Arecibo Radar Observations of 19 High-Priority Near-Earth Asteroids During 2018 and January 2019

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Observing Program

Radar is arguably the most powerful Earth-based technique for post-discovery physical and dynamical characterization of near-Earth asteroids (NEAs). Arecibo radar observations routinely provide images with resolution as fine as 7.5 m revealing surface features, such as boulders, concavities, and ridges, that our SHAPE software (Hudson, 1994; Magri et al., 2007) inverts to obtain spin-state estimates and three-dimensional shape models limited only by echo strength and orientational coverage. Over the long term, our observations will help answer fundamental questions regarding the the diversity of asteroid morphologies and dynamical states, their internal structures and thermal properties, and the importance of non-gravitational and collisional evolution.

NASA's Near-Earth Object Observations program supports the Arecibo planetary radar to observe NEAs for at least 600 hours per year. We propose radar imaging, detailed physical characterization, and orbit refinement of our 19 highest-priority NEAs for calendar year 2018 and early January 2019 using 320.75 hours of telescope time. A companion proposal (Virkki et al.) with a more survey-oriented approach requests at least 248.25 hours to concentrates on basic characterization and precise astrometry for many more objects bringing the total proposed time request to $\sim$570 hours. Proposals to observe NEAs not included in these companion proposals accounted for $\sim$15% of time requests in the last two years such that we expect to surpass 600 hours requested in 2018. In the last 12 months, the Arecibo planetary radar program detected 100 NEAs.

The previous year's proposal (project R3037) requested 454.5 hours of telescope time to observe 23 objects visible in 2017. Through August, 12 objects were visible, accounting for 251.75 hours of our time request, of which 189 hours (75%) were scheduled. The discrepancy is mostly due to the S-band heat-exchanger replacement in July and August, competition for observing time with atmospheric world-day and HF campaigns, and overlap with daily maintenance activities. Noteworthy results include observations of 2014 JO25, an asteroid with a contact-binary shape very reminiscent of Comet 67P/Churyamov-Gerasimenko visited by the *Rosetta* spacecraft, and (190166) 2005 UP156, a rare equal-mass binary asteroid, one of only three known among the NEA population. The remaining four months of the calendar year, plus early January 2018, include 11 high-priority targets and 202.75 hours of telescope time requested. We note that in this proposal, we request fewer hours, partially because there are fewer high-priority objects (19 vs. 23) and we expect to operate in one-klystron mode at half of the nominal output power.

Time requests for each target are dictated by the science goals and the estimated signal-to-noise ratio (SNR). Past experience demonstrates the key factor in our ability to secure shapes and spin-state estimates is good sky and rotational coverage over several days of observations, especially when we lack prior knowledge about the target. For all targets we will measure the

circular polarization ratio and radar cross section, which are gauges of near-surface roughness and near-surface density, provide precise astrometry, and constrain the size, shape, and spin state, which when combined with photometric and/or spectroscopic measurements constrain the optical albedo and composition.

Table 1 describes our targets and lists synergistic observations. The objects requested at the Goldstone radar (more maneuverable, but less sensitive than Arecibo) will have greater coverage from longer daily tracks and observations outside the Arecibo declination window, which may lead to tighter constraints on physical parameters. Overlapping tracks with Goldstone allows for bistatic X- or C-band experiments with resolutions of 3.75 or 1.875 m. Eleven asteroids are possible targets for a coordinated program with the NASA InfraRed Telescope Facility (IRTF) for spectral characterization and application of radar-derived shape information to thermophysical modeling. Speckle tracking (Busch et al., 2010) with the Very Long Baseline Array (VLBA) will be used to resolve the prograde/retrograde-rotation ambiguity of at least two targets. Table 2 lists specific track requests for each target.

