# Methods for studying the Didymos - Dimorphos system using the observations from HyperScout-H instrument onboard of Hera mission


*Marcel Popescu[1], Julia de León[2,3], Michael Küpers[4], Hannah Goldberg[5], Eri Tatsumi[2,3], Monica Lazzarin[6], and Dario Izzo[5]*

(1) Astronomical Institute of the Romanian Academy, Romania (*popescu.marcel1983@gmail.com*); (2) Instituto deAstrofísica de Canarias (IAC), Spain; (3) Departamento de Astrofísica, Universidad de La Laguna, Spain; (4) European Space Agency, European Space Astronomy Centre, Camino Bajo del Castillo s/n, 28692 Villanueva de la Cañada, Madrid, Spain; (5) European Space Agency, European Space Technology Research Center, Keplerlaan, 2201 Noordwijk, The Netherlands; (6) Dipartimento di Fisica e Astronomia, Padova University, Padova, Italy.


## Abstract


The HyperScout-H (HSH) instrument will fly onboard on ESA/Hera spacecraft. This is a planetary defence mission which aims to provide detailed characterization of the (65803) Didymos near-Earth binary asteroid after the DART mission impact.

To prepare the data analysis which will be provided by this instrument we made a sets of simulations presented here. They allowed to imagine various test case for estimating the composition, the phase angle and the space-weathering effects and the possible presence of exogenous material. As input we are using the images provided by the Asteroid Multi-band Imaging Camera (AMICA) for the asteroid (25143) Itokawa.


## Introduction

The ESA/Hera planetary defence mission aims to provide detailed characterization of the (65803) Didymos near-Earth binary asteroid. The HyperScout-H (HSH) instrument, which will fly onboard on the spacecraft, will provide hyperspectral images over 665 - 975 nm wavelength range. The observations will allow to obtain compositional information regarding both asteroids, the main object Didymos and its moon, Dimorphos. Also, they will will complement the data obtained by the main camera (Asteroid Framing Camera) which are used for geomorphological studies. Furthermore, HSH will obtain images with high spatial resolution of the crater generated by the NASA DART impact.

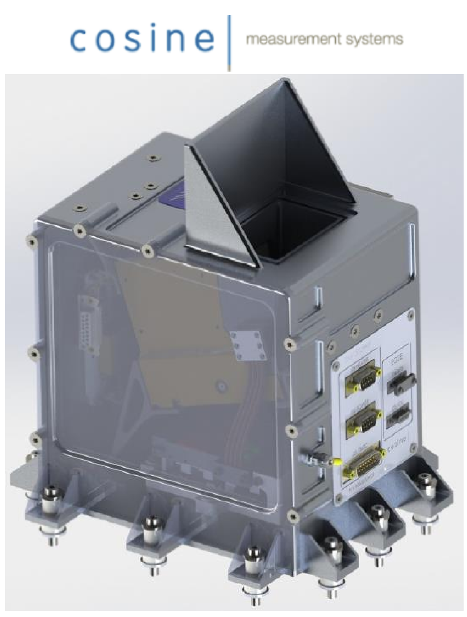
The measurements obtained by HSH instrument represent a key element for understanding the Didymos - Dimorphos system, its composition, the space-weathering effects and the possible presence of exogenous material. This presentation will provide an overview of the ongoing scientific activities, the instrument setup, and the expected results. We introduce the methods that can be used to analyze the data obtained by this instrument.

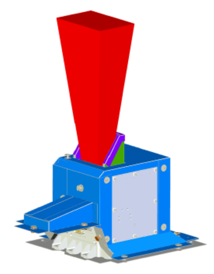
Our first step was to generate test cases by using the images provided by Hayabusa for Itokawa. They were obtained with different broad band filters which cover the HSH spectral interval. We expect similar composition and space-weathering patterns at the surface of Didymos and Dimorphos. Thus, we designed an algorithm to convert these exposures into images as they would have been observed by the HSH.

Second, we implemented a preliminary demosaicking algorithm of the HSH images in order to retrieve the spectra. Two approaches were tested, a basic one which takes into account the pixels position and their corresponding wavelengths, and another one based on the pattern recognition using neural networks.

