If these objects were captured, there remains the question of where they came from. **?** ~~showed~~ show from imaging spectroscopy from Cassini that Phoebe has a surface probably covered by material from the outer solar system and **?** ~~showed~~ show that the satellites of the Jovian Prograde Group Himalia have ~~grey colors~~gray colors, implying that their surfaces are similar to that of C-type asteroids. In that same work, the Jovian Retrograde Group Carme was found to have surface colors similar to the D-type asteroids ~~like~~ as for the Hilda or Trojan families, while JXIII Kalyke has a redder color like Centaurs or ~~trans-neptunian~~ trans-Neptunian objects (TNOs).

For Saturnian satellites, **?** ~~showed~~ show by their colors and spectral slopes that these satellites contain a more or less equal fraction of C-, P-, and D-like objects, but SXXII Ijiraq is marginally redder than D-type objects. These works may suggest different origins for the irregular satellites.

In this context, we used ~~3~~ three databases for deriving precise positions for the irregular satellites observed at the Observatório do Pico dos Dias (1.6 m and 0.6 m telescopes, IAU code 874), the Observatoire Haute-Provence (1.2m telescope, IAU code 511), and ESO (2.2 m telescope, IAU code 809). Many irregular satellites were observed between 1992 and 2014, covering a few orbital periods of these objects (12 satellites of Jupiter, 4 of Saturn, Sycorax of ~~Uranus~~ Uranu,s and Nereid of Neptune).

the comma goes after Uranus in this list, not before the S: it is sometimes difficult to see where a cursor is placed when typing, but it is my error, so only the comma is still needed for this list of 3.

Since their ephemerides are not very precise, ~~predict~~ predicting and ~~observe~~ observing stellar occultations are very difficult, and no observation of such an event for an irregular satellite is found in the literature. The precise star positions to be derived by the ESA astrometry satellite Gaia (?) will render better predictions with the only source of error being the ephemeris. The positions derived from our observations can be used in new orbital numerical integrations, generating more precise ephemerides.

The power of stellar occultations for observing relatively small diameter solar system objects is supported by recent works, such as the discovery of a ring system around the Centaur (10199) Chariklo (?). Once irregular satellites start to be observed by this technique, it will be possible to obtain their physical parameters (shape, size, albedo, density) with unprecedented precision. For instance, in this case, sizes could be obtained with kilometer accuracy. The knowledge of these parameters would in turn bring valuable information for studying the ~~study of the~~ capture mechanisms and origin of the irregular satellites.

The databases are described in Sect. 2. The astrometric procedures in Sect. 3. The obtained positions are presented in Sect 4 and ~~analysed~~ analyzed in Sect. 5. Conclusions are given in Sect. 6.

2. Databases

Our three databases consist ~~in~~ of optical CCD images from many observational programs performed with different telescopes ~~/detectors targeting~~ and detectors that target a variety of objects, among which are irregular satellites. The observations were made at ~~3~~ three sites: Observatório do Pico dos Dias (OPD), Observatoire Haute-Provence (OHP)~~and~~ , and the European Southern

Observatory (ESO). ~~Altogether~~ All together there are more than 8000 FITS images obtained in a large time span (1992-2014) for the irregular satellites. Since the OHP and mostly the OPD database registers were not well organized, we had to start from scratch and develop an automatic procedure to identify and filter only the images of interest, that is, ~~of~~ for the irregular satellites. The ~~instruments and images~~ instrument and image characteristics are described in the following ~~subsections~~sections.

2.1. OPD

The OPD database was produced at the Observatório do Pico dos Dias (OPD, IAU code 874, 45° 34′ 57′′ W, 22° 32′ 04′′ S, 1864 m)[2], located at geographical longitude, in Brazil. The observations were made between 1992 and 2014 by our group in a variety of observational programs. Two telescopes of 0.6 m diameter (Zeiss and Boller & Chivens) and one 1.6 m diameter (Perkin-Elmer) were used for the observations. ~~It was identified~~ Identified were 5248 observations containing irregular satellites, ~~being~~ with 3168 from the Boller & Chivens, 1967 from the Perkin-Elmer, and 113 from the Zeiss.

