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Monitoring of comets activity and composition with the TRAPPIST-North telescope

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Abstract. TRAPPIST-North (**TRA**nsiting **P**lanets and **P**lanetes**I**mals **S**mall **T**elescope) is a 60-cm robotic telescope that was installed in May 2016 at the Oukaimeden Observatory [1]. The project is led by the University of Liège (Belgium) and the Caddi Ayad University of Marrakech (Morocco). This telescope is a twin of the TRAPPIST-South telescope, which was installed at the ESO La Silla Observatory in 2010 [2]. The TRAPPIST telescopes are dedicated to the detection and characterization of planets orbiting stars other than our Sun (exoplanets) and the study of comets and other small bodies in our solar system. For the comets research, these telescopes have very sensitive CCD cameras with complete sets of narrow band filters to measure the production rates of several gases (OH, NH, CN, C_3 and C_2) and the dust [3]. With TRAPPIST-North we can also observe comets that would not be visible in the southern hemisphere. Therfore, with these two telescopes, we can now observe continuously the comets around their orbit. We project to study individually the evolution of the activity, chemical composition, dust properties, and coma morphology of several comets per year and of different origins (New comets and Jupiter Family comets) over a wide range of heliocentric distances, and on both sides of perihelion. We measure the production rates of each daughter molecules using a Haser model [4], in addition to the Afρ parameter to estimate the dust production in the coma. In this work, we present the first measurements of the production rates of comet C/2013 X1 (PANSTARRS) observed with TN in June 2016, and the measurements of comet C/2013 V5 (Oukaimeden) observed in 2014 with TRAPPIST-South.

1. TRAPPIST-North

1.1. TRAPPIST-North : site and instrumentation

TRAPPIST-North is a 60-cm Ritchey-Chretien robotic telescope installed in May 2016 at the Oukaimeden Observatory in Morocco and a twin of the TRAPPIST-South telescope at La Silla, Chile [1]. It is mounted on a German-equatorial direct-drive mount made by ASTELCO, company based in Munich, with a slewing speed of 30 deg/s and tracking accuracy of 1" in 4 minutes. The telescope is equipped with a 2K×2K thermo-electrically cooled Andor IKONL CCD camera with a field of view of 20'x20'. We bin the pixels 2 by 2 and obtained a resulting plate scale of 1.3"/pixel. We observed the comets with HB narrow band filters [3] isolating the cometray emission bands of OH, NH, CN, C_3 and C_2 as well as emission free dust continuum regions BC, GC and RC at three wavelengths(blue, green and red). Images are also taken with broad band B, V, Rc, and Ic Johnson-Cousin filters [3].

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The Oukaimeden Observatory located at 80 km south of Marrakech (Morocco) is operated by the Cadi Ayyad University and was inaugurated in 2007. It is located in the High Atlas Mountains, at an altitude of 2750 m, with a latitude of 31° 12’ 22 (N) and a longitude of -7° 51’ 29 (W). The observatory offers good viewing conditions in the semi-desert area with about 250 clear nights per year [1].

1.2. TRAPPIST and comets

With TRAPPIST we study several aspects of comets. The first one is to follow the evolution of the chemical compositions of thier coma, with narrowband filters comet OH, CN, NH, C_2 and C_3 and to estimate the dust outgassing (using the Afρ proxy) with the continuum filters BC, RC and GC, of the brilliant comets (magnitude $\leq$12) week after week. In order to use the production rate calculations for these daughter molecules and gas/dust ratio to classify chemically comets. The second aspect is to study the coma morphology and determine for instance the rotation period of comets using jet that are revealed different enhancement techniques [5].

2. TRAPPIST-North monitoring of comet C/2013 X1 (PANSTARR)

Comet C/2013 X1 (PanSTARRS) was discovered on December 4^{th}, 2013 with the Pan-STARRS 1 observatory on Mount Haleakala in Hawaii, when it was at a magnitude of 20.2. Follow-up images obtained on December 5^{th} with the 3.6 m Canada-France-Hawaii Telescope and with a 0.51 m f/6.8 Astrograph at Siding Spring confirmed the cometary activity of this object, with a moderately condensed coma of 6” in diameter and a short tail about 2”. Figure 1 shows the image of comet C/2013 X1 (PanSTARRS) in the filter CN taken by TRAPPIST-North telescope on June 14^{th}, 2016 and the corresponding radial profile.

