Gaia observations of naked-eye stars: status update

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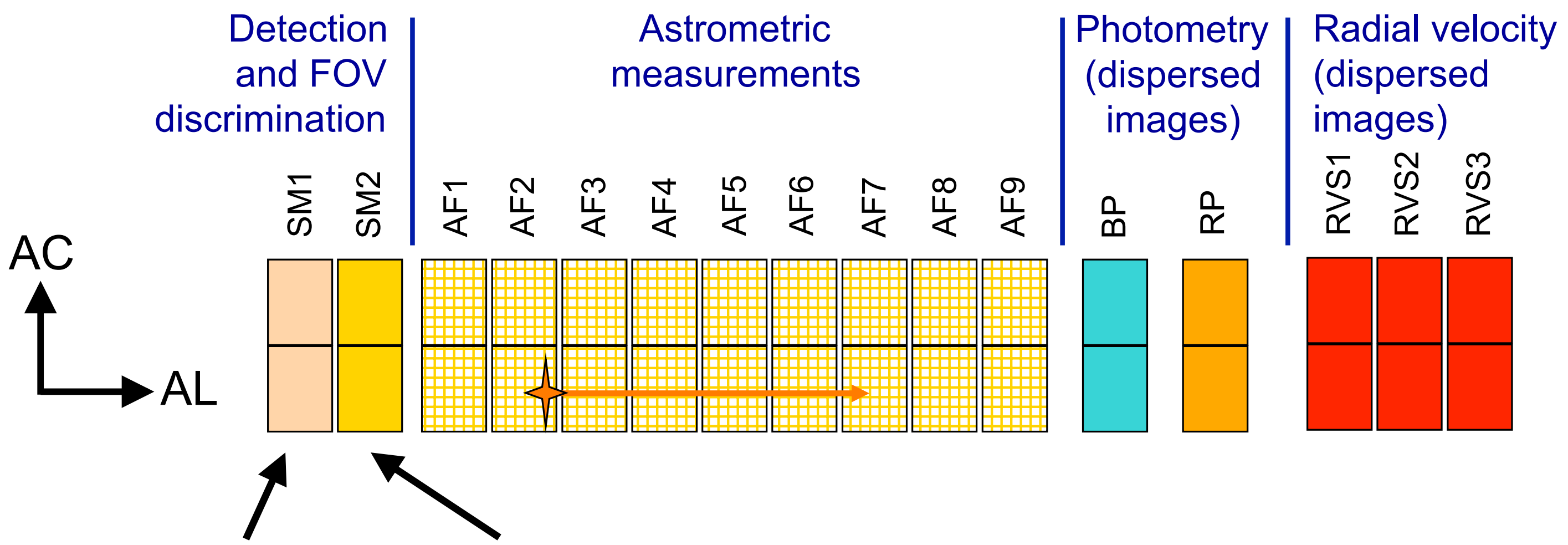
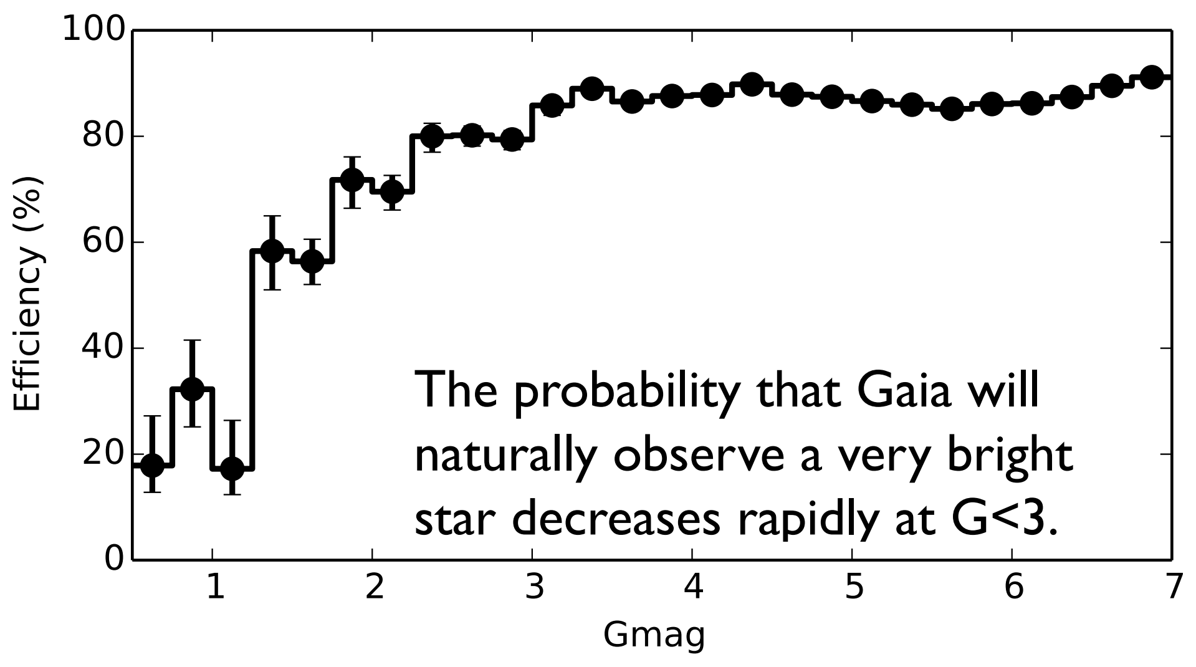
Gaia's bright limit