This is an inhomogeneous database with observations made with ~~9~~ nine different detectors (see Table 1) and ~~6~~ six different filters. The headers of most of the older FITS images had missing, incomplete, or incorrect coordinates or ~~date~~dates. In some cases, we could not identify the detector's origin. The procedures used to overcome these problems are described in Sect. 3.

Table 1. Characteristics of OPD detectors used in this work.

	Perkin-Elmer	
Detector	Image ~~Size~~ size (pixel)	Pixel Scale (μm/px)
CCD048	770 x 1152	22.5
CCD098	2048 x 2048	13.5
CCD101	1024 x 1024	24.0
CCD105	2048 x 2048	13.5
CCD106	1024 x 1024	24.0
CCD301	385 x 578	22.0
CCD523	455 x 512	19.0
IKON	2048 x 2048	13.5
IXON	1024 x 1024	13.5

The plate scale of the telescopes are 13.09"/mm for Perkin-Elmer, 25.09"/mm for Boller & Chivens, and 27.5"/mm for Zeiss.

2.2. OHP

The instrument used at the Observatoire de Haute Provence (OHP, IAU code 511, 5° 42′ 56.5′′ E, 43° 55′ 54.7′′N, 633.9 m)[3] was the 1.2m-telescope in a Newton configuration. The focal length is 7.2 m. The observations were made between 1997 and 2008. During this time only one CCD detector 1024×1024 was used. The size of field is $12' \times 12'$ with a pixel scale of 0.69′′. From these observations, 2408 were identified containing irregular satellites.

[2] Website: http://www.lna.br/opd/opd.html - in Portuguese
[3] Website: www.obs-hp.fr/guide/t120.shtml - in French

2.3. ESO

Observations were made at the 2.2 m Max-Planck ESO (ESO2p2) telescope (IAU code 809, 70°44′1.5″ W, 29°15′31.8″ S, 2345.4 m)[4] with the Wide Field Imager (WFI) CCD mosaic detector. Each mosaic is composed ~~by~~ of eight CCDs of 7.5′ × 15′ (α, δ) sizes, resulting in a total coverage of 30′ × 30′ per mosaic. Each CCD has $4k \times 2k$ pixels with a pixel scale of 0.238″. The filter used was a broad-band R filter (ESO#844) with λ_c = 651.725 nm and $\Delta\lambda$ = 162.184 nm. The telescope was shifted between exposures in such a way that each satellite was observed at least twice in different CCDs.

The satellites were observed in 24 nights, divided in ~~5 runs ,~~ five runs between April 2007 and May 2009 in ~~paralel~~ parallel with, and using the same observational and astrometric procedures of the program that observed stars along the sky path of ~~trans-neptunian~~ trans-Neptunian objects (TNOs) to identify candidates ~~to~~ for stellar occultation (see **??**). A total of 810 observations were obtained for irregular satellites~~were obtained~~.

3. Astrometry

Almost all the frames were photometrically calibrated with auxiliary bias and flat-field frames by means of standard procedures using IRAF[5] and, for the mosaics, using the esowfi (**?**) and mscred (**?**) packages. Some of the nights at OPD ~~didn't~~ did not have bias and flat-field images so the correction was not possible.

The astrometric treatment was made with the Platform for Reduction of Astronomical Images Automatically (PRAIA) (**?**). The (x,y) measurements were performed with ~~2-dimensional~~ two-dimensional circular symmetric Gaussian fits within one ~~Full Width Half Maximum~~ full width half maximum (FWHM = seeing). Within one FWHM, the image profile is ~~well described~~ described well by a Gaussian profile, ~~free from~~ which is free of the wing distortions ~~, which~~ and may jeopardize the center determination**[Note 2: Do you mean "the determination of the center" here?]** . PRAIA automatically recognizes catalog stars and determines (α, δ) with a user-defined model relating the (x, y) measured and (X, Y) standard coordinates projected in the sky tangent plane.

Fine now

We used the UCAC4 (**?**) as the practical representative of the International Celestial Reference System (ICRS). For each frame, we used the six constants polynomial model to relate the (x, y) measurements with the (X, Y) tangent plane coordinates. For ESO, we followed the same astrometric procedures as described in detail in **?**; the (x, y) measurements of the individual CCDs were ~~pre-corrected~~ precorrected by a field distortion pattern, and all positions coming from different CCDs and mosaics were then combined using a ~~3rd degree~~ third-degree polynomial model to produce a global solution**[Note 3: A complete solution? Or do you mean the faux ami sense of "general" or "overall"? If so, use one of those words instead.]** for each night and field observed, and final (α, δ) object positions were obtained in the UCAC4 system.

