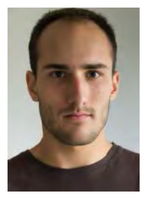
Time comparative photometric study of 67P/CG as seen by VIRTIS-M/H onboard Rosetta



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1. Introduction, data & model

VIRTIS[1] is the imaging-spectrometer onboard Rosetta spacecraft. With two channels (imaging – VIRTIS M – and high spectral resolution – VIRTIS H – spectrometers), it allows us to study the surface of the nucleus of the comet 67P/Churyumov-Gerasimenko between 0,25µm and 5µm. Rosetta observes since August 2014 and has provided a wealth of observations under many geometry and illumination conditions ; this diversity and this **time coverage give us the opportunity to follow potential changes at the surface based on photometric parameter**.

As an indicator of change and because the comet surface is very dark[2,3], we choose the single scattering albedo (SSA, w) defined by the Lommel-Seeliger model with a one-lobe Henyey-Greenstein phase function (p(g)):

$$I/F\,(i,e,g) = \frac{w}{4}\cdot\frac{\mu_0}{\mu_0+\mu}p(g) \quad \left.\begin{matrix}\mu_0=\cos(i)\\ \mu=\cos(e)\end{matrix}\right\} \quad ;\ p(g)=\frac{1-b^2}{(1+2b\cdot\cos(g)+b^2)^{3/2}}$$

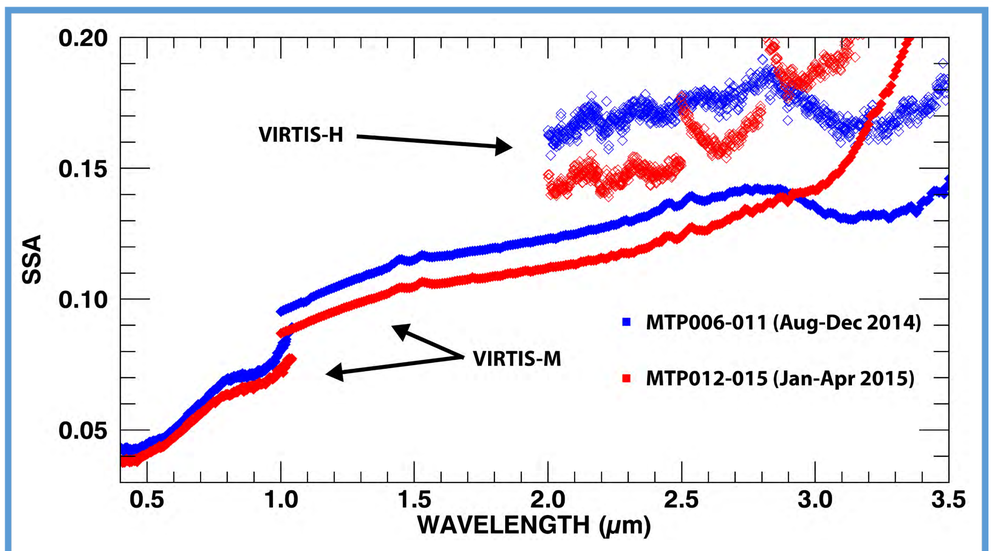


Fig 1: Global SSA for different periods at a global scale with VIRTIS-M (visible and infrared channels) and VIRTIS-H data. Decrease is observed through time (except for red curve at 3,0µm because of the thermal signal where the model is not efficient). Determined b≈-0,38.

Since VIRTIS measures the reflectance (I/F), by correcting with observation geometries (cosines of i and e which are incidence and emergence angles respectively) and having a large phase angle (g) range we compared in a first step the global SSA between two periods: MTP006 (08/2014) to MTP011 (12/2014) and MTP012 (01/2015) to MTP015 (04/2015) ; see figure 1. Each MTP (Medium Term Plan) is approximately one month duration.

