Application of Gaia analysis software AGIS to Nano-JASMINE

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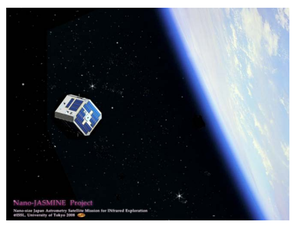
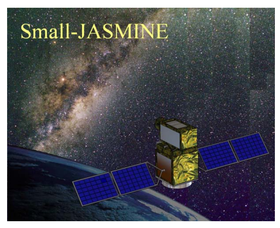
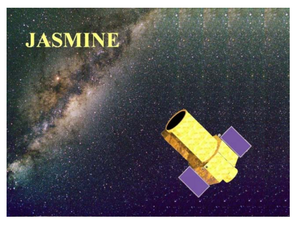
Abstract: The core data reduction for the Nano-JASMINE mission is planned to be done with Gaia's Astrometric Global Iterative Solution (AGIS). Nano-JASMINE is an ultra small (35 kg) satellite for astrometry observations in Japan and Gaia is ESA's large (over 1000 kg) next-generation astrometry mission. The accuracy of Nano-JASMINE is about 3 mas, and this is comparable to the Hipparcos mission, Gaia's predecessor some 20 years ago. It is challenging that such a small satellite can perform real scientific observations. The collaboration for sharing software started in 2007. In addition to similar design and operating principles of the two missions, this is possible thanks to the encapsulation of all Gaia-specific aspects of AGIS in a Parameter Database. Nano-JASMINE will be the test bench for the Gaia AGIS software. We present this idea in detail and the necessary practical steps to make AGIS work with Nano-JASMINE data. We also show the key mission parameters, goals, and status of the data reduction for the Nano-JASMINE.







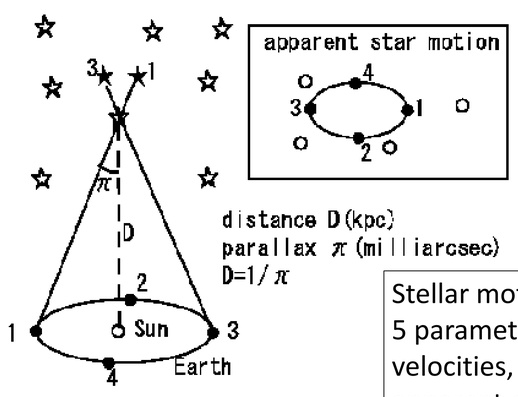
	Nano-JASMINE	Small JASMINE	JASMINE
D	5cm	30cm	1m class
Size/weight	$(50cm)^3$, 35kg	400kg	1500kg
accuracy	3mas@z<7.5	10μas @ K_W<11	10μas @ K_W < 11
survey	whole sky	Several sqr deg.	200 sqr deg.
launch	Aug 2011, Alcantara Cyclone space, cyclone4	Submit small science satellite program in ISAS/JAXA	TBD
operation	2011-2013	2016	2020's

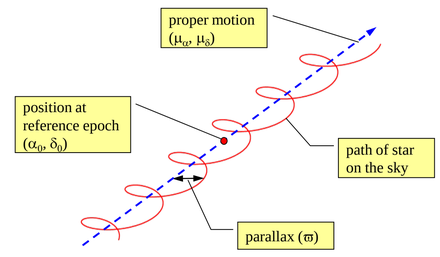
Japanese space astrometry program

What is AGIS: AGIS is the name of the software developed by Gaia team, Astrometric Global Iterative Solution. Astrometric data reduction is essentially the large least square problem.

$$\begin{pmatrix} \boldsymbol{S} & \boldsymbol{U}^{\mathrm{T}} & \boldsymbol{V}^{\mathrm{T}} \\ \boldsymbol{U} & \boldsymbol{A} & \boldsymbol{W}^{\mathrm{T}} \\ \boldsymbol{V} & \boldsymbol{W} & \boldsymbol{C} \end{pmatrix} \begin{pmatrix} \Delta\boldsymbol{s} \\ \Delta\boldsymbol{a} \\ \Delta\boldsymbol{c} \end{pmatrix} = \begin{pmatrix} \boldsymbol{b}_s \\ \boldsymbol{b}_a \\ \boldsymbol{b}_c \end{pmatrix}$$

The vector ***s*** is stellar parameters, ***a*** is satellite attitude parameters, and ***c*** is the calibration parameters. Number of components of ***s*** is 10^7 because each star has 5 astrometric parameters as shown in the below fiture, and number of stars observed is about 2 x 10^6 in Nano-JASMINE. For satellite attitude, we apply statistical model. According to Gaia attitude model, we also apply cubic spline of each quaternion components as the first steps. AGIS can solve the best fit parameters from the observed data iteratively.