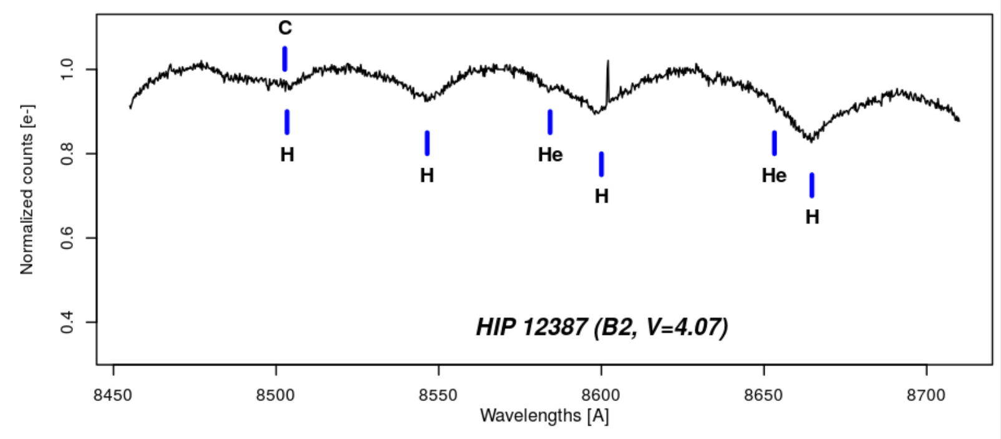
Schematic representation of 2 out of 7 CCD rows in the Gaia focal plane. Stars move from left to right as the spacecraft spins.



The SkyMapper CCDs (SM1 and SM2) identify the the star-like sources that Gaia will observe. Data of stars not identified in the SkyMapper are not downlinked, thus are lost. The original Gaia bright limit of G=6 was improved to G=3 by tuning the onboard parameters of the SkyMapper star detection algorithm (Martin-Fleitas et al 2014, Sahlmann et al. 2016).



The probability that Gaia will naturally observe a very bright star decreases rapidly at G<3.



Gaia Radial Velocity Spectrometer (RVS) spectrum of the very bright B2 star HIP 12387 (V = 4.1) from nominal observations.

For the 230 stars brighter than G=3, we are pursuing two solutions in order to observe them as well:

Forced SkyMapper Imaging: The first consists of forcing the acquisition of full-frame SkyMapper images and has been in operation since the beginning of Gaia's nominal mission.

