Astrometric Reduction of Cassini ISS images of Enceladus in 2015 based on Gaia DR1

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Abstract

We take Gaia DR1 catalogue stars as reference ones to reduce the Cassini ISS images of Enceladus in 2015, and obtain a total of 494 Cassini-centered astrometric observation in right ascension(α) and declination (δ) in the international Celestial Reference Frame(ICRF). Compared to JPL ephemerides SAT367, we derive that their mean residuals are about one hundred of meters in α*cos(δ) and few kilometers in δ, and their standard deviation is not over 2 kilometers. Compared to taking UCAC4 catalogue stars as reference ones, the result shows Gaia DR1 and UCAC4 have the equivalent precision of reduction.

Keywords: Astrometric Reduction; Enceladus; Gaia; Cassini ISS

Introduction

During the past a few years, the Cassini ISS images have been routinely used to measure the astrometric positions of planetary satellites[1-4]. The soft package Caviar has been also implemented for the task[5], which is convenient to reduce space images. Tajeddine et al[2] and Cooper et al[3] have reduced the ISS NAC images of Enceladus before 2014. In the research, the ones in 2015 are measured by Caviar, and some of them are selected for comparing the effects brought from Gaia[6-7] and UCAC4[8].

Method

As described in paper [2,3], to reduce one image by CAVIAR involves two successive steps: pointing correction and limb fitting. In the first step, catalogue stars are be loaded into and taken as reference stars to correct camera's pointing. Obviously, the catalogue stars play an important role in the process. In the second step, the edge of satellite's limb is detected, and then the satellite's center position is computed by fitting its known shape into the edge. To study how much the Gaia catalogue benefits the reduction, we take the same stars from Gaia DR1 and UCAC4 catalogue respectively as reference stars in one image in the first step, and keep the same operation in the second step. Therefore, each image will be reduced twice and has two results, one result is from Gaia DR1, and the other is from UCAC4. Finally, we compare the result pairs of total 368 images to analyze the effects of Gaia DR1. It should be note that only the images in 2015 have been selected to be reduced because Gaia DR1 has only part of stars' proper motion data and their reference epochs are at J2015.0.

Data

All the images of Enceladus in 2015 have been taken by CASSINI ISS NAC from 2015-151T to 2015-337T. All of them are downloaded from PDS website (http://pds-imaging.jpl.nasa.gov). 494 of them have been measured. The following is some typical images.

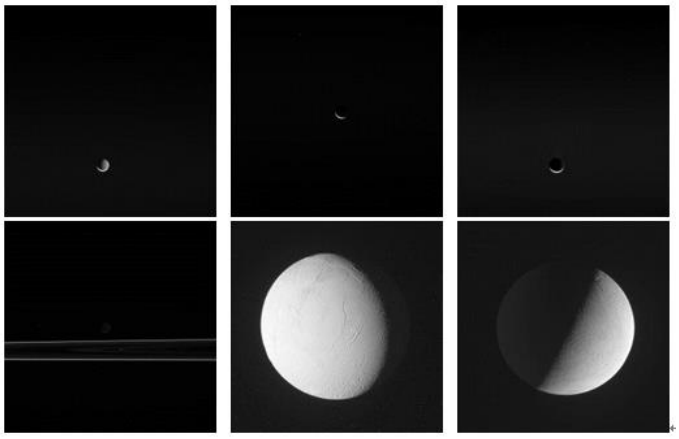

Fig.1 some typical ISS images of Enceladus in 2015

Results

At first, 494 images of Enceladus have been measured to obtain the its

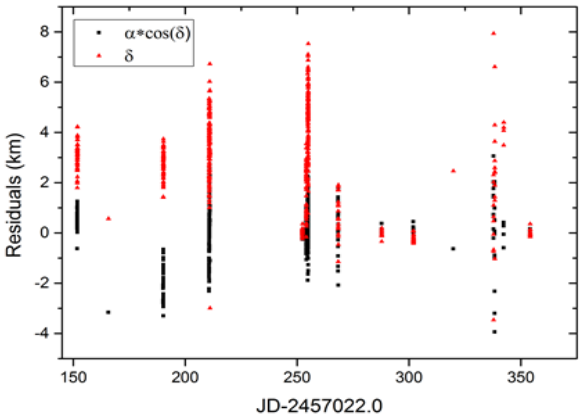

Fig. 2 The residuals in km relative to the JPL SAT367 ephemeris, red triangles are residuals in δ(declination), the squares represent the residuals in α*cos(δ) direction.