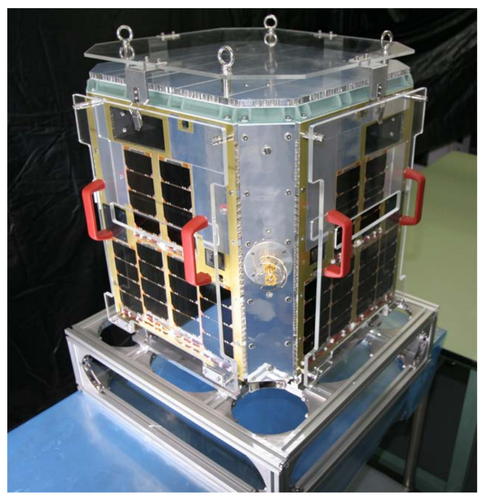


Stellar motion in the celestial sphere can be writte by 5 parameters, two positions in the certain epoch, two velocities, and parallax which is the major axis of apparent elliptic trajectory.

Nano-JASMINE and JASMINE series: We have three astrometric mission in Japan as shown in above table. Observational strategy of Nano-JASMINE is rotating satellite with two beam and is similar to the European large astrometry satellite Gaia. The small JASMINE / JASMINE are pointing satellites with one beam and have different observational strategy from Nano-JASMINE.

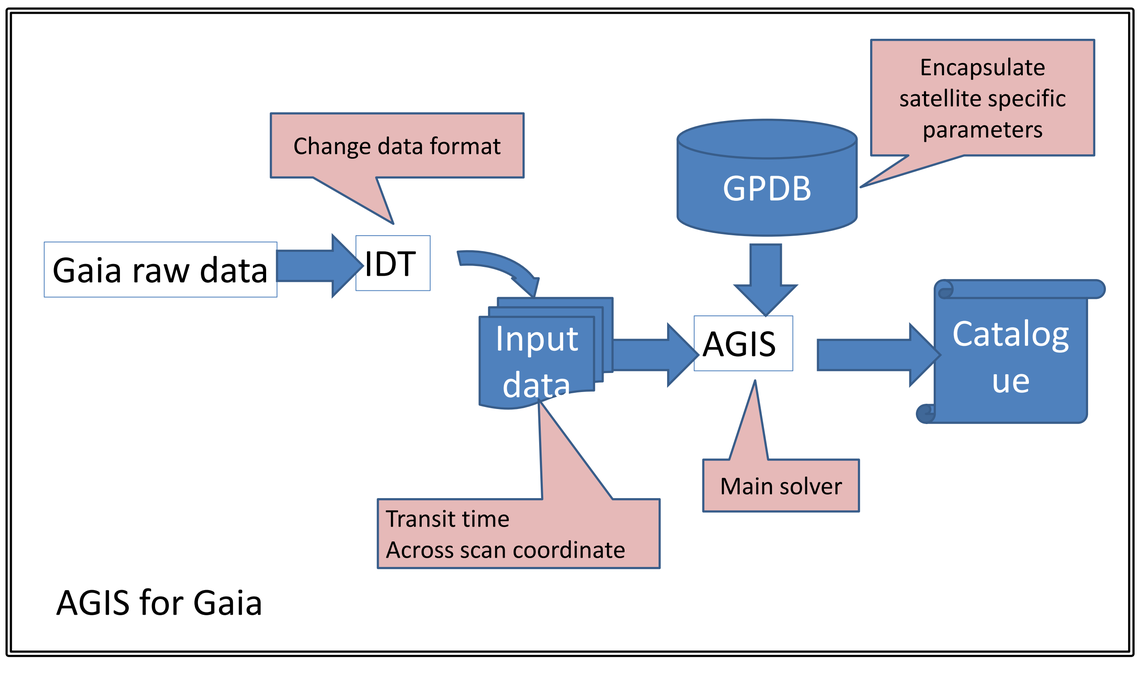
Nano-JASMINE is the first Japanese astrometric satellite and the second one in the world. Launch contract is completed. Nano-JASMINE will be launched at around **Aug 2011** from Alcantara Space Port at Brazil by Cyclone 4 launch vehicle.