## The instrument: HyperScout - H

- The HyperScout line of instruments is developed by cosine (https://www.cosine.nl/) and partners with support from the European Space Agency and the Netherlands Space Office.
- HyperScout® is a the first, full-fledged, miniaturized hyperspectral instrument dedicate to planetary missions.
- It has first been developed as an Earth Observation payload by a European consortium led by Cosine Measurement Systems.
- HyperScout is equipped with a 2D sensor and a filtering element for spectral separation.
- The HyperScout 2 platform offers to the HERA mission a versatile dual-use payload, able to generate valuable data products based on multi-spectral imagery.
- Hyperspectral imaging in the VNIR range of the asteroid is possible.



*The Hyperscout-H, provided by Cosine (NL)*

### Extending the concept → Hyperscout: the macro-pixel

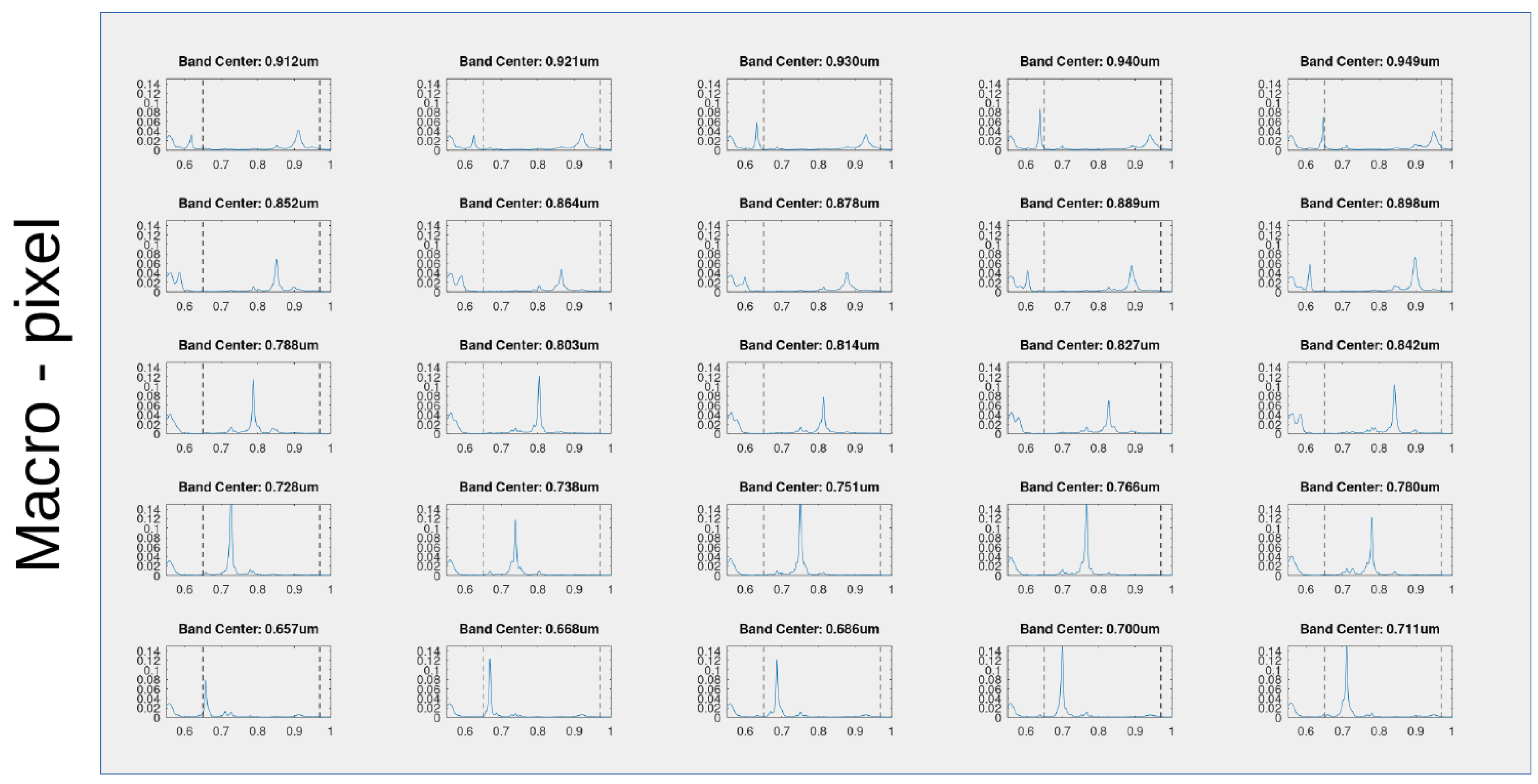



*Fig. 1 Example of macro-pixel configuration. Each sub-pixel represents a narrow band filter, with a specific central wavelength and optical transfer function .*

- Hyperspectral cameras are used by satellites for Earth observations (e.g. DijKstra et al. 2019). In order to recover information we must perform the demosaicking algorithm. We used to approaches: 1) simple reconstruction of the spectral pattern; 2) a neural-network demosaicking algorithm developed by ESA Advanced Concepts Team.