Student Participation

Graduate student Luisa Zambrano-Marin (Granada), member of the local Arecibo team, is using radar scattering models to constrain the surface properties of asteroids and comets. Graduate student Sean Marshall (Cornell) works on shape and thermal modeling of asteroids observed with radar and the IRTF (Marshall et al., 2017) and will join the local Arecibo team in late 2017. Graduate student Jenna Crowell (Central Florida) used radar in the shape and thermal modeling of asteroid 1627 Ivar (R2831; Crowell et al., 2017) and will lead observations of Ivar in 2018. Graduate student Adam Greenberg (UCLA) led observations of asteroids (1566) Icarus (R2960; Greenberg et al., 2017a) and (441987) 2010 NY65 (R3037) and is publishing Yarkovsky-drift measurements based partly on radar astrometry (Greenberg et al., 2017b). Graduate student Cassandra Lejoly (Arizona) observed Comet 45P (R3142) and is analyzing radar cross sections of Arecibo asteroid data. Benjamin Sharkey (now a graduate student at Arizona) was part of the Research Experience for Undergraduates (REU) program in 2015 and a summer research assistant at Arecibo in 2016 shape modeling asteroid (52760) 1998 ML14 (R1172 and R2831) and participated in radar observations. Undergraduate Andy Lopez-Oquendo (UPR Humacao) regularly participated in observations in 2017. Other undergraduate and graduate students are welcome to gain observing and research experience through this proposed work.

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Object	H mag	Diam [m]	P_{spin} [h]	Prev Obs?	Start-End Dates	RTT [s]	SNR /run	Notes	Next App
2015 BN509	20.7	320	5.68	Y	Feb 04-15	52	60	P G I	2112
2014 SR339	18.6	*570*	*2.1*		Feb 08-11	55	70	P G I	2058
3752 Camillo	15.3	*2600*	37.8	Y	Feb 21-24	142	110	G I	2055
1981 Midas	15.2	*2700*	5.22		Mar 21-24	90	220	P G I	2032
388945 (2008 TZ3)	20.4	*250*	44.2		Apr 26-May 02	42	250	P G S I	2020
444193 (2005 SE71)	18.2	*680*	*2.1*		Apr 26-29	62	65	P G I	2058
2013 US3	21.0	*190*	*2.1*		Apr 28-May 01	26	170	P N G	2118
68347 (2001 KB67)	19.9	*310*	*2.1*		May 26-31	25	440	P G I	2051
66391 (1999 KW4)	16.5	1500	2.76	Y	May 25-01	79	100	B P G I	2019
2015 DP155	21.6	*140*	*2.1*		Jun 08-13	23	170	P N G A	2080
441987 (2010 NY65)	21.5	180	4.98	Y	Jun 19-29	27	220	P G Y	2019
1627 Ivar	13.2	7600	4.80	Y	Jul 05-13	311	17	I	2046
398188 Agni	19.5	450	22.0	Y	Jul 23-Aug 01	64	95	P G I	2055
2015 FP118	19.3	*410*	*2.1*		Aug 24-Sep 13	53	50	P G A	-
144332 (2004 DV24)	16.5	*1500*	*2.1*		Sep 13-15	56	280	P G I	2091
2002 VE68	20.5	*240*	13.5		Nov 07-11	41	130	P G I	2026
163899 (2003 SD220)	17.3	1000	285	Y	Dec 18-22	19	52000	P N G X S	2070
2016 AZ8	21.1	*180*	*2.1*		2019 Jan 02-05	31	90	P N G A	2151
2004 XP14	19.7	*340*	100		2019 Jan 03-07	73	90	P G	2047

Table 1: We propose to observe our 19 highest-priority NEAs in a combined 320.75 hours (including transmitter warm-up time; see Table 2 for detailed time requests). Absolute magnitudes H are taken from the JPL Small-Body Database. Rotation periods P_{spin} are taken from the asteroid Lightcurve Database [Warner et al., 2009] when available. Previously observed objects ("Prev Obs?" column) have radar-estimated spin periods consistent with P_{spin}. Italicized periods are assumed very rapid at 2.1 h for $H < 22$, which gives a more conservative signal-to-noise ratio (SNR), and 0.5 h for $H > 22$. Diameters are taken from previous radar observations if available; otherwise italicized diameters are estimates based on H assuming an optical albedo of 0.2. "Start-End" dates bracket the requested tracks. The closest approach is given by the round-trip time, RTT, for light to reach the target and return. Notes include binary asteroids (B), potentially hazardous asteroids (P), NHATS objects (N), Goldstone radar targets (G), possible bistatic X-band targets (X), VLBA speckle-tracking targets (S), possible IRTF near- and thermal-infrared targets (I), Yarkovsky-drift candidates (Y) from Greenberg et al. (2017b), and objects requiring optical astrometry prior to radar observations (A). "Next App" indicates the next comparable close approach to Earth of less than 1.2 times the RTT of the 2018/2019 apparition. Many are not re-observable at the same proximity for several decades meaning this is our best chance to characterize them, while observing 2008 TZ3, 1999 KW4, and 2010 NY65 will help us prepare for their close approaches in the next few years and possibly allow for future confirmations of Yarkovsky drift.

