Istituto Nazionale di Astrofisica
OSSERVATORIO ASTRONOMICO
DI BRERA

Prot. n. 1299/2017

Titolo VI Classe 3

Milano, 10 OTT. 2017

Direzione Generale
Istituto Nazionale di Astrofisica
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Oggetto: richiesta di variazione di bilancio.

L'Osservatorio Astronomico di Brera, a seguito dell'approvazione della minuta del contratto n. 4000114410/15/NL/BW con ESA relativo al progetto "Silicon Pore Optics modelling and simulations" istituzionale (Responsabile Dr. Daniele Spiga), chiede l'autorizzazione alla variazione di bilancio relativa alla fase 2 pari a € 166.645,00 sulla funzione obiettivo 1.05.04.27 in entrata sul cap. 2.01.05.02.001 e in uscita sui capitoli

- 1.01.01.01.009 assegni di ricerca: € 40.000,00
- 1.03.02.02.001.01 missioni per la ricerca scientifica: € 10.000,00
- 1.03.02.99.999.01 altre spese di servizi per la ricerca scientifica: € 55.503,00
- 1.04.01.01.013.03 trasferimenti per progetti di ricerca partecipati: € 61.142,00 (al subcontraente DTU)

Cordiali saluti.

IL DIRETTORE
Dr. Gianpiero Taglaferri

Istituto Nazionale di Astrofisica
OSSERVATORIO ASTRONOMICO
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ESTEC, September 19th 2017

2nd YEAR REVIEW MEETING FOR THE ESA CONTRACT No. 4000114410/15/NL/BW "SILICON PORE OPTICS MODELLING AND SIMULATIONS" (SIMPOSiuM)

Participants:

INITIALS	NAME	DEPT.
BS	Brian SHORTT – project ESA technical officer	ESTEC
IF	Ivo FERREIRA	ESTEC
MB	Marcos BAVDAZ	ESTEC
TO	Tim OOSTERBROEK	ESTEC
DS	Daniele SPIGA – project principal investigator	INAF/OAB
GS	Giorgia SIRONI	INAF/OAB
GP	Gianpiero TAGLIAFERRI	INAF/OAB
DDMF	Desiree DELLA MONICA FERREIRA	DTU
FC	Finn CHRISTENSEN	DTU
AJ	Atefeh JAFARI	DTU
GV	Giuseppe VACANTI	Cosine

Location and time: ESA/ESTEC on September 19th 2017, from 14.00 to 18.00 approx.

DS presents an overview of the project describing the different WP activities and working procedures, along with a synopsis of the activities completed in the 2nd year of the project and the future actions to complete.

DS presents **TN-01: Geometry design of Silicon Pore Optics (OAB resp.).**

- Completed: development of an IDL code to individuate the geometrical parameters to optimally populate the optical module. The design is performed using the effective area as figure of merit, assuming a double cone configuration. Because of the short plates compared with the focal length, the approximation does not affect the effective area (EA) results. An alternative design with shorter plates to increase the off-axis area is discussed as an example of the code output. On-axis and off-axis effective area simulations are shown.
- Action items for OAB:
  - A1/O - Include angular resolution optimization adding polynomial design.
  - A2/O - Provide the design code with a Graphical User Interface (GUI) for easier use, generating a configuration file to feed the effective area simulator.

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A3/O - Include the constraint that the mirror module (MM) length be self-baffling to reduce the stray light.
A4/O - Include a limit to MM width referring to the MM feasibility.
A5/O - Update the simulations as per the reduced Rmax - number of rows as provided by ESA (see below).

- Actions items for Cosine:
  A1/C - Provide the exact maximum feasible width of MMs.
- Actions items for ESA:
  A1/E - Provide update of new telescope design with MM width information per row after analysis done by Cosine.

