

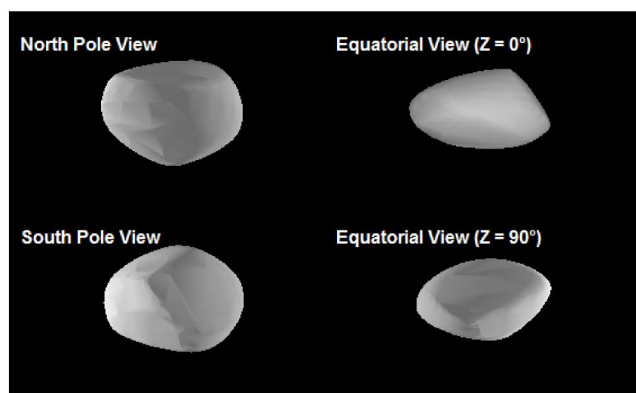


Figure 8: The shape model with the lowest chi-square value.

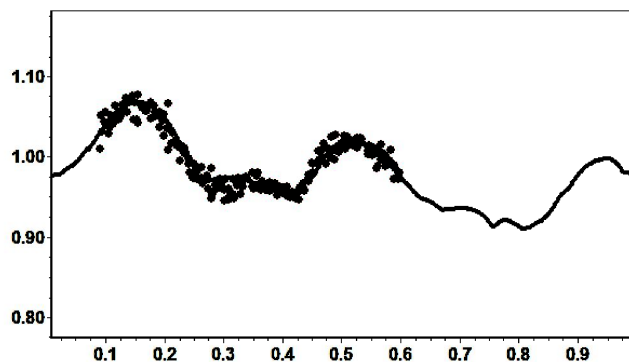


Figure 9: Fit of the data points vs. the model for 2011 August 25.

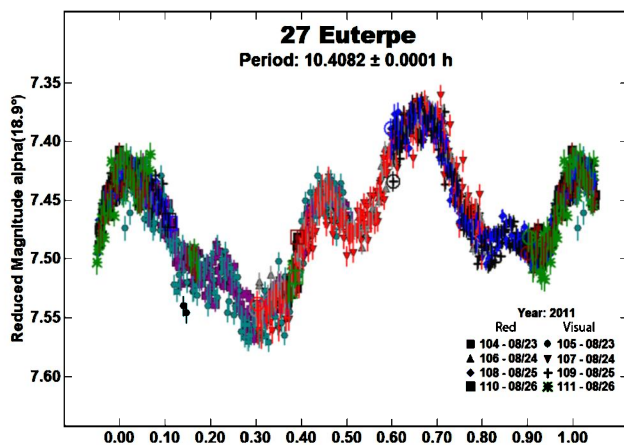


Figure 10: Plot of Cousins V and R observations with V observations zero point shifted 0.47 mag to see if any color changes due to rotational phase could be detected. None were seen to the limit of the noise.

PHOTOMETRIC OBSERVATIONS OF 596 SCHEILA, 1990 BG, 1990 TG1, 1999 CU3, 2000 DM8, 2001 PT9, 2001 SN263, 2002 NP1, 2002 JP9, 2003 UV11, 2006 AL8, 2008 SR1, 2009 BH81, 2009 QC, P/2010 A2 (LINEAR), 2010 JK33, 2010 LY63, 2010 RF12, 2010 UD, P/2010 R2 (LA SAGRA), 2010 YS, 2011 AN16, AND 2011 EZ78

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Twenty-three solar system minor bodies were measured photometrically between 2005 February and 2011 July using robotic telescopes in North America, Europe, and Australia. From the data obtained we determine for these objects their basic physical properties, such as Johnson-Cousins BVRI colors, H-G parameters, diameters, and a Tholen taxonomic classification. We found that 70% of our near-Earth asteroid sample belong to S-, Q-, X-, and C-complexes; 2009 BH81 may be a candidate to a new A type asteroid; 2010 RF12 is an S-type and it has absolute magnitude $H = 28.46 \pm 0.05$, $G = 0.31 \pm 0.06$ and $D = 6 \pm 1$ m; the possible dust envelope around (596) Scheila and P/2010 A2 have similar colors.

