SBNAF, 1st periodic report, part A

The summary for publication should be written as a "stand-alone" text, in a language easily understandable by a broader public and must not contain any confidential data

I.

Summary of the context and overall objectives of the project
This section should include information on:

- *What is the problem/issue being addressed?*
- *Why is it important for society?*
- *What are the overall objectives?*

SBNAF, a Horizon2020-funded benchmark study (2016-2019), addresses critical points in reconstructing physical and thermal properties of small bodies throughout the Solar System. Our target list comprises recent near-Earth and main-belt interplanetary mission targets, main-belt objects (the Gaia "mass/perturber" & "asteroid calibrators" samples), representatives of the Trojan and Centaur populations, and all known dwarf planets and candidates beyond Neptune. The combination of the visual and thermal data from the ground and from space observatories (e.g. Herschel, Spitzer, Kepler-K2, Hubble, and AKARI) is crucial to get full information of the selected bodies and to advance our scientific understanding based on several methods: lightcurve inversion, stellar occultations, thermo-physical modelling, radiometric methods, radar ranging and adaptive optics imaging. We derive their size, spin and shape, thermal inertia, surface roughness, and in some cases even internal structure and composition. By comparing with ground-truth information of targets of interplanetary missions Hayabusa, NEAR-Shoemaker, Rosetta, and DAWN, we can identify limitations in each method and advance the techniques beyond the current state of the art. The development of new tools is crucial for the interpretation of much larger data sets from WISE, Gaia, JWST, or NEOShield-2, and for the operations and scientific exploitation of the Hayabusa-2 mission.
Another important aim is to build accurate thermo-physical asteroid models to establish new primary and secondary celestial calibrators for submm/mm projects like ALMA, SOFIA, APEX, and IRAM, and to provide a link to the high-quality calibration standards of Herschel and Planck.

II.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

This reporting period spans two phases described in the Grant Agreement Section 1.3.2 under points "(a) Early phase (months M01 to M06)" and "(b) Synergy phase (months M07 to M30)". During the early phase, we exploited the existing data and modelling techniques in a classical way, and the bulk of the work was conducted in WP2, WP3, WP4, and WP5. It then shifted to the first half-year of the 2-year-long synergy phase (related deliverables within WP6), in which we combine available data from space and ground, plus remote disk-integrated observations and in-situ observations, and started the development of new techniques, tools and methods that are directly tested and validated against our targets where ground-truth is available from interplanetary missions and direct measurements. The main results so far are manifold and can be seen in more detail on our public web page (see below). Here we enumerate the most important points:

Tools & Services
(1) The public ISAM service (AMU/Poznań) allows the user to display asteroid shapes orientations at any epoch, to generate lightcurves, 3D views and animations and projected silhouettes to conduct shape, illumination- and viewing-related analyses. It is connected to the public deliverable D3.2.
(2) The Gaia-GOSA service (AMU/Poznań) is an interactive tool to support observers in planning photometric observations of asteroids. It uses input from the Gaia orbit and scanning law provided by the ESA and the Minor Planet Center's Solar System bodies' ephemerides service. Deliverable D3.1 is related to this service.
(3) A first working version of the IR database was already set up at Konkoly Observatory even though the connected deliverables D2.5 and D2.6 are planned for upcoming stages.

Products for the planetary community
(4) High-quality predictions for occultation events for 2016 and 2017 (D5.1 and D5.2) produced at IAA/Granada allow amateur and professional astronomers to observe these scientifically important events, key for our benchmarking goals in WP6.
(5) High-quality data products of small body observations by the Herschel Space Observatory based on sophisticated, solar-system specific reduction and calibration schemes (documented in deliverables D2.1, D2.2, D2.3). We delivered these products to the Herschel Science Center to be uploaded to the Herschel Science Archive as "User-Provided Data Products". The lead for the generation of these products is at Konkoly Observatory.
(6) Highly reliable model predictions at mid-IR, far-IR, submm/mm wavelengths of selected asteroids were provided as support for worldwide calibration activities of ground-, airborne-, and space-projects. They are publicly available via the SBNAF public web page and documented in WP4 deliverables D4.1, D4.2, D4.3, and D4.6. Activities are led at MPE/Garching.
(7) The public deliverables of WP6, co-lead by AMU/Poznań and MPE/Garching, are also available on our public page under "Results & Synergies".

