Visible Spectroscopy of NEAs in the Framework of the ESA-SSA P3NEOI Program

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The P3NEOI Spectroscopy of NEAs program

The Solar System group of the *Instituto de Astrofisica de Canarias (IAC)* is member of a consortium of astronomical observatories leaded by Deimos Space S.L.U, that presented a proposal to the ESA ITT no. AO/1-9591/18/D/MR *"P3-NEO-I – Observational support from collaborating observatories"* .

Aims of P3NEOI: to provide ESA with the support of several observatories contributing to the follow-up of relevant objects for orbit computation and physical characterization.

The role of the IAC Solar System Group in P3NEOI: lead the Spectroscopic Observations Work Package (WP) that aim to ***increase the sample of near- Earth Asteroids (NEAs) with known spectral properties***.

Spectroscopic Observations of NEAs in P3NEOI:

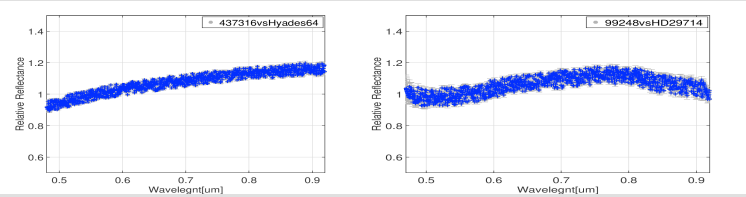

Figure 1: *Example of visible spectra of two of the NEAs (437316 and 99248) observed with ALFOSC spectrograph attached to the 2.5m NOT on Jan. 11, 2020*

The observations: rutinary spectroscopic observations using 2m-class or larger telescopes in the "El Roque de los Muchachos" Observatory (ORM, La Palma, Spain) started late April 2019. Data is obtained in every month.

We use the following telescopes:

- 2.5m Nordic Optical Telescope (NOT)
- 2.5m Isaac Neton Telescope (INT)
- 3.56m Telescopio NazionaleGalileo (TNG)
- The world's largest optical telescope, 10.4m GranTeCan (GTC).

Data with the 2.5m NOT was obtained on 8 different nights (Apr. 24, May 5, June 6, July 18, July 19, Oct. 18, Dec. 2, 2019, and Jan. 11, 2020). A total of 26 spectra of 25 different objects were obtained and reduced (Fig. 1 and Table 1). Additional data was obtained during one observing run (2019-10-01) with the 3.56m TNG (2 asteroids), two observing runs with 2.5m INT (3 objects) and one observing run with the 10.4m GTC (5 objects).