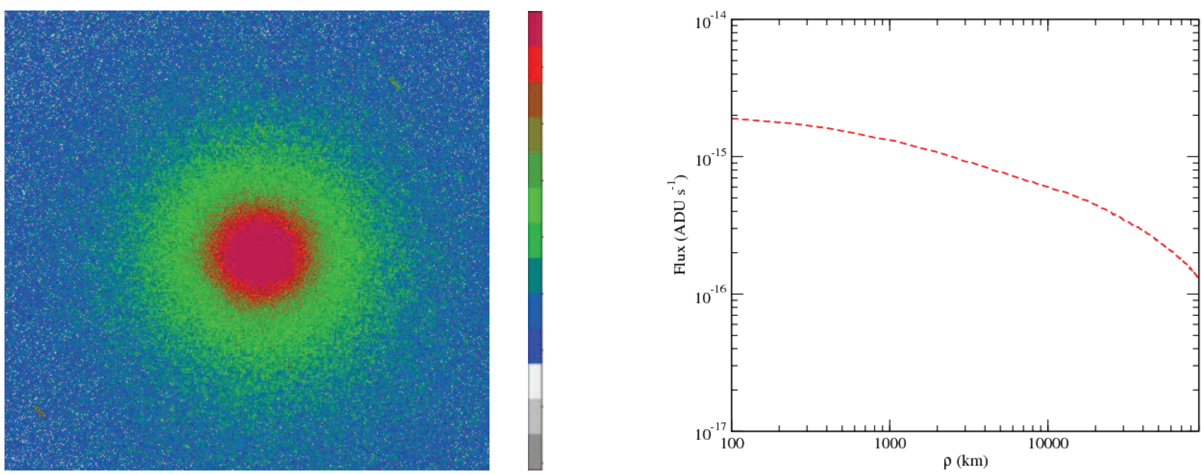

Figure 1. Original image of comet C/2013 X1 (PanSTARRS) in the filter CN taken by TRAPPIST-North telescope on June 14^{th}, 2016 and the corresponding radial profile.

C/2013 X1 is a non-periodic comet, which describes an orbit with an inclination of 163° and an eccentricity of 1.001037. It could be a dynamically old comet; in fact, its orbit suggests that possibility as does its brightening trend since discovery [6].

Table 1. OH, NH, CN, C_3 and C_2 production rates and Afρ for comet C/2013 X1 (PANSTARRS). The blue color corresponds to the TN measurements. r and Δ are the heliocentric and geocentric distances, respectively.

UT Date	r (UA)	Δ (UA)	Production rates Q(OH) $[10^{28}$mol/s]	Q(CN) $[10^{25}$mol/s]	Q(NH) $[10^{25}$mol/s]	Q(C_2) $[10^{25}$mol/s]	Q(C_3) $[10^{25}$mol/s]	Afρ (BC) $[10^2$cm]
2016-06-07.22	1.49	0.81		12.5±0.46		16.70±0.41		8.57±0.33
2016-06-08.25	1.50	0.79	3.73±0.41					
2016-06-10.23	1.51	0.76		12.50±0.41	31.0±2.23	15.70±0.41	2.78±0.11	8.74±0.27
2016-06-14.19	1.54	0.69	3.14±0.64	12.60±0.76		15.50±0.70		09.54±0.42
2016-06-18.18	1.57	0.65	3.02±0.32			18.70±0.55	2.32±0.23	10.70±0.41
2016-06-19.11	1.58	0.65		11.80±0.53	28.4±2.00	18.10±0.76	2.60±0.14	
2016-06-19.15	1.58	0.65	3.44±0.36	12.70±0.44		22.20±0.51		11.90±0.54
2016-06-19.19	1.58	0.65	3.49±0.32	12.60±0.40		21.40±0.45		12.60±0.30
2016-06-27.13	1.65	0.67	2.75±0.24	9.09±0.37		10.70±0.60	2.24±0.18	

3. TRAPPIST-South monitoring of comet C/2013 V5 (Oukaimeden)

C/2013 V5 (Oukaimeden) is a retrograde Oort cloud comet discovered on 12 November, 2013 by the telescope MOSS [2] that is located at the Oukaimeden Observatory. C/2013 V5 is dynamically new, it came from the Oort cloud with a loosely bound chaotic orbit that was easily perturbed by galactic tides and passing stars. Before entering the planetary region, C/2013 V5 had an orbital period of several million years. After leaving the planetary region, it will have an orbital period of about 6000 years. The average production rates obtained by TRAPPIST-South observations at perihelion on September 24, 2014 (r_h=0.63 UA) are: Q(OH)=1.4±0.3 10^{28} mol/s and the rest in 10^{25} mol/s: Q(CN)=6.1±0.3, Q(C_2)=6.9±0.2, Q(C_3)=1.2±0.1, Q(NH)=16.62±1.65. The quantity of dust represented by the Afρ parameter measured in BC filter is 298±14 cm.

