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The unique spectrum of comet C/2016 R2 (PANSTARRS)

Emmanuel Jehin (1) (ejehin@uliege.be), Cyrielle Opitom (2), Damien Hutsemékers (1), Philippe Rousselot (3), Youssef Moulane (1,2), Francisco J. Pozuelos (1), Jean Manfroid (1), Alan Fitzsimmons (4), Chris Gibson (4), Colin Snodgrass (5)
(1) Space sciences, Technologies & Astrophysics Research (STAR) Institute, University of Liège, Belgium (2) European Southern Observatory, Santiago, Chile (3) Institut UTINAM UMR 6213, CNRS, Univ. Bourgogne Franche-Comté, Besançon, France (4) Astrophysics Research Centre, Queen's University, Belfast, UK (5) Institute for Astronomy, University of Edinburgh, Edinburgh, UK

Abstract

We present optical observations of the long period comet C/2016 R2 (PANSTARRS) performed with the high resolution UVES spectrograph at the ESO VLT (Paranal), complemented by low resolution spectra at INT (La Palma) and narrow-band imaging obtained with the TRAPPIST telescopes. We show that this comet has a unique chemical composition, with strong N_2^+ and CO^+ emission lines in the optical, several well detected CO_2^+ bands while the usual radicals CN, C_3, C_2, are very faint. OH, OH^+ and H_2O^+ as well as NH and NH_2, are not detected, suggesting that C/2016 R2 is a comet rich in N_2 and CO ices but poor in water and ammonia. We will present new results obtained from these observations and discuss the origin of this type of comets.

1. C/2016 R2 the blue comet

The returning long period comet C/2016 R2, was discovered on Sep 7, 2016 at 6.3 au from the Sun. While it was already showing a 20" coma at this large distance [6], it is only in December 2017 that it was found that this comet had a very unusual composition. From radio observations the comet appeared to be very rich in CO and very poor in HCN [7] and its optical spectrum was dominated by CO^+ and more surprisingly N_2^+ emission bands [1], while most of the emission bands usually detected in the optical spectrum of comets were not detected (Fig.1)

2. Observations

In order to investigate in detail its coma in the optical, we obtained a total of 5 hours of Director Discretionary Time on C/2016 R2 with UVES, the high-resolution optical spectrograph of the ESO VLT (Paranal), between Feb 11 and 16, 2018. The comet was at about 2.8 au from the Sun and 2.5 au from Earth. We used two different settings to optimally cover the whole optical spectrum (326-1060 nm) with a resolving power of 80,000.

In addition to the UVES spectra, low resolution long slit spectra were obtained on several nights with the IDS spectrograph mounted on the 2.5 m INT telescope at La Palama (late December 2018). The comet was still active at 3.4 au post-perihelion showing the ubiquitous CO^+ and N_2^+ emission spectra.

We also used the TRAPPIST 60-cm telescopes [3] to monitor the general activity of the comet during a year. Instead of the usual large, diffuse, featureless and symmetrical CN coma, the images through the CN filter since December 2017 were rather showing a morphology similar to the CO^+ image. This was indicating that the CN filter was highly contaminated by an ion. The lack of the typical CN and also C_2 coma were already pointing to low abundances of CN and C_2.

3. Results

3.1 The N_2^+ spectrum

The detection of N_2 in comets has been a matter of debate for decades. The N_2 molecule itself cannot be detected in cometary spectra in the optical range, but N_2^+ can be observed in this range thanks to the bands of the first negative group, the (0,0) bandhead being at 391.4 nm. Before the apparition of C/2016 R2 only very few detections of N_2^+ emission lines had been reported from ground based facilities. The discovery of C/2016 R2 presenting numerous N_2^+ bright emissions lines offered a unique opportunity to model its fluorescence spectrum and try to measure for the first time the N isotopic ratio directly in N_2, the main reservoir of nitrogen in the solar nebula.

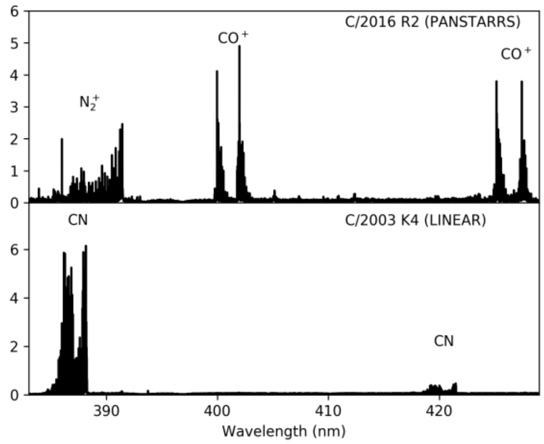

Fig.1. Comparison of UVES spectra of comets C/2016 R2 at 2.8 au and C/ 2003 K4 (LINEAR) at 2.6 au [4].

3.2 The CO^+ spectrum and $^{12}C/^{13}C$ ratio

The CO^+ emission lines appearing in the optical range belong to the comet tail system. Such bright emission lines offered a unique opportunity to test the modeling of its fluorescence. We computed the equilibrium population for CO^+ ions receiving a solar flux at the heliocentric distance and velocity of the comet. In addition these high resolution and high signal-to-noise spectra of CO^+ allowed us to measure the $^{12}C/^{13}C$ isotopic ratio in CO^+ (this conference [5])

3.3 The N_2^+ / CO^+ / CO_2^+ ratios

All those species have strong detected emissions, such that we can compute the abundance ratios between them which are indicators of formation temperatures. We measure a N_2^+/CO^+ abundance ratio of 0.06 ±0:01. Such value would be indicative of a low formation temperature [4].

3.4 Forbidden atomic lines

For the first time the C, N and O forbidden lines have been simultaneously observed in a comet. This is also the first detection of the optical [NI] lines in a comet thanks to the high abundance of nitrogen in this comet. Those lines result from the decay of nitrogen in the metastable state $N(^2D^0)$, probably produced by dissociative electron recombination of N_2^+. From the ratio of the green line to the red doublet of the [OI] lines we derived a Green/Red ratio of 0.23 typical of comets observed at large heliocentric distances (>3 au) [2]. More measurements will be presented to derive CO and CO_2 abundances. Models for [CI] and [NI] emissions are under development and first results will be presented.

3.5 The origin of C/2016 R2

We have performed numerical simulations to study C/2016 R2 dynamic behavior [4]. It is a dynamically middle-age comet, having crossed the planetary region at least 3 times in the past, with perihelion distances of about 2.5 to 3.0 au. This shows that the comet has kept its most volatile ices after several returns. With the low abundance of water this show this comet, which is the best example of its kind so far, has a unique origin different from most of the long period comets observed so far.

Acknowledgements

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