Globalizing Observations: Prospects and Practicalities

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Abstract

To promote fuller awareness we should aim to globalize observations. In a more immediate sense, this addresses the planetary distribution of observing facilities and their access. What components in such facilities occur in 'global networks'? What factors optimize the growth and scientific viability of such a network? What kinds of progress can be expected?

1. Introduction

Astronomers sometimes consider, or encounter, general strategies for improving observational data-acquisition, given built-in limitations of location, diurnal cycle, weather, human capabilities and associated logistics, as well as other factors of the present environment. Prominent among these are the rapidly growing electronics and telecommunications 'revolution', and greater production of manufactured optical and mechanical components of high quality at lower real cost for standard items. The present paper outlines some thinking points — mainly in the area of networking observational (photometric) facilities, though other aspects arise. A fuller version will appear elsewhere (Budding, 1992).

Many related issues were discussed at the Strasbourg Conference on *Coordination of Observational Projects* (eds. C. Jaschek and C. Sterken, 1988), as well as *Multiwavelength Astrophysics* (ed. F. Córdova, 1988). Also bearing on this article are a group of papers appearing in *Automatic Small Telescopes* (eds. Hayes and Genet, 1988), and redeveloped at the JCM on automated telescopes at the IAU General Assembly of 1991 (ed. S. Adelman).

2. Global networks and questions they raise

Numerous global networks, of different types and degrees of complexity exist, eg. the world post-mailing system, meteorological services or the organization of public lending libraries. The recent growth of *computer networks* is ushering in a highly relevant new era of effective communicability (Benn, 1990). Remote logging into a computer or database becomes a standard operation, and from that remote control is foreseen, particularly with automatic (photometric) telescopes (APTs). These represent one of the simplest examples, with telescope and photometer controlled by a computer, which can be remotely accessed, perhaps by a modem and telephone line. But how are things organized?

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DEMAND, SUPPLY AND EFFICIENCY

We should consider first the demands promoting observational networks. Undoubtedly, more data is a primary demand. APTs demonstrate the potential for higher levels of data — not just more, or 'ungapped' data-sets, but data of a fundamentally higher quality (Young *et al.*, 1991). Another key reason, mentioned by Sterken (1988), is basic attestability of observations. If two (or more) facilities independently record the same events then a vital element of proof is added to the result. Of course, this depends on appropriate quality control of separate facilities purporting to observe the same, or similar, objects. Crawford *et al.* (1988) have also commented on educative and developmental functions of robotic observatories.

We can model 'quality' scientific output as a function of the aperture size of used telescopes. Let us write

$$q(r) = f n_{ag}(r) r \sqrt{t(r)}, \tag{1}$$

where q is the rate of scientific output measured by published (observational) information; n_{ag} is the number of astronomers who get observing time; r is telescope aperture size (proportional to S/N, and therefore data quality); t is the average allocation time for each 'getting astronomer'; and f is an adjustment factor, used to estimate aspects of quality science which may be hard to specify exactly. Since $t \propto 1/n_{ag}$ and $n_{ag} \propto n_t$, the number of telescopes of aperture size r, we have

$$q(r) \propto f r \sqrt{n_t(r)}. \tag{2}$$

Now $n_t(r)$ can be set $\propto r^{-m}$ (Figure 1, cf. also Krisciunas, 1988, Fig. 8.6). We can also relate m with m' of an aperture-cost law $C \propto r^{m'}$ (Abt, 1980). This leaves f, which, to account for 'prestige' effects, we set $\propto r^p$. We then find

$$q(r) \propto r^{1+p-m/2}. \tag{3}$$

A value of $m \approx 2.1$ was obtained from data on 186 optical telescopes of aperture >0.5m listed by Kuiper and Middlehurst (1960). A slightly lesser value (1.9) holds for 282 telescopes detailed in the *Astronomical Almanac*, 1981-4. Abt's (1980) values for m' were about 2.4 initially, and 2.1 in the longer term. The general result implies near unitary demand elasticity m'/m, for larger (professional) facilities. Elasticity in supply, however, associated with technological progress and durability, is likely to considerably boost the numbers of smaller facilities.

The value of p is inevitably a matter of speculation, but it clearly has to outweigh the negative effects of both availability ($m/2$) and cost (m') to justify the proposition that best *value* observational astronomy comes from telescopes of largest size. The value productivities (v) of large telescopes were already questioned on this basis by Abt (1980), without respect for the networking possibility.