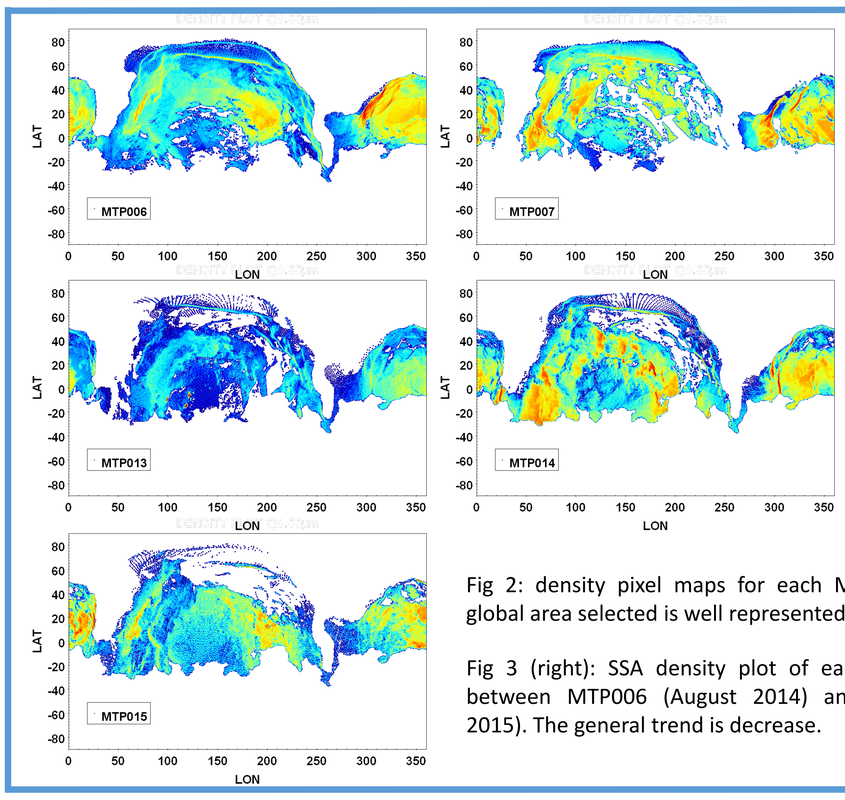


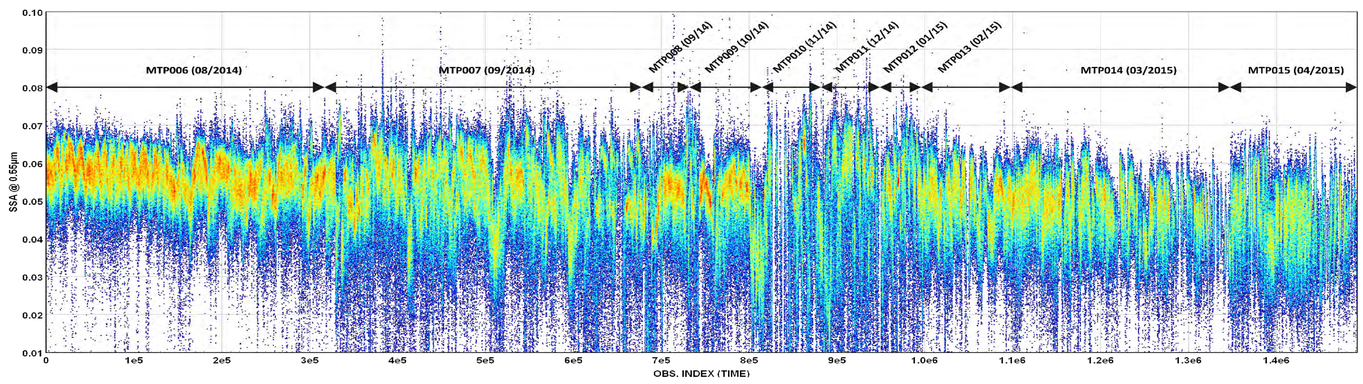
Fig 2: density pixel maps for each MTP selected. The global area selected is well represented.

Fig 3 (right): SSA density plot of each VIRTIS-M pixel between MTP006 (August 2014) and MTP015 (April 2015). The general trend is decrease.

2. Method

From figure 1 we see a decrease of the SSA for both M and H channels of VIRTIS. However the spatial distribution of changes is not known. To realize mapping, it is necessary to make a hypothesis on the b parameter of the phase function. Assuming a value of b=-0,38 determined from the global computation we become able to calculate the SSA for each pixel and then create maps.

