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VOEvent for Solar and Planetary Sciences

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Abstract

With its Planetary Space Weather Service (PSWS), the Europlanet-H2020 Research Insfrastructure (EPN2020RI) project is proposing a compelling set of databases and tools to that provides Space Weather forecasting throughout the Solar System. We present here the selected event transfer system (VOEvent). We describe the user requirements, develop the way to implement event alerts, and chain those to the 1) planetary event and 2) planetary space weather predictions. The service of alerts is developed with the objective to facilitate discovery or prediction announcements within the PSWS user community in order to watch or warn against specific events. The ultimate objective is to set up dedicated amateur and/or professional observation campaigns, diffuse contextual information for science data analysis, and enable safety operations of planet-orbiting spacecraft against the risks of impacts from meteors or solar wind disturbances.

1. Introduction

The PSWS (Planetary Space Weather Service) Joint Research Activities (JRA) will set up the infrastructure necessary to transition to a full planetary space weather service within the lifetime of the project. A variety of tools (in the form of web applications, standalone software, or numerical models in various degrees of implementation) are available for tracing propagation of planetary or solar events through the Solar System and modeling the response of the planetary environment (surfaces, atmospheres, ionospheres, and magnetospheres) to those events. As these tools were usually not originally designed for planetary event prediction or space weather applications, additional development is required for these purposes. The overall objectives of PSWS will be to review, test, improve and adapt methods and tools available within the partner institutes in order to make prototype planetary event/ diary and space weather services operational through PSWS Virtual Access (VA) at the end of the program. One of the goals is: *To identify user requirements, develop a methodology for issuing event alerts, and link those to the planetary event and space weather predictions.* This is the scope of this paper. We first present selected science cases that demonstrate the need for the proposed system. The VOEvent infrastructure is then described, followed with the way we implement it for solar system wide space weather.

2. Science Cases

The forecasting planetary and space weather events is initiated by observations. The observational events can be used as such, or used as inputs for prediction or modeling tools to predict potential subsequent effects.

Planetary meteor impacts have been reported by several teams (including amateurs) in the last decade: First shooting star seen from Mars [1]; amateur astronomer see Perseid hits on the Moon [2]; Fiercest meteor shower on record to hit Mars via comet [3]; Explosion on Jupiter spotted by amateur astronomers [4]. The events are often reported in the news or on amateur online forums. Those transient events are useful for studying the properties of the impacted region. Quick and efficient transmission of them is thus a key step. This methodology is used in astronomy with the Gamma-Ray Bursts alert system [5].

Several studies have been published [6, 7] presenting the observed effects of interplanetary shocks while the hit various planets throughout the solar system, from the Sun to Jupiter, Saturn or even Uranus. Figure 1 shows an interplanetary shock triggered by three coronal mass ejections (CME) in September 2011. The shock has been observed at Earth a few days later (with *in situ* measurement on the WIND spacecraft, as well as in the auroral power monitored by NOAA). It also triggered intense decametric radio emissions at Jupiter three weeks later, that were observed by the STEREO-A/Waves instrument. It finally hit Uranus after a two months journey in the interplanetary medium, with the activation of Uranus atmospheric aurora. The planning of Uranus' aurorae has been prepared using the 1D MHD mSWiM model [8] developed at University of Michigan. This code also confirmed the Jovian radio detection link with the studied event. The major outcome of this study is the first observation of the faint Uranus' aurorae from Earth orbit, and this was only possible thanks to the propagation model.

Several heliospheric propagation models (e.g., [9, 8] have been recently developed and provide the space physics community with time of arrivals of interplanetary shocks, or high energy particle beam at planets or spacecraft in the solar system. Online tools and repositories are providing access to heliospheric simulation runs. The Coordinated Community Modeling Center (CCMC [10]) is a run on demand service center with several propagation models available. Users can also use simulation runs that were previously computed. The French Plasma Physics Data Centre (CDPP [11]) is providing precomputed simulation runs in his AMDA (Automated Multi Dataset Analysis) tool [12] as time series of predicted Solar Wind parameters at the place of the various spacecraft and planets. It also proposes a Propagation Tool [13] that uses both simulation and observational products to derive time of arrivals of Solar Wind events events at the place of the various spacecraft and planets (see Figure 2).

