Chapter 1

Small Telescopes in the New Millennium

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Abstract: As we enter the new millennium, astronomers have or will soon have over fifteen 8-meter class telescopes to work with. However, there is likely to remain a need for small telescopes, especially specialized telescopes that can be optimized for and dedicated to specific task. These can be well justified scientifically for projects ranging from solar system studies to cosmology. Small telescopes also are the heart and soul of teaching and public outreach programs. One thing is changing, however, and that is the definition of "small."

Key words: small telescopes, science priorities, astronomy education

1. INTRODUCTION

The world astronomical community is emerging into the 21st century at the end of a decade devoted to the construction of a new generation of very large telescopes. This telescope-building boom was driven by the continued scientific need to press deeper and fainter and by the increased demand for optical and infrared astronomical observations to support space missions and to follow up on spectacular discoveries in cosmology, star and planet formation, and the general evolution of the contents of the Universe. The drive to larger, better telescopes was also driven by the possibility of improvements in imaging performance and followed the development in the 1980's of almost perfect electronic detectors in the optical and near-infrared. Modern low noise, large format array detectors based on Silicon, Indium-Antimonide and Mercury-Cadmium-Telluride together cover the full range of OIR wavelengths accessible from the ground, 0.3-5 microns, with nearly

100% quantum efficiency and very low readout noise and dark current). The only way to go was up.

Even as larger and larger telescopes are contemplated for their increased collecting area and increased angular resolution, there still is a need for small telescopes in our research and teaching arsenal. As very large telescopes become both more common and more specialized, the demand for time on them has concomitantly increased. Astronomy is a growing field. In the US alone, the size of the professional astronomical community grew by nearly 50. There has been significant growth in the number of colleges and universities with astronomy departments or with significant astronomy components in their physics departments.

A second consequence of the improvement in detectors has been that even “small" telescopes are capable of making forefront observations and obtaining forefront datasets. The most current examples in the US include the wealth of data coming from the 2 Micron All-Sky Survey (two 1.3m telescopes), the Sloan Digital Sky Survey (a wide field 2.5m), the study of rapid bursts with ROTSE 0.45m, supernovae searches with the KAIT 0.76-m telescope, and the search for transients with the LOTIS 4x0.111m cameras, mapping ionized gas in the northern sky with WHAM, the 0.6m Wisconsin H-alpha Mapper, and searches for killer asteroids with the 1m LINEAR telescope.

Lastly, amateur astronomers, often in clubs, are capable of building 1m class telescopes and participating in real astrophysical research such as variable star observations or supernovae searches, and also in the incredibly important arena of public outreach. The same is true for small colleges, where students, using small telescopes and commercially available, intermediate format electronic cameras, can contribute to fundamental research on subjects as varied as the properties of stars to the measurement of distances in the Universe (See almost any issue of the journal of the American Association of Variable Star Observers).

Do we continue to need small telescopes?

2. DRIVERS

There are two simple yet important drivers for the continued support of small telescopes:

2.1 The Right Tool For The Job

Many of the programs in the above paragraph require specialized telescopes, either because of constraints on time and access, field-of-view, survey work or slew characteristics. Monitoring variable objects, especially if full phase coverage is essential, requires telescopes with stable instrumentation and very flexible schedules. Every large telescope currently in operation has a suite of instruments that changes with the phase of the moon—usually a faint object spectrograph and camera when the sky is dark and a high-resolution spectrograph and/or an IR camera and spectrograph for when the moon is up. For very broad scientific programs, such a suite optimizes the scientific output of the observatory. However, there are key programs, such as following SN light curves (Riess et al 1999) or hunting for Machos (Alcock et al 2001) or searches for variable stars (DIRECT, Macri et al. 2001) where the optimal strategy is to have a single instrument, a CCD camera, on the telescope at all times.

