The Introduction of The Nature Satellites Observation and Orbit Update by NTSC

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National Time Service Center
Chinese Academic of Sciences
2012.6 Paris

NTSC

previously called Shaanxi Astronomical Observatory, takes the "Keep close concern with time cycling, formulate calendar of time computing" as faith of the institute.

national-level base-type research institute in assuming the tasks of national standard time generating, keeping and transmitting

improving time keeping and comparison precision of atomic time and has realized striding development by introducing talents, starting the development of high-performance atomic clock, and exploring research fields of positioning and navigation.

Astrometry research.

Background

1973 15th IAU

‘Noting that the ephemerides of most of the natural satellites are based on observations made long ago, and that efforts to improve the ephemerides have been hampered by the paucity of recent observations;

acknowledging that much higher accuracy in the ephmerides of these objects will soon be required, particularly for the exploration of the outer solar system by spacecraft;

Commission 20 urges that a reasonable amount of telescope time be made available for observations useful for the improvement of satellite ephemerides.’

Research History

- observed planetary satellite in successful implement with photo plate since 1987(T)

- 1994 observed Saturn successfully with small field CCD in Sheshan （“brighter moon calibration”）

Research History

“brighter moon calibration”

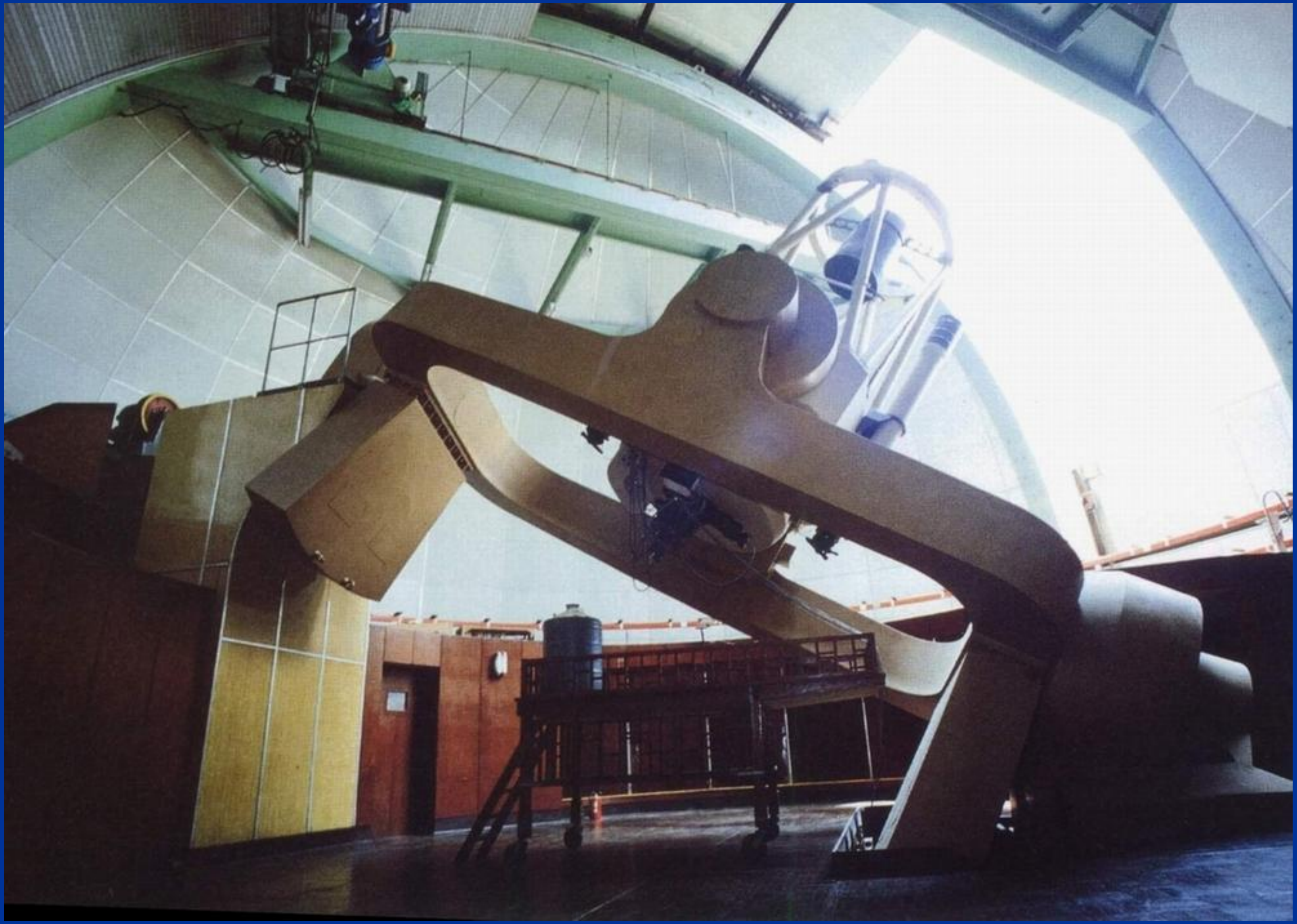
A method to **reduce** the **astrometric** positions of satellites. This method allowed us to determine the positions of satellites although we had a lack of reference stars in each CCD frame so that a classical astrometric reduction from star catalog was not possible to carry out. This was due to both of the following factors: our initial CCD camera had a rather small field of view and, at the same time, there was no available high-density astrometric star catalogue. (Shen et al., 2001) shown that such a method may introduce some systematic errors into the derived satellite positions and must be used only if a classical astrometric reduction is not possible.

Research History

- 2002 began to obverse with big field CCD

- Last year, we equipped a 14 inch aperture telescope mounted an electron cooling CCD for the observation of satellites' occultation.

observation



Observation on Saturn's satellites

1, The eight major satellites' position(8)

1994-1996 451 frames
published in Astron.Astrophys.Suppl.ser

1997-2000 1167 frames
published in Astronomy &Astrophysics.