In order to do a consistent time comparison we choose areas equally observed between the two periods. We eliminate for example south hemisphere tardily imaged and the neck region which is not well covered in the second period. Figure 2 shows density pixel maps of the MTP selected while figure 5 presents the SSA histogram of these MTP. Finally we realized SSA maps (figure 4) for the two sets of MTP and then we compute the difference (figure 6).



3. Results

Histograms in figure 5 take into account the spatial coverage of each MTP by keeping only a comparison between MTP006, 7, 13, 14 and 15 because of the low coverage of the others. We see along these MTP a constant decrease of the albedo. From the entire dataset, the same result is presented in figure 3 which represents a logarithm density plot where each point is a pixel of VIRTIS M visible channel from August 2014 to April 2015. Thus the general trend is visible.

About the spatial information, **it is possible from two SSA maps (figure 4) to study the evolution between our periods**. In map figure 6, red areas means darkening through time while blue areas means brightening. We see that darkening is the major observed phenomenon but some localized areas presents brightening.

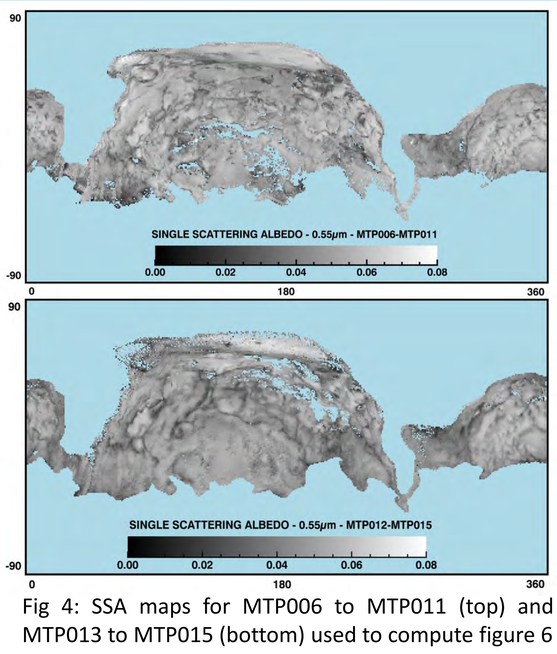


Fig 4: SSA maps for MTP006 to MTP011 (top) and MTP013 to MTP015 (bottom) used to compute figure 6

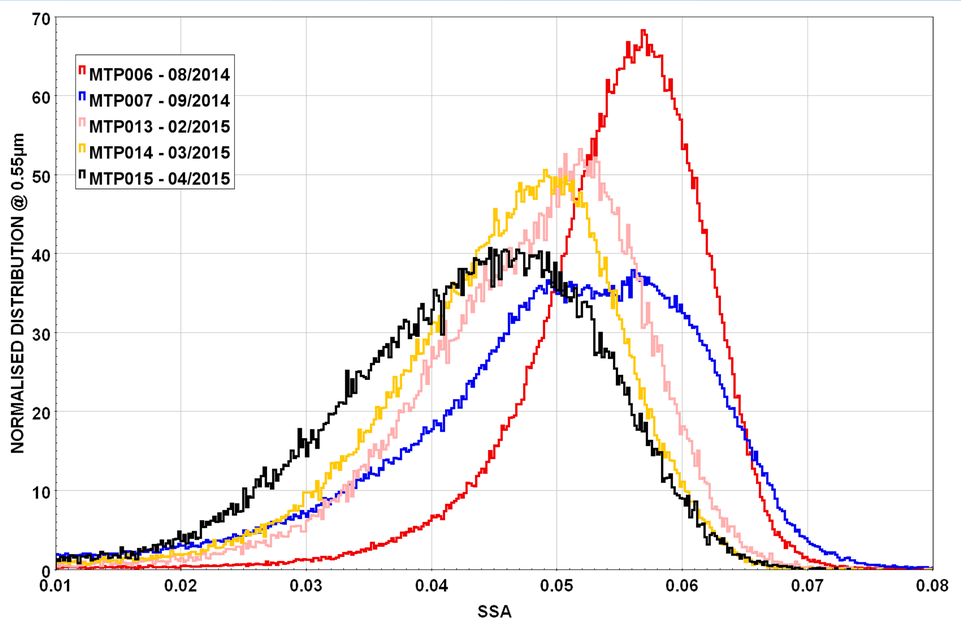


Fig 5: Normalized histogram of the SSA for MTP selected at a global scale for VIRTIS-M visible data.

