Proposal Part B

DOCUMENT 1

START PAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Individual Fellowships (IF)
Call: H2020-MSCA-IF-2016

PART B

ForbMod

This proposal is to be evaluated as:

[Standard EF]

Part B - Page 1 of 22

TABLE OF CONTENTS

DOCUMENT 1 (13-PAGE LIMIT APPLIED)

List of Participating Organisations

Participating organisations	Legal Entity Short Name	Academic (tick)	Non-academic (tick)	Country	Dept./ Division / Laboratory	Supervisor	Role of Partner Organisation
Beneficiary							
Karl Franzens University in Graz	UNIGRAZ	x		Austria	Institute of Physics	Dr. Manuela Temmer	host
Partner Organisation							
Austrian Academy of Science	OEAW	x		Austria	Space Research Institute	Dr. Christian Möstl	Hosting secondments
Partner Organisation							
Christian-Albrechts University in Kiel	CAU	x		Germany	Department of Extra-terrestrial Physics	Prof. Bernd Heber	Hosting secondments

1. Excellence

1.1 Quality and credibility of the research/innovation action (level of novelty, appropriate consideration of inter/multidisciplinary and gender aspects)

Introduction, state-of-the-art, objectives and overview of the action: Galactic cosmic rays (GCRs) have a major impact on Earth and interplanetary space and are therefore of great importance for both Space and Earth sciences. The GCR flux is modulated by the activity of the Sun – high solar activity reduces the GCR flux (e.g. Heber, 2013[1]). On short time scales of several days, depressions in the GCR flux can be seen, so-called Forbush decreases (FDs, Forbush, 1937[2]), which are caused by interplanetary coronal mass ejections (ICMEs). ICMEs are plasma and magnetic field abruptly ejected from the Sun with speeds of up to 2000 of km/s and often associated to shocks. Subsets of these magnetic ejecta have a flux rope configuration, where a flux rope (FR) is a cylindrical plasma structure with magnetic field lines winding around the central axis (Lepping et al., 1990[3]). The strongest FDs often show a two-step profile, which is believed to be caused by a combination of two effects – scattering of the particles in the turbulent ICME shock/sheath region and exclusion of particles from the smoothly rotating ICME magnetic ejecta region. The two were found to be roughly equally effective in GCR modulation, especially when the magnetic ejecta have a FR configuration (Richardson & Cane, 2011[4]). The separation of these two regions are substantial for FD modeling, as they are described by different physical parameters - one has a highly fluctuating magnetic field, whereas the other does not. It was proposed that the primary reason for the GCR decrease, caused by the magnetic ejecta, is the closed magnetic field structure of the FR which is assumed to be empty close to the Sun and of constant size. During its propagation it fills up slowly by GCRs entering the FR due to perpendicular diffusion (Cane, 1995[5]; Kuwabara et al., 2009[6]) and/or drifts (Krittinatham & Ruffolo, 2009[7]) and gyration (Kubo & Shimazu, 2010[8]). The models reflect some of the observational characteristics of FDs caused by ejecta such as symmetric shape and relation of the FD amplitude to the magnetic field strength and the FR size (e.g. Dumbović et al., 2011[9]; 2012[10]; Blanco et al. 2013[11]). However, there are only several modeling efforts to describe the modulation of GCRs by the magnetic ejecta and furthermore, the existing models don't take into account (1) that the FR initial conditions should be constrained by the CME observations during liftoff, and (2) that the CME expands (e.g. Klein & Burlaga, 1982[12]) which introduces a diluting mechanism that competes with diffusion. In addition, FD modeling was so far regarded for only one planet - Earth. Observational studies of FDs were until recently performed using measurements from interplanetary space and Earth. The new Mars Science Laboratory (MSL) mission provided FD observations from Mars surface, allowing for the first time to study FDs at two planets – Earth and Mars (Posner et al., 2014[13]).

This project will focus on the investigation of the influence of the magnetic ejecta on GCRs. **I propose to develop a new FD model which takes into account initial conditions from CME observations as well as the expansion of CMEs in IP space. This model will be adapted to explain both interplanetary spacecraft and planetary ground-based (with or without magnetosphere) measurements and will be evaluated and optimized using measurements at Earth and Mars.** This project aims to develop such a model by achieving **two main objectives: (1) to establish a new GCR diffusion/expansion model to describe the FD, and (2) to study FD observational properties in space and at two different planetary surfaces – Earth and Mars.**

Research methodology and approach: The FD model will be developed based on the perpendicular diffusion of GCRs into the FR, following Cane et al. (1995)[5], which predicts different FD amplitudes and time-profiles for different diffusion coefficients, diffusion times (CME transit times) and FR sizes. CME expansion will be included in the model by removing the assumption that CME does not change size which should lead to slowing down of the diffusion process and increasing FD amplitudes. To test the model

[1] Heber, B., „Cosmic Rays Through the Solar Hale Cycle. Insights from Ulysses", Space Sci. Rev., 176/ 1-4, p. 265-278 (2013)

[2] Forbush, S. E., On the Effects in Cosmic-Ray Intensity Observed During the Recent Magnetic Storm, Physical Review 51, 1108 (1937)

[3] Lepping, R. P. et al., Magnetic field structure of interplanetary magnetic clouds at 1 AU, JGR, 95, 11957 (1990)

[4] Richardson, I. G. & Cane, H. V., „GCR Intensity Response to ICMEs/Magnetic Clouds in 1995 – 2009", Sol. Phys., 270/2, p.609-627 (2011)

[5] Cane, H. V. et al.„The Response of Energetic Particles to the Presence of Ejecta Material", 24th ICRC, Vol4 (Iucci & Lamanna), p.377 (1995)

[6] Kuwabara, T. et al., „Determination of ICME geometry and orientation from ground-based observations of GCRs", JGR, 114/A5 (2009)

[7] Krittinatham, W. & Ruffolo, D., „Drift Orbits of Energetic Particles in an Interplanetary Magnetic FR", ApJ, 704/1, p. 831- 841 (2009)