If ν networked telescopes of aperture r' can be regarded as equivalent to one of size r where $r/r' = \sqrt{\nu}$, we can compare quality science rates at r and r' as:

$$\frac{q_\nu(r')}{q(r)} = \nu^{m/4} e^{-a(\nu-1)}. \tag{4}$$

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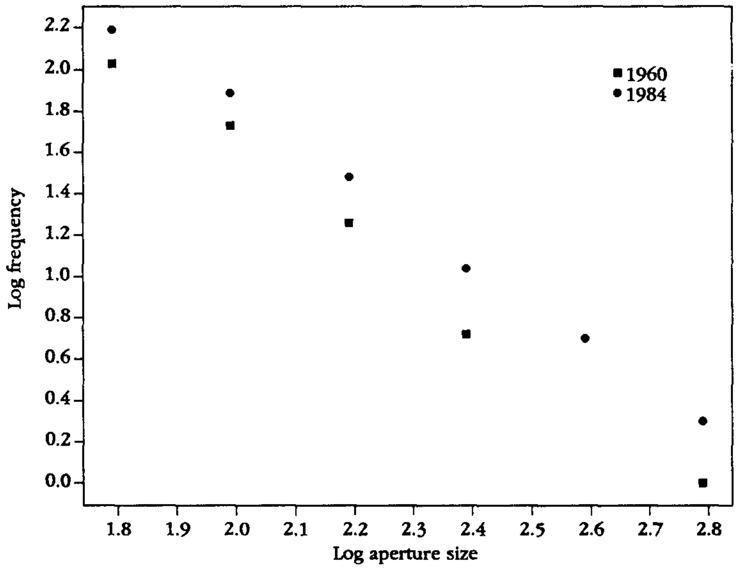

Figure 1 Larger size optical telescope log(frequency) versus log(aperture).

The 'prestige' of ν networked telescopes should be equivalent to that of one of the same effective area, however, the exponential term reflects the communicational difficulty of co-ordinating many smaller telescopes, which exponentiates with increasing ν. On this model we find an optimal group size $(m/4a)$ for effective networking. The cost advantage in networking ν telescopes at a given effective size scales like $\nu^{m'/2-1}$.

Since we are borrowing terms from economists, we may also refer to 'diminishing returns' effects. Two come to mind... the increasing demand for radio frequencies to serve telecommunication needs actually encroaches upon the prevention of radio-pollution, a cause well known to radio-astronomers. Another potential problem is information over-supply — the flooding of computer memory areas with unsolicited data, or the software explosion (Lawden, 1992).

System specification

Planning for a computer network involves a spelling out of key factors such as node interrogation and response rates. One point is the large difference in bandwidth and message time combination for human and machine processors. Modern areal observation involves data collection rates of $\sim$ 10Mbd, though intelligent reduction implies bringing this to a final rate comparable to that of typical human awareness — $\sim$ 10 bd, or perhaps the information rate in scientific papers — $\sim 10^{-3}$ bd (per astronomer). In this way, transmission speeds required for various operations can be estimated. A thousand active users could justify mean network transmission speeds

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of $\sim$ 10 Kbd, which allows sufficient time for front-end processing.

Real time or batch mode operation

Many astronomers know of remote operation through observing by satellite. The IUE retains real time investigator presence during observations, though this is not strictly necessary (cf. Wamsteker, 1988). Batch-mode working suggests sometimes frustrating 'bureaucratic' delays for active users. Faster and more plentiful processing power has tended to push general usage towards on-line timesharing. An implication of this for observations is many small 'intelligent' telescopes, rather than one centralized super-device. One can envisage batch-mode requests to an international observing network agency (perhaps like the proposed 'GNAT' — Crawford, 1992), for new data on an object — in a similar way to seeking out existent, but obscure, data via inter-library loans. The relevant observational task should not be a complex challenge. A sufficiently detailed request is put in, and, some time later, new data comes down an e-mail connection.

Batch-mode operation rules out the sometimes vital element of on-line feedback and correction, as well as lowering the chance of serendipitous discovery. Observation-oriented research astronomers may not favour it, but for routine-type data-acquisition it seems appropriate.

Human issues

A number of other issues, generally connected with the way humans organize themselves, are raised by this subject. These seem inherently complex: some are referred to in Budding (1992).

3. Three levels of global network for astronomy

In time, various categories of electronic linkage to distributed observational facilties may well develop — for present purposes we consider three possible levels of global network, designated simply as high, medium and low.