Observing Requests

Table 2. We request 98 tracks and 320.75 hours to observe 19 asteroids. Requested tracks are marked with a +; unmarked tracks are acceptable alternatives. The rise/set times do NOT include one hour of transmitter warm-up time prior to the source rising. Several days of observations spread over the observing window allow for complete rotational coverage (assuming typical rotation periods) and better constraints on the spin state. Calculations assume the physical parameters from Table 1 and a radar albedo of 0.1. When unknown, the sizes and spin rates used tend to give conservative estimates of the SNR. Nominal system parameters are assumed: transmitter power = 450 kW (single-klystron mode), sensitivity = 10 K/Jy, and system temperature = 24 K.

Request: 5 tracks, 15.25 hours

UT Date **(2015 BN509)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Feb-02	85	9.9	+25	55	11	80	04:16-06:53
2018-Feb-03	76	9.8	+28	58	17	120	04:12-06:38
+ 2018-Feb-04	66	9.7	+32	56	26	190	04:11-06:15
+ 2018-Feb-05	58	9.5	+36	34	42	250	04:25-05:31
...	Target is north of the Arecibo declination window						
+ 2018-Feb-13	52	23.6	+31	73	60	500	17:26-19:33
+ 2018-Feb-14	60	23.4	+25	78	37	320	16:55-19:31
+ 2018-Feb-15	69	23.2	+21	71	23	190	16:39-19:23
2018-Feb-16	78	23.1	+18	63	15	120	16:28-19:13
2018-Feb-17	87	23.1	+15	56	10	75	16:21-19:03

Request: 3 tracks, 10.75 hours

UT Date **(2014 SR339)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Feb-08	54	5.6	-00	31	76	430	00:28-01:24
+ 2018-Feb-08	55	5.8	+10	81	71	630	23:47-02:16
+ 2018-Feb-09	58	6.0	+20	86	59	540	23:44-02:31
+ 2018-Feb-11	63	6.2	+28	70	45	370	00:00-02:26
2018-Feb-12	69	6.3	+35	35	33	200	00:39-01:59

Request: 5 tracks, 17.75 hours

UT Date **3752 Camillo (1985 PA)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Feb-20	139	6.0	+00	14	121	420	23:55-00:58
+ 2018-Feb-21	142	6.0	+07	28	112	580	23:17-01:30
+ 2018-Feb-22	147	6.0	+13	32	98	550	23:01-01:40
+ 2018-Feb-23	154	6.1	+19	32	83	470	22:55-01:41
+ 2018-Feb-24	163	6.1	+25	29	69	360	22:56-01:34
+ 2018-Feb-25	173	6.1	+30	24	56	270	23:03-01:21
2018-Feb-26	184	6.2	+34	16	45	180	23:19-01:00

Request: 5 tracks, 17.25 hours

UT Date **1981 Midas (1973 EA)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Mar-20	91	7.2	+37	16	211	840	23:28-00:16
+ 2018-Mar-21	90	6.7	+31	44	220	1410	22:08-00:18
+ 2018-Mar-22	91	6.2	+24	52	208	1470	21:20-23:57
+ 2018-Mar-23	95	5.8	+17	52	181	1280	20:47-23:30
+ 2018-Mar-24	101	5.4	+11	45	147	980	20:27-22:58
+ 2018-Mar-25	108	5.1	+05	34	114	640	20:18-22:22
2018-Mar-26	117	4.8	+01	20	86	380	20:22-21:40

Request: 6 tracks, 18.25 hours

UT Date **388945 (2008 TZ3)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Apr-22	93	14.0	+13	51	15	110	03:07-05:46
2018-Apr-23	88	14.0	+13	54	18	140	03:03-05:41
2018-Apr-24	83	14.0	+12	57	23	170	03:00-05:37
2018-Apr-25	77	14.0	+12	60	29	220	02:57-05:32
+ 2018-Apr-26	72	14.0	+11	63	37	290	02:55-05:26
+ 2018-Apr-27	67	14.0	+10	66	48	390	02:53-05:21
2018-Apr-28	62	14.0	+09	69	63	530	02:52-05:14
+ 2018-Apr-29	57	14.0	+07	72	85	710	02:51-05:07
+ 2018-Apr-30	51	14.0	+06	74	118	1000	02:52-04:58
+ 2018-May-01	46	14.0	+04	70	168	1400	02:57-04:46
+ 2018-May-02	42	14.0	+01	59	245	1800	03:07-04:28