[8] Kubo,Y. & Shimazu,H., „Effect of Finite Larmor Radius on CR penetration into an Interplanetary Magnetic FR", ApJ, 720/1, p.853-861 (2010)

[9] Dumbović, M. et al., „Cosmic ray modulation by solar wind disturbances", A&A, 531/A91, 17 p. (2011)

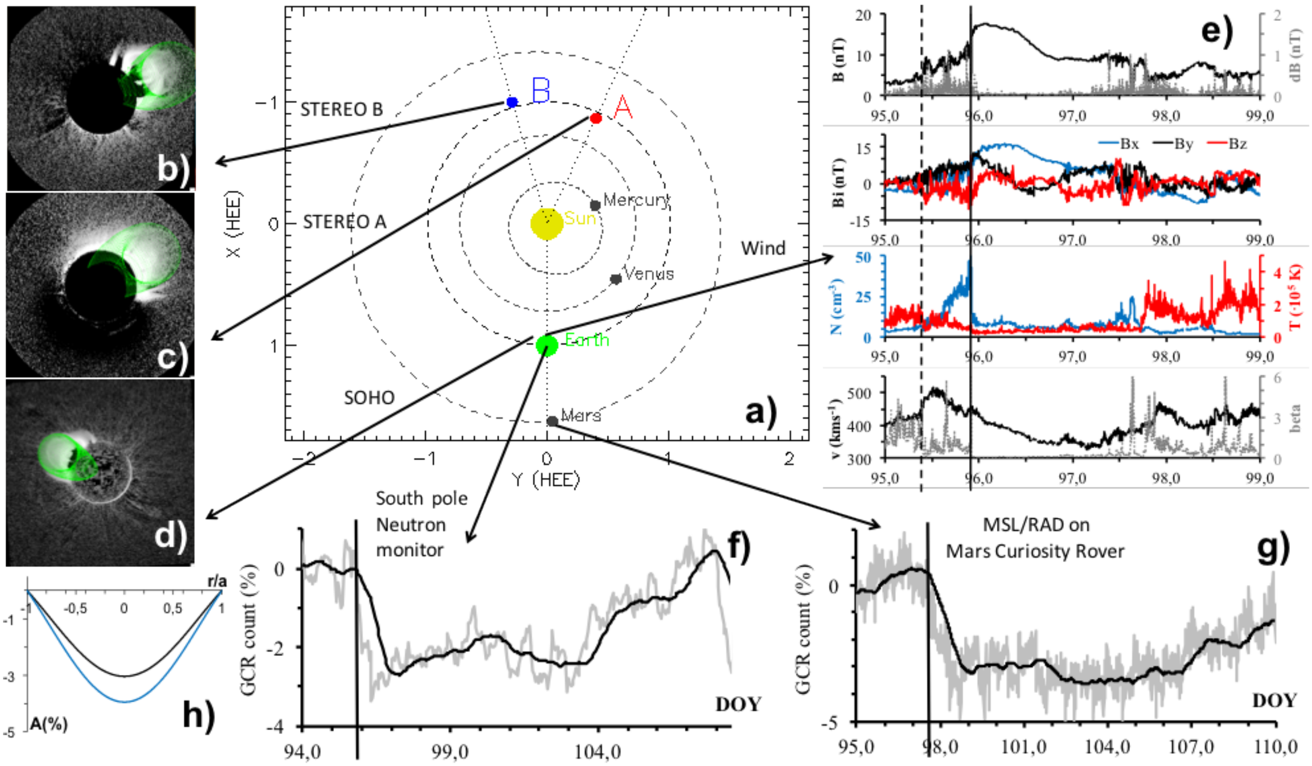
[10] Dumbović, M. et al., „Cosmic ray modulation by different types of solar wind disturbances", A&A, 538/A28, 13 p. (2012)

[11] Blanco,J.J. et al.„„Energetic-particle-flux decreases related to magnetic cloud passages as observed by Helios 1 and 2", A&A, 556, 9 p (2013)

[12] Klein, L. W.& Burlaga, L. F.,"Interplanetary magnetic clouds at 1 AU", JGR, 87, p.613-624 (1982)

[13] Posner, A. et al., "Forbush Decreases on the Martian Surface during the 2014 Mars Opposition", AGU abstract #SH11A-4034 (2014)

against observations, the diffusion time and FR parameters are needed, as well as the expansion factor. This can be obtained only if CME multi-spacecraft measurements are used (at the lift-off time and in situ at the time of FD observation). In order to derive the FR parameters at the CME lift-off time, we will use the Graduated Cylindrical Shell model (GCS, Thernisien et al., 2006[14]) to make a 3D reconstruction of a FR from combined EUV, COR1, COR2 and HI data of the SECCHI suite onboard STEREO spacecraft (e.g. Temmer & Nitta, 2015[15]). GCS uses forward-modeling techniques that allows the user to fit a geometric model of a flux rope to CME observations and provides means for analyzing the 3D morphology, position and kinematics of CMEs. To extract FR parameters from the in situ observations, the Grad Shafranov method will be used (G-S reconstruction, Hu & Sonnerup 2002[16]; Möstl et al. 2012[17]) using in situ solar wind plasma and magnetic field data from ACE, Wind, DSCOVR, and possibly MAVEN spacecraft. Spacecraft FD measurements using SOHO/EPHIN will be used, as well as ground-based measurements from Earth (neutron monitors) and Mars (MSL/RAD).