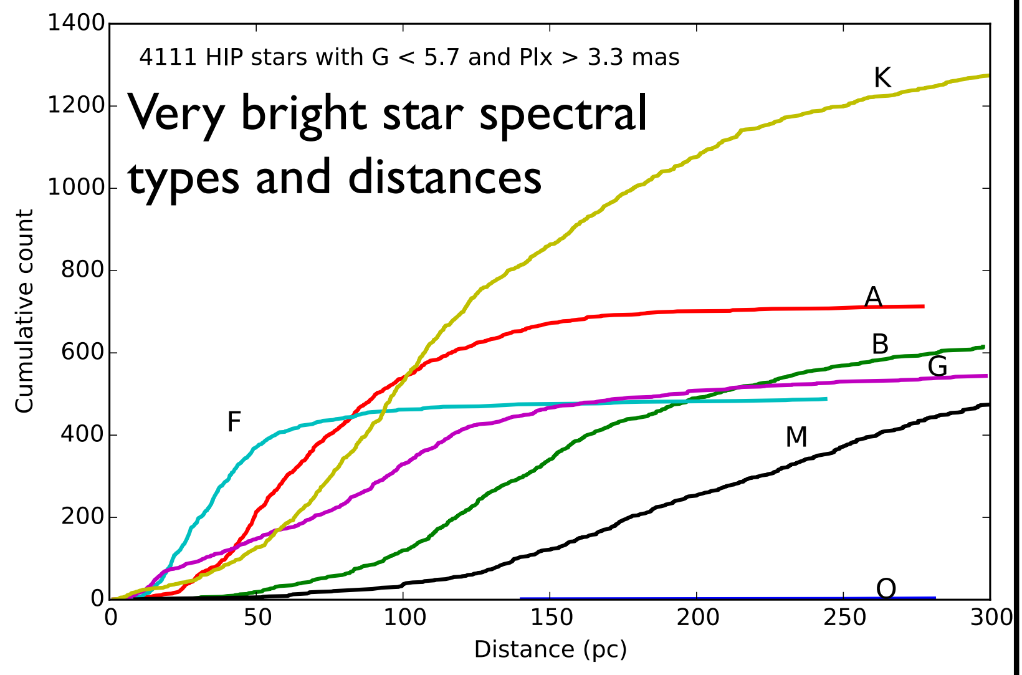
Virtual Object Synchronisation: The second method uses Virtual Objects whose associated CCD windows are placed at defined locations. They usually fall on 'empty' regions of the sky and, for instance, serve to estimate the sky background. The idea of Virtual Object synchronised observations is to predict the focal plane crossing of a very bright star and to place a Virtual Object window on top of it. The method has been successfully tested and its implementation for the brightest 50 stars (G<1.75) is under study.

Very bright star science cases

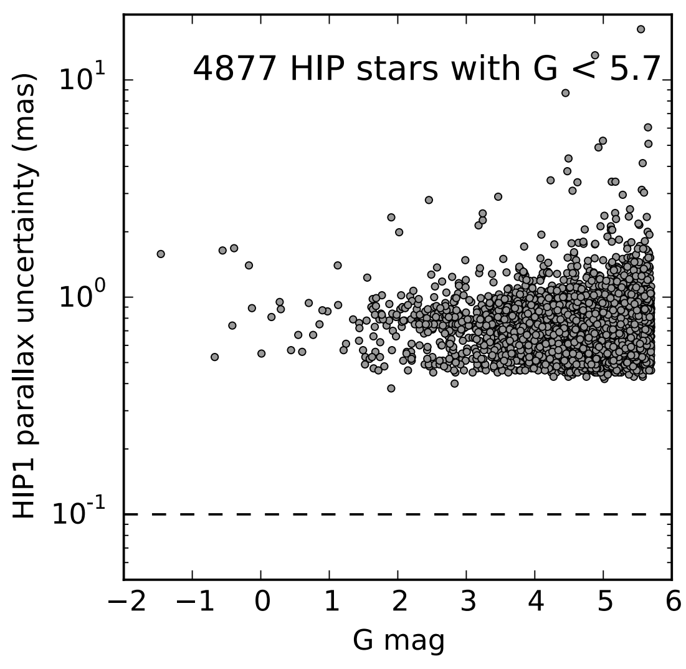
Very bright stars with magnitudes G<6, i.e. the ~6000 stars observable with the naked eye, are among the best studied astronomical objects. Securing Gaia data for those stars is a unique science opportunity, in particular in what concerns astrometry because no other current or planned observatory can obtain global astrometry at sub-milliarcsecond level of this stellar sample.