High

Under this heading comes dedicated equipment involving 'centre-of-excellence' type institutions. There is an implication of highly competitive usage on well specified proposals. A powerful network centre directs proceedings. Project costs can be estimated to be $\sim\$10^6$ (cf. also Wisniewski, 1988). The 'Whole Earth Telescope' (WET), at least in its fully planned form (Nather *et al.*, 1990), may be an example.

WET is a going concern: it has already produced impressive long continuous data runs. A comparable facility, still at the planning stage, is that of a lunar APT network (Zeilik, 1991). This facility is intended as an add-on to the science centred around a large lunar base. Unlike the WET, it is not controlled in real-time by a Principal Investigator. Rather, it has intelligent controllers which schedule and process received observational requests in batch-mode.

MEDIUM

Most progress in networked observations hitherto has been made in medium-level, internationally co-ordinated, generally *ad hoc* observation campaigns with very specific targets. Many of these were reviewed in the Strasbourg Conference of 1988 (*op. cit*). A number of organizations, often centering around certain active professionals, have formed themselves at this level to help propagate campaigns on particular stars, usually with the aim of combining data from multi-site multi-wavelength facilities. One example was the 1990 campaign on AB Dor, which gave rise to thought-provoking correlations between the radio, optical and X-ray 'light curves' (Budding, *et al.*, 1992).

In medium level projects existing equipment is used, so costs are more related to the movements of observers and data-processing. Individual campaigns might involve gross outlays of $\sim\$10^4$, but an organization setting itself up to deal with such projects could arrange for several in a year.

LOW

A potentially significant development of recent times is the the 'PCO', a low-cost, PC-controlled backyard observatory (Hudson *et al.*, 1992). Local groups of individuals with such facilities can network via public bulletin boards. Genet (1992) has envisaged a community of participating (largely amateur) astronomical observers with: a) a large number of users, b) small telescopes, c) an educational function, d) a coordinated approach to observing which can have applications to certain research goals (cf. also Shibata, 1991).

To fix ideas, a sum of say $\$10^3$ buys a telescope of around 20cm aperture. Such a telescope receives photons over a broad-band filter's range from a 5th mag star at around 1MHz, and in terms of photon noise, would be adequate for millimagnitude surveillance of bright (naked-eye) stars, or providing more continuous records on peculiarities of well known but enigmatic objects, eg. η Car.

4. Inferences and final remarks

We can use the formulae of section 2 to make a few general comparisons across the project levels of section 3. Let us suppose that the WET group size is near optimal, so that a in (4) $\sim$ 0.05. We similarly adopt, for exploratory purposes, m=2, m' = 2.5, p = 2. The results are indicated in the table,

On these figures it would appear that quality science is still preferentially generated by high level projects, though medium level work gives comparable value productivity. Low-level work seems unlikely to match the output of these groups, unless it is much easier to organize very large groups than we surmise. On the other hand, the cost advantage of low-level installations will considerably enhance their value productivity if they can form compact active networks.

Projecting here how further developments might be fostered, I offer some suggestions about possible functions of a 'GNAT'-type organization as follows: (a) assist

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Table 1: Quality science rate and value productivity for different network groups.

	H	M	L(a)	L(b)
$\overline{r}$	1	0.5	0.2	0.2
ν	10	40	250	30
q	10^{-3}	4.5×10^{-4}	3.1×10^{-8}	7.6×10^{-5}
v	1	0.63	6.9×10^{-5}	1.4

with communications of high-level programmes; (b) encourage observatory directors to allocate facilities, particularly with regard to batch-mode 'services'; (c) propagate information on remotely controlled observing; (d) help develop smaller, underused or remote facilities; (e) encourage and educate observing amateurs and students; (f) record existence of low-level contributors, receive and communicate their data; (g) process requests for certain types of data from astronomers.

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Discussion

W.Z. Wisniewski: *The network should be financially independent. Even with the best will, directors of observatories cannot easily allocate telescope time unless participants get their own money.*

Budding: I believe that the proposed global network (GNAT-type) organisation provides some financial incentive to directors to help achieve the required function.

C.L. Sterken: *I have a worry about the PCO concept. It will not only increase the diversity of instruments applied, there is also the introduction of an extra parameter, which is the necessary motivation to push the measurements to the level of precision the networks needs. I have no experience with PCO, but I had some experience in multisite campaigns involving personal observations, which in fact are progenitors of PCO. I found it extremely difficult to persuade such participants to push their performances to the millimagnitude level of precision.*

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