PROOF-OF-CONCEPT FIGURE: *a) alignment of Earth and Mars at April 5th 2014; b-d) GCS reconstruction of Earth-directed CME on April 2nd 2014 for STEREO B/COR1 (b), STEREO A/COR1 (c) and SOHO/LASCO C2(d); e) in situ measurements with Wind spacecraft at L1 showing sheath (start marked by a dashed line) and FR (start marked by a solid line); f&g) corresponding FD measurements (start marked by a solid line) with ground-based neutron monitor measurements from the South pole on Earth and ground-based measurements from MSL/RAD on Mars; h) diffusion model FD for diffusion time 85h, diffusion coefficient 10^{19}cm^{2}s^{-1}, and FR radius 0.15 AU without expansion (black line) and with additional 30% contribution from expansion estimated based on the FR density decrease given in Bothmer & Schwenn, 1998[18] (blue line)*

In the first step, the model will be evaluated against a statistical analysis of events during STEREO era using near-Earth events only. For that purpose we will exploit existing lists of identified CME-ICME events, e.g., as provided by the EU-FP7 project HELCATS. This will enable us to check whether the model can explain general statistical properties of FD observations or whether it should be modified by e.g. inclusion of adiabatic cooling due to expansion, which will be neglected in the first step. Due to the scarcity of Earth-Mars alignments within our limited time window (Curiosity rover carrying MSL/RAD landed in August 2012, whereas STEREO 3D reconstructions are most promising until end of 2014 due to the drifting spacecraft locations), we will perform in-depth case studies with a comprehensive analysis of the model against a full

[14] Thernisien, A.F.R., Howard, R.A., and Vourlidas, A., Modeling of Flux Rope CMEs, ApJ, 652:763-773 (2006)
[15] Temmer, M. & Nitta, N. V., "Interplanetary Propagation Behavior of the Fast CME on 23 July 2012", Sol. Phys., 290: 919-932 (2015)
[16] Hu, Q. & Sonnerup, B. U. Ö, "Reconstruction of magnetic clouds in the solar wind: Orientations and configurations", JGR, 107, 1142, (2002)
[17] Möstl, C. et al., "Multi-point Shock and FR Analysis of Multiple ICMEs around 2010 August 1 in the Inner Heliosphere", ApJ, 758, 10 (2012)
[18] Bothmer, V. & Schwenn, R., "The structure and origin of magnetic clouds in the solar wind", Annales Geophysicae, 16: 1-24 (1998)

set of multi-spacecraft observations for Earth-Mars CME-FD events.

Originality and innovative aspects of the research programme: The innovative aspects of the research presented in this proposal are: (1) for the first time we will use solar (CME) observations to constrain initial & boundary conditions in the FD model; (2) for the first time we will take into account that CME evolutionary properties play a role in producing FDs and will incorporate CME expansion as a competing mechanism to diffusion; (3) For the first time we will model FDs and compare them to observations from *two planetary surfaces* (Earth and Mars).

The interdisciplinary aspects: The proposed research connects CME initiation (solar physics) and evolution of ICMEs (heliospheric physics) to the behavior of the GCR flux (heliospheric and planetary physics). The application of this research to various problems offers contribution to subjects related to astrophysics, geophysics and space weather. Recently, Möstl et al (2015)[19] used GCR measurements from MSL/RAD to determine the arrival of an ICME to Mars, indicating the potential and importance of FDs for space weather monitoring. In addition, Lefevre et al. (2016)[20] and Vennerstrom et al. (2016)[21] used GCR measurements from ground-based neutron monitors to determine the arrival of an ICME to Earth in the pre-satellite time period. The new project results will be applied to gain more insight about ICMEs where/when in situ measurements are not available, whereas GCR measurements are available. This would represent a groundbreaking contribution to the research of space weather at Mars and in pre-satellite era at Earth and will be of great use for the space weather community (including space weather prediction centers such as the NOAA in USA or Met Office in UK). The space weather application of the model is especially important in the light of a planned mission in L5 Lagrangian point, which in combination with a coronagraph at L1 provides means for stereoscopic observation and real-time modelling. Another important aspect is considering the consequences of the radiation exposure during space travel (Guo et al., 2014[22]). FD studies, such as this one, improve the knowledge needed for long-term mission planning with respect to harmful GCR exposure and are relevant to space agencies (e.g. NASA, ESA, JAXA…). Project results will be interesting to a broader astrophysical scientific community regarding space weather around Sun-like stars and cosmic ray levels at exoplanets. Finally, possible cosmic ray-cloud link is a hot topic of ongoing climatological studies and therefore the proposed research will be of interest to the climatological scientific community (Kirkby et al., 2016[23]).

The results of the research performed within this project will lead to publication in high quality peer-reviewed journals and will be disseminated at international conferences and workshops, leading to new career possibilities and new collaboration opportunities for the proposer as well as for the host institution. The project will introduce innovation in the European Space sector and include exploitation of space data which are the specific objectives of Horizon 2020 Space.

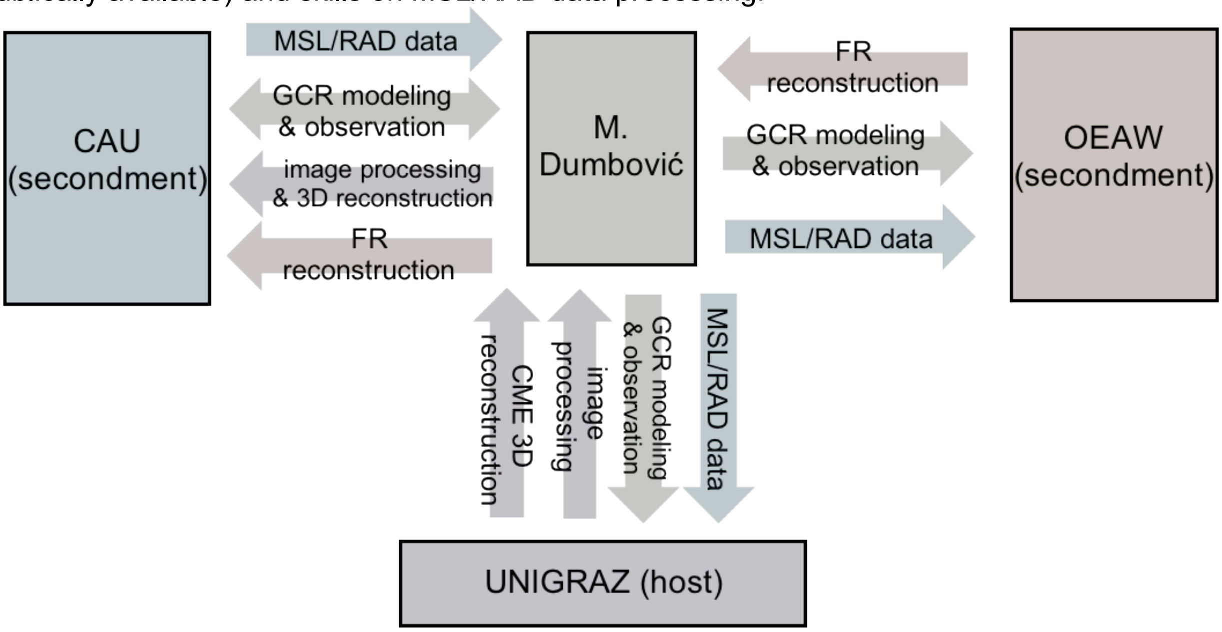
1.2 Quality and appropriateness of the training and of the two way transfer of knowledge between the researcher and the host