## Simulations

**A) Simple case: an homogeneous surface with a typical composition corresponding to an S-type spectrum (similar with Didymos – Dimorphos system):**

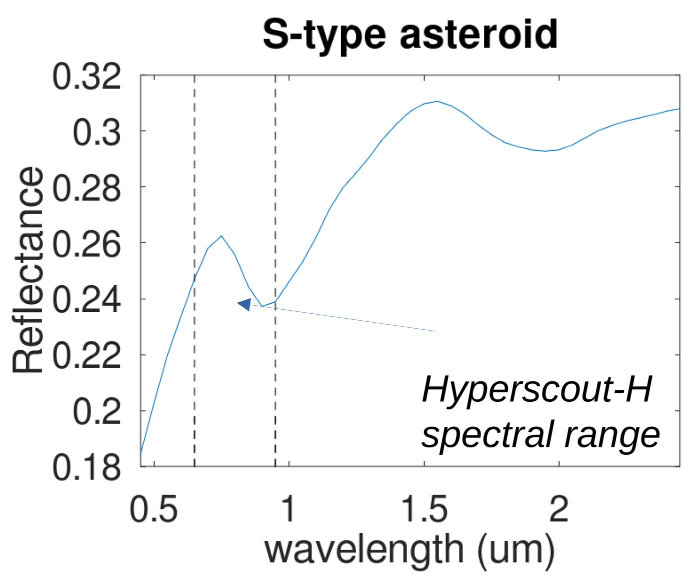



*Fig. 2 The wavelength interval covered by the HSH compared to a typical S-type spectrum .*

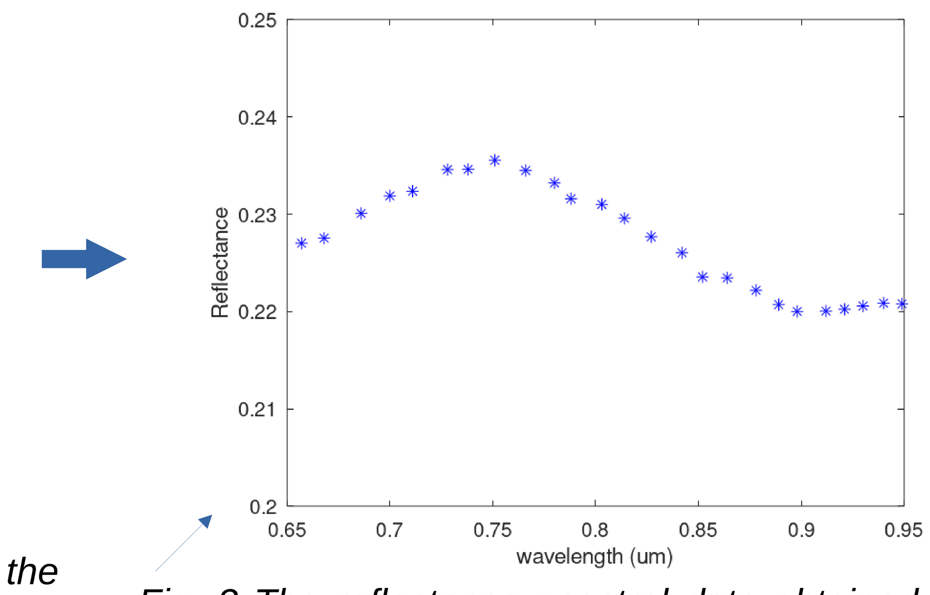



*Fig. 3 The reflectance spectral data obtained using the HSH after all calibrations are performed (accounting for solar flux, and for different filters profiles and transmittance).*