Science cases include but are not limited to:

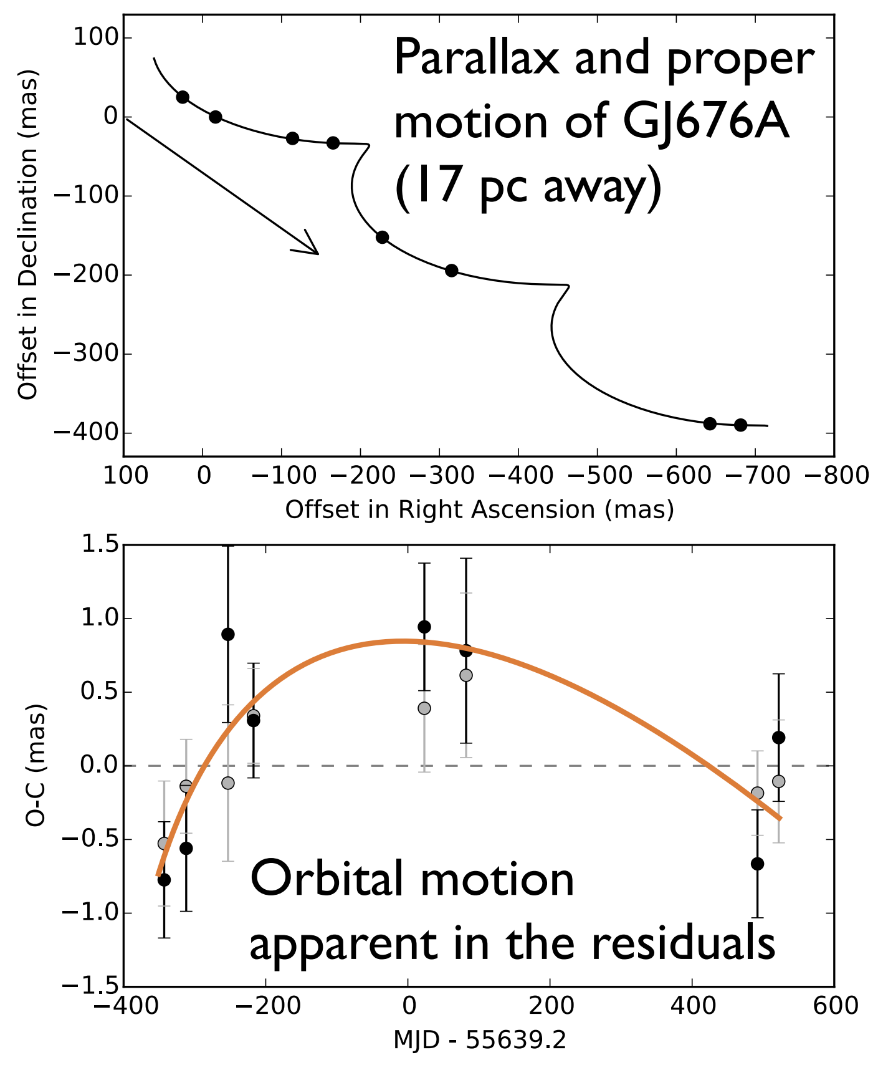
- Parallaxes and proper motions about 10 times more precise than from Hipparcos, e.g. of bright massive stars that are fundamental anchor points for stellar astrophysics.
- Orbit constraints for very bright binary stars (at least 25% of the sample).
- Discover new exoplanets, in particular around very bright A and F stars.
- Accurate masses of known exoplanets discovered by radial velocity monitoring, see the example below:

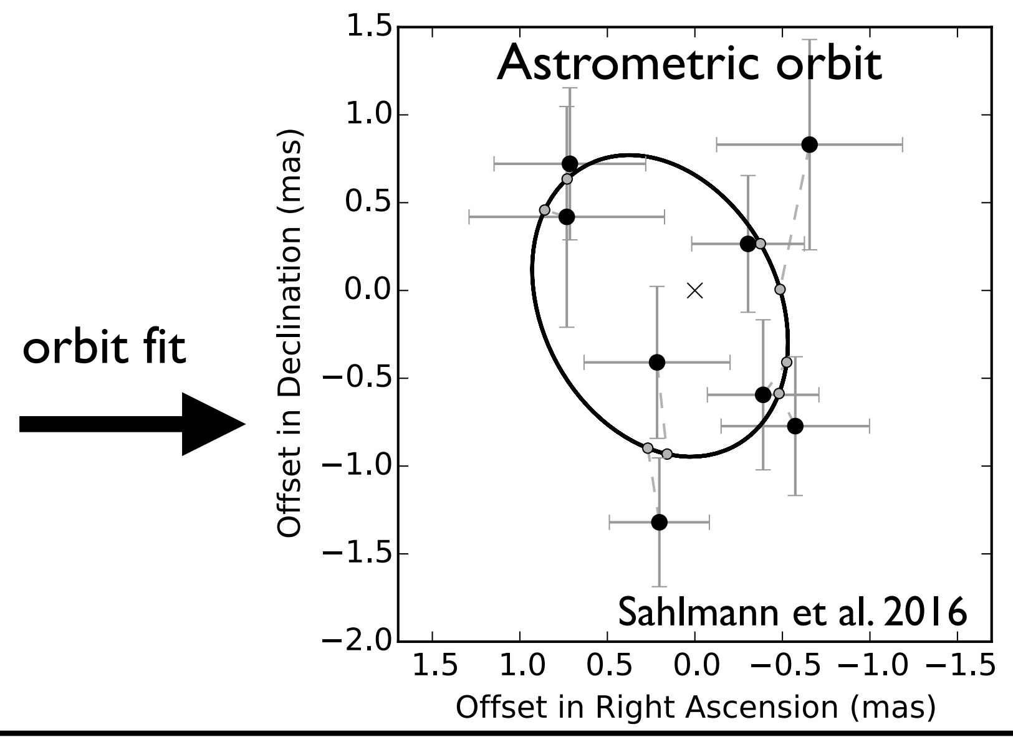


Very bright star spectral types and distances



Very bright star parallax uncertainties from Hipparcos. Gaia parallax uncertainty goal is better than 0.1 mas.