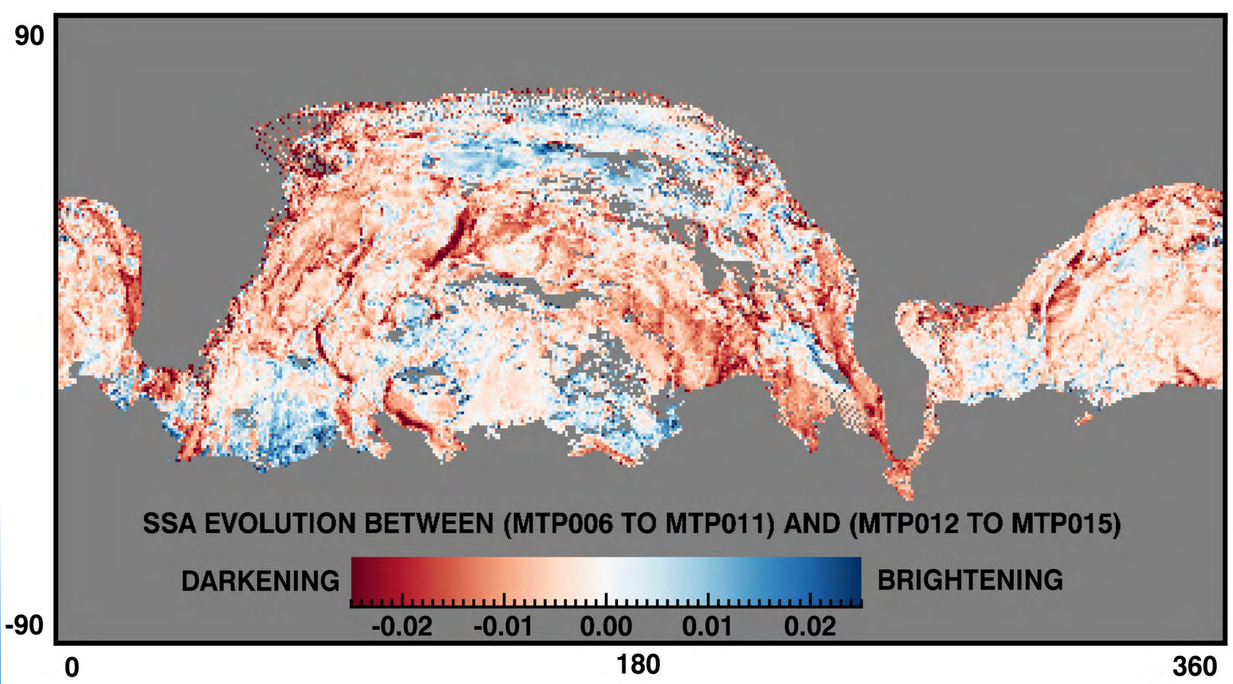


Fig 6: SSA evolution map in the visible range (0,55µm) of VIRTIS-M between Aug-Dec 2014 and Jan-Apr 2015.

4. Conclusion and perspectives

As a general trend the SSA at the surface of comet 67P/CG is decreasing through time in the visible channel. In the infrared range (not presented here) , more fluctuations are observed and no clear trend is identified - a small increase between MTP007 to 12, as opposed to MTP006, 13, 14 and 15.

Since monitoring of the visible channel of VIRTIS displays no evidence of change in transmission, **these observations may have two possible origins:**

- The model used is not accurate enough to describe the surface physical properties, e.g. the phase function; different options will be tested in the future.
- Regional darkening/brightening are real, e.g. darkening could result from a decrease in the amount of water ice in the subsurface while a brightening could be the opposite.

To complete the study we plan to:

- Study other spectral indicators (such as spectral slope) and investigate lastest observations
- Cross-correlate albedo variations with the morphology observed in high resolution OSIRIS images

1.Coradini et al. 2007, SSR,128,529 2.Sierks et al. 2015, Science, 347, 1044 3. Fornasier et al., A&A 583, A30 (2015)