2002-2008
large quantity of CCD observations in reduction and analysis

Included in a new catalogue of observations of the eight major satellites of Saturn

A&A 493, 1183–1195 (2009)
DOI: 10.1051/0004-6361:200810203

Astronomy & Astrophysics

A new catalogue of observations of the eight major satellites of Saturn (1874–2007)★

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ABSTRACT

Context. The lastest catalogue of observations includes about 51 000 observations (over 3500 nights) of Saturn's satellites from 1874 to 1989. Since 1989, many observations have been published, often in different formats, based on the publication.
Aims. Our new catalogue of observations of the eight major satellites of Saturn includes the observations of the previous catalogues, newly published data and also old observations left out of the previous catalogue. The observations are tabulated in a consistent format.
Methods. We give, for each observation, the corrections applied for reduction such as refraction, aberration or phase effects. Furthermore, when it was possible, the instrument and catalogue are also indicated.
Results. The new catalogue presents more than 130 000 observations (over 6000 nights) of the eight major satellites of Saturn from 1874 to 2007.

Key words. catalogs – planets and satellites: individual: Saturn – astrometry

Our observation of Saturn's eight major satellites included in COSS08

Table 3. Catalogue used for the astrometric reduction of some references.

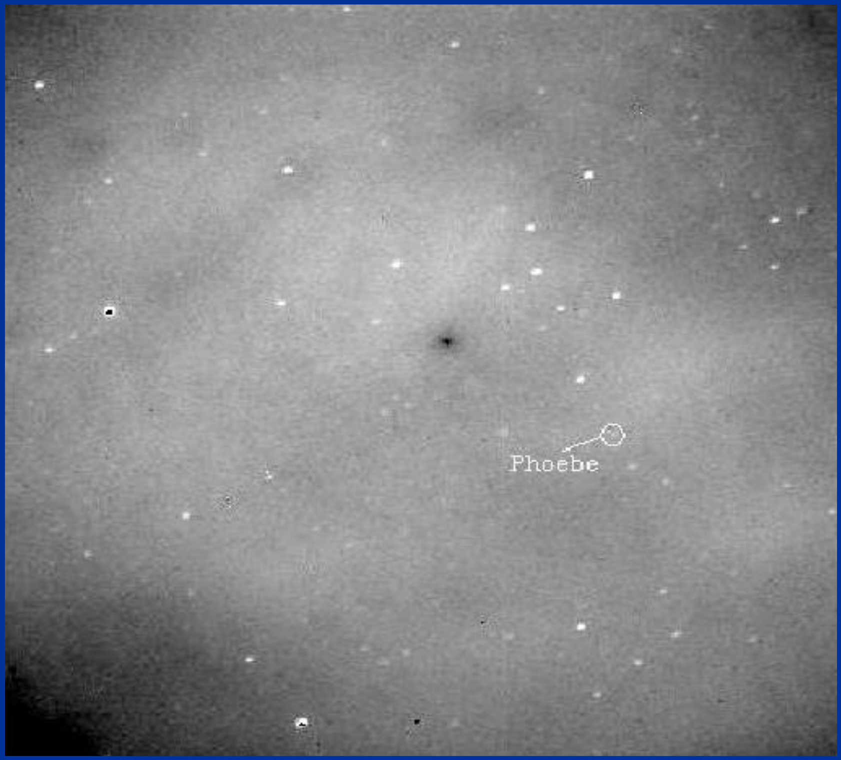
Ref. Code	Reference	Catalogue
12	Soulié & Pourteau (1968)	SAO
14	Soulié (1972)	SAO
17	Soulié (1975)	SAO
24, 28	Soulié (1978)	SAO
35	Soulié et al. (1981)	SAO
46	Dourneau et al. (1989)	SAO
47	Veillet & Dourneau (1992)	S2-S3-S4-S5-S6 D87
48	Veillet & Dourneau (1992)	SAO & Perth70
49	Veillet & Dourneau (1992)	AGK3 & SAO
52	Dourneau et al. (1986)	AGK3
53	Dourneau et al. (1985)	AGK3 (for 1981) & SAO (for 1982)
509	Izhakevich (1991)	Catalogue PPM
510	Tolbin (1991)	Catalogue FK5/FK4
512	Tolbin (1991)	Catalogue FK5/FK4
520	Veiga et al. (1999)	GSC corrected by PPM
521	Harper et al. (1997)	S3-S4-S5-S6 HT93
522	Harper et al. (1999)	S3-S4-S5-S6 HT93
523	Stone (2000)	Catalogue AST
524	Stone & Harris (2000)	Catalogue AST
525	Kisseleva & Chanturiya(2000)	Catalogue ACT
531	Filippov et al. (2001)	Catalogue ACT
532	Izakevich (2001)	Catalogue ACT
533	Belizon et al. (2001)	1976 IAU reference system
537	Voronenko et al.(1991)	Hipparcos/Tycho & ACTRC
538	Voronenko (2001)	Hipparcos/Tycho & ACTRC
539	Vienne et al. (2001)	S3-S4-S5-S6 TASS1.7
543	Stone (2001)	Catalogue – Tycho-2 (ICRF)
545	Veiga et al. (2003)	S3-S4-S5-S6 TASS1.7
547	Abrahamian et al. (1993)	Catalogue FOCAT-S (FK5,J2000)
548	Walker et al. (1978)	Catalogue – SAO
552	Carlsberg (1999)	1976 IAU reference system
601	Dourneau et al. (2007)	Catalogue – Tycho-2 (ICRF)
602	USNO Flagstaff (2000-2007)	Catalogue – Tycho-2 (ICRF)
603	Qiao et al. (1999)	S3-S4-S5-S6 HT93, TASS1.7, TS88, D87
604	Qiao et al. (2004)	S3-S4-S5-S6 TASS1.7
605	French et al. (2006) HST PC	Rings
606	French et al. (2006) HST WF2	Rings
607	French et al. (2006) HST WF3	Rings
608	French et al. (2006) HST WF4	Rings

Table 5. Statistics for the ten most numerous observation references.