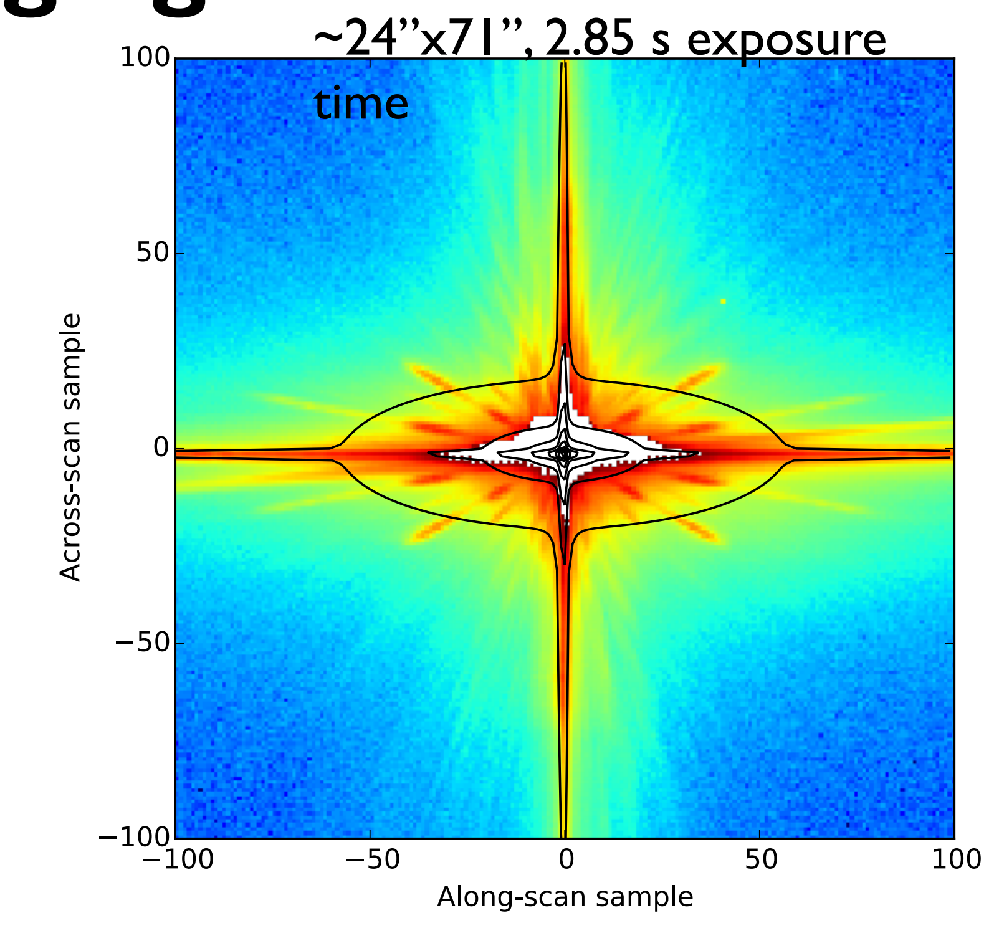




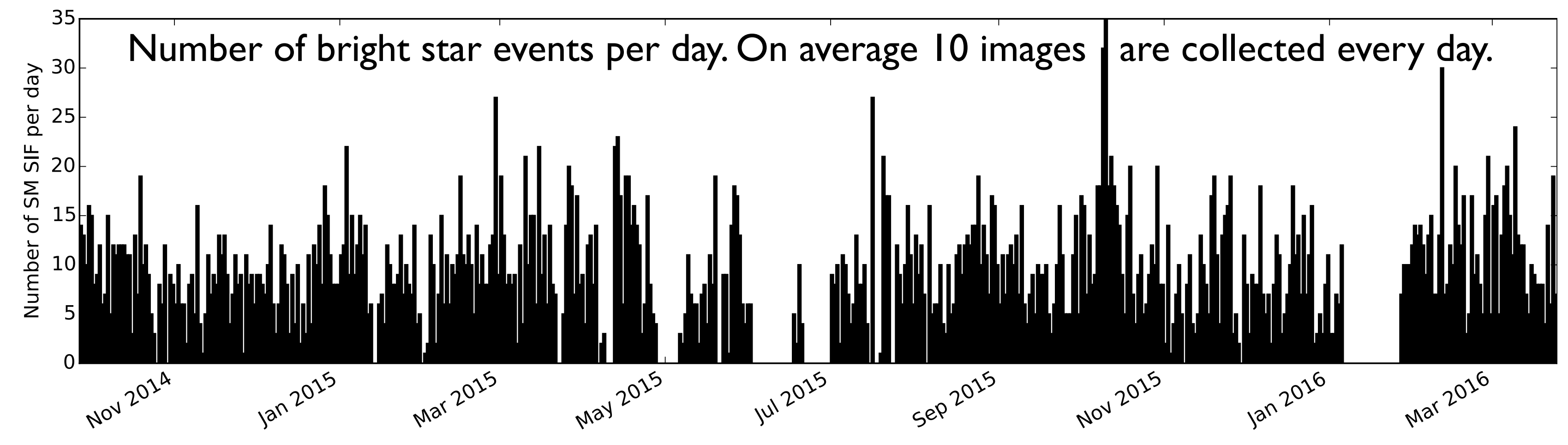
The astrometric orbit of GJ676A caused by planet b from FORS2/VLT astrometry and HARPS-S radial velocities (Sahlmann et al. 2016). The planet's true mass is ~6.7 Jupiter masses. Gaia naked-eye star observations can make similar work possible for tens of known exoplanets.

