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Asteroid		Date	Phase Angle	Time h.	Num. Obs
644	Cosima	2012-12-11	1.3	5.7	102
644	Cosima	2012-12-12	1.8	3.2	53
644	Cosima	2013-01-04	12.6	3.7	86
644	Cosima	2013-01-05	13.0	6.0	107
644	Cosima	2013-02-04	21.3	3.0	74
644	Cosima	2013-02-08	21.9	4.0	80
2038	Bistro	2013-04-13	9.9	5.0	146
2038	Bistro	2013-04-14	10.0	5.0	157
2038	Bistro	2013-04-15	10.3	4.0	106
2038	Bistro	2013-04-17	10.8	4.8	118
2038	Bistro	2013-05-03	15.7	3.7	70
2038	Bistro	2013-05-04	16.0	3.4	76
2448	Sholokhlov	2013-05-13	12.0	4.4	117
2448	Sholokhlov	2013-05-14	12.1	4.3	99
2448	Sholokhlov	2013-05-23	14.4	4.4	79

TARGET ASTEROIDS! OBSERVING TARGETS FOR OCTOBER THROUGH DECEMBER 2013

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Asteroids to be observed by the Target Asteroids! program during the period of July to September 2013 are presented. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and, hence, easier to observe for small telescope users and 2) analogous to (101955) Bennu, the target asteroid of the OSIRIS-REx sample return mission.

Introduction

The *Target Asteroids!* program strives to engage telescope users of all skill levels and telescope apertures to observe asteroids that are viable targets for robotic sample return. The program also focuses on the study of asteroids that are analogous to (101955) Bennu (formerly 1999 RQ36), the target asteroid of the NASA OSIRIS-REx sample return mission.

Even though many of the observable objects for this program are faint, acquiring a large number of low S/N observations allows many important parameters of the asteroid to be determined. For example, an asteroid's phase function can be constrained by obtaining photometry taken over a wide range of phase angles. There is a direct correlation between the phase function and albedo. The absolute magnitude can be estimated by extrapolating the phase function to a phase angle of 0°. By combining the albedo and absolute magnitude, the size of the object can be estimated.

An introduction to the program can be found at Hergenrother and Hill (2013).

Quarterly Targets

There are many list asteroids that are observable in very large telescopes. For this observing plan only objects that become brighter than V = 20.0 are listed. A short summary of our knowledge about each asteroid and 10-day (shorter intervals for objects that warrant it) ephemerides are presented. The ephemerides include rough RA and Dec positions, distance from the Sun in AU (r), distance from Earth in AU (Δ), V magnitude, phase angle in degrees (PH) and elongation from the Sun in degrees (Elong).

The selected targets are split up into four sections: 1) Carbonaceous *Target Asteroids!* List targets, 2) *Target Asteroids!* List targets of unknown type, 3) Non-carbonaceous *Target Asteroids!* List targets, and 4) Other asteroids analogous to the OSIRIS-REx target Bennu.

The ephemerides listed below are just for planning purposes. In order to produce ephemerides for your observing location, date and time, please use the Minor Planet Center's Minor Planet and Comet Ephemeris Service:

http://www.minorplanetcenter.net/iau/MPEph/MPEph.html

or the *Target Asteroids!* specific site created by Sergio Foglia of the International Astronomical Search Collaboration (IASC) at

http://iasc.scibuff.com/osiris-rex.php .

Carbonaceous *Target Asteroids!* List Objects

None this quarter.

Target Asteroids! Objects of unknown type

(163249) 2002 GT (a=1.34 AU, e=0.33, i=7.0°, H = 18.5)
Unlike the other objects on the *Target Asteroids!* List which are only potential spacecraft targets, 2002 GT is an actual mission target. The Deep Impact/EPOXI spacecraft is scheduled to fly-by this asteroid in 2020. As a result, an international observing campaign has been conducting observations for much of 2013. In June of 2013, the asteroid peaked in brightness at V = 16.3 which is the brightest it gets before the 2020 fly-by. *Target Asteroids!* observations have identified a ~3.76 h rotation period *Target Asteroids!* members are especially encouraged to obtain photometry over a range of phase angles this quarter which will be important for determining its phase function.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	07 23.6	+18 44	0.46	1.01	19.4	76	78
10/11	07 39.2	+15 29	0.47	1.06	19.4	70	84
10/21	07 51.3	+12 27	0.48	1.11	19.3	64	90
10/31	07 59.2	+09 37	0.48	1.16	19.2	58	98
11/10	08 01.7	+07 03	0.48	1.21	19.1	52	106
11/20	07 58.2	+04 50	0.47	1.26	19.0	45	116
11/30	07 47.9	+03 06	0.46	1.32	18.8	37	127
12/10	07 31.1	+02 04	0.46	1.37	18.6	28	139
12/20	07 09.6	+01 53	0.47	1.41	18.5	20	151
12/30	06 46.9	+02 33	0.50	1.46	18.5	14	159