Similarly, for large area surveys that do not require the deepest possible imaging, the aerial coverage of a small telescope varies inversely as the square of the diameter of the telescope for fixed focal ratio. Since modern, state of the art, large area detectors can cost as much as a small telescope (the going rate last year for a 2048x2048 pixel HgCdTe array was nearly a quarter of a million dollars), paving a large angular extent on a small telescope is almost two orders of magnitude cheaper on a 1m than an 8m. Classic examples again are 2MASS and WHAM (Reynolds et al 1998). Generally, the size of a telescope needed for imaging surveys to provide object identifications for spectroscopy goes as the square-root of the relative spectral resolution; in the case of imaging through normal filters (R = 5) relative to classification spectroscopy or that needed for galaxy radial velocity dispersions (R=500), the number is $\sim(500/5)^{1/2} = 10$, so a 1m telescope can serve effectively as a finder for a 10-m assuming other site and telescope characteristics are equal. This argument is the same as that used well over half a century ago to justify the building of the 1.2-m Palomar Schmidt telescope to serve as a “finder” for the 200-inch Hale telescope, and is still valid today. (Note: To be fully correct, one needs to modify the above formula to take into account the different spatial resolutions and noise sources to estimate the proper ratio for any specific case. For example, if the diffraction limit, rather than the natural site seeing limit, is reached at both telescopes, a somewhat large imaging telescope is required.) Also rather curiously, if a bright supernova went off in our Milky Way or one of our nearby neighbor galaxies in the Local Group, we would need a good spectrograph (like the ones at the 1.5m telescopes at Mt. Hopkins and Cerro Tololo) to follow it up—the instruments on the very large telescopes would saturate in less than the minimum allowable integration time!

Finally, in the tool department, there are projects like survey spectroscopy of bright galaxies where Bowen's law (Bowen 1964, Case B) for moderately extended objects holds. That is to say the gain in signal to-noise goes only linearly with telescope diameter. If small telescopes can use multi-object spectrographs, such as the 120-fiber spectrograph on the 1.2m SRC Schmidt telescope, currently being used for the 6dF survey, the bang for the buck can be enormous. Again, the match of a high quality instrument with a specific scientific objective (in this case the southern 2MASS Redshift Survey, Huchra 2001) yields a winning strategy with a very small telescope.

2.2 Education, Training and Public Outreach

Despite the promise of the web and "Virtual" observatories, there is still no substitute for getting kids to telescopes. Here kids can be defined as primary and secondary school students, undergraduates, graduate students, especially those interested in instrumentation, and anyone else interested in seeing the sky up close and personal (kids at heart!). As of June 2002, there were almost 260,000 amateur astronomy sites listed on the web and over three million astronomy sites overall. Of all the sciences, there is little doubt that astronomy has the greatest public appeal and almost all of that is positive (in contrast to nuclear physics, which has a rather mixed public reputation). Of all the physical sciences, astronomy is the only one with a host of its own public and private "museums"—planetaria. The National Air and Space Museum is the Smithsonian's biggest draw.

Astronomy is also one of the best hooks for getting college students interested in science. Statistics compiled by the AIP and the AAPT indicate that more undergraduates take general astronomy than just about any other science course. Astronomy problems are usually very visual and can be used to convey a number of very fundamental concepts. Using telescopes to do such problems, by eye at a general level and with low-cost electronic cameras for more advanced courses, is rated over and over again as one of the best learning experiences for college students. In fact, since there is so much real science that can be done with small telescopes, it is one of the best ways of involving advanced undergraduates in research. The number of small to intermediate (0.6-1.0m) "teaching" telescopes is astronomical, and it is not expensive to provide them with very reasonable instrumentation for even more advanced projects (Kannappan et al. 2002). For example, I'm now involved in a project to provide a local secondary school with a well-instrumented 24-inch telescope!

And at higher levels, small telescopes provide opportunities for graduate students to learn first hand about instrumentation, often by being involved in building or operating new, simple instruments—I still remember working with Jim Gunn to implement a new image intensified camera for the Palomar 60-inch when I was a student. While at the National Observatories and at most major private observatories students are neither encouraged nor often allowed to experiment with instrumentation on 8m class telescopes, building simple instruments for small telescopes is one of the best ways of training students (Barden, Ramsey & Truax 1980; Claver 1992), including training them in developing and leading the construction of instrumentation.

3. SUMMARY

There is clearly a need for small telescopes, even in the era of 8m behemoths and planning for 20, 30 50 and 100m giant and "overwhelmingly large" telescopes. This need is driven by two important tasks: (1) fundamental research most economically and efficiently done on small telescopes, and (2) education, training and public outreach. For research, the definition of small is evolving. It still includes the 1m class telescopes and smaller for specific tasks, but now also includes survey telescopes like the SDSS 2.5m. In almost all such cases, telescopes and projects like this deserve, nay, required national funding since their products are of and in the national interest.

For teaching, it is hard to beat small telescopes and the now low cost associated instrumentation for getting students and the public involved. In these cases, support for such telescopes is in the purview of the institution—school, college, university, planetarium—that operates them.

Whatever the future holds for giant telescopes and the science that drives them, cost effective, well instrumented, small telescopes have their place in the arsenal of science. The author would like to thank all his colleagues in crime—doing cosmology with small telescopes—over the last three decades. This paper was written at the Aspen Center for Physics, which is supported by the NSF and NASA.

4. REFERENCES

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