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Automatic detection of solar phenomena using high-resolution GREGOR images

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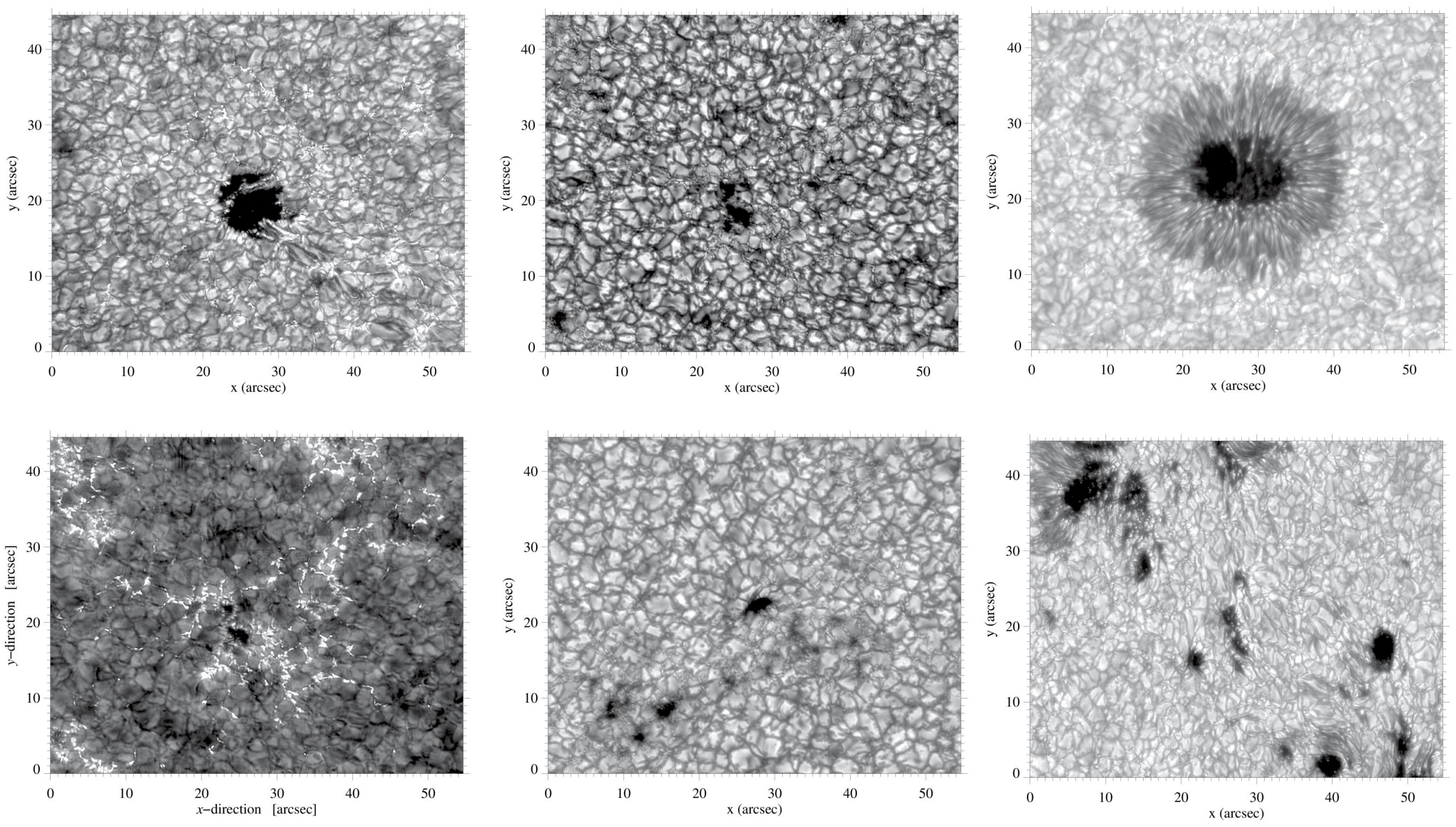
Abstract