Reference	Satellite	μ_α	σ_α	μ_δ	σ_δ	N_α	N_δ
Vienne et al. (2001)	S1	–0.016	0.083	0.001	0.078	216	216
(539)	S2	0.014	0.092	–0.006	0.067	861	861
($\Delta\alpha\cos\delta, \Delta\delta$)	S3	0.004	0.080	0.003	0.065	2048	2048
	S4	–0.007	0.062	0.000	0.055	1570	1570
	S5	0.014	0.084	–0.002	0.063	4739	4739
	S6	0.007	0.106	0.009	0.087	1484	1484
	S7	–0.084	0.118	–0.038	0.121	322	322
	S8	–0.107	0.090	0.010	0.068	524	524
USNO Flagstaff 1999–2006	S1	0.000	0.000	0.000	0.000	0	0
(602)	S2	0.000	0.000	0.000	0.000	0	0
(α, δ)	S3	–0.040	0.172	0.011	0.139	116	116
	S4	0.006	0.105	–0.011	0.130	203	203
	S5	0.016	0.090	0.004	0.117	364	364
	S6	0.068	0.115	–0.038	0.112	405	405
	S7	–0.005	0.259	0.050	0.321	300	300
	S8	–0.012	0.105	–0.010	0.137	353	353
Pascu (1982) priv. comm.	S1	–0.055	0.223	–0.017	0.157	57	57
(31)	S2	–0.009	0.125	–0.022	0.157	110	110
($\Delta\alpha\cos\delta, \Delta\delta$)	S3	–0.003	0.074	–0.003	0.099	140	140
	S4	–0.012	0.066	0.003	0.108	166	167
	S5	0.013	0.064	–0.023	0.079	209	209
	S6	–0.011	0.066	0.024	0.081	228	228
	S7	0.050	0.236	–0.075	0.171	11	11
	S8	–0.028	0.146	0.033	0.145	217	216
USNO (1929)	S1	–0.002	0.198	–0.083	0.221	122	121
(4)	S2	–0.006	0.169	–0.080	0.167	129	127
(p, s)	S3	–0.008	0.169	–0.002	0.185	487	483
	S4	0.006	0.159	–0.006	0.166	280	281
	S5	0.008	0.154	–0.031	0.198	694	690
	S6	–0.002	0.214	0.025	0.274	581	575
	S7	–0.010	0.380	0.128	0.468	89	88
	S8	–0.004	0.210	0.158	0.169	120	117
Harper et al. (1999)	S1	0.172	0.234	–0.064	0.099	14	15
(522)	S2	–0.081	0.600	–0.056	0.241	118	119
($\Delta\alpha\cos\delta, \Delta\delta$)	S3	–0.017	0.093	–0.003	0.099	277	277
	S4	0.015	0.087	–0.005	0.112	219	219
	S5	–0.004	0.238	–0.012	0.188	1068	1068
	S6	0.065	0.146	–0.030	0.112	336	336
	S7	0.103	0.222	0.056	0.326	189	187
	S8	–0.148	0.123	0.118	0.107	189	189
Qiao et al. 2004	S1	0.040	0.255	0.062	0.136	44	44
(604)	S2	–0.081	0.185	0.063	0.248	141	141
($\Delta\alpha\cos\delta, \Delta\delta$)	S3	0.008	0.126	–0.002	0.154	236	236
	S4	–0.018	0.090	0.028	0.105	246	246
	S5	0.020	0.132	–0.003	0.148	862	862
	S6	0.002	0.099	–0.038	0.120	241	241
	S7	0.000	0.000	0.000	0.000	0	0
	S8	–0.090	0.075	–0.100	0.075	66	66
Harper et al. (1997)	S1	[illegible]	[illegible]	[illegible]	[illegible]	73	73
(521)	S2	–0.022	0.109	–0.007	0.163	199	199
($\Delta\alpha\cos\delta, \Delta\delta$)	S3	–0.011	0.079	–0.002	0.089	221	221
	S4	0.003	0.072	0.000	0.079	214	214
	S5	0.023	0.118	–0.006	0.129	852	852
	S6	–0.015	0.087	0.009	0.096	157	157
	S7	0.043	0.203	0.043	0.144	88	88

2, Phoebe’s positions

Take by CASSINI in 2004



Phoebe CCD photograph (1/12/2003)

- **2003-2004 115 positions for Phoebe**

Set		N_u	JPL		SHN		IMCCE	
			σ	μ	σ	μ	σ	μ
2003	$\Delta\alpha\cos\delta$	101	0.058	0.014	0.056	–0.096	0.061	0.139
	$\Delta\delta$	101	0.078	–0.023	0.077	–0.094	0.078	–0.018
2004	$\Delta\alpha\cos\delta$	14	0.257	0.103	0.261	0.631	0.257	0.304
	$\Delta\delta$	14	0.376	–0.004	0.381	–0.010	0.376	0.011

Phoebe position compared with JPL、IMCCE、SHN ephemeris 2003-2004

Author	N_u	σ_α	μ_α	σ_δ	μ_δ
Veiga	60	0.140	–0.080	0.260	0.290
Fienga	163	0.148	0.156	0.177	0.154
Peng	50	0.068	–0.011	0.061	–0.073
This paper	101	0.058	0.014	0.078	–0.023

Compared our results with Veiga et al. (2000)、Fienga et al.(2002) and Peng et al.(2004)

- **2005-2008 1173 positions for Phoebe, the residuals of observations are about 0.1 arcsec.**(5)