DDMF presents **TN-02: SPO ray-tracing simulations (DTU resp.)**

- Completed: DTU performed McXtrace simulations for a Wolter-I profile at pore level for the entire ATHENA mirror module assembly and at a single MM level. Possible variations (e.g., primary cone + secondary curvature) of the design can be easily implemented in McXtrace owing to the high modularity of the program. Design and coating are reported in the technical note. The simulation did not consider the reflectivity of the rib sidewalls, but it can be enabled in McXtrace easily. The simulations with individually misaligned Wolter-I mirror modules are shown, evidencing an excellent agreement with last years' results. ESA appreciates that the same results are confirmed via completely different codes and approaches. DTU also started to implement scattering effects using scattering diagrams computed by OAB from measured surface PSDs at selected energies and angles. An appropriate waviness profile is modelled and superposed to the nominal profile in order to reproduce – passing by geometric optics methods - the scattering distribution. Preliminary results are shown.
- Actions items for DTU:
  A1/D - Extend the simulation to the entire telescope structure.
  A2/D - Include scattering off the reflecting surfaces, comprising data from Cosine which should be available end of year.
  A3/D - DTU code shall also allow changing the alignment of the ribs (parallel vs converging).
  A4/D - Simulate alternative geometries coming from the design code.
  A5/D - Similar to TN-01, the generation of the config/setup files for McXtrace shall be included in a user-friendly GUI.

DS presents **TN-03: Ray-tracing of displaced SPO mirror modules (OAB resp.)**

- Completed: This year's activities have started the analysis of primary-secondary misalignments within individual MMs. The test case (an inner radius mirror module) was simulated by ray-tracing with ZEMAX. Sensitivity analysis of the focal spot displacement/broadening and effective area losses to the different species of misalignments is shown. Results of the analysis of primary-secondary misalignments are consistent with previous analyses done by ESA/Cosine and confirming required alignment accuracies.
- Action items for OAB:
  A6/O - Extend the simulation of to the entire mirror module assembly, assuming a statistical distribution for misalignments.
  A7/O - The simulation shall also allow the easy input of a displacement/rotational maps of the misalignments per MM. These maps can be generated by the structural/thermal FEM tools.

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DDMF presents **TN-04: SPO stray-light simulations (DTU resp.)**

- Completed: DTU implemented in McXtrace the stray light (SL) simulation at 1 keV and 6 keV, using the single pore of each MM in the ATHENA mirror assembly as a representative of the optical performances. The simulation returned the fraction of SL contamination at the optics exit or within the WFI detector area.
- Actions items for DTU:
  - A6/D - Extend the simulation to the whole telescope.
  - A7/D - Include possible misalignments and the scattering model being implemented in McXtrace.

DS presents **TN-05: modelling of SPO diffraction effects (OAB resp.)**

- Completed: The diffraction pattern computation in 1D geometry is complete. The rib modulation has been introduced in the computation, concluding that the simulations in 1D geometry can be performed using the usual Fresnel diffraction formulae, just renormalizing the PSF to the obstructed value of the effective area. The 2D code is more appropriate to perform the simulations in X-rays and UV for a single mirror module with the source at finite distance or infinity, aligned to the central pore or off-axis in pitch and yaw directions. The cases in -1/+1 wedge configuration and with variable rib thickness along the plate has been included. Simulations are compared with UV bench data in Media-Lario, showing an interesting agreement. Moreover, the focal spot centroid simulated in UV corresponds very well to the one simulated in X-rays. This is a very important aspect for alignment and assembly.
- Action items for OAB:
  - A8/O - Extend the simulation to a group of assembled MMs.
  - A9/O - As per Cosine's request, simulate in UV light the primary-to-secondary stack misalignment, as this would allow one to align and glue the MM in a UV facility rather than in the BESSY beam line.
  - A10/O - Endow the input/output part of the diffraction simulation program with a GUI interface (the computational core works better on a server, and in any case without graphical interface).

