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Launching the VASCO Citizen Science Project

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Abstract: The Vanishing & Appearing Sources during a Century of Observations (VASCO) project investigates astronomical surveys spanning a time interval of 70 years, searching for unusual and exotic transients. We present herein the VASCO Citizen Science Project, which can identify unusual candidates driven by three different approaches: hypothesis, exploratory, and machine learning, which is particularly useful for SETI searches. To address the big data challenge, VASCO combines three methods: the Virtual Observatory, user-aided machine learning, and visual inspection through citizen science. Here we demonstrate the citizen science project and its improved candidate selection process, and we give a progress report. We also present the VASCO citizen science network led by amateur astronomy associations mainly located in Algeria, Cameroon, and Nigeria. At the moment of writing, the citizen science project has carefully examined 15,593 candidate image pairs in the data (ca. 10% of the candidates), and has so far identified 798 objects classified as "vanished". The most interesting candidates will be followed up with optical and infrared imaging, together with the observations by the most potent radio telescopes.

Keywords: surveys; transients; SETI; citizen science

1. Introduction

Anomalous objects in astronomy are a gold mine for expanding our knowledge about extreme physical conditions and identifying new astrophysical phenomena. Anomalies have always fascinated astronomers and many important discoveries were first regarded as such. For instance, when the first optical spectra of the radio-emitting quasars 3C 273 and 3C 48 were acquired, astronomers encountered weird and unusual spectra that they considered anomalous, only to soon understand these quasi-stellar objects were in fact highly redshifted [1,2]. Likewise, when the first pulsars were discovered [3], the unexpected pulsating radio signals were considered so unlikely that Little Green Men were suggested as a serious possibility. With further investigation, astronomers ultimately developed an understanding of the physics underlying these entirely natural, albeit extreme objects.

Some anomalies have come to stay with us as interesting examples of rare astrophysical objects. An example is *Przybylski's star* [4], a variable star showing unusual amounts of iron and nickel in its spectrum while having high abundances of, e.g., strontium and uranium. Another is the well-known transient *η Carinae*, whose lightcurve showed a giant outburst followed by a slow fading over decades. Other previously well-known astrophysical anomalies have fallen from prominence, following explanation of the underlying physics or identification of the supposed anomaly as an artifact—for example *Halton Arp's redshift anomalies* [5,6] now believed to be chance overlaps in images, but which were once the subject of a grand quarrel among cosmologists in the 1980s.

Some recent anomalies have received much attention in the media; for example *'Oumuamua*, a cigar-shaped interstellar visitor that followed a non-gravitationally bound orbit and does not seem like the most common comet [7], or, *Tabby's Star* [8], a star with an unusual slow dimming caused by obscuration due to an uneven ring of surrounding dust [9], and *Ross 128*, a red dwarf, also figured in the media due to its unusual emission. These examples may need another few years of examination before we understand the key details of the physical mechanisms involved, and it is possible that once we do understand them, we will no longer even consider them anomalies. The same goes for *Fast Radio Bursts* (FRBs), a completely novel class of poorly understood transients, for which the responsible mechanism(s) remain a hotly debated topic. Already in the early 2000s, the importance of a state-of-the-art development of methods to identify fascinating anomalies was discussed by, e.g., Djorgovski et al. (2000, 2001) [10,11]. The importance of anomalies with respect to Searches of Extra Terrestrial Intelligence (SETI) was carefully discussed in the same papers. A recent work that compiles a list of anomalies is the *Breakthrough Listen Exotica Catalog* [12].

One of the successful ways of identifying anomalies is through citizen science projects, where volunteers help scientists in scrutinizing the extremely large datasets assembled by astrononomical surveys. Citizen science projects have already earned a good reputation by leading to interesting discoveries. We can thank the *Galaxy Zoo* project [13,14] for improving our understanding of galaxy evolution, utilizing visual inspection of images of galaxies acquired by the Sloan Digital Sky Survey (SDSS) and subsequent classification according to the most suitable morphological class. An important consequence of this citizen science project was the discovery of "Green peas", a rare class of galaxies with very low masses and high star-formation rates that looked round and green [15]. Interesting astrophysical anomalies such as, e.g., *Hanny's Voorwerp* [16]—a rare quasar ionization echo—and *Tabby's Star* (KIC 8462852) are the results of such citizen science searches. Citizen science projects are now getting competition from machine learning-based identification of