The near-Earth asteroids 1990 BG, 1990 TG1, 1999 CU3, 2000 DM8, 2001 PT9, 2002 NP1, 2002 JP9, 2003 UV11, 2006 AL8, 2008 SR1, 2009 BH81, 2009 LE, 2009 QC, 2010 JK33, 2010 LY63, 2010 RF12, 2010 UD, 2010 YS, 2011 AN16, 2011 EZ78 and main belt objects 596 Scheila, P/2010 A2 (LINEAR), and P/2010 R2 (La Sagra) were observed between 2005 February and 2011 June at Australia, Spain and USA. Instrumental characteristics of telescopes used in the three observation sites are defined in Table I. Our goal in this work was to estimate, if possible, the BVRI color indices and H and G parameters. Using the asteroid's colors, we then attempted to assign a taxonomic class based on the Tholen system.

Details about our photometric reduction and calibration procedure can be found in Betzler *et al.* (2010). An evaluation of the efficiency of our correlating color index to Tholen taxonomy was described by Ye (2011). When there is an ambiguity in the taxonomical classification, we chose the taxonomic class that is most compatible with the mean of Tholen's class colors. Color compatibility was determined using the L1 norm, which is most robust method. Object colors and classifications are show in Table II. The H and/or G parameters were determined using an object's

mean V magnitudes taken from photometric data published in the MPEC and the FAZ routine available in *MPO Canopus*.

(596) Scheila. Dahlgren and Lagerkvist (1995) classified this main belt asteroid as an X-complex member. Larson (2010) reported a comet-like structure in observations taken at 2010 December 11.44–11.47 UT. Jewitt *et al.* (2011), based on Hubble Space Telescope (HST) observations, suggest that the observed cometary activity was the effect of a collision of Scheila with a previously unknown 35-m main belt asteroid. We observed Scheila at Mayhill (G2) at 2010 December 15.49 UT. 16 images of 30-s exposure in B, V, R, and I filters were obtained. Our colors do not agree with the colors for any Tholen taxonomic type.

1990 BG. 1999 BG was classified as S type in the SMASS II taxonomic system by Binzel *et al.* (2004). We observed this object at Mayhill (G1) at 2010 January 26.50 UT, obtaining 16 images of 60-s exposure in B, V, R and I filters. Our colors matched with a SQ type supported the previous classification.

1990 TG1. 1999 TG1 was observed at Haleakala (FTN) at 2005 February 09.36 and 16.44 UT; 12 images were obtained in B, V, and R filters. Our mean colors matched with a SQ type. Using our V magnitudes 14.85 ± 0.07 and 14.50 ± 0.01 , $G = 0.2 \pm 0.1$ and $p_v = 0.20 \pm 0.07$, typical of S type asteroids (Warner *et al.*, 2009), we found $H = 14.44 \pm 0.02$ and a diameter $D = 2.43 \pm 0.02$ km. Our H is ~ 0.3 mag brighter than the $H = 14.7$ reported on the JPL Small-Body Database Browser.

1999 CU3. This object was classified as type SI by Binzel *et al.* (2004). The asteroid has a synodic rotation period of 3.7817 h and lightcurve amplitude of 0.81–1.25 mag (Pravec *et al.*, 2005). Radar observations in 2001 revealed that 1999 CU3 is a highly-elongated and irregularly-shaped object (Benner, 2003). This asteroid was observed at Haleakala (FTN) at 2005 February 16.41 and 19.44 UT, obtaining 12 images in B, V, and R filters. Our mean colors matched with an S type. The error in V-R is greater than 10%. This could suggest a problem with the color index determination. However, our two color indexes and V magnitudes corresponding to rotational phase $\Phi = 0.27$ and 0.52 match those of Pravec *et al.* (2005). Therefore, the V-R error may mean a color variation with rotational phase. There is a reasonable hypothesis because the object has an irregular shape. Using our V magnitudes, we found $H = 16.8 \pm 0.2$ and $D = 1.28 \pm 0.09$ km. Our H value is consistent with the $H = 17.0$ reported on the JPL web site.