As can be seen from my track record, throughout my previous research I acquired knowledge and skills regarding GCR modulation. I have substantial experience in both ground-based neutron monitor and spacecraft (SOHO/EPHIN) observation of FDs and observation of their interplanetary and solar sources using a variety of instruments onboard Wind, ACE, SOHO, and SDO satellites, as well as ground-based solar observations in white-light and H-alpha. Within a bilateral project CORAMOD, which aims to model FDs, I acquired skills and knowledge regarding GCR modulation modeling. I would like to gain new knowledge and skills regarding advanced image processing and application of 3D image reconstruction methods (e.g. GCS), where M. Temmer and her group are well acknowledged if not world-leading experts. These skills will be transferred with training activities described in the work plan. On the other hand, the group is inexperienced regarding the GCR modulation, therefore, they will profit from my scientific knowledge and skills, which will be transferred via group discussions, seminars and joint research activities. GCR modulation knowledge, especially the new project results, will be also transferred to the UNIGRAZ climatology group to pursue a possible collaboration regarding the research of the possible FD-cloud link. A 2-month secondment is planned at OEAW/SRI where I will train with C. Möstl, one of the leading experts on Grad-Shafranov reconstruction. At OEAW/SRI I will not only transfer my skills regarding GCR modulation through joint research activities and weekly seminar series, but will also establish contact

---

[19] Möstl, C. et al., „Strong coronal channelling and interplanetary evolution of a solar storm up to Earth and Mars", Nat. Comm., 6/ 7135 (2015)
[20] Lefevre, L. et al., Detailed Analysis of Solar Data Related to Historical Extreme Geomagnetic Storms: 1868 – 2010, Sol. Phys.,291 (2016)
[21] Vennerstrom, S. et al., Extreme geomagnetic storms - 1868-2010, Sol. Phys.,291 (2016)
[22] Guo, J. et al., „Variations of dose rate observed by MSL/RAD in transit to Mars", A&A, 577/A58, 6pp (2015)
[23] Kirkby, J. et al., "Ion-induced nucleation of pure biogenic particles", Nature, 533/ 7604 pp. 521-526 (2016)

with the exoplanet group to pursue a possible collaboration concerning GCRs on exoplanets. Another 2-month secondment is planned at CAU, where I will work with B. Heber, one of the leading experts on GCR modulation and detection, to strengthen my skills regarding GCR modulation observation & modeling, while transferring the newly acquired advanced image processing and 3D reconstruction, as well as FR reconstruction knowledge and skills to his group trough joint discussions and weekly seminar series. In addition, I will also work with J. Guo who is in charge of the MSL/RAD data at CAU and investigates observational properties of FDs at Mars and Earth and will provide me with the MSL/RAD data (which are not publically available) and skills on MSL/RAD data processing.



During the project I will also gain a number of complimentary skills. I will strengthen dissemination skills through written and oral presentations of scientific results via publications, seminars and conference presentations, as described in Section 2.2. Furthermore, I will gain teaching, interpersonal and communication skills through collaboration with scientists from the host and secondment institutions, but also through guidance of students, as I will co-supervise M. Temmers students. As a part of my current group at Hvar Observatory I was very active in organizing international scientific meetings and public outreach events, hence, all included parties will profit from the exchange of experiences and information in these areas. This PI-project, under the supervision of M. Temmer, will help me to greatly improve my project management skills which I already started to obtain as a PI of project PoKRet at my current institution.

1.3 Quality of the supervision and of the integration in the team/institution

Doc. Dr. Manuela Temmer is assistant professor at UNIGRAZ since 2010 and well established researcher in solar and heliospheric physics with expertise for CMEs (coronagraphic/heliospheric image processing and 3D reconstruction, their propagation and relation to flares, physical processes of interacting CMEs and space weather effects at Earth). She published 229 scientific papers, mostly related to eruptive phenomena in the solar atmosphere and their interplanetary propagation with more than 3100 citations and h-index=35. She was a PI of seven research projects, most notably *ESA-SSA Austria's Expert Service Center Heliospheric Weather Austria, eHEROES* (EU FP7-SPACE, task leader), *CMEs – dynamic evolution in the heliosphere* (FWF; Austrian Science Fund), *3D properties of coronal mass ejections* (Austrian Research Promotion Agency) and *Forces governing CMEs and forecasting of CME arrival times* (Austrian Academy of Sciences). She is the Topical Editor (Solar Corona & Heliospheric Physics) for the scientific journal "Annales Geophysicae", Science Officer for Solar Physics in the EGU Division Solar-Terrestrial Science and Co-Leader of the international VarSITI Project ISEST. Her collaboration network includes scientists in the field of solar and heliospheric physics from more than 20 world-wide institutions (e.g. Lockheed Martin, NASA Goddard, RAL UK, ESA). She has a high level of experience in supervising researchers (1 PhD, 5 MSc and 2 BSc thesis) and is the co-leader of the solar and heliospheric physics group at the Institute of Physics at UNIGRAZ with ~15 Msc, PhD and PostDoc students.