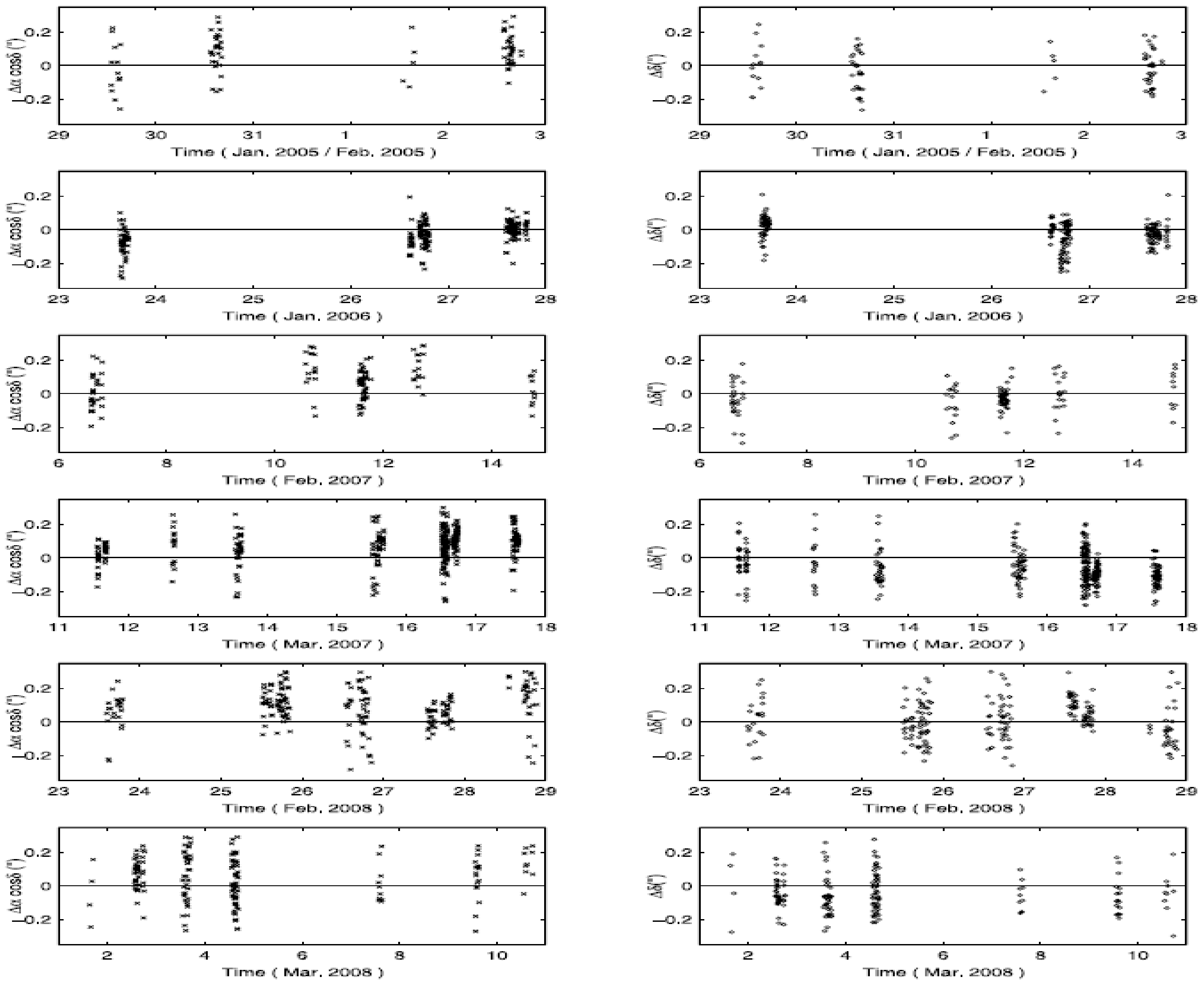


Figure 1. (O−C) of Phoebe in 2005–2008 relative to the six sets of observations, derived from the comparison of all our observations with the JPL SAT317 ephemeris. From top to bottom, panels refer to the 0.80-m, 1.56-m, 1.56-m, 1.00-m, 1.00-m and the 1.56-m telescopes.

Positions of Phoebe using in Cassini

THE ASTRONOMICAL JOURNAL, 128:492–501, 2004 July

THE ORBITS OF THE MAJOR SATURNIAN SATELLITES AND THE GRAVITY FIELD OF SATURN FROM SPACECRAFT AND EARTH-BASED OBSERVATIONS

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ABSTRACT

We have fitted numerically integrated orbits for the major Saturnian satellites to a large set of astrometric observations over the time interval 1966 September to 2003 December and to data obtained with the *Pioneer 11*, *Voyager*, and *Cassini* spacecraft. The results of the fit are new ephemerides for the satellites and a revised gravity field for the Saturnian system. We include an accuracy assessment for the ephemerides and the gravity parameters.

Key words: planets and satellites: general — planets and satellites: individual (Saturn) — solar system: general

Tolbin 1987	$\Delta\alpha$	64	0.115	$\Delta\delta$	64	0.115
E. Bowell 1988, private communication	$\Delta\alpha$	7	0.305	$\Delta\delta$	7	0.434
K. Shen 1988, private communication	$\Delta\alpha$	55	0.188	$\Delta\delta$	55	0.171
Dourneau et al. 1989	$\Delta\alpha \cos\delta$	472	0.304	$\Delta\delta$	472	0.234
Carlsberg Consortium 1989	α	68	0.290	δ	68	0.272
Carlsberg Consortium 1991	α	642	0.242	δ	642	0.189
M. Rapaport 1989, 1992, private communications	α	80	0.189	δ	80	0.334
Veillet & Dourneau 1992	$\Delta\alpha \cos\delta$	1159	0.142	$\Delta\delta$	1159	0.105
Rohde & Pascu 1993	$\Delta\alpha \cos\delta$	15	0.119	$\Delta\delta$	15	0.141
P. Nicholson 1994, private communication	$\Delta\alpha \cos\delta$	14	0.089	$\Delta\delta$	14	0.115
Standish 1996	$\Delta\alpha$	494	0.155	$\Delta\delta$	494	0.139
Harper et al. 1997	p	1238	0.296	l	1238	0.271
Vass 1997	$\Delta\alpha \cos\delta$	2497	0.169	$\Delta\delta$	2495	0.161
Harper et al. 1999	p	1454	0.130	l	1454	0.156
Qiao et al. 1999	p	610	0.166	l	610	0.201
Veiga & Vieira Martins 1999	$\Delta\alpha$	773	0.274	$\Delta\delta$	773	0.228
G. Krasinsky 2000, private communication	$\Delta\alpha$	420	0.219	$\Delta\delta$	420	0.178

Observation of Uranian satellites

- 1995-1997 864 frames
  the Uranus’ five major satellites
  The precision is in 0.03-0.05 arcsec.

