectable!*</u>

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Some examples

- Planetary, BD or other companions to (sdB) stars :

  displacement: $\alpha_* = (M_p/M_*)(a_p/1\ \mathrm{AU})(d/1\ \mathrm{pc})^{-1}$ arcsec

- Case 2: $M_* = 0.5\ M_\odot$, $M_p = 60\ M_{Jup}$, a= 1 AU

- d=100 pc: $\alpha_* = 600$ µas, fair game!

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Some examples

- Planetary, BD or other companions to (sdB) stars :
  - Critically depends on system geometry
  - Larger masses of secondary → better
  - Larger orbit → better
  - Complementary to RV method
  - Extremely close systems will be problematic

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Gaia – data releases

- Every release contains improved data of previous releases (data types in the following are highlights, and thus not entirely complete, for full version, see Gaia release scenario)
- 1st release, mid 2016
  - α,δ, G-mag, if 90%of sky covered
  - Single stars
  - "100000" stars project, full enhanced kinematics of the HIP stars
  - Maybe a surprise :-) hint: see Michalik, Lindegren & Hobbs, 2014, A&A 574, 115
- 2nd release, early 2017
  - 5 par astrometrics for single stars
  - BP/RP integrated photometry
  - RVs for single stars
- 3rd release, 2017/18 (TBC)
  - Full astrometry for binaries with 2months$<T_{orb}$75% observing time
  - Object classification, astrophysical parameters incl. RP/BP/RVS spectra for wellbehaved objects

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Gaia – data releases

- 4th release, 2018/19 (TBC)
  - Variable star classification, epoch photometry
  - Solar system results, preliminary orbital solutions
  - Non-single stars catalogues
- ***Final release, 2022 (TBC)***
  - **Everything!!!!!**

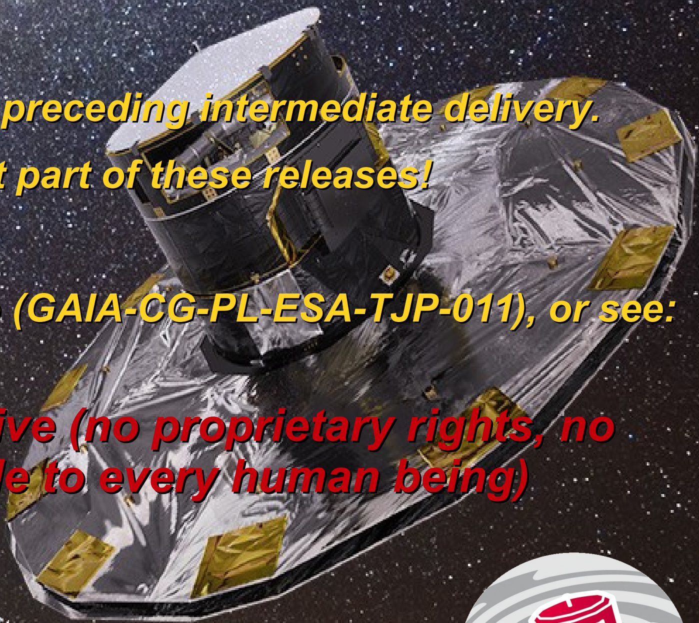
All steps include the a re-delivery of the data delivered in the preceding intermediate delivery.

Science alerts will be issued as soon as possible, and are not part of these releases!

Exact release dates subject to shifts within schedule

Reference: T.Prusti: Gaia Intermediate Data Release Scenario (GAIA-CG-PL-ESA-TJP-011), or see:
http://www.cosmos.esa.int/web/gaia/release

Condition of accessing data at time of release: be alive (no proprietary rights, no protected data times, release is immediately available to every human being)



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- CDS, ADS and other public data archives and repositories
- Figures and pictures are courtesy of the source indicated on the relevant pages, and if there is no source info, they are to be considered to be courtesy to ESA.

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