Due to the high-reputation of the research groups at the Institute of Physics and their associated Kanzelhöhe Observatory, UNIGRAZ is a world-wide leading institution in the research on space weather. The group currently participates in ~6 national, bilateral and international projects and has a publication

rate of ~20 papers per year. Their research is centered around the physics of CMEs, flares and associated waves, the heliospheric evolution of CMEs and their space weather impact, numerical modelling of coronal magnetic fields and flows and coronal holes and their relation to the solar wind. As a part of the group, I will participate in weekly group meetings where ongoing research is discussed as well as weekly group seminars, where researchers and students present their work to the group. Through these weekly meetings and seminar series, all the group members profit from the exchange of scientific knowledge and improve their presenting and interpersonal skills. It is common practice in the group that people with different level of experience work in the same office and share knowledge and that each member of the group receives support from the whole group, in different aspects (scientific discussions, programing & computing skills, dissemination formats/skills etc.). On a monthly basis, astrophysical colloquia are organized, with talks from visiting scientists on various astrophysical topics to increase the networking capability of the group as well as of interested individuals. Seminars at the Institute level will be a good opportunity to transfer GCR modulation knowledge, especially the new project results to the UNIGRAZ climatology group to pursue a possible collaboration regarding the research of the possible FD-cloud link. As a member of the research group, I will fully benefit from this international network of collaborations as well as contacts to other research areas. Described measures will ensure integration in the different areas of expertise, disciplines, and international networking opportunities. Furthermore, as a member of the group I will be included in all public outreach initiatives of the group (as described in Section 2.3) as well as social events (joint lunch breaks, movie nights, joint sport activities, Christmas parties). Since the group is international, the official language of the group is English and there will be no language barrier, but also UNIGRAZ offers courses for German as additional means for integration. In addition, UNIGRAZ provides a variety of administrative support to facilitate my integration such as a "Welcome Center", support with contract and housing and a University doctor.
During secondment at CAU and OEAW/SRI I will be integrated in scientific groups led by B. Heber and C. Möstl, respectively. At both institutions periodic seminars are given by members of the group which cover different subjects related to their work. Thus I will have opportunity to learn and discuss a variety of subjects related to GCR measurements and modelling at CAU and CME-related subjects at OEAW/SRI, and have the opportunity to present my own work in the scope of this project and get feedback from other members of the two groups, from two different aspects, respectively.

1.4 Capacity of the researcher to reach or re-enforce a position of professional maturity/independence

My research career started 6 years ago with finishing my MSc thesis on interplanetary sources of FDs. During my PhD studies, I independently developed space weather tools for CME geo-effectiveness and GCR-effectiveness forecast, within the EU-FP7 project COMESEP. Due to my experience and expertise on the determination of ICME arrival times at Earth and Mars based on cosmic ray data, I was invited to participate in several research studies which resulted in peer-reviewed publications in highly ranked journals (see citations/footnotes 19, 20, and 21). These examples show that I already achieved a level of independent thinking, which I am eager to develop further. My track record and a number of projects I participated show that I have made a significant research progress so far, recognized in 2016 when I was selected as one of 4 fellows of the national fellowship "For Women in Science". Furthermore, I developed a number of complementary skills, e.g., project management (as PI of the ESF project PoKRet), reviewing scientific papers and projects, organisation of several international scientific meetings, presenting (both scientific meetings and public outreach), observations with the double white-light/H-alpha solar telescope, as well as people skills (teamwork, collaboration). According to my status of career, my research is already well recognized by the scientific community (NASA/ADS h-index 7) and I have already established a collaborative network, which I would like to expand in the future. I am highly motivated to continue this career path, to strengthen existing and gain new scientific and complementary skills, to develop my own ideas and thus reach a position of professional maturity and independence to become a group leader. The proposed research and training will immensely contribute in reaching this goal. First of all, I will conduct the proposed research independently. The supervisor will monitor my progress and I will make the most out of scientific discussions with her, however, my independent ideas will be implemented through research activities and interpretation of the results, especially regarding the GCR aspect. As a part of the group, I will be included in joint research, where each member contributes with a specific expertise, further developing independent thinking. With training activities, I will gain new knowledge and scientific skills (as described in Section 1.2) which will help me become a more comprehensive researcher able to take a lead on research projects/studies with broad knowledge. Managing this fellowship as my own project will strengthen my management skills and I will be able to improve them via advisement from a very experienced supervisor. Through co-supervision of students with my supervisor I will obtain leadership skills, which is a substantial capacity of any group leader. Finally, through the planned dissemination activities, I will increase my visibility in the scientific community and expand my existing collaborative network. For this, a Career Development Plan will be made at the beginning of the project which will encompass my described ambitions and a plan based on the research and training in order to achieve the desired career goals. Upon finishing the project, I plan to build up on the acquired experience and continue research as a group leader. It is noteworthy to mention that the supervisors group has previous positive examples of producing independent researchers, who established their own groups at other institutions (e.g. Alexander Warmuth at Leibniz-Institut for Astrophysics in Potsdam and Christian Möstl at OEAW/SRI).

2. Impact

2.1 Enhancing the potential and future career prospects of the researcher

The project is expected to have a significant impact on my career prospects. The networking and visibility I will achieve through the realization of this project will open up new collaboration opportunities needed for future scientific projects. The scientific excellence and dissemination are important for attaining future fellowships and taking an international lead position in research studies and projects. The award of the prestigious Marie Sklodowska-Curie Actions EU fellowship would be a considerable addition to my curriculum vitae, that will certainly enhance my career development. Therefore, a realization of this project will strengthen my foundation for follow-up employments as independent Postdoc researcher. After the fellowship I would like to return in Croatia to continue my scientific career as a PI or Co-PI of international (possibly HORIZON 2020) or national projects. In Croatia, a PostDoc on a foreign institution is necessary for the advancement in the academic rank and an important factor for various national research grants. A successful continuation of my scientific career (in Croatia) will have a positive impact on the European society with respect to the key priorities of the European Research Area reform agenda: (1) optimal circulation and transfer of scientific knowledge - I will bring the newly acquired knowledge and skills and transfer them to colleagues and future graduate and post graduate students; (2) more effective national research systems – I will use the knowledge, skills and experience acquired during the fellowship for future competitive and excellent research; (3) optimal transnational co-operation and competition – I will use the extended network of researchers attained during the fellowship for future collaborations (e.g. collaborative projects); (4) gender equality and gender mainstreaming in research – I will remain in science and attain a leading research position. Finally, the results of this project and my future research will contribute to the space weather monitoring and predictions, which are important to protect European assets (e.g. satellites, power grids) from the potentially harmful solar activity. Therefore, it will also have a potential economic impact.