We are proud to mention that the scientific outcome of our first year's work has been published in refereed journals. We counted 17 published refereed publications and 8 submissions that are directly related to SBNAF or have significant SBNAF individual/team contributions. All accepted publications are available in open access (astro-ph archive), and have the EU project-related acknowledgement (except the very earliest ones). Many have been presented in international conferences and workshops, the most important of which was the DPS2016 (11 contributions). We counted 14 publically available SBNAF-related abstracts for posters and talks, and approximately about 25 additional workshop/conference contributions.
The SBNAF team is very often involved in outreach events and activities and produces a wide range of outreach and educational material for the public. The most important science results are also connected to press releases (see public web page).

III.
Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

Our benchmark objects have often ground-truth information from interplanetary missions. This kind of ground-truth information is unique in astronomy and leads to wide applications for objects without ground-truth information relevant to various projects in the planetary community outside SBNAF. It helps us to investigate limitations of current modelling techniques, to refine them beyond the state of the art, and to provide strategies for optimized observing campaigns at visual and thermal wavelengths.

The socio-economic impact in the short term is difficult to quantify, but our tools and scientific results will surely contribute to the Basic Science demanded by the growing focus of Industry on mining asteroids and in-situ resource utilisation. The SBNAF results are immediately available to the astronomical community and to many amateur astronomers. Thanks to the occultation predictions and Gaia-GOSA services, amateur observers are providing substantial support for our project and spurring interest on our small-body studies among the general public. Along with other public outreach activities, this helps to broaden society's appreciation of our field, which is often reduced to the "impact hazard" question, and of astronomy and science in general. For example, our work is also scientifically relevant to profound problems such as the formation and evolution of our Solar System or the delivery of water and complex organic molecules to Earth.

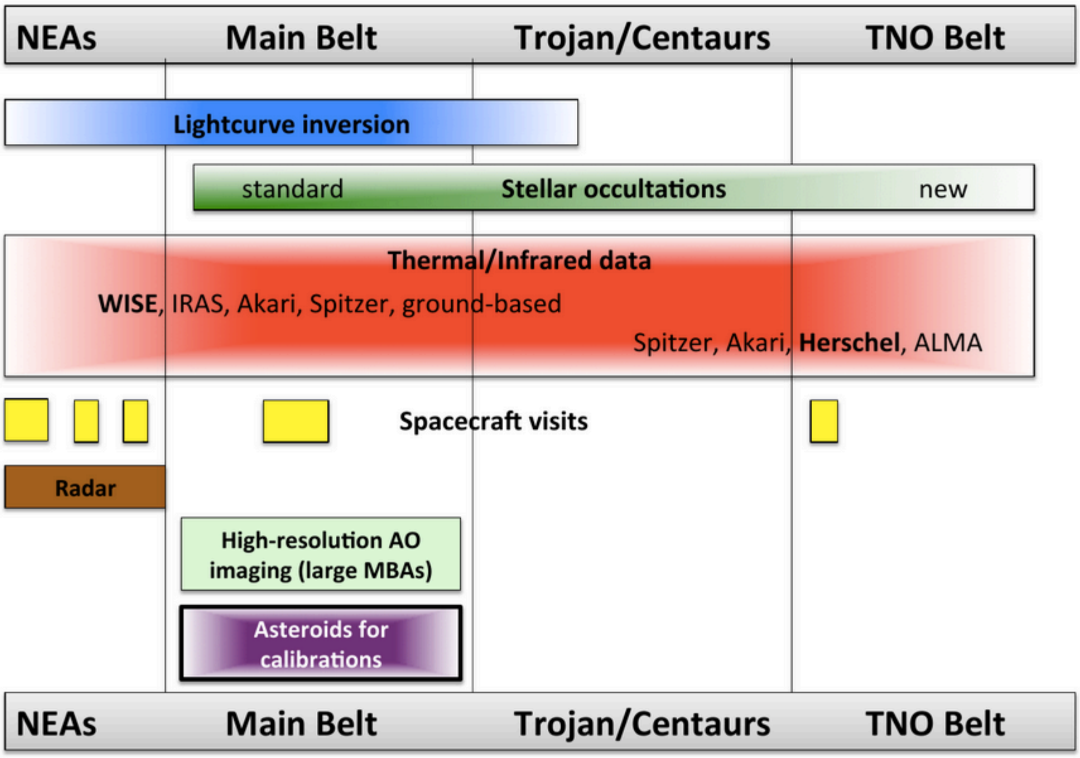
IV.