- 1998-2007 1049 frames 2576 positions
  The paper is in amending. (D)

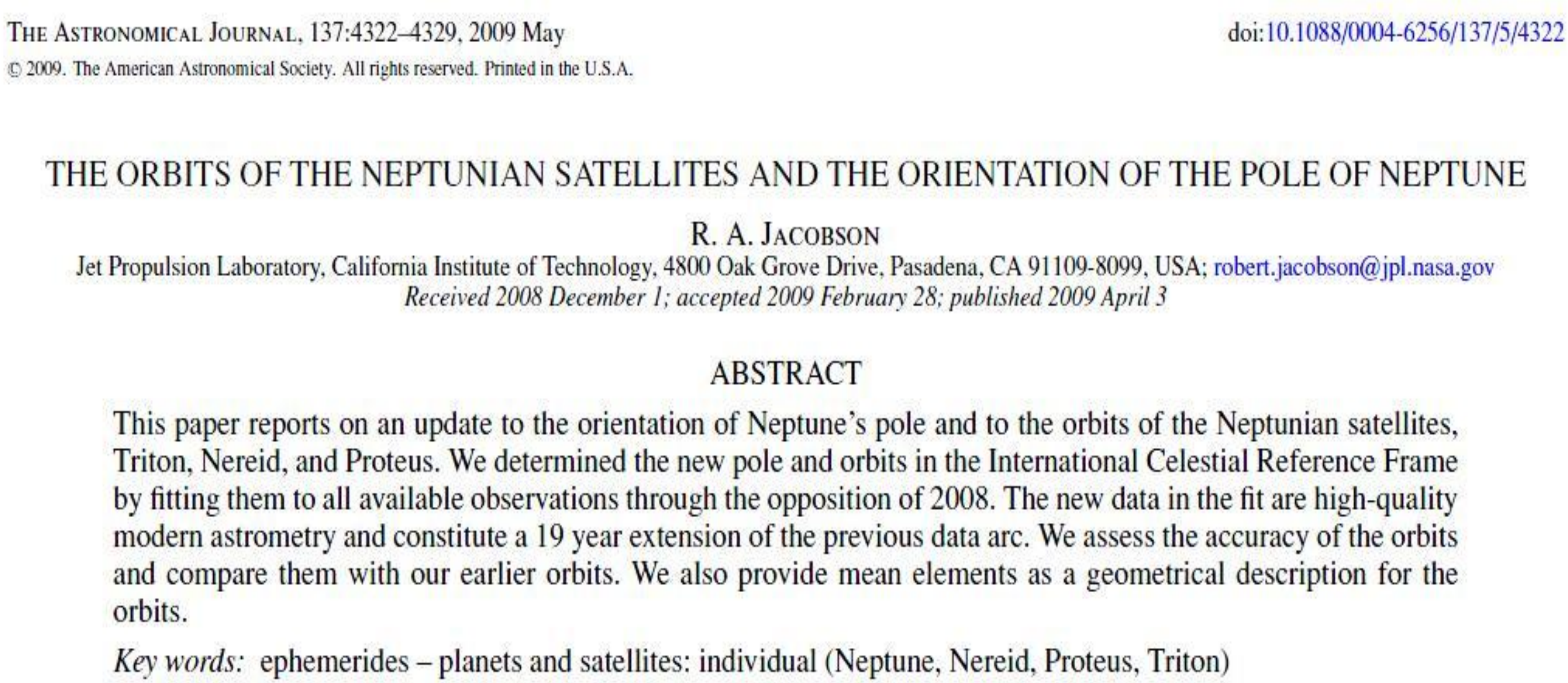
Observation of Neptune’s satellites

1,Triton

- **1996、2003、2005、2006 frames in total**
  Residuals of observations are 0.04 arcsec

Typical Triton CCD frame (Sheshan station 1.56m telescope)

Using in JPL's orbit improvement of Neptune


THE ASTRONOMICAL JOURNAL, 137:4322–4329, 2009 May
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THE ORBITS OF THE NEPTUNIAN SATELLITES AND THE ORIENTATION OF THE POLE OF NEPTUNE

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ABSTRACT

This paper reports on an update to the orientation of Neptune's pole and to the orbits of the Neptunian satellites, Triton, Nereid, and Proteus. We determined the new pole and orbits in the International Celestial Reference Frame by fitting them to all available observations through the opposition of 2008. The new data in the fit are high-quality modern astrometry and constitute a 19 year extension of the previous data arc. We assess the accuracy of the orbits and compare them with our earlier orbits. We also provide mean elements as a geometrical description for the orbits.

Key words: ephemerides – planets and satellites: individual (Neptune, Nereid, Proteus, Triton)

Source	No.	Type	rms	No.	Type	rms
Veiga et al. (1996)	51	$\Delta\alpha\cos\delta$	$0\farcs080$	51	$\Delta\delta$	$0\farcs046$
Veiga & Vieira Martins (1996)	422	$\Delta\alpha\cos\delta$	$0\farcs099$	422	$\Delta\delta$	$0\farcs138$
Veiga & Vieira Martins (1998)	759	$\Delta\alpha\cos\delta$	$0\farcs156$	759	$\Delta\delta$	$0\farcs212$
Stone & Harris (2000)	402	α	$0\farcs142$	402	δ	$0\farcs167$
Stone (2000)	114	α	$0\farcs112$	114	δ	$0\farcs103$
Owen (2001, private communication)	6	α	$0\farcs059$	6	δ	$0\farcs018$
Stone (2001)	162	α	$0\farcs091$	162	δ	$0\farcs113$
Stone (2002, private communication)	133	α	$0\farcs098$	133	δ	$0\farcs110$
Owen (2003, private communication)	50	α	$0\farcs042$	50	δ	$0\farcs058$
Stone (2003, private communication)	152	α	$0\farcs093$	152	δ	$0\farcs108$
Martins et al. (2004)	65	α	$0\farcs135$	65	δ	$0\farcs119$
Owen (2004, private communication)	57	α	$0\farcs063$	57	δ	$0\farcs065$
Stone (2004, private communication)	145	α	$0\farcs084$	145	δ	$0\farcs108$
Stone (2005, private communication)	164	α	$0\farcs094$	164	δ	$0\farcs124$
Monet (2006, private communication)	135	α	$0\farcs115$	135	δ	$0\farcs124$
Owen (2006, private communication)	4	α	$0\farcs080$	4	δ	$0\farcs031$
Arlot et al. (2008)	184	α	$0\farcs089$	184	δ	$0\farcs119$
Monet (2007, private communication)	22	α	$0\farcs077$	22	δ	$0\farcs110$
Harris (2007, private communication)	81	α	$0\farcs102$	81	δ	$0\farcs145$
Owen (2007, private communication)	26	α	$0\farcs082$	26	δ	$0\farcs087$
Qiao et al. (2007)	940	α	$0\farcs039$	940	δ	$0\farcs032$
Owen (2008, private communication)	30	α	$0\farcs074$	30	δ	$0\farcs086$
Harris (2008, private communication)	123	α	$0\farcs115$	123	δ	$0\farcs149$