2.2 Quality of the proposed measures to exploit and disseminate the action results

The dissemination strategy is directed towards different targets and will therefore be achieved at several different levels to fully achieve the potential impact of the action and exploitation of the results for scientific improvement (impact on solar, heliospheric and planetary physics and space weather studies), protection of (European) assets (space weather application) and public policymaking (long-term human exploration of space). All project results will be made publically available via project website, following the intellectual property standard of the host institution and they will not be used for commercial purposes. The following strategy is planned:

(1) Dissemination to the groups at host and secondment institutions – at the very first level the research will be disseminated to the group members of the host and secondment institutions through seminar talks, topical meetings and discussions. Furthermore, project results will be disseminated to the UNIGRAZ climatology group and to the OEAW/SRI exoplanet group to encourage exploitation of the project results in these fields. Additionally, through co-supervision, the results will be disseminated to about a dozen students in the supervisors group at undergraduate and graduate level who will be encouraged to use the results in their future studies as a part of their master/PhD thesis.

(2) Dissemination to the scientific community - The project results are expected to introduce innovative model and ideas and make an impact on solar, heliospheric, planetary physics as well as space weather scientific communities. Therefore, it will be disseminated via publications (highly ranked journals) and scientific meetings in order to bring attention and influence/improve future studies on the subject. Participation at four major conferences related to the subject of research are planned (exact time-schedule depends on the actual start of the project): AGU (yearly in December), EGU (yearly in April), ECRS/ICRC (yearly in August/September) and ESWW (yearly in November). The project results

will be published by at least two first author papers, as indicated in the work plan, which will be submitted to the best and most appropriate journals in the field (Nature Astronomy – new Nature journal specialized for astronomy, publishing monthly from January 2017; Astrophysical Journal or Astrophysical Journal Letters; Solar Physics – publishing open access is free of charge for UNIGRAZ). The first paper (submitted by the end of year 1) will describe the new FD model and analyse results in the light of the statistical study of events at Earth, whereas the second paper (submitted by the end of year 2) will analyse FD model results in the light of a case study of selected multi-spacecraft events. In addition, at least 2 co-author papers per year are planned (based on my previous publication rate), but even more contributions are expected, because whenever I complement a joint event analysis with my expertise and newly acquired skills I will co-author a paper which will also be submitted to the best journals in the field. To ensure maximum availability and visibility of the project results appropriate budget resources will be allocated to publish open access papers and services such as arXiv.org and ResearchGate will be utilized.

(3) Dissemination to the wider research and innovation community – Conferences are specifically targeted (ESWW, EGU), to reach the wider research and innovation community, including the industrial sector and representatives from space weather prediction centers (e.g. National Oceanic and Atmospheric Administration in USA or Met Office in UK) and space agencies (e.g. NASA, ESA, JAXA). Therefore, through dissemination (oral and poster presentations) at these conferences, I will bring the attention of the broader space weather community about the project results and their application for space weather forecasting leading to the possible exploitation of the results for real-time space weather forecast and long-term mission planning.

2.3. Quality of the proposed measures to communicate the action activities to different target audiences

The communication plan is directed towards several different target audiences to call attention about my research, but also about science in general and to address the public policy perspective of EU research and innovation funding. Therefore, communication activities can be divided based on the target audience, the objective and communication activities:

(1) *dissemination of the scientific results* that targets at the scientific and wider research and innovation community with the objective to call attention about my research and encourage exploitation of my research result. It will be achieved through activities described in Section 2.2 but also through Varsiti newsletter (at the start of the project an article will be written in the scope of the newsletter "Highlight of young scientist" series)

(2) *outreach activities for students and children* with the objective to call attention about my research but also about science in general. It will be achieved through joint outreach activities of the group: Long night of research (LNR - the biggest research-related event across Austria; talks, guided tours, discussions, etc.; 13.04.2018); Graz Space day (GSD - chat with scientists, experiments, rocket building, etc.; October 2017 & 2018); organization of observing interesting astronomical phenomena (no planetary transits or solar eclipses visible from Austria during project, but there will be one partial lunar eclipse 7/8 Aug 2017 and one total lunar eclipse 27/28 Jul 2018); Institute of Physics - open days with lectures for school groups (events organized in cooperation with schools; pupils field trip to UNIGRAZ/Institute of Physics for a guided tour, lectures and discussions with scientists; exact dates of these events are not known far in advance). In addition, I plan to give public outreach lectures in my country of origin in the scope of Festival of Science (FS - one week-event in April in Croatia; workshops, talks, etc.; April 2018 & 2019) and I will remain a member of the National commission for competition in Astronomy in Croatia as a reviewer of exams and student astronomical projects.

(3) *communication to the general public* with the objective to call attention about my research and science in general, and to address the public policy perspective of EU research and innovation funding. It will be achieved using both one-way and two-way exchange. A project website will be established with the support of the "Science IT team" at the host institution. The website will describe my research field and the project and it will be continuously updated with project results and news. Major project results will be spread via media communication (written, radio or TV statements), supported by the UNIGRAZ Press+Communication Office. Finally, it will be achieved through joint outreach activities of the group as described in outreach activities for students and children.