2000 DM8. 2000 DM8 was classified as Sq type by Binzel *et al.* (2004). We observed this object at Nerpio (G7) at 2011 February 12.97 UT. We obtained 9 images of 44-s exposure in V, R, and I filters. Our colors match a QR type supported the previous classification.

2001 PT9. We observed this object at Moorook (G9) at 2010 February 25.59 UT, obtaining 16 images of 20-s exposure in B, V, R, and I filters. Our colors match a C type.

2001 SN263. We refined our previous results (Betzler, Brum and Celedon, 2008) and found a rotation period $P = 3.202 \pm 0.003$ h and lightcurve amplitude $A = 0.19 \pm 0.03$ (Figure 1). The analysis also confirmed detections of mutual events for this trinary asteroid and the previous orbital period estimate of one of the system's components.

2002 JB9. We observed this object at Officer (G9) at 2011 June 02.50 UT and obtained 12 images of 40-s exposure in B, V, and R filters. Our colors match a B type.

2002 NP1. This object was observed at Haleakala (FTN) at 2009 July 29.48 UT. Three images in B, V, and R filters were obtained. Our colors match an RS type. Trilling *et al.* (2010) reported an albedo of $p_v = 0.25$ and $D = 0.81$ km for this object. Combining this value with our previous result, an S type classification is more appropriate for this object.

2003 UV11. 2003 UV11 was classified as Xk type by M. D. Hicks and T. Trong (see Benner, 2011a). We observed this object at Nerpio (G7) at 2010 October 27.02 and 28.89 UT and obtained 32 images of 18-s exposure in B, V, R, and I filters. Our mean colors agree with an FB type.

2006 AL6. This object was observed at 2006 February 18.50 UT at Haleakala (FTN). Three images in B, V, and R filters were obtained. Our colors do not allow us to distinguish between a C or X-complex member. We classified this object as an FX type. Also, we found $V = 20.32 \pm 0.01$ at the time of observation. This is about 0.8 mag fainter than predicted by the Minor Planet Center (MPC) ephemerides. This result may suggest that this object has a large amplitude lightcurve or low albedo.

2008 SR1. 2008 SR1 was observed at Haleakala (FTN) at 2008 October 10.53 UT. We obtained two images in B and V filters. We found $B-V = 0.739 \pm 0.003$ and $V = 18.77 \pm 0.04$. This magnitude nearly agrees with the $V = 18.9$ from the MPC ephemerides.

2009 BH81. 2009 BH81 was observed at Haleakala (FTN) at 2009 February 27.58 UT. Three images in B, V, and R filters were obtained. Our colors match an A type.

2009 QC. The object was observed at Haleakala (FTN) at 2009 August 24.47 UT, when we obtained three images in B, V, and R filters. Our colors match an AR type.

2010 JK33. 2010 JK33 was observed at Haleakala (FTN) at 2010 June 03.36 UT, when we obtained three images in B, V, and R filters. We classify this object as an AQ type.

2010 LY63. The object was observed at Moorook (G9) at 2010 September 12.52 UT. We obtained 18 images in V, R, and I filters. Our colors match an Xc type.

2010 RF12. 2010 RF12 was observed at Siding Spring (FTS) at 2010 September 07.61 UT, when we obtained six images, divided in two consecutive sequences, using Sloan g, r, and i filters. We converted the Sloan colors (Table III) to the Johnson-Cousins photometric system using the transformation equations from Chonis and Gaskell (2008). The asteroid's mean colors matched with a SR type. Using our V magnitude estimate and mean MPC magnitudes, we found $H = 28.46 \pm 0.05$ and $G = 0.31 \pm 0.06$ (Figure 2). The G value suggests an S-type classification for this object (see Warner *et al.*, 2009). The H magnitude, combined with the S-complex typical albedo, implies $D = 6 \pm 1$ m.