Request: 4 tracks, 14.25 hours

UT Date **444193 (2005 SE71)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Apr-25	63	14.3	+33	55	58	410	03:38-05:33
+ 2018-Apr-26	62	14.0	+27	73	62	520	02:58-05:29
+ 2018-Apr-27	62	13.7	+21	80	63	560	02:31-05:15
+ 2018-Apr-28	62	13.5	+14	77	61	540	02:14-04:53
+ 2018-Apr-29	64	13.3	+08	65	56	450	02:07-04:25
2018-Apr-30	66	13.1	+02	43	49	310	02:12-03:47

Request: 4 tracks, 12.75 hours

UT Date **(2013 US3)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
+ 2018-Apr-28	27	11.9	+30	155	157	1900	00:54-03:11
+ 2018-Apr-29	26	11.9	+20	191	170	2300	00:36-03:21
+ 2018-Apr-30	26	12.0	+10	174	168	2170	00:39-03:10
+ 2018-May-01	27	12.0	+01	91	150	1370	01:10-02:32

Request: 8 tracks, 23.75 hours

UT Date **68347 (2001 KB67)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-May-24	43	1.7	+01	54	68	500	13:27-14:44
+ 2018-May-25	37	1.4	+04	95	115	1090	12:41-14:37
+ 2018-May-26	31	0.8	+10	138	192	2260	11:53-14:17
+ 2018-May-27	27	0.1	+16	174	305	4030	10:59-13:37
+ 2018-May-28	25	23.2	+24	184	413	5600	10:00-12:33
+ 2018-May-29	25	22.0	+30	156	435	5450	08:58-11:05
+ 2018-May-30	26	20.8	+34	108	349	3680	07:57-09:31
+ 2018-May-31	30	19.7	+35	85	231	2140	06:54-08:18
+ 2018-Jun-01	34	18.9	+34	85	142	1300	05:54-07:31
2018-Jun-02	40	18.3	+33	85	84	750	05:06-06:59
2018-Jun-03	46	17.8	+31	82	52	460	04:29-06:36
2018-Jun-04	53	17.5	+30	77	33	280	04:01-06:17
2018-Jun-05	60	17.3	+29	72	21	180	03:39-06:02
2018-Jun-06	67	17.1	+27	67	14	120	03:21-05:50

Request: 8 tracks, 27.75 hours

UT Date **66391 (1999 KW4)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-May-24	86	20.4	+01	28	74	380	08:04-09:25
+ 2018-May-25	82	20.0	+05	45	87	570	07:17-09:20
+ 2018-May-26	79	19.6	+10	56	98	730	06:36-09:03
+ 2018-May-27	78	19.1	+15	61	104	800	05:59-08:38
+ 2018-May-28	79	18.7	+19	62	102	800	05:24-08:07
+ 2018-May-29	81	18.2	+24	59	94	710	04:53-07:31
+ 2018-May-30	84	17.7	+27	53	81	580	04:25-06:53
+ 2018-May-31	89	17.2	+30	45	67	440	04:00-06:14
+ 2018-Jun-01	95	16.8	+32	37	53	320	03:38-05:36
2018-Jun-02	101	16.4	+34	30	42	220	03:18-05:00
2018-Jun-03	109	16.0	+35	24	33	160	03:00-04:28
2018-Jun-04	117	15.7	+36	19	25	110	02:43-03:58

Request: 7 tracks, 23.25 hours

UT Date **(2015 DP155)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Jun-07	25	17.6	+37	68	123	950	04:36-05:33
+ 2018-Jun-08	24	17.9	+32	150	140	1670	04:17-06:18
+ 2018-Jun-09	24	18.2	+27	192	152	2050	04:14-06:45
+ 2018-Jun-10	23	18.4	+22	213	161	2290	04:18-07:03
+ 2018-Jun-11	23	18.7	+17	217	165	2380	04:28-07:14
+ 2018-Jun-12	23	18.9	+12	200	161	2240	04:43-07:18
+ 2018-Jun-13	24	19.1	+06	167	152	1910	05:04-07:15
+ 2018-Jun-14	24	19.3	+01	105	138	1330	05:34-06:59