3. Quality and Efficiency of the Implementation

3.1 Coherence and effectiveness of the work plan

Month →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP1 - management					R1					R2					R3					R4				D3
WP2 - training	M1						M3							M4										
WP3 - model&statistics					M2							D1												
WP4 - model&case study																						D2		
WP5 - dissemination&outreach																								
secondments						OEAW							CAU											
conferences							AGU				EGU					ECRS		ESWW					EGU	
public outreach events					GSD					LNR +		FS					GSD						FS	
milestones	M1				M2		M3							M4										
deliverables												D1										D2		D3

*Gantt chart explanation: R1-R4 – reports to the supervisor (see Section 3.3); D1-D3 – deliverables; M1-M4 – milestones; OEAW and CAU – secondment institutions; AGU, EGU, ECRS and ESWW – conferences (see Section 2.2); GSD, LNR, FS, GSD – public outreach activities (see Section 2.3)

List of Deliverables		List of milestones	
deliverable	Work package/task	milestone	Work package/task
D1 - First-author paper 1 (described in Section 2.2)	WP3 - Model&statistics; Tasks 3.1 and 3.2	**M1 -** Basic image processing and 3D CME reconstruction skills obtained	WP2 - Training; Task 2.1
D2 - First-author paper 2 (described in Section 2.2)	WP4 - Model&case study; Tasks 4.1 and 4.2	**M2 -** CME-ICME-FD list with GCS and FD parameters compiled	WP3 - Model&statistics; Task 3.1
D3 - Final project report (described in Section 3.3)	WP1 - Management	**M3 -** Full CME-ICME-FD list with GCS, G-S and FD parameters compiled	WP2 - Training; Task 2.2
		M4 - Case study events selected based on multi-spacecraft data availability	WP2 - Training; Task 2.3

Project activities are divided into 5 work packages (WPs):

WP1–management: activities/measures are described in Section 3.3

WP2–training: encompasses all training activities at the host and secondment institutions which are divided into several tasks based on the nature of the training and where the training will take place:

Task 2.1 – 1-month intense training in image processing techniques (UNIGRAZ): I will learn basic as well as advanced image processing techniques using IDL/SolarSoft on event data available at the host institution server (multi-spacecraft image data with special focus on 3D CME reconstruction and GCS modeling). At the end of this training period, I will be able to process multi-point remote sensing image data and 3D CME reconstruction with GCS (M1) and will start with research activities in WP3/T3.1. 3D CME geometry parameters near the Sun are needed as an input (initial & boundary conditions) for the FD model, therefore, these training activities are vital for the research activities.

Task 2.2 – 2-month training in FR reconstruction (OEAW): during this secondment I will be trained in G-S reconstruction using the compiled event list (M2) and Python programs available at OEAW/SRI server. The G-S reconstruction is used to obtain the interplanetary FR characteristics, namely the size and orientation, which is needed for the statistical analysis and comparison to the model results which will be done in the scope of WP3/T3.2. At the end of this secondment I will be able to do FR reconstructions from in-situ data and have compiled a list of events needed for the statistical analysis (M3).

Task 2.3 – 2-month training in Mars data processing (CAU): during this secondment I will identify possible weaknesses of the FD model as revealed by the statistical analysis and regard possible inclusion of adiabatic cooling. I will be trained in MSL/RAD data processing and will select suitable event(s) for the multi-spacecraft case study (M4). MSL/RAD data are essential for the study of FD observational properties at Mars and comprehensive analysis of FD model against a set of multi-spacecraft measurements that will be done in WP4.

Task 2.4 – continuous training activities (UNIGRAZ): all training activities without a specific timeframe, which will take place during the entire duration of the project: (1) implementing the newly acquired knowledge and skills from tasks T2.1-T2.3; (2) attending image processing courses that UNIGRAZ offers as a part of their academic studies, as well as attending weekly group seminars, where research using these skills is presented and discussed; (3) training modeling & programming skills through development and adaptation of the FD model; (4) complementary skills (described in Section 1.2)

WP3–model&statistics: research activities regarding the development of the model and compilation of the event list for statistical analysis divided into two tasks:

Task 3.1 – compilation of the event list: with reaching M1 an event list will be compiled. In a first step existing CME-ICME lists will be identified, exploited and complemented with FD observations and GCS results (M2). In the next step, during the secondment at OEAW, the list will be complemented with G-S reconstruction results and therefore fully compiled (M3). Duration – 6 months.
Task 3.2 – development & evaluation of FD model: includes development of the model, statistical analysis of the event list compiled in T3.1 and its comparison to the model results. Expansion will be included by assuming that the general solution of the diffusion model applies trough a series of quasi-stationary cases where the radius of FR changes according to self-similar expansion. Model predictions of FD amplitude dependence on diffusion/transit time and FR radius will be tested against observational statistics, where diffusion coefficient will be estimated empirically. This task will start comparatively with T3.1 and continue throughout WP3 to insure enough time for its implementation. Duration – 11 months.
WP4–model&case study: research activities regarding the possible adaptation of the model and a comprehensive case study using multi-spacecraft observation (tasks will run comparatively):
Task 4.1 – compiling the case study data: as a first step, events will be selected based on multi-spacecraft data availability (M4), as a second step, data for selected events will be compiled and processed and an observational case study will be made. Duration – 12 months.
Task 4.2 – adaptation & evaluation of FD model: if the statistical analysis reveals shortcomings of the model it will be adapted by including additional mechanism (adiabatic cooling). The model will be prepared for a case study evaluation, where the model will be constrained by GCS and in situ parameters and predicted/observed FDs will be compared and analyzed. Duration – 12 months.
WP5–dissemination&outreach: all activities are described in Sections 2.2 and 2.3