2002 NV16 (a=1.24 AU, e=0.22, i=3.5°, H = 21.3)
2002 NV16 is a low delta-V target that has been identified as a possible target for both robotic sample return missions and human explorations. Observations obtained during the Spring of 2013 found a rapid rotation period of ~0.91 h. Though it only peaks at a magnitude of V ~ 18.6 this October/November, photometry this quarter will be vital for determining its phase function and refining the rotation period.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	11 43.2	-06 34	0.04	0.97	29.0	168	12
10/11	09 28.6	-08 21	0.04	0.97	19.7	124	54
10/21	08 19.0	-08 14	0.06	0.99	18.8	97	80
10/31	07 43.1	-07 57	0.08	1.01	18.6	79	97
11/10	07 17.7	-07 28	0.10	1.03	18.6	63	112
11/20	06 54.2	-06 27	0.11	1.06	18.6	49	126
11/30	06 30.5	-04 41	0.13	1.09	18.7	36	139
12/10	06 07.6	-02 05	0.16	1.12	18.8	25	151
12/20	05 48.6	+01 03	0.19	1.16	19.0	19	158
12/30	05 35.6	+04 22	0.22	1.19	19.4	19	156

2007 CN26 (a=1.29 AU, e=0.27, i=7.6°, H = 20.8)
2007 CN26 is yet another potential spacecraft target with little known about it. It peaked at V=16.5 in early September 2013. The close approach presented a good opportunity to observe it over a wide range of phase angles from 26° to ~130°. This quarter the asteroid is slowly fading from view. Phase function photometry in October is requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	02 04.9	-21 51	0.14	1.12	18.1	30	145
10/11	01 47.5	-22 23	0.18	1.16	18.6	26	149
10/21	01 35.4	-21 22	0.24	1.20	19.2	26	148
10/31	01 28.4	-19 23	0.30	1.24	19.9	28	144
11/10	01 26.1	-16 50	0.36	1.29	20.5	30	139
11/20	01 28.0	-13 58	0.44	1.33	21.0	33	133
11/30	01 33.4	-10 58	0.52	1.37	21.5	35	127
12/10	01 41.7	-07 56	0.61	1.40	22.0	37	121

Non-carbonaceous *Target Asteroids!* List objects

(3361) Orpheus (a=1.21 AU, e=0.32, i=2.7°, H = 19.0)
Orpheus is a V-type asteroid on a low delta-V orbit with a rotation period of 3.6 h and lightcurve amplitude of ~0.3 magnitudes. Orpheus should have a relatively high albedo similar to other V-type asteroids. Phase function photometry over a range of phase angles will allow us to confirm whether its albedo is high.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	01 51.4	+10 45	0.30	1.28	17.8	17	158
10/11	01 39.6	+07 48	0.24	1.23	16.9	7	171
10/21	01 18.7	+03 04	0.19	1.18	16.3	8	171
10/31	00 48.6	-03 41	0.15	1.13	16.4	25	151
11/10	00 10.2	-12 10	0.13	1.08	16.5	46	129
11/20	23 24.1	-21 40	0.11	1.02	16.8	69	105
11/30	22 24.9	-31 29	0.11	0.97	17.5	95	79
12/10	21 01.2	-39 57	0.10	0.92	19.0	123	52
12/20	19 16.3	-42 59	0.12	0.88	22.6	151	26

2001 QC34 (a=1.13 AU, e=0.19, i=6.2°, H = 20.0)
All that is known about 2001 QC34's physical characteristics is that it is a Q- or O-type asteroid. Phase function and lightcurve photometry will shed more light on this viable spacecraft target.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	22 08.8	+21 32	0.26	1.21	18.8	31	141
10/11	21 52.1	+18 26	0.26	1.19	19.0	39	132
10/21	21 44.5	+15 08	0.27	1.16	19.2	47	122
10/31	21 45.2	+12 06	0.28	1.13	19.4	54	113
11/10	21 53.1	+09 32	0.28	1.10	19.6	60	105
11/20	22 06.6	+07 27	0.29	1.07	19.8	66	98
11/30	22 24.4	+05 45	0.29	1.04	19.9	72	92
12/10	22 45.9	+04 18	0.28	1.01	19.9	77	87
12/20	23 10.1	+02 53	0.27	0.98	20.0	83	82
12/30	23 36.6	+01 16	0.25	0.96	20.0	88	77