Forced SkyMapper Imaging

At every predicted passage of a very bright star, Gaia records 5 seconds of SkyMapper full-frame data. The PSF core saturates (white pixels) and a nominal model (contours) does not reproduce the high spatial frequencies, but the images (~5'x6') contain plenty of astrometric information. These data are non-nominal and treated with an off-line pipeline (Sahlmann et al. 2016, Gaia Collaboration 2016).

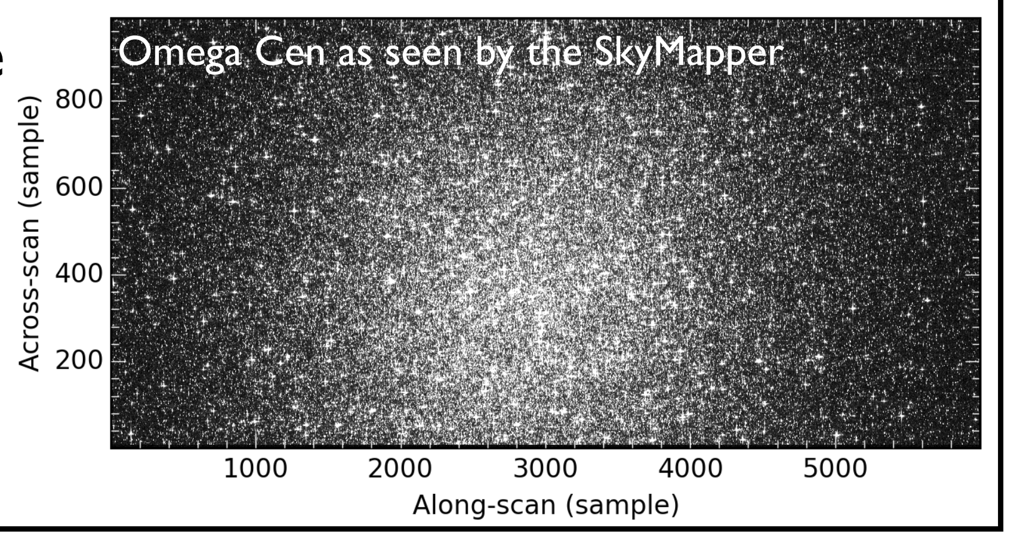


Advantages: This is a non-invasive, well-tested method with negligible increase in telemetry. It is in operation since October 2014.
Disadvantages: Only SkyMapper data are collected, which have a fixed integration time (CCD gating) and are undersampled by a factor of two (~0.11"x 0.35" sample size) compared to the astrometric field CCD data. The more powerful solution of virtual object synchronisation can mitigate this.