Triton positions residuals statistics

largest quantity, highest accuracy

Included by IMCCE

Observations Ephémérides Bibliographie Paramètres Liens dans WWW

Centre de Données sur les Satellites Naturels. Observations. Positions astrometriques

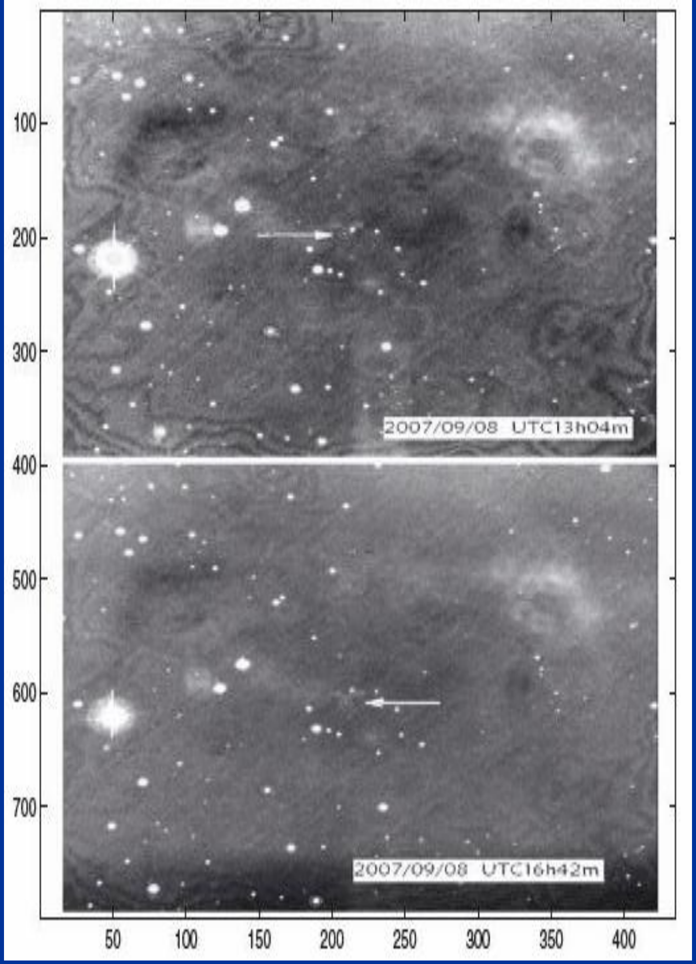
Satellites principaux de Neptune | Nomenclature | Retour ...

period	posi-tions	obser-vation			Content	Data	*	files	entry Y M D
2001-2001	3	CCD, abs	Table Mountain	Communicated by Owen (2001)	Content	Data	-	nm0001	01/07/06
2001-2001	3	CCD, rel	Table Mountain	Communicated by Owen (2001)	Content	Data	-	nm0002	01/07/06
1989-1994	433	CCD, rel	874 - Itajuba	Veiga & Vieira Martins(1996)	Content	Data	-	nm0003	01/07/06
1995-1997	759	CCD, rel	874 - Itajuba	Veiga & Vieira Martins(1998)	Content	Data	-	nm0004	01/07/06
1999-1999	3	CCD, abs	Table Mountain	Communicated by Owen (1999)	Content	Data	-	nm0005	01/07/06
1999-1999	3	CCD, rel	Table Mountain	Communicated by Owen (1999)	Content	Data	-	nm0006	01/07/06
1998-2000	188	CCD. abs	Flagstaff	Stone R.C.(2001)	Content	Data	-	nm0007	02/06/21
1984-1986	56	phot.rel	U.S.N.O.	Walker, Harrington (1988)	Content	Data	-	nm0008	05/09/24
1975-1977	28	phot.rel	U.S.N.O.	Walker et al. (1978)	Content	Data	-	nm0009	05/09/24
1979-1983	114	phot.rel	U.S.N.O.	Harrington, Walker (1984)	Content	Data	-	nm0010	05/09/24
1877-1877	29	vis. rel	U.S.N.O.	Holden (1881)	Content	Data	-	nm0011	05/09/24
2001-2005	323	CCD. abs	U.S.N.O.	JPL Planetary Ephem. Data	Content	Data	-	nm0012	06/02/23
2000-2002	66	CCD, abs	874 - Itajuba	Vieira Martins et al. (2004)	Content	Data	-	nm0013	06/03/06
2005-2006	144	CCD. abs	Flagstaff	JPL Planetary Ephem. Data	Content	Data	-	nm0014	07/01/22
1996-2006	943	CCD. abs	337 - Sheshan	Qiao R.C. et al.(2007)	Content	Data	-	nm0015	07/05/09
1990-1990	5	phot.abs	188 - Majdanak	Communication from observers	Content	Data	-	nm0016	09/04/29
1986-1993	54	phot.abs	119 - Abastumani	Chanturia,Kisseleva (2006)	Content	Data	-	nm0017	10/05/31