Table 1. Mean values of residuals relative to the JPL SAT367 ephemeris, including standard deviations in different directions.

	Sample (px)	Line (px)	α*cos(δ) (arcs)	δ （arcs）	α*cos(δ) (km)	δ (km)
Mean	-0.00775	0.32179	0.00913	0.41008	0.07567	2.8488
SD	0.14662	0. 25246	0.18017	0.32102	1.11737	1.88615

Table 2. Mean values of residuals in pixels, arcseconds and kilometres relative to the JPL SAT367 ephemeris, including standard deviations.

		Sample (px)	Line (px)	α*cos(δ) (arcs)	δ （arcs）	α*cos(δ) (km)	δ (km)
Gaia DR1	mean	-0.00439	0.35809	0.01248	0.45691	0.10129	3.146
	SD	0.12883	0.16561	0.16177	0.20604	1.14044	1.52775
UCAC4	mean	-0.0152	0.35016	-0.0047	0.44649	0.01867	3.06762
	SD	0.14589	0.17275	0.18254	0.21581	1.27889	1.58425

observed positions by Caviar with Gaia DR1, and then the observation residuals relative to JPL ephemerides SAT367 are computed. The figure 2 display every images' residuals in km in α*cos(δ) and δ direction. The table 1 lists the corresponding mean and standard deviation values for these residuals in sample, line direction and in arcsecond and km in α*cos(δ) and δ directions.

After that, 368 images of them with over 3 reference stars are selected, and have been reduced by caviar with UCAC4 again. These results are used to be compared with the corresponding results from Gaia DR1. Figure 3 displays the difference between the residuals from Gaia DR1 and UCAC4 in α*cos(δ) and δ. Table 2 lists the means and standard deviations of the residuals relative to SAT367 that caused by Gaia DR1 and UCAC4 in different directions.

From Fig.3 and table 2, we can find that Gaia DR1 and UCAC4 have equivalent effects. Although their corresponding means and standard deviations have slightly difference, UCAC4 tends to give slightly better mean values while Gaia DR1 tends to bring better standard deviations, overall, they have no significant difference. This is because the astrometric reduction's error comes from a few sources, which conceal the benefits from Gaia DR1's improvement.

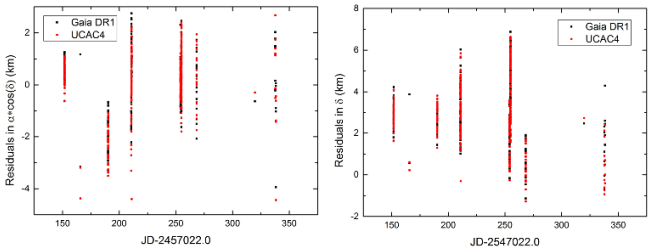

Fig. 3 The residuals relative to JPL ephemerides SAT367 in α*cos(δ) and δ directions when the Gaia DR1 and UCAC4 is used respectively.

Conclusion

We use Gaia DR1 catalogue stars as reference ones to reduce a total of 494 ISS images of Enceladus in 2015, and obtain 494 observation in right ascension (α) and declination (δ) in the international Celestial Reference Frame (ICRF). Compared to JPL ephemerides SAT367, we derive that their mean residuals are from one hundred of meters to a few kilometers, and their standard deviation is not over 2 kilometers. 368 images of them have been selected to be reduced again by taking UCAC4 catalogue stars as reference ones. Compared to these results, we can find Gaia DR1 and UCAC4 have the equivalent precision of reduction.

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