Other Asteroids Analogous to the OSIRIS-REx Target Bennu

(447) Valentine (a=2.98 AU, e=0.04, i=4.8°, H = 9.0)
One of two large Main Belt asteroids being targeted this quarter, Valentine is an 80 km diameter dark (albedo = 0.07) carbonaceous X-type asteroid. It rotates once every 9.65h with a lightcurve amplitude of 0.18 magnitudes. Minimum phase angle is reached on December 2 at 0.2° and V = 12.7.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	05 01.1	+21 15	2.35	2.87	14.1	19	112
10/11	05 03.1	+21 26	2.23	2.87	13.9	17	121
10/21	05 02.5	+21 35	2.12	2.88	13.8	15	131
10/31	04 59.1	+21 41	2.03	2.88	13.6	12	142
11/10	04 53.3	+21 45	1.96	2.88	13.4	9	153
11/20	04 45.5	+21 46	1.92	2.88	13.1	5	165
11/30	04 36.4	+21 44	1.90	2.88	12.8	1	177
12/10	04 27.1	+21 41	1.91	2.89	13.0	3	171
12/20	04 18.7	+21 37	1.95	2.89	13.3	7	159
12/30	04 11.9	+21 34	2.02	2.89	13.5	11	147

(535) Montague (a=2.57 AU, e=0.03, i=6.8°, H = 9.3)
The other large Main Belt asteroid is Montague. It is slightly smaller than Valentine (~74 km), slightly darker (0.05 albedo) and

a C-type. It rotates once every 10.25 h with a 0.25 magnitude lightcurve amplitude. Minimum phase angle is reached on December 14 at 0.3° and V = 12.4.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	05 47.3	+20 36	2.18	2.56	14.1	23	101
10/11	05 53.4	+20 48	2.05	2.56	14.0	22	109
10/21	05 56.9	+21 00	1.93	2.56	13.8	20	118
10/31	05 57.6	+21 15	1.82	2.56	13.6	18	128
11/10	05 55.2	+21 32	1.73	2.55	13.3	15	139
11/20	05 49.7	+21 52	1.65	2.55	13.1	11	150
11/30	05 41.5	+22 14	1.59	2.55	12.9	7	162
12/10	05 31.4	+22 35	1.56	2.55	12.5	2	174
12/20	05 20.7	+22 54	1.56	2.54	12.6	3	173
12/30	05 10.7	+23 11	1.59	2.54	12.9	7	160

(3200) Phaethon (a=1.27 AU, e=0.89, i=22.2°, H = 14.6)

Phaethon is well known as a possible comet due to its association with the Geminid meteor shower of December. Whether the shower was produced by cometary activity or a series of splitting events, the Geminids are now one of the strongest annual showers. Recently Phaethon has been observed to display comet-like activity around perihelion (Jewitt et al. 2013, Li and Jewitt 2013). It is a B-type asteroid similar to Bennu, the OSIRIS-REx target. Though carbonaceous, it is not as dark as many other carbonaceous asteroids (albedo 0.11). A rotation period of 3.60 h and amplitude of up to 0.34 magnitudes have been measured for this 5 km near-Earth asteroid.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/21	15 28.9	-04 41	0.75	0.47	16.4	107	27
10/31	17 12.6	+01 21	0.65	0.71	16.3	94	45
11/10	18 53.6	+06 31	0.68	0.90	16.2	76	62
11/20	20 13.4	+09 35	0.79	1.07	16.5	62	73
11/30	21 11.1	+11 11	0.96	1.22	16.9	52	78
12/10	21 53.6	+12 10	1.15	1.36	17.3	45	78
12/20	22 26.6	+12 56	1.36	1.48	17.7	40	76
12/30	22 53.9	+13 41	1.56	1.59	18.1	36	73

(52760) 1998 ML14 (a=2.41 AU, e=0.62, i=2.4°, H = 17.5)

