French fireball network FRIPON

François Colas[1], Brigitte Zanda[2], Jérémie Vaubaillon[1], Sylvain Bouley[3], Chiara Marmo[3], Yoan Audureau[3], Min Kyung Kwon[1], Jean-Louis Rault[6], Stéphane Caminade[3], Pierre Vernazza[4], Jérôme Gattacceca[5], Mirel Birlan[1], Lucie Maquet[1], Auriane Egal[1], Monica Rotaru[7], Cyril Birnbaum[7], François Cochard[6] and Olivier Thizy[6]

[1] **IMCCE, Observatoire de Paris, Paris France**
francois.colas@imcce.fr

[2] **DIMPMC, Muséum National d'Histoire Naturelle, Paris, France**
Zanda@mnhn.fr

[3] **GEOPS, Université Paris Sud, Orsay, France**
sylvain.bouley@gmail.com

[4] **LAM, Institut Pytheas, Marseille, France**
pierre.vernazza@lam.fr

[5] **CEREGE, Institut Pytheas, Marseille, France**
gattacceca@cerege.fr

[6] **FRIPON, Collaborative Team, Paris, France**
f6agr@orange.fr

[7] **Universciences, Paris, France**
Monica.Rotaru@universcience.fr

FRIPON (Fireball Recovery and Interplanetary Observation Network) was recently founded by ANR (Agence Nationale de la Recherche), its aim being to connect meteoritical science with asteroidal and cometary sciences, in order to better understand our solar system formation and evolution. The main idea is to cover all the French territory to collect a large number of meteorites (one or two per year) with an accurate orbit determination, allowing to pinpoint possible parent bodies. 100 all-sky cameras will be installed at the end of 2015, creating a dense network with an average distance of 100 km between the stations. To maximize the accuracy of the orbit determination, we will mix our optical data with radar data from the GRAVES transmitter received by 25 stations (Rault et al., 2015). As the network installation and the creation of research teams for meteorites involves many persons, at least many more than our small team of professionals, we will develop a participative science network for amateurs called Vigie-Ciel (Zanda et al., 2015). It will be possible to simply use our data, participate in research campaigns or even add cameras to the FRIPON network.

1 Scientific goals

The aim of the project FRIPON is to answer questions that arise about the connections between meteorites and asteroids. It is easy to study a meteorite in a laboratory but we have no idea from where it came from because its orbit is unknown for most of them. On the other hand, we have currently more than 700000 orbits of asteroids with quite no physical information. However these parameters are crucial for understanding the origin and evolution of the solar system. In recent years the planet migration theory has shown that it is possible to find very primitive objects in the main asteroid belt, and that these objects may hit the Earth due to the non-gravitational Yarkovsky forces. It is therefore essential to know the orbits of the collected meteorites to connect their dynamical history and composition. The main goals of FRIPON are to recover fresh meteorites fallen over France and to compute accurate orbits of fireballs connected or not with a meteorite.

2 The network

To allow triangulation measurements of fireballs, we decided to implement one observatory every 80–100 km. As France presents a surface of about 650000 km^2, we need about 100 cameras to cover the whole territory.

Optical Network

Like other fireball networks, we decided to use fish eye lenses to cover the whole sky. Our cameras are based on the Sony chip ICX445, allowing a good efficiency for low light measurements during night time, but also very short exposure times for day time observations. Compared to older networks mainly based on analogic video devices, the improvements of FRIPON are: digital cameras using 1.2 megapixels chips, 10^{-6} sec exposure time for day time, 30 fps, GigE Vision protocol and PoE (Power over Ethernet) allowing 100 m long single cables.

Radio network

The optical network is very efficient to measure the fireball geometry, but speed determination is less easy with only a few points on fish eye pictures. Nevertheless, speed is preeminent for the semi axis orbit measurement, and therefore fundamental to pinpoint the origin of fireballs and the association with possible parent bodies. We will use radar echoes of the GRAVES system dedicated to observe low altitude satellites (Rault et al., 2015). The transmitter is usable all over France, a 200 km spacing being sufficient between radio observatories, so only ¼ of the optical stations will be fitted with radio equipment. The goal is the measure relative speeds thanks to the Doppler-Fizeau effect.

3 Reduction pipeline

The FRIPON project is open source both for hardware (distribution of the cameras by Shelyak Instruments, though compatible cameras can be used) and software[1]. We developed a pipeline based on GigE Vision cameras, but it will be easy to use other camera drivers.

Acquisition

The FreeTure software (Audureau et al., 2015) is developped for Linux and Windows. It is nominally written for GigE Vision cameras. Our hardware configuration is a i3 processor, 8Gb of RAM (for image buffering), 32Gb SSD for system installation and 1Tb HDD for data.

Detection

For detection, FreeTure will use the subtraction of two consecutive frames with a detection threshold. It will analyze the pixels detected on several consecutive frames, to determine the speed of the object and hence the reality of a meteor observation. As the software stores previous images, it can store images centered on each detection.