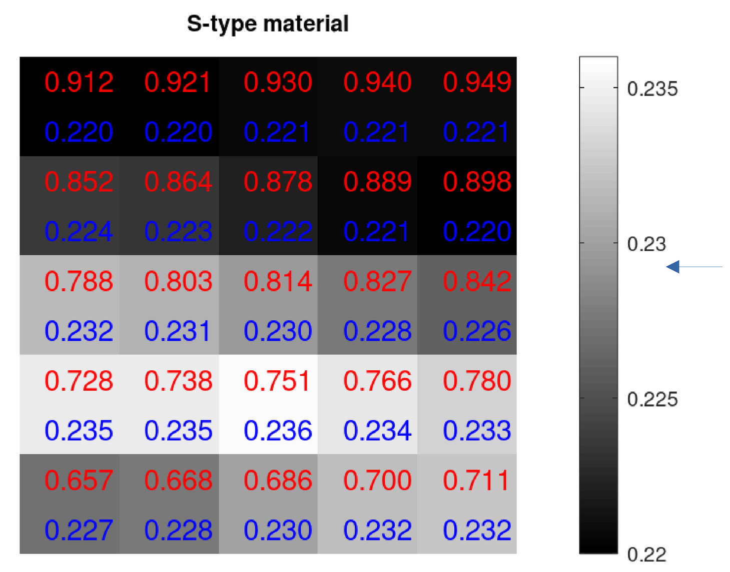



*Fig. 4 The macro-pixel. The red color shows the central wavelength corresponding to each pixel. The blue color shows the reflectance corresponding to this S-type material.*

**B) Simulations strategy:**

- 1) Select a set of images corresponding to an asteroid surface
- 2) For each pixel assume representing the surface reflectance assume a spectral function
- 3) Apply a HSH transfer function to the input in order to obtain the simulated image

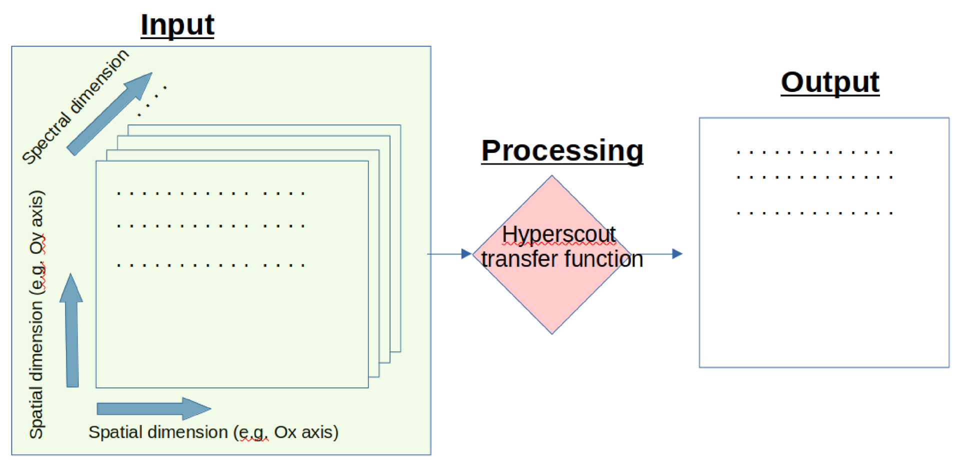



*Fig. 5 Simulations strategy schematic*

**C) Example using Bennu's surface:**

*Spectral assumptions:*

- If the reflectance is larger than 0.05, assuming a **basaltic material (V-type spectrum)**
- If the reflectance is between 0.015 and 0.05, assuming a **carbonaceous material (C-type spectrum)**
- If the reflectance is bellow 0.015, assuming a shadow (**flat spectrum**)

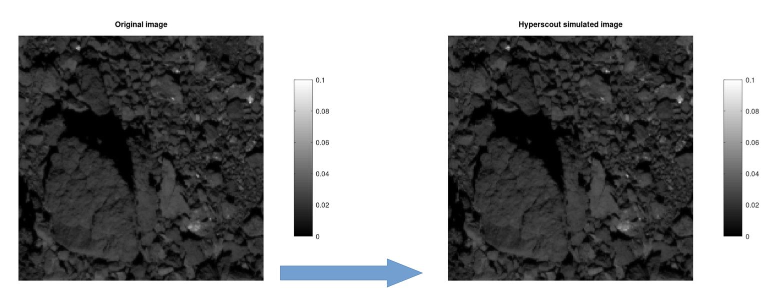


*Fig. 6 Converting an image of Bennu's surface obtained by MapCam instrument onboard of OSIRIS -Rex to a simulated one corresponding to HSH instrument.*

**C) Itokawa:**

- We are using the image sets of three (out of six) visible bands with central wavelengths of 0.700, 0.861, and 0.960 μm taken by the Asteroid Multi-band Imaging Camera (AMICA) (Saito et al., 2006; Ishiguro et al 2007, Ishiguro et al., 2010, Koga et al. 2018) onboard the Hayabusa spacecraft for asteroid (25143) Itokawa. We are linearly interpolating between these wavelengths.
- These sets of images were taken at a istance of of ~20 km from the asteroid mass center, and they cover the entire surface of Itokawa. The spatial resolution of the images used in this study is ~2 m/pixel (comparable with the expected one for HSH in the latest stages of the mission).
- (25143) Itokawa is an S-type asteroid as Didymos - Dimorphos system. We expect to find similar features.