Much is already known about 1998 ML14. Radar observations made in 1998 found a diameter of 1 km, albedo of 0.27 and a nearly spherical shape. Additional spectroscopic and photometric observations identified it as either an S, Sq or V type and a rotation period of 14.98 h. The near-spherical shape results in a very low lightcurve amplitude allowing a phase function to be measured with little interference from rotational variations. A large range of phase angles are observable during the last 4 months of 2013, from ~140° in early September when the 1998 ML14 will be V ~ 19.3 to a minimum of 3.5° in late December.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	08 07.9	+26 48	0.24	0.94	17.8	97	70
10/11	08 08.3	+27 06	0.29	0.99	17.7	84	80
10/21	08 09.3	+27 17	0.34	1.05	17.8	72	89
10/31	08 07.4	+27 33	0.37	1.11	17.8	62	99
11/10	08 00.3	+28 00	0.40	1.19	17.8	51	111
11/20	07 46.9	+28 35	0.42	1.27	17.7	40	124
11/30	07 27.3	+29 08	0.46	1.36	17.7	29	138
12/10	07 03.9	+29 24	0.50	1.45	17.7	18	153
12/20	06 40.6	+29 16	0.56	1.53	17.7	8	168
12/30	06 20.7	+28 48	0.64	1.62	17.9	4	173

(251346) 2007 SJ (a=2.01 AU, e=0.53, i=8.2°, H = 16.8)

Little is known about this upcoming radar target. It peaks around magnitude V = 15.3 in early January. Astrometry, phase function photometry and lightcurve observations are requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	02 11.3	+33 03	0.69	1.60	18.1	23	142
10/11	02 05.3	+35 45	0.58	1.52	17.5	20	148
10/21	01 53.1	+38 20	0.49	1.44	17.0	19	152
10/31	01 33.9	+40 32	0.41	1.37	16.5	20	152
11/10	01 08.7	+41 59	0.35	1.29	16.2	26	146
11/20	00 40.5	+42 26	0.30	1.22	16.0	35	136
11/30	00 13.1	+41 53	0.25	1.15	15.8	45	124
12/10	23 49.0	+40 37	0.21	1.08	15.7	57	112
12/20	23 26.8	+38 52	0.17	1.03	15.5	71	100
12/30	22 59.5	+36 05	0.13	0.98	15.3	87	86

2010 CL19 (a=1.54 AU, e=0.65, i=7.3°, H = 17.6)

Yet another object that little is known about. This year's close flyby results in 2010 CL19 brightening to V ~ 15 at the end of November and provides an opportunity to obtain photometry over a large range of phase angles for a relatively bright object.

DATE	RA	DEC	Δ	r	V	PH	Elong
11/10	17 09.0	-12 30	0.24	0.80	20.8	140	31
11/15	17 50.0	-12 15	0.18	0.85	19.9	137	36
11/20	19 04.9	-11 03	0.12	0.91	18.1	125	50
11/25	21 19.6	-06 18	0.10	0.97	15.9	97	78
11/30	23 44.7	+01 10	0.11	1.03	15.2	65	109
12/05	01 10.0	+05 37	0.16	1.09	15.6	47	125
12/10	01 55.3	+07 46	0.22	1.14	16.2	40	132
12/20	02 40.9	+09 52	0.35	1.25	17.3	35	133
12/30	03 05.9	+11 09	0.50	1.35	18.2	35	129

2013 NJ (a=1.28 AU, e=0.28, i=4.2°, H = 21.8)

A very recent discovery, nothing is known about 2013 NJ's physical characteristics. With H of 21.8, rapid rotation (< 2 h period) is very possible. It is a possible radar target in late November, early December.

DATE	RA	DEC	Δ	r	V	PH	Elong
11/26	15 47.6	-60 22	0.01	0.98	18.3	140	40
11/27	11 29.6	-72 33	0.01	0.98	15.8	116	64
11/28	07 52.3	-56 25	0.01	0.99	14.6	90	90
11/29	07 00.4	-39 45	0.01	0.99	14.5	71	108
11/30	06 40.2	-29 03	0.01	0.99	14.7	60	120
12/01	06 29.5	-22 14	0.02	1.00	14.9	52	127
12/02	06 22.9	-17 39	0.02	1.00	15.2	47	132
12/03	06 18.4	-14 23	0.03	1.00	15.5	43	136
12/04	06 15.1	-11 57	0.03	1.01	15.7	40	139
12/05	06 12.5	-10 03	0.03	1.01	15.9	38	141
12/10	06 05.1	-04 37	0.05	1.03	16.7	29	149
12/20	05 58.9	+00 02	0.09	1.07	17.9	22	157
12/30	05 56.3	+02 52	0.14	1.11	18.7	20	158

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