Main desig.	All desig.	Wavelength	Tax	Date of Obs.	Tel/Inst.	Grism	Slit	UT. Start	Exp. Time (s)	Airmass	SAs	m_V	r_helioc(au)	Phase (deg)
8645	8645|1988 TN|1992 UB6	Visible	V	19/02/2020	NOT/ALFOSC	Grism#4	1,3	21:28:00	2x360	1,06	HD75949	17,4	2,439	14,3
12538	12538|1998 OH	Visible	S	18/07/2019	NOT/ALFOSC	Grism#4	1,3	22:25:00	4x300	1,00	HD133623	17,4	1,349	46,5
52768	52768|1998 OR2	Visible	Xk	19/02/2020	NOT/ALFOSC	Grism#4	1,3	21:45:00	2x600	1,03	SA9878	15	1,233	31,5
66146	66146|1998 TU3	Visible	Q	02/12/2019	NOT/ALFOSC	Grism#4	1,3	22:18:00	1x600	1,58	Landt121333	16,1	1,073	64,0
90403	90403|2003 YE45	Visible	Sq	19/07/2019	NOT/ALFOSC	Grism#4	1,3	22:48:00	3x600	1,11	SA115271	16,6	1,046	75,7
99248	99248|2001 KY66	Visible	Sq	11/01/2020	NOT/ALFOSC	Grism#4	1,3	22:14:00	2x900- 1x 600	1,02	HD29714	18,1	1,629	23,8
112221	112221|2002 KH4	Visible	Sq	04/06/2019	NOT/ALFOSC	Grism#4	1,8	23:32:00	3x450	1,45	SA107684	17,3	1,371	46,6
137926	137926|2000 BJ19	Visible	Q	11/01/2020	NOT/ALFOSC	Grism#4	1,3	21:40:00	1x300	1,57	SA115271	17,4	1,484	33,3
162004	162004|1991 VE|1997 WP23	Visible	Xn	11/01/2020	NOT/ALFOSC	Grism#4	1,3	23:56:00	1x300	1,14	HD29714	16,9	1,181	33,0
162082	162082|1998 HL1	Visible	Sv	18/10/2019	NOT/ALFOSC	Grism#4	1,3	21:45:00	1x300	1,47	HD212809	15	1,026	59,9
173561	173561|2000 YV137	Visible	Sr	18/07/2019	NOT/ALFOSC	Grism#4	1,3	22:36:00	4x600	1,02	HD133623	18	1,141	58,8
216258	216258|2006 WH1	Visible	Q	03/12/2019	NOT/ALFOSC	Grism#4	1,3	3:45:00	1x600	1,50	SA1121333	16,8	1,109	14,6
257744	257744|2000 AD205	Visible	B	04/06/2019	NOT/ALFOSC	Grism#4	1,8	3:07:00	3x600	1,05	SA107684	17,9	1,260	33,9
355256	355256|2007 KN4	Visible	T	04/06/2019	NOT/ALFOSC	Grism#4	1,8	19:42:00	3x300	1,33	SA107998	16,3	1,338	23,5
381906	381906|2010 CL19	Visible	K	24/04/2019	NOT/ALFOSC	Grism#4	1,8	5:03:00	3x600	1,33	SA1021081	17,4	1,272	34,6
437316	437316|2013 GS3	Visible	T	11/01/2020	NOT/ALFOSC	Grism#4	1,3	20:29:00	1x600	1,15	Hyades64	16	1,120	30,0
453778	453778|2011 JK	Visible	Sq	24/04/2019	NOT/ALFOSC	Grism#4	1,8	19:47:00	3x600	1,36	SA1021081	17,6	1,030	77,3
453778	453778|2011 JK	Visible	Q	04/06/2019	NOT/ALFOSC	Grism#4	1,8	5:44:00	3x600	1,02	SA107998	16,5	1,087	56,0
489486	489486|2007 GS3	Visible	B	19/10/2019	NOT/ALFOSC	Grism#4	1,3	22:04:00	1x300	1,01	Hyades64	17,3	1,103	44,1
492143	492143|2013 OE	Visible	Cg	18/10/2019	NOT/ALFOSC	Grism#4	1,3	20:49:00	1x600	1,12	HD212809	18,1	1,385	32,4
528650	528650|2008 WX32	Visible	Xc	10/05/2019	NOT/ALFOSC	Grism#4	1,8	19:42:00	2x600	1,09	SA1021081	17,4	1,119	45,6
2003 OC3	2003 OC3	Visible	A	19/02/2020	NOT/ALFOSC	Grism#4	1,3	23:56:00	2x600	1,57	SA9878	16,9	1,059	60,2
2015 AP43	2015 AP43	Visible	Cb	10/06/2019	NOT/ALFOSC	Grism#4	1,8	23:10:00	1x300 - 5x250	1,43	SA107684	17,6	1,127	34,6
2016 AU130	2016 AU130	Visible	Sv	19/07/2019	NOT/ALFOSC	Grism#4	1,3	20:27:00	3x300	1,63	SA115271	16,6	1,244	7,2
2018 XG5	2018 XG5	Visible	S	10/05/2019	NOT/ALFOSC	Grism#4	1,8	23:26:00	2x450	1,04	SA8544486	16,8	1,074	45,0
2020 AV2	2020 AV2	Visible	Sa	11/01/2020	NOT/ALFOSC	Grism#4	1,3	21:28:00	2x900	2,56	HD218676	18	0,605	94,3