Request: 5 tracks, 15.50 hours

UT Date **441987 (2010 NY65)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Jun-16	59	5.8	+13	80	15	130	15:22-18:00
2018-Jun-17	52	5.9	+15	93	23	220	15:19-18:02
2018-Jun-18	46	6.0	+18	109	37	380	15:19-18:05
+ 2018-Jun-19	39	6.1	+22	127	64	700	15:23-18:08
+ 2018-Jun-20	33	6.3	+28	137	115	1300	15:38-18:07
+ 2018-Jun-21	27	6.6	+36	78	217	1920	16:31-17:41
...	Target is north of the Arecibo declination window						
+ 2018-Jun-28	33	16.4	+35	80	113	990	01:45-03:13
+ 2018-Jun-29	39	16.6	+30	108	63	630	01:27-03:47
2018-Jun-30	46	16.8	+26	104	37	370	01:23-04:00
2018-Jul-01	52	16.9	+22	94	23	220	01:21-04:05
2018-Jul-02	59	16.9	+20	84	15	140	01:21-04:07

Request: 5 tracks, 14.75 hours

UT Date **1627 Ivar (1929 SH)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Jun-23	339	14.6	+11	13	13	47	23:41-02:12
2018-Jun-24	338	14.6	+10	13	13	47	23:38-02:08
2018-Jun-25	336	14.6	+10	13	13	47	23:35-02:04
2018-Jun-26	335	14.6	+10	13	13	47	23:32-02:00
2018-Jun-27	333	14.6	+09	13	14	48	23:30-01:56
2018-Jun-28	332	14.7	+09	13	14	49	23:27-01:52
2018-Jun-29	331	14.7	+09	13	14	49	23:25-01:48
2018-Jun-30	329	14.7	+08	13	15	50	23:22-01:43
2018-Jul-01	328	14.7	+08	13	15	51	23:20-01:39
2018-Jul-02	326	14.7	+07	13	15	52	23:18-01:35
2018-Jul-03	325	14.7	+07	12	15	53	23:16-01:31
2018-Jul-04	323	14.7	+07	12	15	53	23:14-01:27
+ 2018-Jul-05	322	14.8	+06	12	16	53	23:13-01:23
2018-Jul-06	320	14.8	+06	12	16	53	23:11-01:18
+ 2018-Jul-07	319	14.8	+05	12	16	54	23:10-01:14
2018-Jul-08	318	14.8	+05	11	16	54	23:09-01:10
+ 2018-Jul-09	316	14.8	+04	11	17	53	23:08-01:05
2018-Jul-10	315	14.8	+04	11	17	52	23:08-01:01
+ 2018-Jul-11	313	14.9	+03	10	17	52	23:08-00:56
2018-Jul-12	312	14.9	+03	10	17	52	23:08-00:51
+ 2018-Jul-13	311	14.9	+02	9	18	51	23:08-00:46
2018-Jul-14	309	14.9	+02	9	18	51	23:09-00:41
2018-Jul-15	308	15.0	+01	8	18	50	23:10-00:35
2018-Jul-16	307	15.0	+01	8	19	49	23:11-00:29

Request: 4 tracks, 14.00 hours

UT Date **398188 Agni (2010 LE15)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Jul-18	108	20.4	+27	42	16	100	03:57-06:27
2018-Jul-19	104	20.4	+26	44	18	120	03:46-06:19
2018-Jul-20	100	20.3	+26	47	21	140	03:35-06:11
2018-Jul-21	96	20.2	+25	49	24	160	03:24-06:02
2018-Jul-22	92	20.1	+24	52	27	190	03:13-05:53
+ 2018-Jul-23	89	19.9	+23	55	31	230	03:02-05:44
2018-Jul-24	85	19.8	+21	58	36	270	02:50-05:34
2018-Jul-25	82	19.7	+20	60	41	310	02:38-05:23
+ 2018-Jul-26	79	19.6	+18	63	47	370	02:26-05:11
2018-Jul-27	76	19.4	+17	65	54	430	02:14-04:58
2018-Jul-28	73	19.3	+15	66	61	490	02:03-04:44
+ 2018-Jul-29	71	19.1	+13	67	70	560	01:52-04:29
2018-Jul-30	68	19.0	+10	66	78	620	01:42-04:11
2018-Jul-31	66	18.8	+08	63	87	680	01:34-03:52
+ 2018-Aug-01	64	18.6	+05	57	95	700	01:27-03:29
2018-Aug-02	63	18.4	+02	47	104	670	01:24-03:02
2018-Aug-03	62	18.3	-00	26	110	580	01:31-02:25

