ABSTRACT. A few percent of all stars are variable, yet over 90% of variables brighter than 12 mag have not been discovered yet. There is a need for an all-sky search and for the early detection of any unexpected events: optical flashes from gamma-ray bursts, novae, dwarf novae, supernovae, “killer asteroids.” The ongoing projects like ROTSE, ASAS, TASS, and others, using instruments with just 4 inch aperture, have already discovered thousands of new variable stars, a flash from an explosion at a cosmological distance, and the first partial eclipse of a nearby star by its Jupiter-like planet. About one million variables may be discovered with such small instruments, and many more with larger telescopes. The critical elements are software and full automation of the hardware. A complete census of the brightest eclipsing binaries is needed to select objects for a robust empirical calibration of the accurate distance determination to the Magellanic Clouds, the first step toward the Hubble constant. An archive to be generated by a large number of small instruments will be very valuable for data-mining projects. The real-time alerts will provide great targets of opportunity for follow-up observations with the largest telescopes.

1. INTRODUCTION

The aim of this paper is to present an outline of the idea which, I expect, will lead to the development of a series of long-term observing projects, with the general goal to monitor all sky for variability. This concept is not new, and I am not in a position to present a full historical background. However, it is well known that projects of this kind were carried out in the past and resulted in a magnificent archive of several hundred thousand photographic plates at Harvard and elsewhere. There are several ongoing projects which image all sky visible from a particular site every clear night and archive the data, for example, ROTSE and LOTIS. There are several other projects under development, and in various stages of implementation, for example, ASAS, STARE, and TAROT. A lot of information about these and many other projects is available on the World Wide Web. The links can be found on my home page. This paper has been influenced by my experience with OGLE (Udalski, Kubiak, & Szymański 1997) and ASAS (Pojmański 2000), and to a large extent it presents my plans for the future.

The existing catalogs of variable stars are very incomplete. Pojmański (2000) discovered almost 4000 variable stars brighter than $I = 13$ mag in a small area of the sky, just 300 deg$^2$. Only 4% of these are listed in any catalog of variable stars, while 96% are new discoveries. Using archive ROTSE data Akerlof et al. (2000) found 1781 periodic variable stars brighter than 14 mag in 2000 deg$^2$; 90% of these were new discoveries. All these observations were made with very small, automated instruments, with an aperture of only 4 inches. There may be about one million variable stars in the whole sky accessible to ROTSE and ASAS, waiting to be discovered.

Why should we bother? The simplest answer is: because those variables are out there. For those who would like to know more specific reasons, I shall list some in the next section; also see Paczyński (1997).

How should the searches be done? There are many approaches. Some are very focused, like ROTSE and LOTIS, concentrating on a single goal: to detect optical flashes associated with gamma-ray bursts. In addition to a large number of upper limits, there was one spectacular discovery of an optical flash associated with the GRB 990123, which peaked at 9 mag (Akerlof et al. 1999), with the source being at a large redshift, $z = 1.6$. By design ROTSE archives the data, but a broad search of variability is not high on the priority list, though it has generated an interesting paper (Akerlof et al. 2000). Other projects, like VSNET, monitor variability of a large number of preselected stars. Still other projects, like ASAS, are not focused on any particular type of variability or any specific objects, with a broad goal to monitor everything that varies in brightness (stars, active galactic nuclei, etc.) or position...
Jupiter in the summer of 1994. Cloud and a collision of the comet Shoemaker-Levy with ples are the supernova 1987A in the Large Magellanic bring astronomy to the general public. Some recent exam-

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standing and/or a better calibration of the particular type of follow-up observations, which will provide a better under-

particular point of view, and analyze it in great details with various objects can be only observed. However, given a large number of objects an astronomer may select one (or several) which is the simplest, the “cleanest” from some particular point of view, and analyze it in great details with follow-up observations, which will provide a better understanding and/or a better calibration of the particular type of objects and/or processes.

In a large sample some very rare objects or events will be detected. A spectacular example from the past is FG Sagit-tae, a nucleus of a planetary nebula undergoing a helium shell flash in front of our telescopes (Woodward et al. 1993, and references therein). Some may provide spectacles which bring astronomy to the general public. Some recent examples are the supernova 1987A in the Large Magellanic Cloud and a collision of the comet Shoemaker-Levy with Jupiter in the summer of 1994.

Fully automated real-time data processing will provide instant alerts for a variety of unique targets of opportunity: optical flashes from gamma-ray bursts, novae, dwarf novae, supernovae, gravitational microlensing events, small aster-

oids that collide with Earth every year, and so on. Such alerts will provide indispensable information for the largest and most expensive space- and ground-based telescopes, which have tremendous light-collecting power and/or resolution but have small fields of view.

The archive of photometric measurements will provide a documentation of the history for millions of objects, some of which may turn out to be very interesting in the future. The Harvard patrol plates and the Palomar Sky Survey atlas provide an excellent example of how valuable an astronomical archive can be.

New objects and phenomena will be discovered; this is virtually guaranteed whenever the volume of data increases by several orders of magnitude.

