VIGIE-CIEL, A CITIZEN SCIENCE PROJECT ABOUT METEORS, METEORITES AND CRATERS.

B. Zanda[1,2], A. Steinhausser[1], F. Colas[2], S. Bouley[3,2], E. Lewin[4] and the FRIPON and Vigie-Ciel teams[5].
[1]Muséum national d'Histoire naturelle, Paris France (brigitte.zanda@mnhn.fr), [2]Institut de Mécanique Céleste et de Calcul des Ephémérides, Paris, France, [3]Université Paris-Saclay, Orsay, France, [4]Université Grenoble-Alpes, Grenoble, France, [5]FRIPON/Vigie-Ciel teams, Observatoire de Paris and MNHN – Paris, France.

Résumé : Vigie-Ciel est un projet de science citoyenne conçu en France pour inviter le grand public à contribuer à l'étude du flux, de l'origine et de la nature des matériaux extraterrestres qui atteignent la surface de la Terre. Son objectif initial était de récupérer les météorites dont la chute a été détectée par le réseau de caméras FRIPON. Toutefois, les citoyens peuvent désormais apporter leur contribution de diverses autres manières, notamment en recherchant des cratères d'impact terrestres non encore détectés sur le site web de Vigie-Cratère, en signalant des bolides et en hébergeant une caméra FRIPON.

Introduction: Research on fireballs and meteorites has always aroused fascination among the general public because of the beauty of shooting stars and the age and extraterrestrial origin of meteorites. A fireball observation network called FRIPON [1,2] has been setup in France and the neighboring countries under the leadership of the Observatoire de Paris and funded by ANR (Agence Nationale pour la Recherche). FRIPON detects fireballs and allows us to calculate meteorite strewn fields within 24h so that searches can be launched very early on and meteorites can be recovered before they alter significantly. Meteorites in France have always been recovered by the general public because of the need to search all over the place, including in private land. It is thus important that the general public be aware of the scientific value of meteorites and be willing to contribute to our project by helping us find them on the ground, but also by participating to the detection of fireballs and the identification of impact craters on Earth. The citizen science counterpart of the FRIPON network is the Vigie-Ciel project, led by the Muséum national d'Histoire naturelle (MNHN) and originally funded by the "Investissements d'Avenir" program. As participation is more effective if the people involved are informed and trained, Vigie-Ciel also contributes to scientific education on meteors, meteorites and impact craters and, more generally in planetology.

1. A collaborative science program The study of extraterrestrial materials is at the crossroads of geology and astronomy. To our knowledge, no citizen science program on this topic existed up to now. The MNHN has had experience in citizen science networks in natural history for close to 30 years. It runs a series of programs on varied topics (birds, bees, bats, plants in towns…) built over time by a number of researchers with the help of associations involved in nature study and protection. Astronomy, on the other hand, is well known to be the oldest science, and therefore the oldest collaborative science as a professional astronomer is quite a "new" concept (only a few hundred years) compared to astronomical history (a few thousand years). Numerous citizen science programs have been developed on the subject over the world and most specifically in France.The Vigie-Ciel program was hence developed by the two leading French institutions with an interest in citizen sciences and in natural history or astronomy.

2. The Vigie-Ciel protocols Vigie-Ciel was originally concerned mostly with the recovery of meteorites in the field following detections made by the FRIPON network. However, various ways of participating developed over time, in relation with fireball detection and impact crater indentification (www.vigie-ciel.org).
Fireball detection When a fireball appears in the sky it may be seen by numerous people and their observations may be useful in tracking it. The American Meteor Society (AMS) has long been collecting such information and has designed an automated way of displaying the results including a computed likely trajectory. FRIPON/Vigie-Ciel has teamed up with AMS to invite participants to report their observations on the AMS website (www.vigie-ciel.imo.net) which also displays which cameras have observed the bolide and the trajectory calculated by FRIPON, so that any significant discrepancy can be investigated. Such a partnership proves useful to all parties : participants can immediately visualize how many more persons have reported seeing the bolide and get an estimate of its trajectory, while the AMS efforts benefits from the communication from Vigie-Ciel and its British sister network UKMON by a significant boost in the number of reports. For example, for the latest meteorite dropper event in France at the time this abstract is written (April 16th, 2022), there were more than two hundred reports out of which 80% came through the Vigie-Ciel and the UKMON websites. For the most motivated citizens, it is possible to participate in a more systematic way to the surveillance of fireballs by acquiring a FRIPON workstation (camera and computer) which can be put on the network and contribute to its densification and, thus, to its effectiveness.

Training session at the beginning of field seach party

Meteorite search campaigns Searching for a meteorite on the ground is not an easy task. Several test campaigns have allowed us to identify the main issues that have to be dealt with. These are related to: (1) the respect of le-gislation, private property and the inhabitants of the area; (2) the logistical aspects in order to have well-coordinated groups of a reasonable size in the field; (3) the implementation of an efficient communication towards the general public, but also towards the local authorities and the inhabitants of the area. If, for the time being, no meteorites have been found in France through the efforts of FRIPON/Vigie-Ciel, three meteorites have been recovered in the neigboring countries (Cavezzo in Italy [3], Winchcombe in England [4] and Kindberg in Austria [5]) with a contribution of FRIPON equipment and/or through the search methods that were designed by the FRIPON/Vigie-Ciel teams. As in earlier times, all these discoveries involved curious citizens who reached out to scientists, but at least two new factors were also implicated : (1) observations by a professional and/or an amateur camera network which led to a computation of the strewn field and (2) multiple communication channels through the press, the social networks and specially designed leaflets.

Terrestrial impact crater identification In order to further contribute to determining the flux of extraterrestrial material to Earth through geologic times, citizens are also invited to participate in the identification of the "missing" terrestrial impact craters on shaded relief images on the *Vigie-Cratère* website (www.vigie-cratere.org) [6].

3. The Vigie-Ciel network and tools Information and training of potential participants is an essential part of the Vigie-Ciel program and we are still working at improving it with the help of our national, regional and local partners who also play a major role in setting up the field search campaigns when a meteorite is deemed to have fallen in a neighboring area. Such campaigns could not be set up without their active help and their their knowledge of the local territory. These partners, who come from various contexts, are often involved in scientific outreach. They comprise planetariums, natural history museums, astronomy clubs, but also schools, village or town halls... and a large fraction of them also host a FRIPON camera. The Vigie-Ciel National Team offers them training, support and tools – which are still being improved – to perform these tasks. The pedagogic tools we developed include exhibits, a field search training protocol and a set of suitcases containing meteorites, meteowrongs and various tools to study the properties of rocks, which has been reproduced 22 times and distributed in France in the former (smaller) administrative region. These pedagogic suitcase sets are designed to be used by our partners to train interested amateurs and/or to be lent to other structures who wish to become local partners of the project (after they have received a training). So far, the National Team has trained about three times as many instructors as the number of suitcase sets and these, in turn, have the ability to coach new trainers and animators and to organize public outreach events. One of these suitcase sets resides with the Pierre de Lune association in Rochechouart and is to be demonstrated in Cofolens on June 30, 2022 in the course of ICF-CIRIR 2022.

4. Conclusion Vigie-Ciel is a citizen science project designed in France to invite the general public to contribute to studying the flux, origin and nature of extraterrestrial materials that reach the surface of the Earth. Its original focus was on recovering meteorites whose fall was detected by the FRIPON camera network. However, citizens can now contribute in various other ways, which include searching for previously undetected terrestrial impact craters on the Vigie-Cratère website, reporting fireballs and hosting a FRIPON camera.

Set of Vigie-Ciel pedagogic suitcases

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