2010 UD. The object was observed at Haleakala (FTN) at 2010 September 07.61 UT. Three images in B, V, and R filters were obtained. Our colors match a QV type.

2010 YS. 2010 YS was observed at Haleakala (FTN) at 2011 January 04.58 and 05.52 UT. Six images in B, V, and R filters were obtained. We classify this object as a VQ type. Assuming a Q-type, we found $D = 77 \pm 9$ m and $H = 23.1 \pm 0.3$, which agrees with JPL's $H = 22.5 \pm 0.6$.

P/2010 A2 (LINEAR). P/2010 A2 was discovered by the LINEAR survey on 2010 January 06. It was classified as a short-period comet based on the orbit and diffuse appearance (Birtwhistle *et al.*, 2010). Observations of this object revealed near nucleus structures never seen before in a comet (Jewitt and Soares-Santos, 2010; Licandro *et al.*, 2010). Jewitt *et al.* (2010), based on HST observations, suggest that observed structures are the effect of a disruption through high velocity collisions or rotational spin-up under the action of radiation torques. P/2010 A2 was observed at Haleakala (FTN) at 2010 January 22.43 UT. Three images were taken in B, V, and R filters. The object's colors are very similar to those found for 596 Scheila. We postulate that the similarity in colors is due to a similar nature of a possible dust coma around these objects.

P/2010 R2 (La Sagra). This main belt comet was observed at Haleakala (FTN) at 2010 September 19.26 UT. Two images in V and R filters were obtained. We found $V-R = 0.395 \pm 0.003$ and $V = 18.30 \pm 0.06$, which is close to the $V = 18.4$ predicted from MPC ephemerides.

2011 AN16. The object was observed at Siding Spring (FTS) at 2011 February 09.50 UT. Two images in B and V filters were obtained. We found $B-V = 0.638 \pm 0.002$.

2011 EZ78. This object was classified as S type by M. D. Hicks (see Benner, 2011b). We observed this object at Nerpio (G7) at 2011 July 09.10 UT, obtaining 16 images of 20-s exposure in B, V, R, and I filters. Our colors match an S type, which agrees with the previous classification.

Acknowledgments

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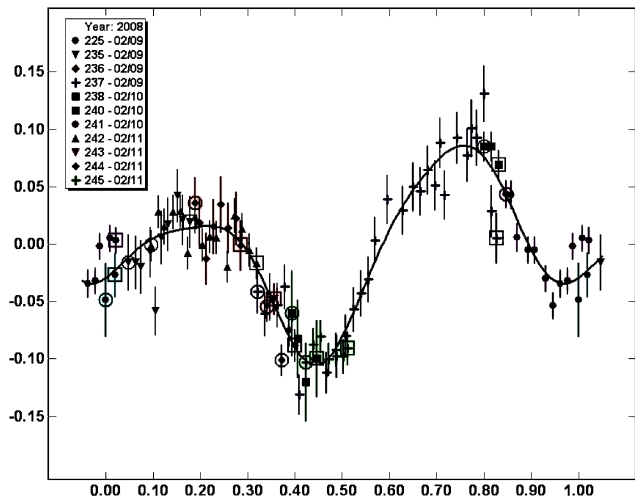


Figure 1. 2001 SN263 lightcurve adjusted in a period of 3.202h. Zero phase corresponds to HJD (LTC) 2454505.509637.