2、Nereid

- 2006-2007 112 frames
  Residuals of observations are 0.2 arcsec

Photo by Voyager II

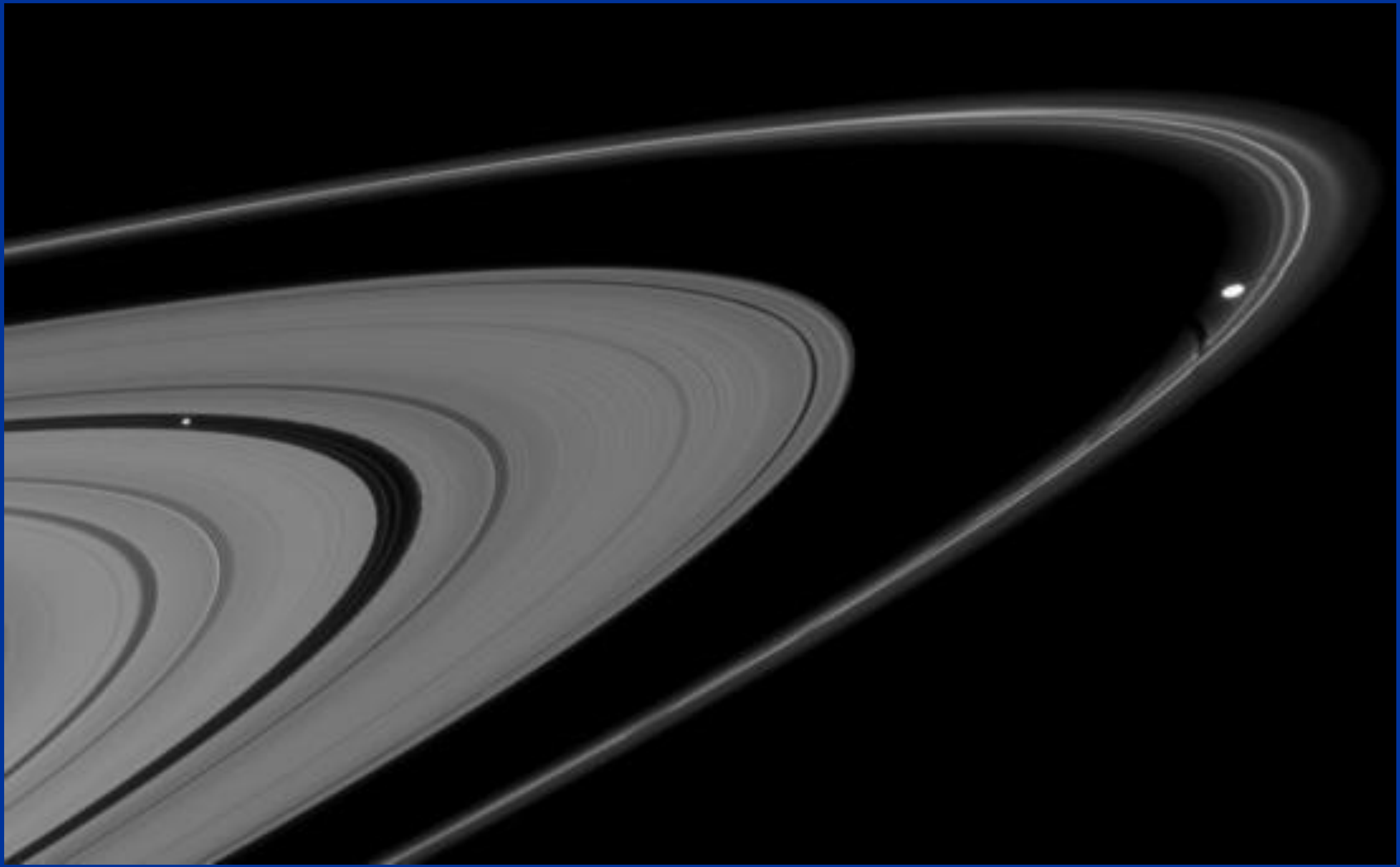


Typical Nereid CCD frame (Xinglong station 1.56m telescope)

Nereid’s positions residuals statistics

Source	No.	Type	rms	No.	Type	rms
Whipple (1995, private communication)	3	$\Delta\alpha$	$0\rlap{.}''520$	3	$\Delta\delta$	$0\rlap{.}''181$
Veiga et al. (1996)	7	$\Delta\alpha\cos\delta$	$0\rlap{.}''210$	7	$\Delta\delta$	$0\rlap{.}''310$
Monet (1998, private communication)	4	α	$0\rlap{.}''183$	4	δ	$0\rlap{.}''092$
Veiga et al. (1999)	171	$\Delta\alpha\cos\delta$	$0\rlap{.}''185$	171	$\Delta\delta$	$0\rlap{.}''125$
Veiga et al. (1999)	56	α	$0\rlap{.}''123$	56	δ	$0\rlap{.}''155$
MPC (2000)	9	α	$0\rlap{.}''439$	9	δ	$0\rlap{.}''555$
MPC (2001)	6	α	$0\rlap{.}''486$	6	δ	$0\rlap{.}''196$
MPC (2002)	6	α	$0\rlap{.}''282$	6	δ	$0\rlap{.}''120$
MPC (2003)	1	α	$0\rlap{.}''451$	1	δ	$0\rlap{.}''262$
MPC (2004)	30	α	$0\rlap{.}''428$	30	δ	$0\rlap{.}''298$
MPC (2005)	39	α	$0\rlap{.}''314$	39	δ	$0\rlap{.}''333$
MPC (2006)	104	α	$0\rlap{.}''332$	104	δ	$0\rlap{.}''323$
MPC (2007)	76	α	$0\rlap{.}''229$	76	δ	$0\rlap{.}''314$
MPC (2008)	27	α	$0\rlap{.}''426$	27	δ	$0\rlap{.}''397$
Qiao et al. (2008)	112	α	$0\rlap{.}''208$	112	δ	$0\rlap{.}''188$

Orbit update



- **Taylor-Shen theory:**

  The one of the four famous Saturn satellites orbit theories to the orbit of the eight major satellites of Saturn

