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Seasonal temperature effects on comet 67P/Churyumov-Gerasimenko as inferred from Rosetta/VIRTIS

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Abstract

The Visible InfraRed Thermal Imaging Spectrometer (VIRTIS) [1] on board the orbiter of the ESA Rosetta mission operates in the spectral range 0.25-5.1 µm. VIRTIS is continually used to map and investigate the surface composition of the comet nucleus in its uppermost layer within a depth of a few tens of microns [2,3,4]. Moreover, the temperature of these surface layers can be mapped utilizing VIRTIS' long wavelength spectral measurements. To do this, the VIRTIS team uses a Bayesian approach to nonlinear inversion [5], which was already adopted in the past for other small bodies [2,5]. The superficial layer sampled by VIRTIS is significantly different from the much thicker layers sampled by the Microwave Instrument for the Rosetta Orbiter (MIRO) [6]. Furthermore, VIRTIS is not sensitive to physical temperatures on the nightside of the comet, where the signal is considerably low. Typically, 170 K is the minimum surface temperature that can be measured while preserving small formal errors (<1 K on retrieved temperatures). Temperatures below ~170 K have increasingly lower accuracy, and should be carefully interpreted.

In previous papers, we have provided a thorough description of surface temperature maps and thermal properties of comet 67P/Churyumov-Gerasimenko as derived from infrared data acquired by Rosetta/VIRTIS in the early Mapping phase carried out in August and September 2014 [e.g., 7,8]. We divided those maps into intervals of true local solar time and we evaluated, for the available coverage, the average daily temperatures. In addition, we studied correlations between temperature and albedo at different wavelengths, and derived diurnal temperature profiles for several local sites, representative of as many macro-regions of the comet [e.g., 8].

In this new work, we focus on effects determined by the season and the heliocentric distance. Due to the low thermal inertia of the nucleus surface material, the surface temperature is essentially dominated by the instantaneous value of the solar incidence angle. Small values of this angle result in high surface temperatures, but, due to comet 67P's obliquity, for each location the smallest achievable value of insolation angle depends on the season. During 2014, VIRTIS' visible and infrared measurements covered only the northern regions of the cometary surface and the equatorial belt became gradually unveiled, while the southern region is going to be revealed from 2015 onwards.

In addition, the heliocentric distance strongly affects the surface temperature. This is a larger effect in comets than in asteroids, due to the wide range of heliocentric distance values spanned by comets. However, on the basis of temperature data returned by the VIR instrument onboard Dawn, it was possible to discern the effect of the heliocentric distance also in the large asteroid Vesta [5].

When Rosetta started its global mapping observation campaign, i.e. in early August 2014, the heliocentric distance of comet 67P was ~3.6 AU, while it decreased to 3.0 AU on 11 November 2014, to 2.0 AU on 27 March 2015, and the perihelion passage is expected on 13 August 2015 at 1.24 AU from the Sun. By relating surface temperatures as measured by VIRTIS to three variables: solar incidence angle, true local solar time and heliocentric distance, for a given location on the surface (chosen particularly in the equatorial region, which experienced different seasons), we aim to separate the relative contributions due to season and to the heliocentric distance.

These results are unprecedented for a comet, given the unique ability of Rosetta to closely observe a cometary nucleus over a long period of time. In principle, such work may deepen the knowledge of the thermal properties of the cometary nuclei. However, the increase in activity on a global scale that accompanies the perihelion passage implies to consider other effects such as sublimation and changes in the surface composition and roughness.

The inference of seasonal changes in thermophysical properties is clearly an ambitious goal for the future, but this work poses a first constraint in this regard.

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