Site	Telescope	Camera
Mayhill NM, USA (GRAS G1)	12" f/11.9 Takahashi	FLI IMG1024
Mayhill NM, USA (GRAS G2)	12" f/11.9 Takahashi	SBIG ST8E
Nerpio (Spain) (GRAS G7)	CDK17 17" f/6.8	SBIG STL1100M
Moorook/Officer (Australia) (GRAS G9)	RCOS 12.5" f/6.3	SBIG ST10
Haleakala HI, USA (FTN)	2m f/10 TTL	DillCam/EM01
Siding Spring (Australia) (FTS)	2m f/10 TTL	EM03

Table I. Equipment used for observations.

Object	B-V	V-R	R-I	Tholen
1990 BG	0.8 ± 0.1	0.409 ± 0.002	0.41 ± 0.01	SQ
1990 TG1	0.82 ± 0.01	0.54 ± 0.03		SQ
1999 CU3	0.82 ± 0.05	0.49 ± 0.07		S
2000 DM8		0.430 ± 0.006	0.35 ± 0.01	QR
2001 PT9	0.70 ± 0.02	0.37 ± 0.02	0.386 ± 0.009	C
2002 JB9	0.673 ± 0.004	0.35 ± 0.01		B
2002 NP1	0.9 ± 0.1	0.54 ± 0.02		S
2003 UV11	0.63 ± 0.03	0.38 ± 0.07	0.28 ± 0.05	FB
2006 AL8	0.63 ± 0.01	0.41 ± 0.02		FX
2008 SR1	0.739 ± 0.003			
2009 BH81	1.0 ± 0.1	0.54 ± 0.02		A
2009 QC	1.03 ± 0.01	0.40 ± 0.03		AR
2010 JK33	1.24 ± 0.05	0.43 ± 0.03		AQ
2010 LY63		0.401 ± 0.005	0.380 ± 0.006	XC
2010 RF12	0.84 ± 0.04	0.46 ± 0.02	0.36 ± 0.01	S
2010 UD	0.85 ± 0.01	0.42 ± 0.03		QV
2010 YS	0.96 ± 0.05	0.38 ± 0.06		VQ
2011 AN16	0.638 ± 0.002			
2011 EZ78	0.87 ± 0.02	0.494 ± 0.003	0.428 ± 0.002	S
596 Scheila	0.520 ± 0.004	0.488 ± 0.006	0.385 ± 0.009	
P/2010 A2 (LINEAR)	0.58 ± 0.01	0.427 ± 0.008		
P/2010 R2 (La Sagra)		0.395 ± 0.003		

Table II. Summary of color indexes and taxonomic classifications

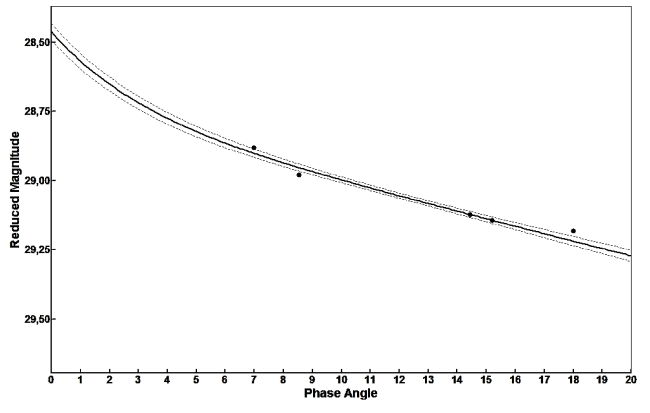


Figure 2. Plot of the reduced magnitude of 2010 RF12 versus the phase angle. The solid black line is corresponding to a curve with $H = 28.46 \pm 0.05$ and $G = 0.31 \pm 0.06$.

Seq	g-r	r-i	g
1	0.63 ± 0.01	0.15 ± 0.01	17.70 ± 0.02
2	0.721 ± 0.001	0.13 ± 0.04	17.5 ± 0.1
Mean	0.68 ± 0.05	0.14 ± 0.01	x

Table III. Sloan colors and q magnitudes of 2010 RF12