OK, if means total solution.

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[4] Website: www.eso.org/sci/facilities/lasilla/telescopes/national/2p2.html
[5] Website: http://iraf.noao.edu/

Table 8. CDS data table sample for Himalia.

RA (ICRS) h m s	Dec ° ′ ″	RA error (mas)	Dec error (mas)	Epoch (jd)	Mag	Filter	Telescope	**IAU code**
16 59 11.6508	-22 00 44.855	17	12	2454147.78241319	16.0	C	BC	**874**
16 59 11.6845	-22 00 44.932	17	12	2454147.78332384	15.8	C	BC	**874**
16 59 11.7181	-22 00 44.978	17	12	2454147.78422477	16.0	C	BC	**874**
16 59 11.7818	-22 00 45.143	17	12	2454147.78602662	15.9	C	BC	**874**
16 59 11.8188	-22 00 45.232	17	12	2454147.78693750	16.0	C	BC	**874**
17 17 11.0344	-22 47 19.415	30	24	2454205.63885463	16.1	U	BC	**874**
17 17 11.0270	-22 47 19.381	30	24	2454205.63959167	16.1	U	BC	**874**
17 17 11.0258	-22 47 19.366	30	24	2454205.64031875	16.1	U	BC	**874**
17 17 11.0192	-22 47 19.417	30	24	2454205.64104583	16.1	U	BC	**874**

This sample corresponds to 9 observations of Himalia from February 16, 2007 and April 15, 2007. Tables contain the topocentric ICRS coordinates of the irregular satellites, the position error estimated from the dispersion of the ephemeris offsets of the night of observation, **the UTC time of the frame's mid-exposure in ~~julian~~ Julian date**, the estimated magnitude, the filter used, the telescope origin **and correspondent IAU code**. The filters may be U, B, V, R, or I following the Johnson system; C stands for clear (no filter used), resulting in a broader R band magnitude, RE for the broad-band R filter ESO#844 with $\lambda_c = 651.725$ nm, and $\Delta\lambda = 162.184$ nm (full width at half maximum) and "un" for unknown filter. E, OH, PE, BC, and Z stand ~~respectively~~ for the ESO, OHP, Perkin-Elmer, Bollen & Chivens and Zeiss telescopes, respectively.

Table 9. Comparison of positions obtained with **?**.

Satellite	OPD	OHP	ESO	Total	Jacobson
	Number of positions				
Himalia	854	357	23	1234	1757
Elara	403	187	46	636	1115
Lysithea	60	84	90	234	431
Leda	6	48	44	98	178
Pasiphae	295	248	66	609	1629
Callirrhoe	9	-	16	25	95
Megaclite	-	-	10	10	50
Ananke	52	141	57	250	600
Praxidike	-	-	2	2	59
Carme	90	204	37	331	973
Sinope	41	169	11	221	854
Themisto	-	-	16	16	55
Phoebe	1239	516	32	1787	3479
Siarnaq	-	20	56	76	239
Paaliaq	-	-	11	11	82
Albiorix	-	-	46	46	137
Sycorax	-	-	35	35	237
Nereid	803	-	99	902	716

Comparison between the number of positions obtained in our work with the number used in the numerical integration of orbits by the JPL as published by **?**.**[Note 4: This just repeats the title in detail, which is not the point of a table note. Move it to the running text, if that helps after removing here.]**

Better would be to just use this rather than the title, in that case.

calibrated and should be used with care. The position errors were estimated from the dispersion of the ephemeris offsets of the night of observation of each position. Thus, these position errors are probably overestimated ~~, as~~ because there must be ephemeris errors present in the dispersion of the offsets. These position ~~catalogues~~ catalogs are freely available in electronic form at the CDS (see a sample in Table 8) and at the IAU NSDC data base at www.imcce.fr/nsdc.

The number of positions acquired is significant compared to the number used in the numerical integration of orbits by the JPL (**?**) as shown in Table 9.