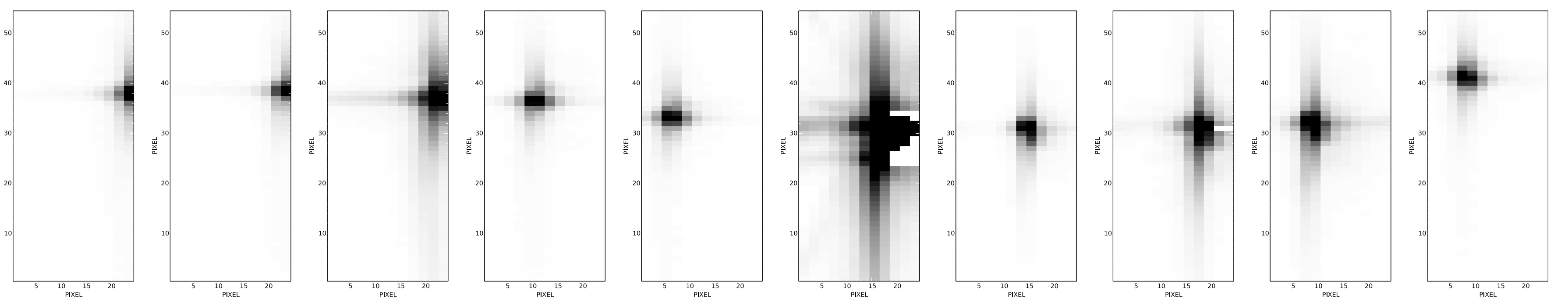
Number of bright star events per day. On average 10 images are collected every day.

In addition to very bright stars, the technique of forced SkyMapper imaging is also applied to capture images of extremely dense fields (to mitigate effects of crowding) and of events when stars are observed close to Jupiter's limb (for scene reconnaissance).



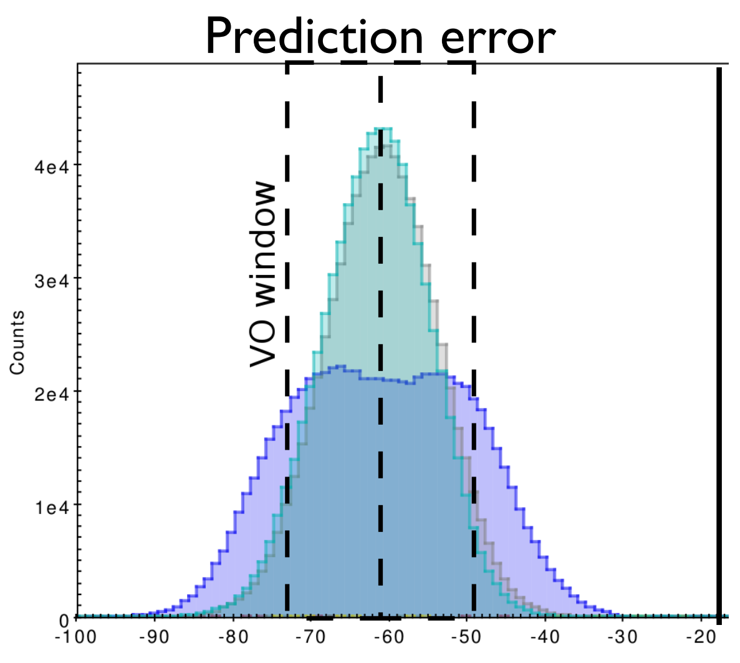
Virtual Object Synchronisation

Because Gaia is constantly spinning and precessing, this method relies on accurate temporal (~9 ms) and spatial (~1") predictions of very bright star passages in the Gaia focal plane.



Ten windows with very bright star images that were collected using virtual object synchronisation.

These prediction capabilities were demonstrated in several tests reaching ~70% success rates (capture of the stellar core), see blue histogram. Using improved prediction models we aim at >90% success rate.
Advantages: This method gives access to SkyMapper, astrometric field, and spectro-photometric data of extremely bright stars.



Conclusions

There is no bright limit for Gaia astrometric observations, however core saturation poses challenges both for naturally detected stars (G<6) and in the forced SkyMapper images. Virtual object synchronisation may mitigate some of those problems for the 50 stars brighter than G=1.75.

Acknowledgements

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References

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