Table 1*: list of targets observed with the 2.5m NOT in low-resolution visible spectroscopic mode using ALFOSC@NOT camera spectrograph.*

Data base and analysis: We will make this database available at the Small Bodies Node of the NASA Planetary Data System (PDS) in the near future.
This will include the spectral classification obtained using the procedures of the M4AST tool (http://m4ast.imcce.fr/index.php/index/analyze) described in detail by Popescu et al. (2012) as in Fig. 2.

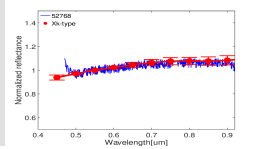

Figure 2*: Spectral classification of asteroid 52768 derived with M4AST .*

Science with P3NEOI data

Spectrocopy of the first known Atira asteroid, 2020 AV_2

Visible and near-infrared spectroscopy obtained in the framework of P3NEOI program allowed us to study the physical properties of 2020 AV2, the first known asteroid with an orbit inside that of Venus (Popescu et al. 2020)

Physical characterization of 2020 AV_2, the first known asteroid orbiting inside Venus orbit

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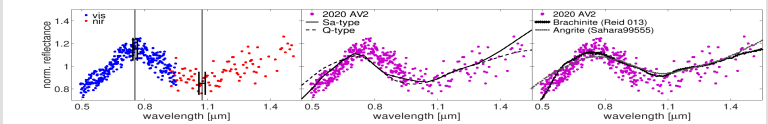

Figure 3*: Spectral matching of 2020 AV2. All spectra are normalized at 1.25 µm. The combined visible - near infrared spectrum is shown on the left-hand side panel. The positions of the reflectance maximum at 0.745 µm and of the band minimum at 1.075 µm, together with the associated error-bars, are shown by the two markers. The comparison with the Sa-type and the Q-type is shown in the middle panel. The best meteorite spectral fit is shown on the right-hand panel.*

Based on the obtained spectra (Fig. 3) we conclude that 2020 AV_2 is a Sa-type asteroid with a diameter of 1.50 km by considering the average albedo of A-type and S-complex asteroids (p_V = 0.23), and the absolute magnitude (H= 16.40 mag). The wide spectral band around 1 µm shows the signature of an olivine rich composition. The estimated band centre BIC = 1.08 +/- 0.02 µm corresponds to a ferroan olivine mineralogy similar to that of brachinite meteorites.

Spectral characterization of Arecibo targets

One of our priorities is the spectral characterization of NEAs targets de Arecibo Observatory (AO) in cooperation with the AO **Planetary Radar Science Group.** Eight of the 25 NEAs observed with the NOT were observed with Arecibo (Fig. 4)

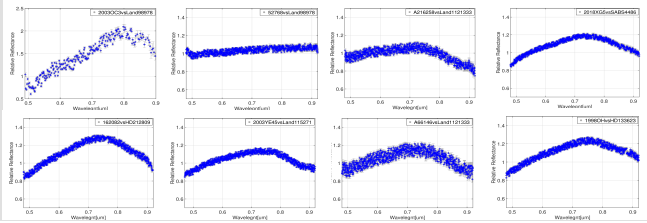

Figure 4*: visible reflectance spectra obtained with the NOT of 8 NEAs targets of the AO Planetary Radar Science Group program: 12538 (1998 OH); 90403 (2003 YE45); 66146 (1998 TU3); 162082 (1998 HL1); 2018 XG5; 216258 (2006 WH1); 2003 OC3; 52768 (1998 OR2)*

REFERENCES: Popescu, M., Birlan,M., & Nedelcu, D. A. 2012,A&A, 544, A130; Popescu, M. et al. 2020, MNRAS in press.

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