The 1.5-meter GREGOR[1] telescope, Europe's largest solar telescope located on the island of Tenerife (Spain), produces a huge amount of data with its three main instruments. In particular, the High-Resolution Fast Imager (HiFI) can acquire up to 4 TB of images per day. The instrument is in operation since 2016 and comprises two synchronized cameras with 2560 × 2160 pixels each. The achieved frame rates are up to 50 Hz. Only the reduced data are archived at the Leibniz Institute for Astrophysics Potsdam (AIP) and are publicly available after one year (or two years for PhDs). In the past three years, data were recorded on 82 days, producing a total amount of about 30,000 files and 6 million images. The images were acquired with different filters, thus different structures such as granulation, sunspots, pores, and small bright points can be identified on the Sun. This wealth of data is well suited for **automatic classifi-cation and image identification** algorithms. As part of the Horizon 2020 project "SOLARNET", we will explore this data archive for identification of solar phenomena using convolutional neural networks (CNNs) or other deep learning algorithms. The goal is to create a toolkit for object identification, which can be applied to any type of high-resolution solar images.

Examples of observations with HiFI at GREGOR



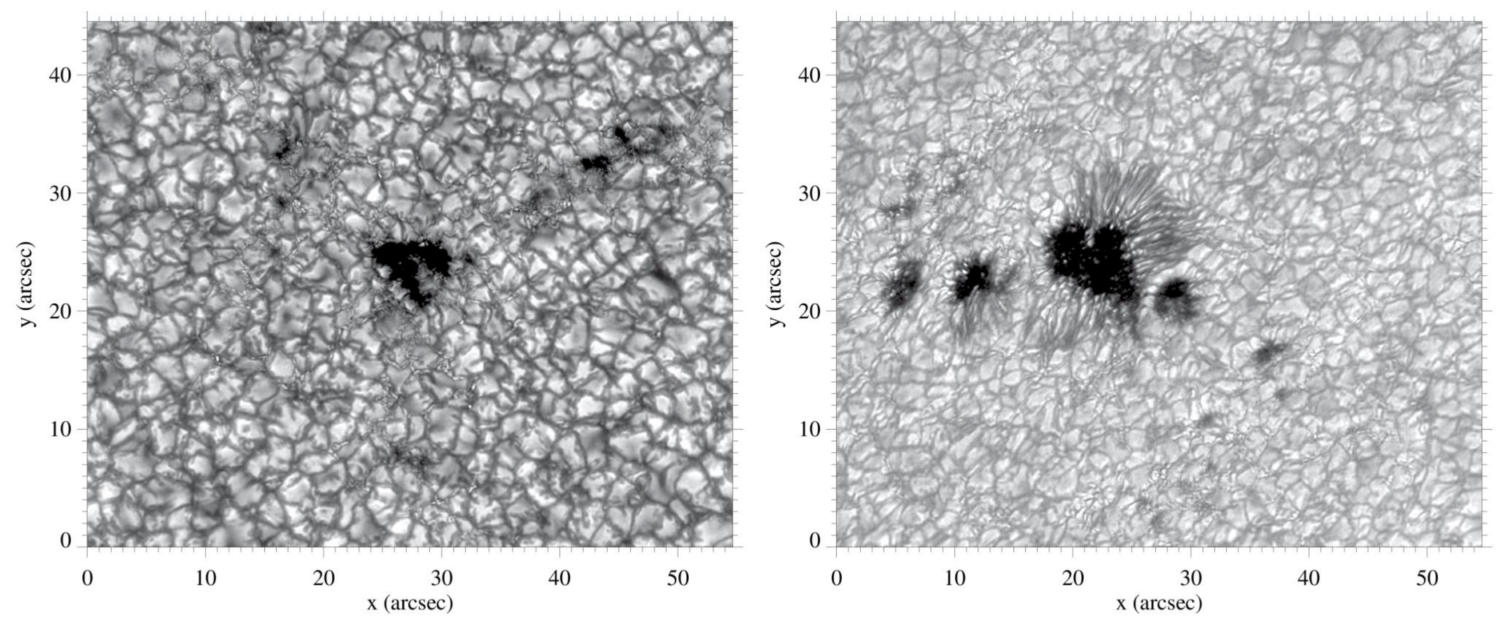


***Figure 1**: Examples of filtergrams taken with HiFI at various positions across the solar disk between the years 2016–2018. The used filters were Ca II H (3968 Å), G-band (4307 Å), and blue continuum at 4505 Å. The images were Speckle-restored using KISIP[2]. The goal is to automatically identify dark or bright objects, such as pores, sunspots, and magnetic bright points in these images.*

Small-Scale Object Detection

Photospheric bright points (BPs) are the smallest observable manifestations of the magnetic field on the solar surface. Their average size is on the order of 0.35″.