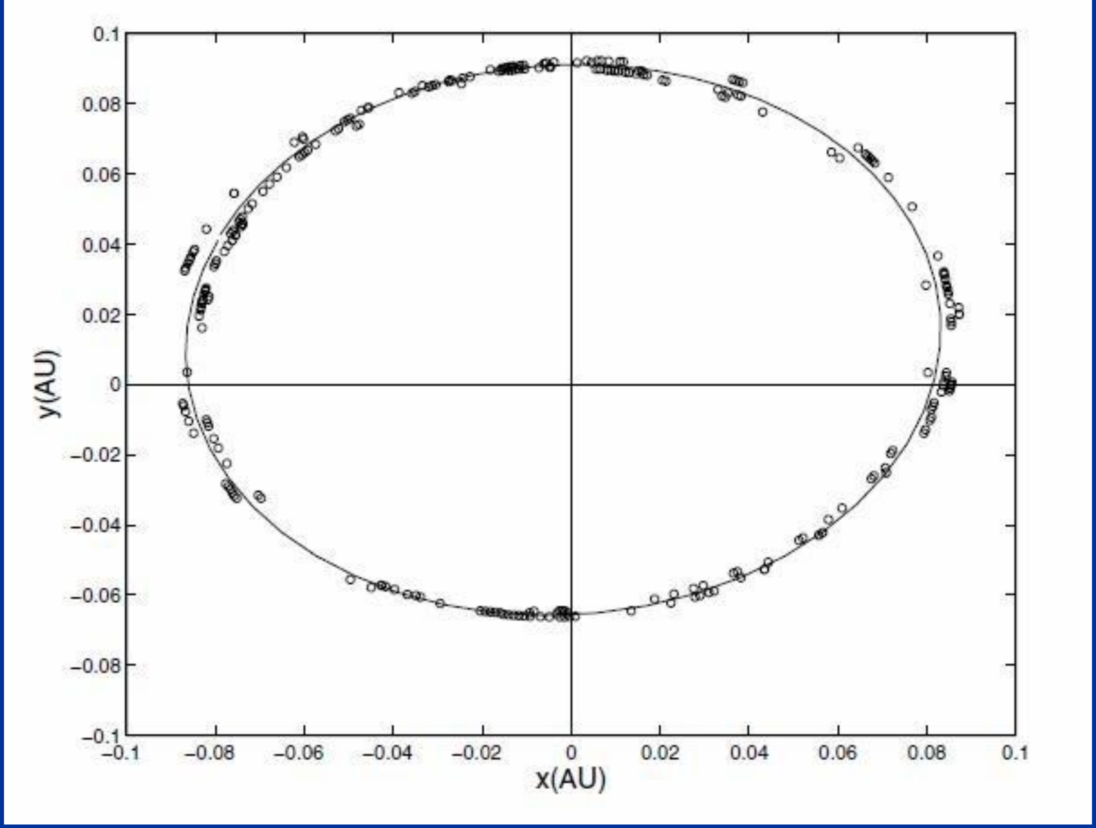
- **Validate TASS theory**

  Calculation the Iapetus orbit elements variation in last 200 years. Improve the necessity and advantage of TASS theory

➢ Phoebe's motion theory research

The 12th order R-K-N numerical integration method

We used 12th-order –Runger –Kutta-Nystrom formula numerical integration to obtain an adequate fit to the 100 years observations, in order to improve the orbit of Phoebe and update the new determination of the mass of Saturn: Msa=3497.0e-1 Msun



Distribution for the observations on Phoebe orbit projected on the Earth's mean equator J2000

文 献	土星系质量 (m_{sa}/m_{sun})	测定方法
Gacia (1972) [14]	$3\,501.47^{-1} \pm 1.77$	分析法，多星加权平均
Sinclair (1977) [15]	$3\,498.45^{-1} \pm 0.031$	分析法，多星加权平均
Sinclair & Taylor (1985) [7]	$3\,497.15^{-1} \pm 0.026$	数值法，多星对
Shen (1990) [16]	$3\,497.10^{-1} \pm 0.000\,13$	数值法，多星对
Null et al (1981) [17]	$3\,498.09^{-1} \pm 0.22$	空间测量
Campbell et al (1989) [18]	$3\,497.90^{-1} \pm 0.018$	空间测量
IAU1976 天文常数系统 (1983) [1]	$3\,498.50^{-1}$	综合加权平均
Shen (1993) [2]	$3\,498.00^{-1} \pm 0.14$	数值法，多星对
Jacobson (2004) [19]	$3\,497.89^{-1} \pm 0.005$	空间、地面多手段综合
Jacobson (2006) [20]	$3\,497.90^{-1} \pm 0.000\,1$	空间、地面多手段综合
本 文 (2007)	$3\,497.00^{-1} \pm$	数值法，单颗星

The fit yields new determination of the mass of Saturn: Msa=3497.0e-1Msun, with the data used over one century.

Papers:

- **The Determination of the Mass and the Dynamical Flattening j2 of Saturn via Improving the Orbit by Numerical Integration of Titan RHEA Iapetus** Acta Astronomica Sinica, Vol.35:2, 1994
- **Redetermination of the orbit of Iapetus.** proceedings of the 172nd Symposium of the International Astronomical Union 1996
- **1994-1996 CCD astrometric observations of Saturn's satellites and comparison with theories. A&A** 137,1-5,1999
- **An Analysis of Satellite Calibration Methods for CCD Astrometry of Saturn's Satellites A&A** 2001(03)
- Uranian satellites in 1995/97 **A&A** 2002

- **Astrometry of five major Uranian satellites in 1995-1997** **A&A** v.391, p.775-779 (2002)
- **Study and Development of Contemporary Theories on the Motion of the Uranian Major Satellites** **PROGRESS IN ASTRONOMY** 2004 22 (01)
- **Re-determination of Phoebe's orbit** **A&A** Volume 437, Issue 3, July III 2005, pp.1109-1113
- **CCD astrometric observations of Phoebe in 2003-2004** **A&A** Volume 454, Issue 1, July IV 2006, pp.379-383
- **Astrometric observations of triton** MNRAS Volume 376, Issue 4, 2007

- **Comparisons of Positioning Measurements with Two Calibration Methods for Uranian Satellites** **Journal of Time and Frequency** 2007 30（2）
- CCD astrometric observations of faint satellites and update of their orbits Proceedings of the International Astronomical Union, IAU Symposium, Volume 248, p. 93-95
- **Astrometric observations of Nereid in 2006-2007 MNRAS Volume 391, Issue 4 2008**
- **1996-2006 observations of Triton MNRAS** 376.1707Q 2007
- **CCD astrometric observations of Phoebe in 2005-2008 MNRAS 2011,413(2)**
- **Updated Phoebe's orbit** **MNRAS** 2011,417(3)

Awards:

National Prize for Natural Sciences :

second clsaa prize

Shaanxi province Scientific and Technical Awards :

third class prize

Shaanxi Academy of Sciences Progress prize in science and technology: second clsaa prize

Thank You