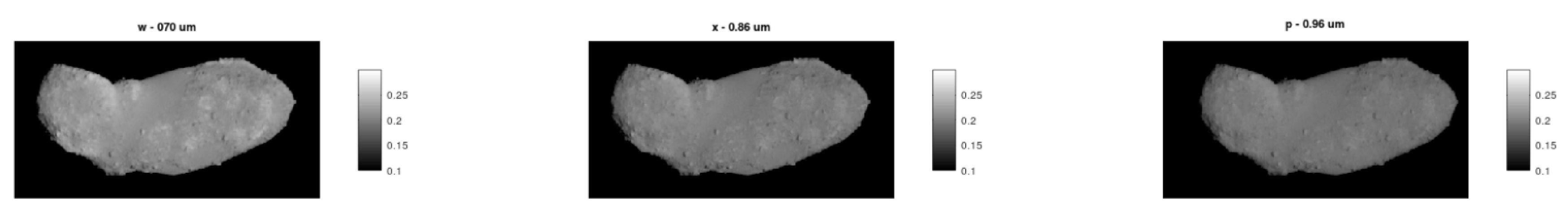
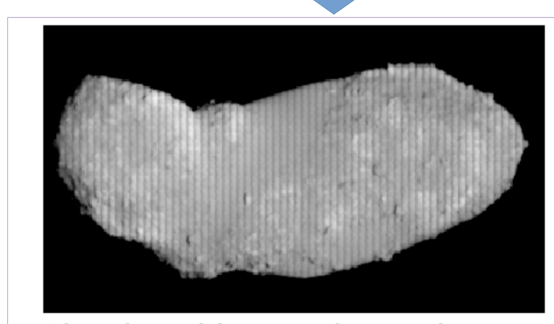
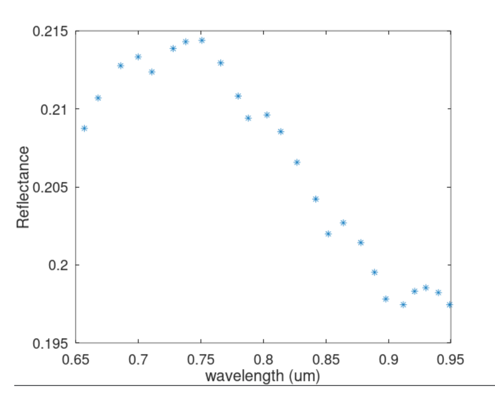



*Fig. 7 The images of the surface of (25143) Itokawa obtained by AMICA instrument using the optical filters w (centered at 0.700 um), x (at 0.861 um), and p at 0.960 um. Credit Saito et al., 2006; Ishiguro et al 2007, Ishiguro et al., 2010, Koga et al. 2018.*

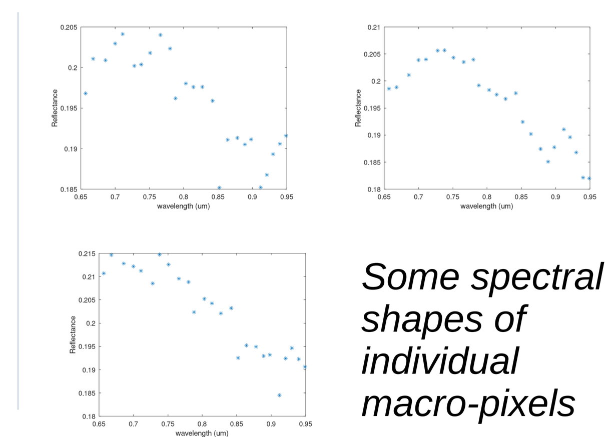
HSH transfer function



*Simulated image for Itokawa corresponidng to HSH instrument*




*Average derived spectrum*



*Some spectral shapes of individual macro-pixels*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