3.2. Appropriateness of the allocation of tasks and resources

The research objectives are to develop a new FD model based on GCR diffusion and CME expansion and to study FD observational properties in space and at two different planetary surfaces – Earth and Mars. In T3.2 an analytical diffusion/expansion model will be developed to describe the FD. The model results will be tested against the results of the statistical analysis done in T3.1, which will give us insight whether the model can explain basic FD properties and whether or not it will need inclusion of adiabatic cooling. If necessary, this adaptation of the model will be done in T4.2. The observational properties of FDs will be studied by statistical analysis of Earth-detected FDs (T3.1) and by case study of selected event(s) for which a full set of multi-spacecraft observation, including ground-based measurements from Earth and Mars are available (T4.1). In order to conduct research activities, training activities are needed, as described in WP2, where their timeframe is suitably selected in order to ensure uninterrupted flow of research activities and maximum use of their potential. Resources needed to achieve these objectives are mostly knowledge-based and will be ensured trough training. Infrastructural resources (computing power/servers, programming languages/licences, previously developed programs, data, access to journals) will be provided by the host and partner institutions, as explained in Section 3.4. Consequently, person-month available for research, training and networking costs will be spent for smaller computer equipment (laptop with proper hub & adapters, tablet, portable hard disc, etc.; 3.000,00 EUR), travel expenses & dissemination (secondment in Kiel, public outreach in Croatia, 5 planned conferences and 2 short visits and workshops to be decided during project; 13.000,00 EUR), publication of open access paper and other incidental costs (3.200,00 EUR) and is therefore appropriate in relation to the activities proposed.

3.3 Appropriateness of the management structure and procedures, including risk management

Organisation and management structure will be achieved at several levels. On a first level I will manage the project, where milestones and deliverables will serve as intrinsic monitoring mechanisms by which I will be able to evaluate whether I am performing activities according to the work plan. On a second level, I will be monitored by the supervisor. Four 1-2 page written reports (R1-R4) to the supervisor are foreseen which will not only act as monitoring mechanisms, but also serve as a base for the final project report which will be given to the European Commission (D3). Additionally, the supervisor will make periodical appraisal interviews, as is the standard practice in her group. Weekly group discussions and seminars will also act as monitoring mechanisms, because the group monitors progress of each member through these meetings. Finally, the quality of management will be ensured through UNIGRAZ quality management system which applies to all members of the UNIGRAZ staff. The accountancy office will monitor project finances and provide monthly reports to both me and my supervisor. Administrative aspect of the project (administrative issues regarding salary, travel, holidays, acquisition of equipment etc.) will be done by the administrative office of UNIGRAZ.

There is a minor administrative risk regarding the exact implementation of the work plan due to uncertainty regarding the project start. Some items of the work plan (conferences, outreach) are developed with the assumption that the project starts in June 2017 (based on the indicative timetable given within this call). If the project starts at some other time, planned events change dates or are cancelled, deviations from the work plan might appear. The contingency plan involves minor changes by removing and substituting planned events so that the rest of the work plan does not suffer from the changes. Research risks and corresponding contingency plans are given in the table below.

RISK	CONTINGENCY PLAN
A full list of CME-ICME-FD events for statistical analysis will be compiled in several steps, depending on training activities and achieved milestones, therefore, there is a risk of delay in compiling this list.	Since I will use existing CME-ICME lists as basis, this risk is very low. I will comparatively work on statistical analysis and compilation of the list, including new events as I progress. In worst-case scenario the list will include less events than planned (but still enough for the results to be significant).
In order for event to be suitable for case study we need to have a CME detected with at least one of the STEREO spacecraft and SOHO/LASCO, and an ICME that hit both Earth and Mars frontally at the time after Curiosity rover landed. Mars and Earth are not frequently aligned, furthermore Curiosity rover landed recently, whereas STEREO mission is nearing its end, which might result in difficulties finding suitable events.	Earth and Mars were aligned in 2014 where several CMEs that hit Earth were detected with STEREO and several FDs were observed with MSL/RAD. At least one of these events (see proof-of-concept figure) has a full set of multi-spacecraft measurements, therefore, this risk is medium low. In the worst case scenario I will not find any more of ”perfect examples”, therefore a comprehensive case study will be performed using this event and ”less perfect” events will be taken into consideration.
As with any model, there is a risk that FD model will not be able to explain observation even with adaptations and optimizations, because one simply cannot know upfront whether his theory is valid and whether the model will work. I will try to adapt the model, but realistically, if major problems with the model would occur there would not be enough time to ”fix it” or start from scratch.	This is the highest risk of the project, since it endangers the achievement of the project aim (new FD model to explain observation). If the model does not work, the research will still have a high impact because it will show to the scientific community what not to pursue (information on how things don’t work is often more valuable than information how things MIGHT work). I will focus on pinpointing the problems with the model and which of the aspects are troubling.

3.4 Appropriateness of the institutional environment (infrastructure)

UNIGRAZ is one of the largest universities in Austria with 32,500 students and 4,300 employees, of which 3,000 are scientists. It regards itself as a centre of research in natural sciences and has a lot of experience in helping international researchers. Services are provided devoted in helping foreign employees to find housing and to deal with administration due to mobility (contracts, taxes, etc.). These services are not only available upon arrival but throughout the employment. I will be appointed under a fixed term employment contract with full social security and pension schemes and will have the support that all UNIGRAZ employees have: administrative support which helps with contract and housing, personnel office, University doctor, quality management office, access to journals, free-off-charge open access publication in Springer journals (e.g. Solar Physics). The Institute of Physics at UNIGRAZ will provide a high performance server with IDL licence and SolarSoft installed, extensive database of observational data that the group has compiled over the years, as well as programs for data processing (e.g. GCS), high speed internet and IT service office for software support, help with data handling, weekly backup of data and general IT support. I will be given office space with table, PC and access to server and high speed internet. The IT service and accounting service will help me procure other equipment I might need during the project (e.g. laptop, tablet, portable hard disc). In addition to the infrastructural and logistic support the host is committed that I am well integrated into the group, as described in Section 1.3. The administrative support by UNIGRAZ will be provided during the secondments as well, whereas the partner institutions, CAU and OEAW/SRI will provide office space, high speed internet access and IT support. I plan to use my laptop during secondments (which I will acquire at the start of the project), but if needed partner institutions will provide me with a desktop PC. At OEAW/SRI C. Möstl will provide me with the needed programmes for Grad-Shafranov reconstruction, as well as with support and training in installing them on my laptop and using them. At CAU B. Heber and J. Guo will provide me with the MSL/RAD data, routines for data processing, support in installing them on my laptop and training in using them.