Address (URL) of the project's public website

http://www.mpe.mpg.de/~tmueller/sbnaf/

Images attached to the Summary for publication

- *Image Name:* SBNAF_ObjectsMethods.png
- *Image Description:* Overview of the different techniques applied to minor bodies at different distances from the Sun. The range where a given technique can be used is very restricted, making the reconstruction of object properties more complex and strongly dependent on the availability of suitable data.
- *Actions:* none



DELIVERABLES: automatically done from the entries in the EU portal.

MILESTONES:

1. Kick-off, MPG, 01-May-2016
   → Kick-off meeting took place at IAA/Granada: Apr 13-15, 2016; minutes are available on SBNAF internal webpage.
2. Benchmark study, UAM, 01 Apr 2017
   → The entire SBNAF project is a "benchmark study" which means that work in this field will continue for the next two years. However, we have developed several key elements relevant for this milestone: (i) a new approach to give errors for shape solutions and to visualize good and bad parts of the shape solution; (ii) visibility maps to illustrate the surface coverage related to the available data; (iii) recipes to test spin/shape solutions (occultations, radar, radiometry, AO imaging, in-situ properties); (iv) deliverables D6.2, D6.3, D6.5, with conducted work on ground-truth objects Eros, Itokawa, Hebe, and Lutetia, and ongoing work on Ryugu, Bennu, Ceres, and Vesta. There are also several publications related to MS02 (see also list of publications):
   - Shape Models and Physical Properties of Asteroids, by Santana-Ros et al. 2017
   - 3-D shape of asteroid (6) Hebe from VLT/SPHERE imaging: Implications for the origin of ordinary H chondrites, Marsset et al., A&A, submitted
   - Shaping Asteroids with Generic Evolution (SAGE), Bartczak & Dudzinski, MNRAS, submitted
   - Statistical analysis of the ambiguities in the asteroid period determination, Butkiewicz-Bąk et al., MNRAS, submitted

- Photometric survey, modelling, and scaling of long-period and low-amplitude asteroids, Marciniak et al., in preparation

And several contributions to the ACM2017 conference:

- Shape uncertainty of asteroid models from inversion techniques
- Debiasing asteroid spins and shapes - observations, modeling, and validation
- Asteroid shape reconstruction from radar echo images

We also organized a full session on "Small bodies near and far" in the upcoming EPSC2017 conference in Riga/Latvia in September 2017.

RISKS

1. **Loss of key personnel**; Probability: L, Severity: H 1, 2, 3 ... The WP leaders will take early actions to ensure that critical information and knowledge is shared within the WP staff.
2. **Timely recruitment**; Probability: L, Severity: M 1, 2, 3 ... All participants have broad pools and networks of highly qualified young students which will facilitate the recruitment process at the involved universities and renowned institutes.
3. **Problems in handling the large amount of infrared data from multiple sources from space and ground**; Probability: L, Severity: M 2 Setting of priorities in the handling of space data: highest priority Herschel, Planck, Akari observations; lower priority for other sources.
4. **Failure of non-convex inversion techniques**; Probability: M, Severity: M 3 Going back to validated convex lightcurve inversion techniques.
5. **Problems in finding unique shape and spin-axis solutions for objects without ground-truth information**; Probability: M, Severity: L 3, 6 Attempt to obtain very high quality photometric measurements, and thermal measurements if needed, to improve model solutions; requests to the planetary (and amateur) community for support in observations.
6. **Problems in merging very different observing techniques in single inversion tools**; Probability: M, Severity: M 3, 6 Development of independent tools for each observing technique in question; manual merging/adjustment of solutions only at the end of the process (semi-automatic handling of different information sources).
7. **Low quality of calibration products at submm/mm where the asteroid emission is not well characterised**; Probability: M, Severity: H 4 Elimination of specific asteroids for submm/mm calibration; establishment of extensive observing programmes at submm/mm facilities for model refinement and validation.
8. **Missing ground-truth information for several targets**; Probability: L, Severity: M 4, 6 Attempt to obtain highest quality information from ground and airborne observations for partial compensation; assignment of quality code for the deliverables and the final model solutions.
9. **Problems with observations (rejection of proposal, weather conditions, technical problems)**; Probability: M, Severity: M 5 Re-submission of proposal, attempt to obtain data on institute-owned small telescope; attempt to broaden telescope networks.