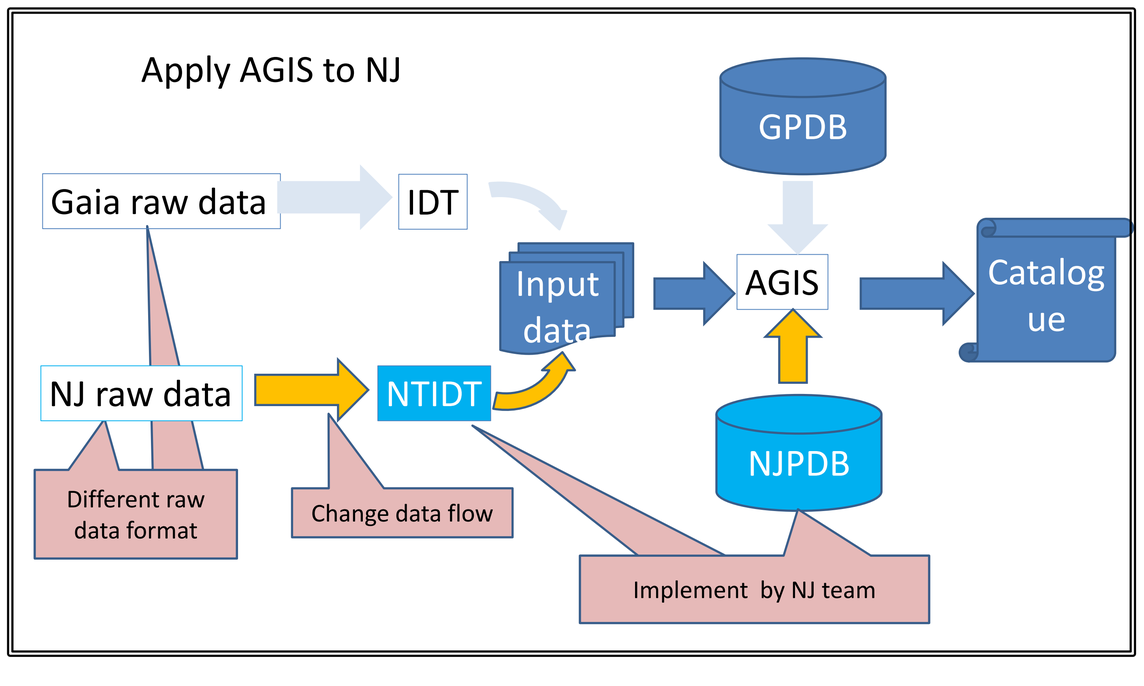
At this summer, flight model is completed and now testing.



Nano-JASMINE Flight Model

In AGIS, the input data is only the transit time and across scan coordinate in the observed stellar position, and the satellite specific parameters are encapsulated within database(PDB). The part of calculating the two input parameters from the observational data (IDT) is separated from the main solver / iterator. We can apply AGIS to Nano-JASMINE only by replacing IDT and PDB from Gaia specific version to Nano-JASMINE specific version as shown in below figure.





Implementation status:

The downloaded data of Nano-JASMINE is the stellar images of 9 x 5 pixel values. On the other hand, the basic input value is the transit time of the star and across scan coordinate of the image.

Centroid: We should calculate the center of the stellar image. The photo center is not a real center of the stellar image. The principal components as shown in the right figures have the information of the image center. The first component denotes the shape of stellar images. The second and third one means the shift of the image center of each directions. By sampling the coefficients of these two components, the normalization which is the PSF dependent values, will be estimated. Across scan coordinates are written in the unit "pixel". For along scan coordinate, we have GPS time of each TDI line in on-board data and can convert bari centric time.

Radiation damage: By the effect of the radiation, the PSF changes and centroid will be shifted. NJ team measure the change of CTI and within two years operation, CTI will be about 10^{-4}. The effect will be similar to that of Gaia. From the analysis of Gaia members, the shift will be written as the third polynomial of the magnitude. In that case, the AGIS "calibration model" can be applied. The coefficients of the polynoomial will be estimated simultaneously as other parameters.

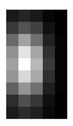
Proper motion: In Nano-JASMINE and also in Gaia, proper motion accuracy is improved by combining the Hipparcos data and using the long time baseline(more than 20 years with 1 mas accuracy). One of our member in ESA modify the AGIS for doing this.

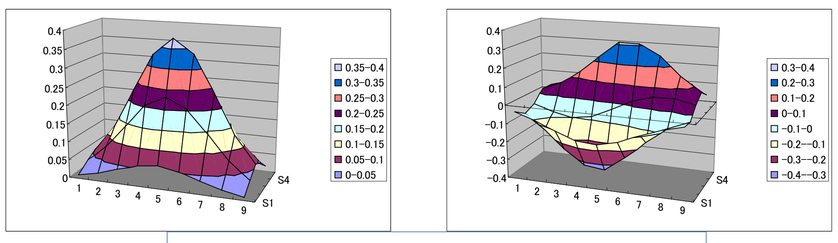
Future plan: We are planning small-JASMINE after the Nano-JASMINE. The observational strategy is different. So, we cannot apply AGIS to small-JASMINE easily. So, we start to implement more general least square solver.

New implementation will support the flexibility for replacing models. For example in Nano-JASMINE, we can replace the attitude model from the statistical (cubin spline) model to physical model. By doing so, it will be helpful for the design of the next small scientific satellite.

By replacing the attitude model and also replacing observation model, we will able to apply the software to small-JASMINE data.

Sample of the Stellar image





The first two principal components

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