# Replenishing the sparse data cubes from the near infrared spectral imager Hyperscout-H of the Hera mission

B. Grieger, J. de León, H. Goldberg, T. Kohout, G. Kovács, M. Küppers, B. V. Nagy, M. Popescu



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#### **Double Asteroid Redirection Test (DART)**

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Impacted Dimorphos on 26th September 2022



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Will inspect the Didymos system from late 2026.

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#### Hyperscout-H hyperspectral imager



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Conclusions

25 at one stroke — 25 images at 25 different wavelengths Well, not quite ...



#### ▶ The sensor has $2048 \times 1088$ pixels.

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 The sensor has 2048 × 1088 pixels.
These are grouped into macro pixels of 5 × 5 original pixels, Replenishing the sparse data cubes

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• The sensor has  $2048 \times 1088$  pixels.

These are grouped into macro pixels of 5 × 5 original pixels, which have 25 different center wavelengths from 657 to 949 nm Replenishing the sparse data cubes

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• The sensor has  $2048 \times 1088$  pixels.

These are grouped into macro pixels of 5 × 5 original pixels, which have 25 different center wavelengths from 657 to 949 nm dubbed F1–F25. Replenishing the sparse data cubes

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• The sensor has  $2048 \times 1088$  pixels.

- These are grouped into macro pixels of 5 × 5 original pixels, which have 25 different center wavelengths from 657 to 949 nm dubbed F1-F25.
- Only <sup>1</sup>/<sub>25</sub> of the full 2048 × 1088 × 25 cube pixels are populated, i. e., 4 %.

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## Monochromator image ( $25 \times 25$ pixels cut out)



The monochromator emits light at 700 nm (and – almost – nothing else). Replenishing the sparse data cubes

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Simulated cube

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Reconstructed image planes

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## Monochromator image ( $25 \times 25$ pixels cut out)



- The monochromator emits light at 700 nm (and – almost – nothing else).
- This wavelength is picked up by F4

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## Monochromator image $(25 \times 25 \text{ pixels cut out})$



- The monochromator emits light at 700 nm (and – almost – nothing else).
- This wavelength is picked up by F4 and somewhat by its neighbors F3 and F5.

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## Monochromator image $(25 \times 25 \text{ pixels cut out})$



- The monochromator emits light at 700 nm (and – almost – nothing else).
- This wavelength is picked up by F4 and somewhat by its neighbors F3 and F5.
- ► For later reference, marks F17.

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## Monochromator image (150×150 pixels)





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## Monochromator image (150×150 pixels)



#### ► F4 replenished image

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## Monochromator image (150×150 pixels)



#### ► F17 replenished image

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#### Monochromator image and spectra



#### ► F4 replenished image

- We look at spectra from the replenished cube at 
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- which are in F17 pixels.

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#### Monochromator image and spectra



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## Simulated cube (F1, 450×450 pixels cut out)



 Easy case: spectrum is the same everywhere.

But there are brightness variations, mostly due to shading. Replenishing the sparse data cubes

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## Simulated cube (F1, $25 \times 25$ pixels cut out)



- Easy case: spectrum is the same everywhere.
- But there are brightness variations, mostly due to shading.

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#### Simulated cube (F1, $25 \times 25$ pixels cut out)



• smooth brightness

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#### Simulated cube (F1, $25 \times 25$ pixels cut out)



<sup>•</sup> uneven brightness

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## The de2 approach 🛄



We only have a single measurement  $f'(i, j, k_{i,j})$  at each spatial pixel (i, j).

- **•** Separate the normalized spectrum  $\hat{f}(i, j, k)$  and the brightness scaling factor b(i, j), so that the retrieved spectrum is  $f(i, j, k) = b(i, j) \hat{f}(i, j, k)$ .
- ▶ We use only *ratios* of measured values from two adjacent pixels, e.g.,  $f'(i,j,k_{i,i})$  $f'(i,i+1,k_{i,i+1})$ .
- **•** This allows to compute  $\hat{f}(i, j, k_{i,i})$  from its nearest neighbors:

$$\hat{f}(i,j,k_{i,j}) = rac{1}{4} \hat{f}(i,j+1,k_{i,j+1}) \, rac{f'(i,j,k_{i,j})}{f'(i,j+1,k_{i,j+1})} + \cdots$$

▶ To compute  $\hat{f}(i, j, k)$  for  $k \neq k_{i,j}$ , we assume that  $\hat{f}$  is spatially smooth:

$$\hat{f}(i,j,k_{i,j}) = \frac{1}{4} \hat{f}(i,j+1,k_{i,j}) + \cdots$$

▶ When  $\hat{f}$  has converged, we set  $b(i,j) = \frac{f'(i,j,k_{i,j})}{\hat{f}(i,j,k_{i,j})}$ 

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## The de2 approach



We only have a single measurement  $f'(i, j, k_{i,j})$  at each spatial pixel (i, j).

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- ▶ We use only *ratios* of measured values from two adjacent pixels, e.g.,  $f'(i,j,k_{i,i})$  $f'(i,i+1,k_{i,i+1})$ .
- **•** This allows to compute  $\hat{f}(i, j, k_{i,i})$  from its nearest neighbors:

$$\hat{f}(i,j,k_{i,j}) = \frac{1}{4} \hat{f}(i,j+1,k_{i,j+1}) \frac{f'(i,j,k_{i,j})}{f'(i,j+1,k_{i,j+1})} + \cdots$$

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## Direct replenishing (nearest micro pixel)

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#### Conclusions



- We have replenished a simulated data cube with the simple direct approach and with our homegrown approach de2.
- Both approaches have problems with strong spatial gradients in the (normalized) spectrum.
- de2 is much better than the direct approach in dealing with strong spatial brightness gradients.
- We will do more tests with more realistic test data and also try other approaches.

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