DS presents **TN-06: particle tracing and magnetic diverter assessment (OAB resp.)**

- Completed: A magnetic diverter (MD) design has been provided, following the Halbach array design. The performances have been tested using an IDL code that simulates the magnetic field of an assembly of magnetic bars and triangular wedges with variable orientation of the magnetic dipole moments. The Halbach array generates a strong magnetic field within the bore but approximately cancels out in the outer space. The residual magnetic field at the center of the focal plane would be well below the 1 G limit. Assuming a magnetic remanence of 1.3 T (typical of Neodymium magnets), the simulation shows a reduction of protons < 70 keV in the WFI area by an 11- to a 20-fold factor, considering different angular spreads of the proton beam out of the optics. The Halbach dimensions were set in order to avoid any X-ray beam obstruction within the ATHENA field of view. ESA suggests to use as input for the simulation an angular dispersion of the particles even larger than the 2 deg Gaussian rms (at every reflection) adopted initially, in order to test and design the Halbach array in the worst possible case. The presented configuration has a 90 kg total mass, and is also subject to

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intense forces that tend to disrupt it. Thicker magnets would be more effective at deflecting particles, but also much heavier and difficult to maintain in place. A simulation interfacing a GEANT4 output, simulating the proton interaction with the SPOs, and elaborated by the ESA-supported AREMBES project is also shown. The data exchange between the two projects has been approved by the respective ESA officers. There are definite locations in the bore of the MD from where protons can reach the detector: ESA suggests to make the field more intense at these locations changing locally the magnet thickness, on condition that the magnetic field on the focal plane does not exceed the prescribed limits.

- Action items for OAB:
  A11/O - continue the simulations using the GEANT4 output as they are made available, varying the thickness of the magnets. ESA suggests to focus the work on the simulation of the required B-field map inside the Halbach to deflect all protons (or up to a given confidence level) coming through the mirror up to a given threshold of energies (up to 100 keV) and/or given soft proton populations from AREMBES activities. The detailed modelling of the Halbach and its implementation will be covered by another TDA (C204-119FM) and will take into account issues like coercivity, alignment errors, lifetime effects, etc... ESA will ensure coordination between the analyses done on this TDA and on the magnetic diverter TDA.

DDMF and DS present **TN-07: analysis of X-ray data of SPOs (DTU and OAB resp.)**

- On-going: DTU collected a large amount of data at BESSY from 2012 on. The results show that the cleaning necessary to activate the silicon bonding removes the B_4C layer. This will decrease the low-energy EA by 25% to 40%. DTU is cooperating with Cosine to find a solution. Proposals are to switch to SiC or to use a mask to cover reflecting areas. DTU also noticed a thermal evolution of the coating performances with the thermal cycle used by cosine for annealing. Vibration tests show that annealing may be skipped. All the cited effects deal with the B_4C removal or thinning. These are not detectable at DTU Space 8 keV facility but are clearly observed with energy scans at BESSY at lower energies (3-10 keV), and this should be studied. The SiC back-up solution should now be seriously taken into account. OAB shows that, for previous measurements of coated SPO plates before lift-off and cleaning, roughness measurement and XRS measurements are in good agreement. Last year's AFM measurements on coated SPO plates before lift-off, cleaning or stacking showed that 1) the multilayer deposition seem to improve the surface roughness, 2) photoresist residues can double the roughness (from 3 Å to 6 Å rms). At 1 keV, the effect on the PSF is negligible, while at 5-6 keV the average HEW expected for ATHENA increases by 1 arcsec with respect to a residue-free surface. The situation goes worst with increasing energy.
- Action items for DTU:
  A8/D - perform new tests at BESSY on new coatings, as soon as beam time is made available.
- Action Items for OAB:
  A12/O - continue metrology and X-ray tests on the SPO plate samples.

All the details can be retrieved from the technical notes delivered to ESA:
https://www.dropbox.com/sh/vvbbl6ewkxnajgm/AAAmaXFEfnsbE973TCYNz6Dya?dl=0

The presentations have also been posted to the group Dropbox folder,
https://www.dropbox.com/sh/tcm7l7h0h58o9rl/AABNWoHZ4Y8WSthSSi0SlECla?dl=0

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Conclusion: BS appreciates the activities of the 2nd year and considers them fully satisfactory. The project passes to the 3rd year of contract. The new ESA technical officer will be Ivo Ferreira, he is the point of contact from now on for all matters relating to this contract.

The review is considered successful and the invoice can be submitted once the signed minutes of meeting are available.

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