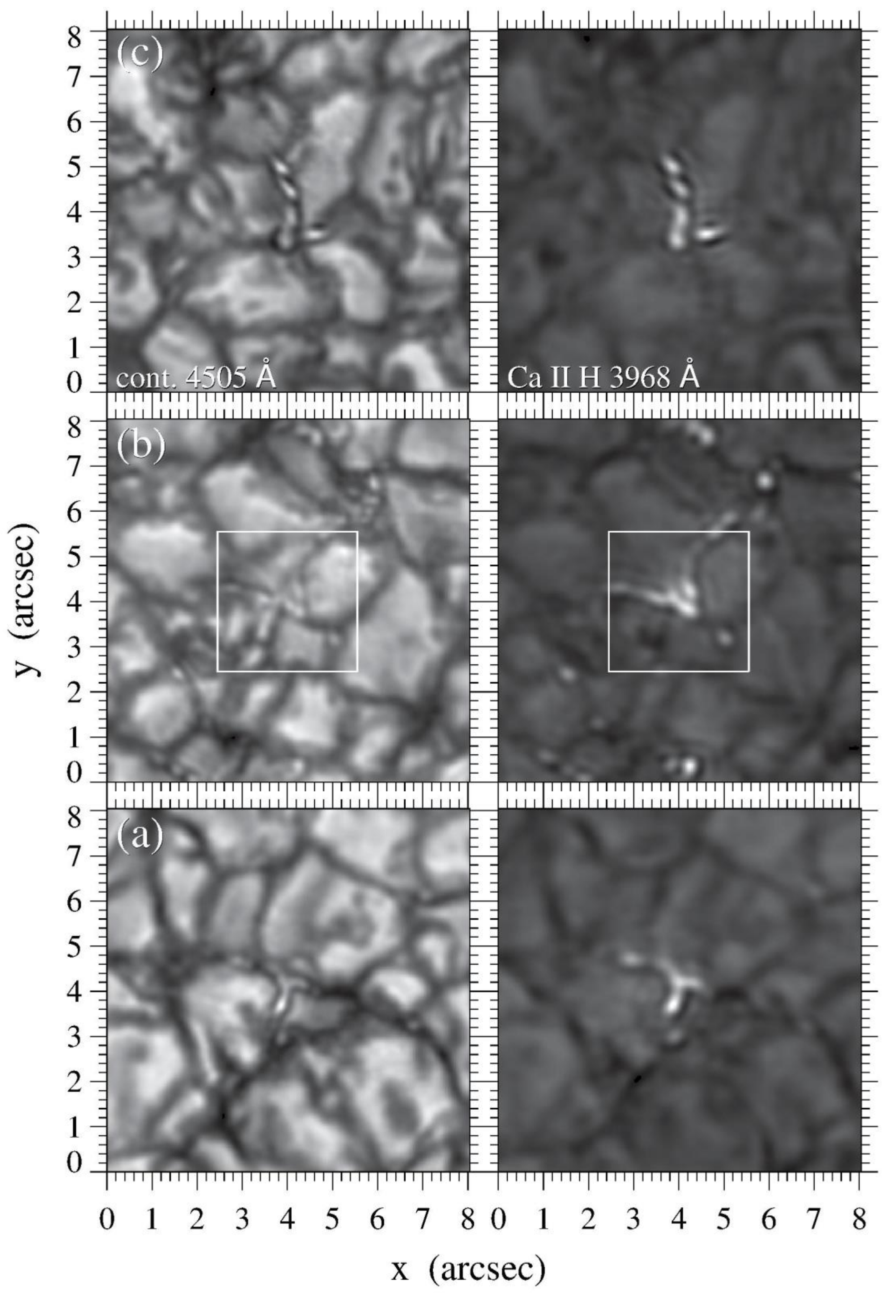


***Figure 2**: Example of small-scale objects, observed with two different filters, to detect in high-resolution solar observations.*

Object Identification – Machine Learning Approach

We intend to extract the positions of several solar objects using supervised machine learning. Therefore we have to create a training data set where we label all the solar objects which we want to identify. An example of a few data sets is shown in Fig. 1 and the input bounding boxes are shown in Fig. 3. As input, we give the central coordinates of each bounding box and its width and height (Fig. 4). As a proof of concept, we tested the machine learning algorithm YOLOv3 (Redmon & Farhadi[3]) on solar full-disk data (see poster B16, Diercke et al.). The algorithm is a single shot object detector and uses a region-based convolutional neural network (CNN) with 53 convolutional layers. The first results from the full-disk data indicate the feasibility of the endeavor but also point out some issues. It is important to have enough training data, which in the case of HiFI images should be fulfilled. Even more important is that detecting small-scale objects (Fig. 2) in large grayscale images appears to be challenging. Further work in the field was carried out by Pang et al.[4], who used remote sensing region-based ($\mathcal{R}^2$)-CNN to detect tiny objects sufficiently. A successfully trained machine learning algorithm will enable a large-scale searchable archive.