Astrometry

As it is difficult to measure stars fainter than magnitude 1 on a single frame, we use 1 min stack images or a 10 sec single exposure. Our goal is to reach 0.1 pixel accuracy (Kwon et al., 2015).

Orbits and strewn fields

Presently, we are using standard two locations algorithms. As the FRIPON network will allow multi detection, we will develop in the next months a dedicated method. Our code is based on a robust method (Borovicka, 1990). The orbit is calculated using the SPICE Toolkit developed by NAIF-NASA. To start our pipeline, we used a standard model (Ceplecha, 1987) for the dark flight computation and the strewn field determination.

[1] http://fripon.github.io/freeture/

4 Meteorite recoveries

Research on fireballs and meteorites has always been of interest to the general public, due to the beauty of the shooting stars in the night sky and to the extraterrestrial origin of meteorites. FRIPON will detect fireballs and hence allow us to define meteorite strewn fields within 24 hours, so that meteorite searches can be launched very early. Because of the need to search all over France, including on private land, it is important that the general public will be aware of our project and be willing to help or to participate. Indeed, as the main goal of FRIPON is to recover fresh meteorites (within a few days), our aim is to be able to organize a search campaign with at least 50 persons to scan an area of a few km^2 within a week. Help from the public would hence be most helpful but it is also important to have an operational and trained research team. This project thus appears as a unique occasion to involve the public in a scientific project while promoting informal scientific education. This prompted us to set up Vigie-Ciel, a citizen science network centered on meteorite recovery. FRIPON is an open network based on open-source softwares, and it will accept citizen-run cameras. In addition to fireballs, it will allow scientists and Vigie-Ciel participants to study anything that can be observed by all-sky cameras: bird migrations, bats, clouds, lightning, etc. The data will be freely available to all.

5 Vigie-Ciel

The prime object of Vigie-Ciel is to exploit data from the FRIPON network that will be fully operational by the end of 2015. Participation could involve:

- use of the free data produced by the network to study phenomena other than fireballs seen by the cameras: for example cloud cover, bats, bird migrations, lightning, etc.;
- direct participation in the network by acquisition of a FRIPON compatible camera and/or radio;
- development of software based on the FreeTure open-source platform;
- participating in the network with images made with digital cameras or visual witnesses obtained and/or sent with smartphones;
- participating in meteorite search campaigns, or online search for unknown impact structures in aerial photographs of the Earth's surface;
- attendance at educational programs (general public or students; conferences, exhibits, workshops, etc.).

Participants will benefit at a number of levels, one of which is simply the involvement in a scientific quest, obtaining a better understanding of the scientific results obtained by the program and being, in some cases, associated by name with declarations of new meteorites and new craters as well as with scientific publications. Another benefit will be belonging to a community with a large variety of participants, including scientists, and participating in a project with field work and other informal contacts.

Vigie-Ciel will have a website expected to be fully operational by the spring of 2017. Like FRIPON, the program is structured around regional poles in order to be in close contact with the public all over France to obtain a good knowledge of local conditions and to be able to form search teams that can be active within 48 hours in the case of a meteorite fall. The centers mainly rely on planetariums, scientific museums and other outreach structures that are connected to the FRIPON network through the scientific centers constituted by local/regional scientific laboratories.

Another goal of Vigie-Ciel is to involve any scientific domain connected to astronomy (from our solar system to the whole universe) and to earth sciences. A good example is Rochechouart (the only known meteorite impact crater in France) where the public will be able to see in the same museum both impact breccias and fireball online detections. Another example is the ability to search for unknown impact structures in aerial photographs of the Earth in an online program similar to Galaxy Zoo.

6 Conclusion

At present, the hardware is completely defined and tested. 60 locations are under installation, and we hope to have the whole network set up for the end of 2015. FreeTure source is already distributed on-line and an official release will be available soon, to be fully operational for the end of 2015. One goal of this "open project" is that it can be easily copied, first in Europe to build a network unprecedented in size and eventually worldwide.

Vigie-Ciel is designed to let the public participate in a true research quest on the universe and reconnect with science using their natural attraction to fireballs and meteorites. It will be based on new information technology but also on direct contacts with the scientists using pedagogic tools that will be specifically designed to show how to recognize a meteorite, to observe radio meteors, etc.

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Figure 1 – Installation of a FRIPON video camera on the roof of the Natural History Museum of Vienna, Austria. From left to right: Ludovic Ferrière, Curator of the rock collection of the Vienna Natural History Museum, Pascal Teixeira Da Silva, Ambassador of France in Vienna, Sylvain Bouley, FRIPON Co Investigator , Orsay University, Francois Colas, FRIPON Principal Investigator, Paris Observatory, Brigitte Zanda, Curator of the French national meteorite collection, Musée National d'Histoire naturelle, and Jean-Louis Rault, FRIPON radio network investigator.

François Colas during his lecture (Photo by *Christoph Niederhametner*).