Request: 6 tracks, 17.75 hours

UT Date **(2015 FP118)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2018-Aug-21	78	13.7	+20	64	13	100	18:49-21:35
2018-Aug-22	72	13.8	+22	68	17	140	18:47-21:32
2018-Aug-23	67	13.8	+24	72	21	180	18:47-21:29
+ 2018-Aug-24	62	13.8	+26	75	28	240	18:48-21:23
+ 2018-Aug-25	58	13.9	+29	75	37	310	18:52-21:16
+ 2018-Aug-26	53	13.9	+32	69	49	400	19:02-21:04
+ 2018-Aug-27	49	14.0	+36	43	67	440	19:28-20:37
...	Target is north of the Arecibo declination window						
2018-Sep-11	54	1.1	+37	19	46	250	05:58-06:32
+ 2018-Sep-12	59	1.1	+34	52	34	240	05:23-07:04
+ 2018-Sep-13	64	1.2	+31	60	26	200	05:08-07:15
2018-Sep-14	69	1.2	+29	62	20	160	04:58-07:20
2018-Sep-15	74	1.2	+27	62	16	120	04:50-07:22

Request: 3 tracks, 9.50 hours

UT Date **144332 (2004 DV24)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
+ 2018-Sep-13	70	18.0	+35	36	131	780	22:18-23:43
+ 2018-Sep-14	61	18.0	+22	80	209	1820	21:32-00:16
+ 2018-Sep-15	56	18.0	+06	70	280	2270	21:41-23:52

Request: 6 tracks, 21.00 hours

UT Date **(2002 VE68)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
+ 2018-Nov-07	41	23.6	+31	94	134	1270	23:55-02:03
+ 2018-Nov-08	43	23.5	+25	110	113	1160	23:30-02:07
+ 2018-Nov-09	46	23.4	+20	109	92	950	23:17-02:02
+ 2018-Nov-10	49	23.4	+15	100	74	730	23:11-01:53
+ 2018-Nov-11	52	23.3	+11	87	59	550	23:09-01:40
+ 2018-Nov-12	55	23.3	+07	73	47	400	23:10-01:25
2018-Nov-13	59	23.2	+04	57	37	280	23:15-01:08
2018-Nov-14	63	23.2	+01	40	30	180	23:23-00:48
2018-Nov-15	67	23.2	-00	17	24	130	23:42-00:19

Request: 5 tracks, 16.25 hours

UT Date **163899 (2003 SD220)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
+ 2018-Dec-18	23	15.6	+34	135	33900	384000	13:27-15:09
+ 2018-Dec-19	21	16.0	+28	218	41500	588000	13:24-15:55
+ 2018-Dec-20	20	16.5	+20	258	48200	755000	13:37-16:25
+ 2018-Dec-21	19	16.9	+11	248	51800	794000	14:04-16:40
+ 2018-Dec-22	19	17.3	+02	155	51200	606000	14:53-16:31

Request: 4 tracks, 14.00 hours

UT Date **(2016 AZ8)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
2019-Jan-01	42	19.4	+01	57	31	230	16:33-17:52
+ 2019-Jan-02	38	19.3	+06	100	43	430	15:56-18:04
+ 2019-Jan-03	35	19.1	+12	132	56	640	15:28-18:03
+ 2019-Jan-04	33	18.9	+19	150	73	890	15:07-17:51
+ 2019-Jan-05	31	18.7	+27	144	88	1040	14:54-17:22
2019-Jan-06	30	18.3	+36	67	98	830	15:09-16:16

Request: 5 tracks, 17.00 hours

UT Date **(2004 XP14)**	RTT [s]	RA [h]	Dec [deg]	Runs	SNR /run	SNR /day	UT rise-set
+ 2019-Jan-03	74	3.9	+33	45	83	550	00:40-02:30
+ 2019-Jan-04	73	3.8	+26	64	86	670	00:06-02:41
+ 2019-Jan-04	74	3.7	+18	67	84	680	23:51-02:36
+ 2019-Jan-05	75	3.6	+11	60	77	600	23:49-02:20
+ 2019-Jan-07	79	3.5	+04	43	67	430	00:00-01:52