Many science teams and space missions could take advantage of such predictions in the recent years (Smart 1, Rosetta, MEx, MAVEN, VEx, HST, MSL, Dawn), within the next five years (Exomars, Juno, HST/JWST, Solar Orbiter) and ona longer term (Bepi-Colombo, JUICE). This list of missions will be used to prioritize the event catalogs, tools or models that will be implemented in the PSWS alert system.

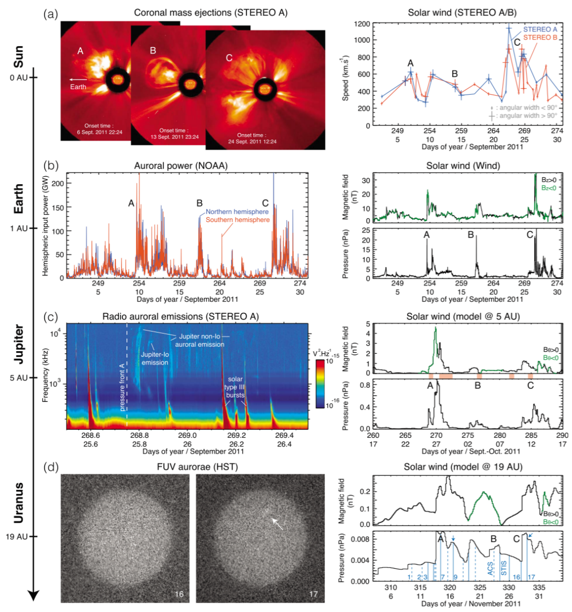

Figure 1: Following an interplanetary shock throughout the solar system, from the Sun to Uranus. Figure extracted from [7]

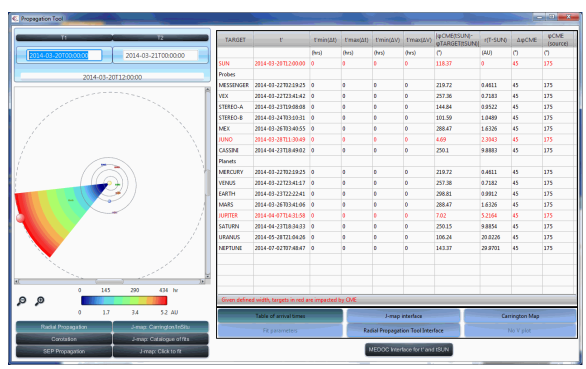

Figure 2: CDPP Propagation Tool

3 Fripon

Meteorite composition have not change since the formation of the solar system, Fripon project propose to use a network of 100 cameras and 25 radio detectors to cover the French territory and detect the meteor orbit and the area of impact. Fripon will calculate impact position and gives area of impact in a private network that will be broadcasted by the Observatoire de Paris VOEvent Broker.

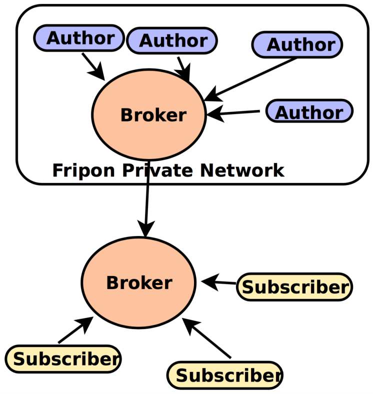

Figure 3: fripon network

4 VOEvent

VOEvent [14] is a standardized language used to report observations of astronomical events; it was officially adopted in 2006 by the International Virtual Observatory Alliance (IVOA). Though most VOEvent messages currently issued are related to supernovae, gravitational microlensing, and gamma-ray bursts, they are intended to be general enough to describe all types of observations of astronomical events, including gravitational wave events.