10. **Failure in matching results from remote observations with ground truth data from in-situ measurements**; Probability: M, Severity: M 6 Modifications will be required in the inversion tools and techniques, as well as in radiometric techniques. Depending on the complexity of the problem, it might be needed to include external experts for specific aspects (e.g., to fully integrate information from radar measurements)

Risk State of Play:

- *Reference Reporting Period:* 1
- *Did you apply the risk-mitigation measure?* No, it was not necessary so far.
- *Did the risk materialize?* No.
- *Please add here your comments:* No comments.
- *If the risk-mitigation measures couldn't be applied, please explain why:* No comments
- *Unforeseen Risks*: Nothing has changed with respect to the risk description in the Grant Agreement.

PUBLICATIONS

No, Type, Title, Authors, Title of the Journal/Proc./Book, Date of Acceptance, DO, Repository Link, Actions

The SBNAF project and the results of our work (and SBNAF contributions to other projects) are published in open access journals or on arXiv (Astrophysics).
Publication dates up to 03/2017.

2016 (SBNAF work or major SBNAF contribution; SBNAF acknowledgement):

1. ADDED!!! 11/2016: Uninterrupted optical light curves of main-belt asteroids from the K2 Mission, Szabó, R.; Pál, A.; Sárneczky, K.; Szabó, Gy. M.; Molnár, L.; Kiss, L. L.; Hanyecz, O.; Plachy, E.; Kiss, Cs., 2016, A&A 596, 40, arXiv:1609.02759, DOI: 10.1051/0004-6361/201629059
2. DONE!!! 12/2016: Results from the 2014 November 15th multi-chord stellar occultation by the TNO (229762) 2007 UK126, Benedetti-Rossi, G.; Sicardy, B.; Buie, M. W.; Ortiz, J. L.; Vieira-Martins, R.; Keller, J. M.; Braga-Ribas, F.; Camargo, J. I. B.; Assafin, M.; Morales, N.; and 19 coauthors, 2016, AJ 152, 156; arXiv:1608.01030; DOI: 10.3847/0004-6256/152/6/156

2017 (SBNAF work or major SBNAF contribution; SBNAF acknowledgement):

3. ADDED!!! 00/2017: Shape Models and Physical Properties of Asteroids, Santana-Ros, T.; Dudziński, G.; Bartczak, P., 2017, Assessment and Mitigation of Asteroid Impact Hazards, Astrophysics and Space Science Proceedings, Volume 46. ISBN 978-3-319-46178-6. Springer International Publishing Switzerland, 2017, p. 55; arXiv: https://arxiv.org/abs/1705.05710; DOI: 10.1007/978-3-319-46179-3_4
4. ADDED!!!! 02/2017: The heart of the swarm: K2 photometry and rotational characteristics of 56 Jovian Trojan asteroids, Szabó, Gy. M.; Pál, A.; Kiss, Cs.; Kiss, L. L.; Molnár, L.; Hanyecz, O.; Plachy, E.; Sárneczky, K.; Szabó, R., 2017, A&A 599, 44; arXiv:1609.02760; DOI: 10.1051/0004-6361/201629401
5. ADDED!!! 02/2017: Spectral and rotational properties of near-Earth asteroid (162173) Ryugu, target of the Hayabusa2 sample return mission, Perna, D.; Barucci, M. A.; Ishiguro, M.; Alvarez-Candal, A.; Kuroda, D.; Yoshikawa,