A specific example of targets for calibration to be provid-
ed by the all-sky searches are the detached eclipsing binaries. The distance to the Magellanic Clouds is the important step toward the determination of the Hubble constant, and its uncertainty is the largest contributor to the error in the $H_0$ obtained by the *Hubble Space Telescope* Key Project (see Mould et al. 2000, and references therein). The most direct and accurate distance to the Large and Small Magellanic Clouds obtainable with current technol-

ogy is a century-old method based on detached eclipsing binaries. An excellent outline of the method with a complete list of historical references and the up-to-date status is pro-

vided by Kruszewski & Semeniuk (1999). For the method to be fully trusted it has to be calibrated with relatively nearby, and hence bright, eclipsing binaries toward which purely geometric distances can be measured by means of paral-

laxes or a combination of astrometry and radial velocity amplitudes. To select the best object for the task a complete list of such systems is needed, yet the existing catalogs are very incomplete (see Paczyński 1997; Pojmański 2000).

2. THE GOALS

The many goals of all-sky variability searches were listed and discussed in the past (Paczyński 1997). The following is a brief summary.

A well-calibrated survey with a well-described search method will provide large complete samples of eclipsing binaries, pulsating stars, exploding stars, stars with large proper motions, quasars, asteroids, comets, and other types of objects. Complete samples are important for statistical studies of the galactic structure, the stellar evolution, the history of our planetary system, and so on.

A large number of variables of any specific type will allow future selection of the “cleanest,” simplest objects. A physicist in his or her laboratory may create conditions which allow a study of a specific phenomenon with a minimum of disturbances. An astronomer cannot influence the universe; various objects can be only observed. However, given a large number of objects an astronomer may select one (or several) which is the simplest, the “cleanest” from some particular point of view, and analyze it in great details with follow-up observations, which will provide a better understanding and/or a better calibration of the particular type of objects and/or processes.

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3. ALERTS AND ARCHIVES

It is somewhat surprising that while there are several examples of various alert systems that work well (e.g., microlensing alerts by MACHO in the past, OGLE, and to some extent EROS in the past as well as now), large archives of variability are not so easy to find. There are technical as well as sociological or psychological problems. While my experience is mostly based on microlensing searches, similar patterns can be found elsewhere.

Some projects, like OGLE, try to release as much data as possible. The reason: there is far too much data for a small team to fully analyze, and the more citations there are to OGLE, the better it is for the project. Still, only a small
fraction of the total has been released as quality control, calibration, and so on, are very labor intensive and time consuming. Microlensing photometry is placed on the Web in near real time, but catalogs of pulsating and eclipsing stars take at least a year to prepare, while there has been no general release of $\sim 10^7$ photometric measurements of $\sim 10^5$ variables of many kinds. VSNET provides data for many interesting variable stars at their Web site. Another example of almost immediate release of data is provided by the All-Sky Monitor team on the Rossi X-Ray Timing Explorer, though the volume is relatively modest and hence easy to handle.

I expect that before too long robust enough software will be developed to allow virtually all data from projects like OGLE and ASAS to be put on the Web in near real time. The question remains: how many teams will be willing to follow this policy? I think it depends on the way the community evaluates the performance of a project and on the policy according to which tenure positions are filled. It will be difficult to persuade many to make their data instantly available to the public if the intellectual effort and ingenuity needed for developing a fully functional system (hardware and software) will be considered to be less valuable than the “science” of plotting quantity “$Y$” versus quantity “$X$” and discovering a correlation in somebody’s well-calibrated data.

A related issue is: should a survey project be broken down into the well-defined elements, each done by a single person or a small group? Or should the whole effort be combined in a very large team, with all papers having several dozen authors listed alphabetically and no way to find out whom to credit and whom to blame for different parts of the project? It is rare that more than a few people do the real work on which a particular paper is based. Is it more sensible to put all the names together or to cite as separate papers the well-defined parts of the whole project? Note that OGLE has only six or eight members on its team, while ASAS is a single-person operation. A very successful DUO project (Alard 1996a, 1996b) was mostly a work of a single graduate student. Variability monitoring can also be done by amateur astronomers, as demonstrated by AAVSO, and recently by TASS (Richmond et al. 2000). There is nothing intrinsic to all-sky variability searches that requires huge teams and a near anonymity of the real doers. Can the division of labor, with a proper recognition of the diverse contributions, be implemented in astrophysics? It works in the economy: “The greatest improvement in the productive powers of labour, and the greater part of the skill, dexterity, and judgment with which it is anywhere directed, or applied, seem to have been the effect of the division of labour” (Smith 1776).

I think that in a matter of just a few years it will be possible to have unrestricted access over the Internet to the up-to-date information about the status of any bright variable star, as well as its past variability, with the due credit being automatically given to those who will have provided the data. It is likely that only some people and some teams will follow this open policy, but this may be sufficient to make it practical and to see what impact will it have on astronomy in general. I expect, or at least I hope, that major contributors to the data archives and the alerts will be respected enough to be offered tenure jobs at the major universities.

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