The VOEvent system is already used by several large-scale projects: the Gamma-Ray Coordinate System (GCN) [5]; the Large Synoptic Survey Telescope (LSST) []; the European Low Frequency Array (LOFAR); or the Solar Dynamic Observatory (SDO). That last project has scopes included in PSWS goal. In each of those projects, VOEvent is used for fast transmission of transient observations. In PSWS, we plan to use VOEvent for both observations and predictions.

Messages are written in XML, providing a structured metadata description of both the observations and the inferences derived from those observations. VOEvent messages are designed to be compact and quickly transmittable over the internet. The version of the VOEvent standard is 2.0, at the time of writing.

As shown on Figure 4, there are three types of nodes: Author, Broker and Subscriber. The Authors are issuing VOEvent. The Brokers are dispatching the VOEvents received from Authors to Subscribers. Subscribers are receiving VOEvents from Brokers. The large scale network is composed of a series of Brokers that are also Subscribers of other Brokers. The Authors must assign a unique IVOA identifier [15] to each issued VOEvent. The Subscribers will only take into account VOEvents with new identifiers. In order to update an event (e.g., update the predicted time of an event, after improved processing), a new VOEvent must be issued as an update of a previous VOEvent with reference to the previous VOEvent identifier. This system ensures consistency and avoids conflicting messages. In the PSWS project, each event will be referred to as with its identifier in catalogs shared with VESPA (Virtual European Solar and Planetary Access), the data distribution infrastructure of EPN2020RI [16].

A VOEvent message contains the following tags:

`<who>` Describing who is responsible (the author and the publisher) for the information contained in the message;

`<how>` a description of the instrumental setup on where the data were obtained;

`<what>` the data (such as source flux) associated with the observations of the event;

`<why>` inferences about the nature of the event;

`<wherewhen>` description of the time and place where the event was recorded. This draws from the Space-time Coordinate (STC) recommendation to the IVOA.

A well-formed VOEvent message must validate against the VOEvent XML schema. A valid message may omit most of the informational tags listed above, but since the creation of VOEvent messages is done automatically, most opt to transmit the fullest content available.

5 Test implementation

We use a tool developed in the frame of LOFAR (Low Frequency Array), for dispatching transient alerts: Comet. It is a freely available, open source implementation of VTP (VOEvent Transfer Protocol).

Acknowledgements

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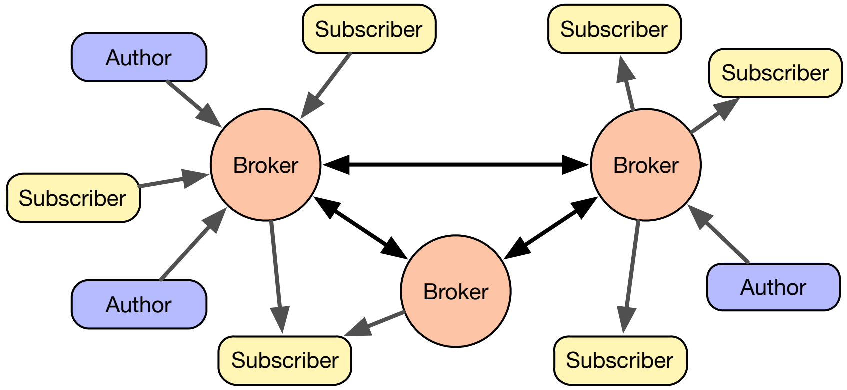

Figure 4: Architecture of VOEvent network.

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[10] CCMC, "Coordinated community modeling center."

[11] CDPP, "Centre de données de la physique des plasmas."

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[13] CDPP, "Propagation tool."

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