M.; Kim, M.-J.; Fornasier, S.; Hasegawa, S.; Roh, D.-G.; Müller, T. G.; Kim, Y., 2017, A&A 599, L1; DOI: 10.1051/0004-6361/201630346

6. DONE!!! 02/2017: Large Halloween Asteroid at Lunar Distance, Müller, T. G.; Marciniak, A.; Butkiewicz-Bak, M.; Duffard, R.; Oszkiewicz, D.; Käufl, H. U.; Szakáts, R.; Santana-Ros, T.; Kiss, C.; Santos-Sanz, P., 2017, A&A 598, A63; arXiv:1610.08267; DOI: 10.1051/0004-6361/201629584
7. ADDED!!! 03/2017: Results from a triple chord stellar occultation and far-infrared photometry of the trans-Neptunian object (229762) 2007 UK126, Schindler, K.; Wolf, J.; Bardecker, J.; Olsen, A.; Müller, T.; Kiss, C.; Ortiz, J. L.; Braga-Ribas, F.; Camargo, J. I. B.; Herald, D.; Krabbe, A., 2017, A&A 600, A12; arXiv:1611.02798; DOI: 10.1051/0004-6361/201628620
8. DONE!!! 03/2017: Discovery of a satellite of the large trans-Neptunian object (225088) 2007 OR_{10}, Kiss, Csaba; Marton, Gábor; Farkas-Takács, Anikó; Stansberry, John; Müller, Thomas; Vinkó, József; Balog, Zoltán; Ortiz, Jose-Luis; Pál, András, 2017, ApJL 838, L1; arXiv:1703.01407; DOI: 10.3847/2041-8213/aa6484
9. 03/2017: Hayabusa-2 Mission Target Asteroid 162173 Ryugu (1999 JU_3): Searching for the Object's Spin-Axis Orientation, Müller, T. G.; Durech, J.; Ishiguro, M.; Mueller, M.; Krühler, T.; Yang, H.; Kim, M.-J.; O'Rourke, L.; Usui, F.; Kiss, C.; and 20 coauthors, 2017, A&A 599, A103; arXiv:1611.05625; DOI: 10.1051/0004-6361/201629134

Dissemination/Communication

Not clear if we have (or can) enter anything here, but this is included in part B.
I contacted Rémy to ask him about this topic. Probably nothing has to be given.

Specify the total funding amount used for Dissemination and Communication activities linked to the project
Total Funding Amount: 0.00
Specify the number of Dissemination and Communication activities linked to the project for each of the following categories
Organisation of a Conference: 0
Organisation of a Workshop: 0
Press release: 0
Non-scientific and non-peer-reviewed publication (popularised publication): 0
Exhibition: 0
Flyer: 0
Training: 0
Social Media: 0
Website: 0
Communication Campaign (e.g. Radio, TV): 0
Participation to a Conference: 0
Participation to a Workshop: 0
Participation to an Event other than a Conference or a Workshop: 0
Video/Film: 0
Brokerage Event: 0

Pitch Event: 0
Trade Fair: 0
Participation in activities organized jointly with other H2020 projects: 0
Other: 0

Specify the estimated number of persons reached, in the context of all dissemination and communication activities, in each of the following categories

- Scientific Community (Higher Education, Research): 0
- Industry: 0
- Civil Society: 0
- General Public: 0
- Policy Makers: 0
- Media: 0
- Investors: 0
- Customers: 0
- Other: 0

Patents (IPR)
Not applicable

Innovation
Not applicable

Gender
AMU: Female: AM, MBB, DO; Male: PB, GD, TSR
MPE: Female: ---; Male: TM, VAL
Konkoly: Female: EVV, ATF; Male: CK, GM, RS
IAA: Female: EFV; Male: JLO, RD, PSS, NM