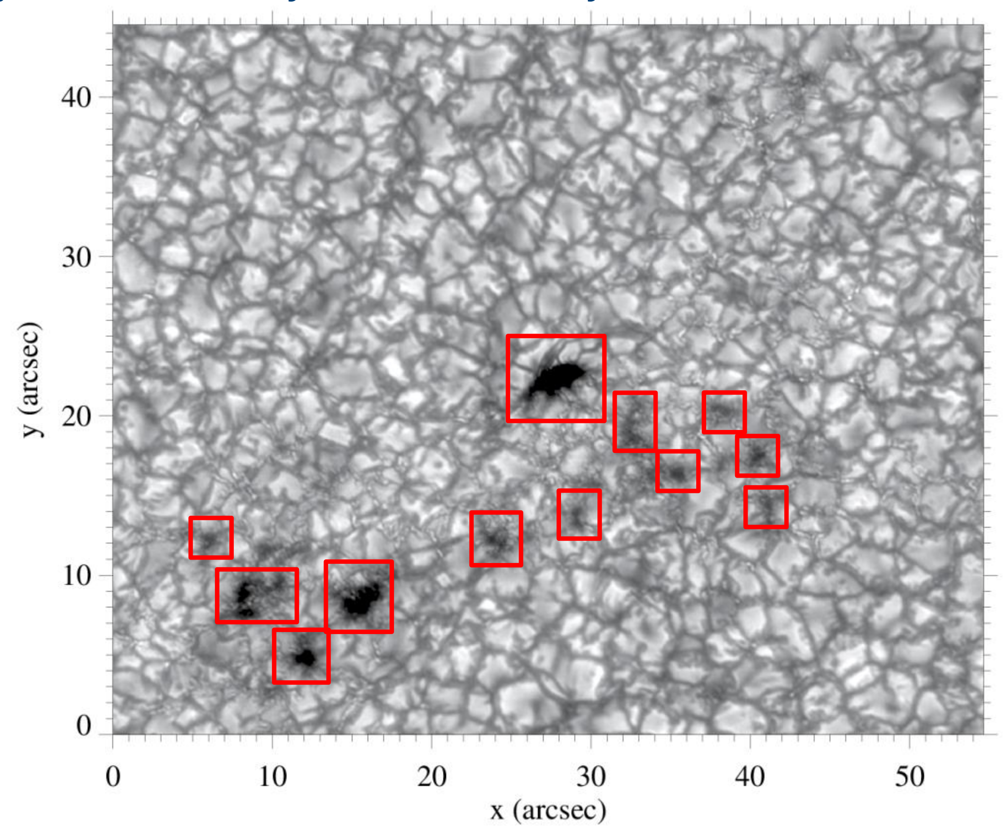


***Figure 3**: Example of selected bounding boxes for the machine learning algorithm as a training and test set.*

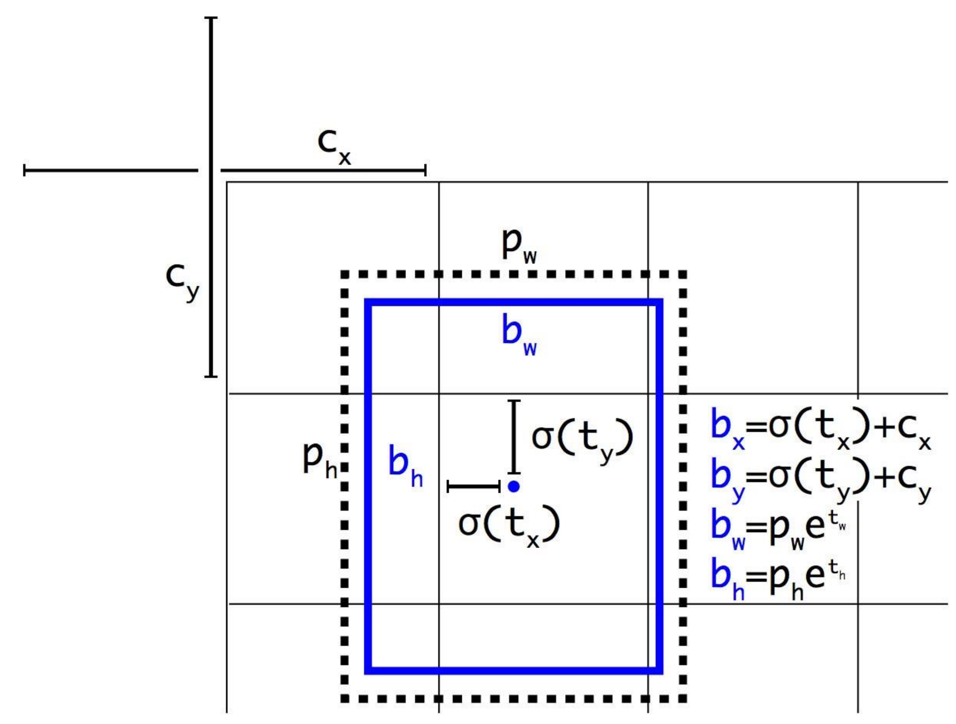


***Figure 4**: Bounding boxes with dimension priors and location prediction. t_x and t_y are the center coordinates of the predicted bounding box with width and height t_w and t_h. Image taken from Redmon & Farhadi[3].*

References

[1]Schmidt et al., *AN*, Vol. 333 (9), p. 796, 2012
[2]Wöger & von der Lühe, *SPIE*, Vol. 7019, id. 70191E, 2008
[3]Redmon & Farhadi 2018, arXiv:1804.02767
[4]Pang et al. 2019, IEEE Transactions on Geoscience and Remote Sensing

The 1.5-meter GREGOR solar telescope was built by a German consortium under the leadership of the Leibniz-Institut für Sonnenphysik (KIS) in Freiburg with the Leibniz-Institut für Astrophysik Potsdam (AIP), the Institut für Astrophysik Göttingen, and the Max-Planck-Institut für Sonnensystemforschung in Göttingen as partners, and with contributions by the Instituto de Astrofísica de Canarias and the Astronomical Institute of the Academy of Sciences of the Czech Republic. SJGM acknowledge the support of the project VEGA 2/0004/16.