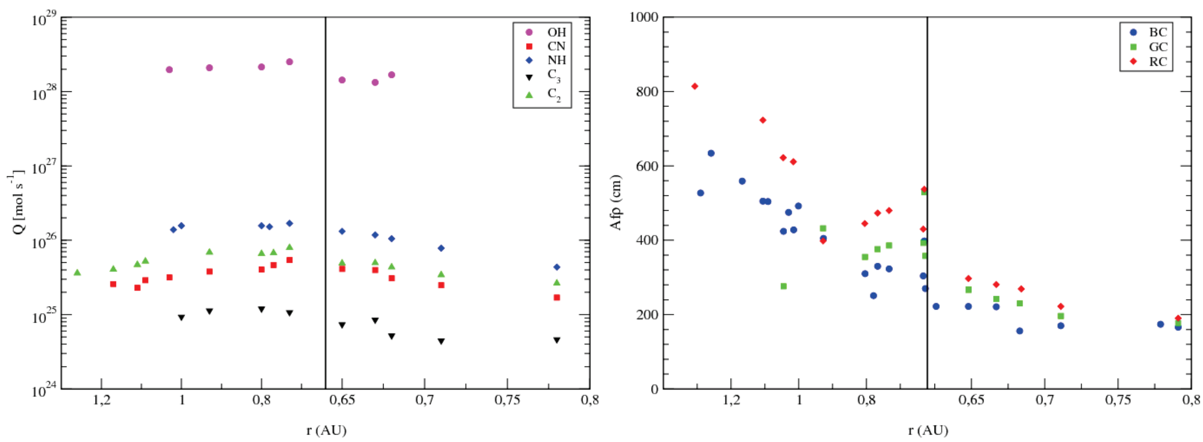

Figure 2. OH, CN, NH, C_2 and C_3 production rates and Afρ parameter measured from narrow band BC, GC, and RC continuum filters as a function of the heliocentric distance. The vertical line in the middle shows the perihelion (r=0.62 AU) of comet C/2013 V5. Note that the scale of the graphic for the heliocentric distance is not the same before and after perihelion.

The ratio of the production rates compared to OH and CN help to classify the comets. A'Hearn *et al* [7] showed that there are two main categories of comets: one category is characterized by a depletion of carbon chain species, the other is typical having no depletion of C_2 and C_3. The mean value of the ratio $Q(C_2)/Q(CN)$ for a typical comet is 1.5, the limits of this ratio for a comet showing no depletion is between 0.7 and 2. The average obtained for Oukaimeden comet during its 2014 passage, is $Q(C_2)/Q(CN)$=1.36, so this comet has a typical composition [8].

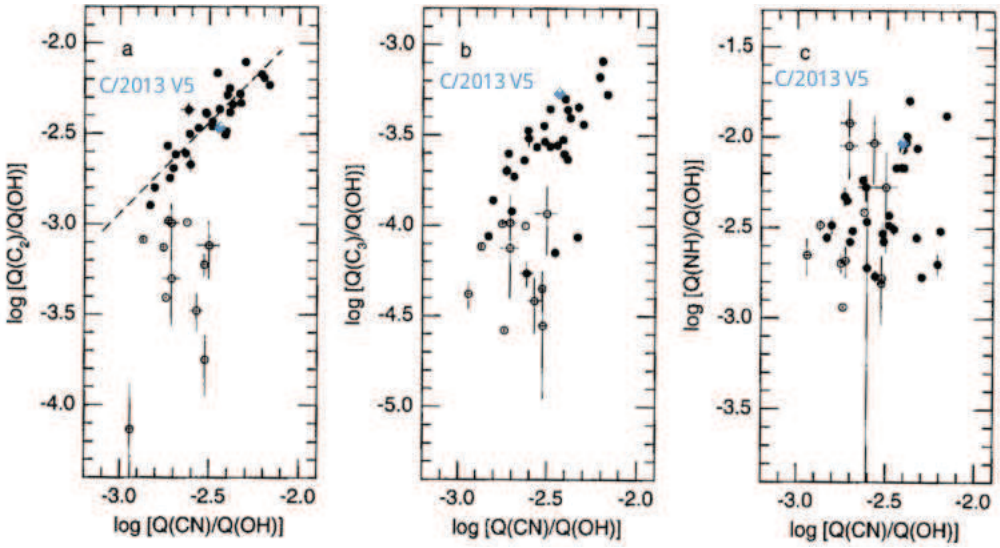

Figure 3. Logarithm of the ratio of C_2 production rate, C_3 and NH relative to OH as a function of the logarithm of relative CN production rate relative to OH, for a lot of comets.These data for 41 comets and C/20113 V5 marked in blue. Error bars are shown on all points but in most cases are smaller than the points. Filled symbols indicate comets in the typical taxonomic class.

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