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Discovery potential of small/medium-size optical telescopes : A study of publication patterns in *Nature* (1993-95)

Gopal-Krishna and S. Barve
National Centre for Radio Astrophysics, TIFR, Pune Univ. Campus, Pune 411 007, India

The search after truth, and its eager pursuit, are peculiar to man
Cicero

1. Modern astronomy : A game of multiple wavelengths

The tendency of the celestial objects to radiate across the entire electromagnetic spectrum from decametre to γ - *ray* wavelengths, has been the impetus behind the present era of multi-wavelength astronomy. While the optical band remained our sole window to the universe throughout most of the history, the past 5-6 decades have witnessed the genesis and dramatic progress of other branches of astronomy, encompassing the radio, sub-millimetre, infrared, X - *ray* and γ - *ray* bands. The short wavelength astronomy owes its rapid growth, in particular, to the advent of the satellite era in the recent decades, and space astronomy is likely to play an increasingly prominent role at practically all the wavebands in the coming decades.

The various electromagnetic bands yield complementary information and have their inherent strengths and limitations. It is generally acknowledged that the optical band, though quite narrow, is particularly richly endowed with the diagnostics of physical conditions. It is therefore not surprising that objects found through other electromagnetic windows need to be observed in the optical, in order that their basic identity can be established and astrophysics pursued.

Over the past decade, there has been a phenomenal rise in both the volume and scope of the astronomical literature. This brings several *global* questions to the fore. For instance, one would like to examine the underlying patterns in the published literature, in order to be able to grapple with questions such as the relative roles of different wavebands, astrophysical areas and telescope classes in generating new insight through important results obtained in recent years. This has motivated us to undertake a long-term study, the first instalment of which is reported here. This is based on an analysis of the astronomy papers published in the journal *Nature* during the 3-year period 1993-95. The choice of this journal reflects its strong committment to publishing only the most promising findings, based on truly original work. This is reflected in the outstandingly high *'Impact Factor'* of *Nature vis-a-vis* other reputed periodicals in the field of Astronomy & Astrophysics (Table 1). Some of these other journals will be included later in an expanded version of the present study (see, also, S. Barve, 1997, M. Lib. dissertation, Univ. of Pune).

Table 1. 'Impact Factors' for some prominent Astronomy journals$.

Journal	Impact Factor (1995)
Nature	27.074
Annual Review of Astronomy & Astrophysics	12.452
Astrophysical Letters Communication	3.938
Monthly Notices of the RAS	3.813
Astrophysical Journal	3.484
Astronomical Journal	2.847
Astronomy and Astrophysics Review	2.364
Astronomy and Astrophysics	2.294
Publ. of the Astron. Soc. of Japan	1.402
Publ. of the Astron. Soc. of the Pacific	1.387

$ Impact Factor is a measure of the frequency with which the 'average' article in a journal has been cited in a particular year. (SCI-Journal Citation Reports, 1995, Philadelphia).

2. Some key questions and emerging patterns

During the period 1993-95, a total of 218 astronomy papers were reported in *Nature*. These include *Letters, Articles* and *Review* articles. In order to quantify our search for publication patterns we have classified these papers according to 'Area', 'Category' and 'Band', as defined below.

Area : The five broad Areas into which the papers have been classified are: *(i) Solar system; (ii) Galactic; (iii) Extragalactic; (iv) Cosmology; and (v) Others.*

Category **:** The four main categories defined for the papers are: *(i) Observational, (ii) Theoretical, (iii) Analysis,* and *(iv) Miscellaneous.*

Note that the *Analysis* category refers to the papers presenting an analysis of already published data (except when the data were taken from large, archival databases, in which case the paper was placed in the *Observational* category). The *Miscellaneous* category is meant for the papers reporting mainly computer simulations, laboratory experiments, instrumention and other technical developments. *Review articles* are also assigned to the *Miscellaneous* category.

Band : The electromagnetic spectrum is divided into the following main bands: *(i) Radio; (ii) IR / Millimetre (including sub-millimetre, far-infrared, mid-infrared); (iii) Optical (including near-infrared), (iv) Ultra-violet; and (v)* X/γ *- rays.*

Additional data organization was carried out in response to the following questions:

(a) Relative roles of large and medium / small-size telescopes in each waveband. The quantitative indicator employed is the number of observational papers in which the principal role was played by the telescopes of thé different aperture classes.

(b) Relative contributions of different countries, i.e., the number of papers in the different *categories*, originating from different countries (on the basis of the first author's affiliation).

(c) Size of the author-list for papers under the different categories.

Area-wise distribution of the publications:

Table 2 gives the Area-wise distribution of the papers for the 4 *categories*. It is interesting that the two dominant areas in the *Observational* category are *Galactic* and *Extragalactic*, while the top rank in the Theoretical category is held by papers on the *Solar system.*

Table 2. Division among the five main 'Areas'.

Category	Year	Extragalactic	Galactic	Cosmology	Solar System	Misc.	Total
Observational	1993	16	20	1	10	-	47
	1994	16	15	6	4	-	41
	1995	10	14	5	9	-	38
		42 (33%)	49 (39%)	12 (10%)	23(18%)	-	126
Theoretical	1993	6	5	-	9	-	20
	1994	5	1	3	6	1	16
	1995	1	2	2	8	-	13
		12(25%)	8(16%)	5(10%)	23(47%)	1(2%)	49
Analysis	1993	1	3	3	3	1	11
	1994	-	2	2	3	-	7
	1995	-	1	-	1	-	2
		1(5%)	6(30%)	5(25%)	7(35%)	1(5%)	20
Others	1993	-	3	1	2	2	8
	1994	-	3	1	2	1	7
	1995	-	3	1	3	1	8
		-	9(39%)	3(13%)	7(31%)	4(17%)	23

Category-wise distribution of the publications:

Of the total 218 papers reported during the 3-year period, the lion's share went to the *Observational* category (58%), followed by *Theoretical* (22%), *Others* (11%) and *Analysis* (9%). The pre-eminent position of the *Observational* category is found to be a persistent feature over the 3 years. Note that the principal input to the papers in this category comes from observations, though theoretical interpretation of the observations may as well be a part of the paper.

The role of the different electromagnetic spectral windows (BANDS) :

Table 3 presents the year-wise distribution of all 126 '*observational*' papers according to the electromagnetic waveband through which the principal new information reported in the paper was secured. The most striking result is that *optical* band consistently outperformed all other bands in each of the three years. Averaged over the 3-year period, the optical band accounts for 41 % of all observational papers reported in *Nature*. The close runners for the second and third places are the *radio* and the high energy (X/γ - ray) bands.

Table 3. Division of papers among the different 'Bands'.

Year	Radio	Infrared - MM	Optical/Near - IR	UV	X/Gamma-ray	Total
1993	12(26%)	2(4%)	22(47%)	2(4%)	9(19%)	47
1994	9(22%)	7(17%)	11(27%)	3(7%)	11(27%)	41
1995	6(16%)	3(8%)	18(47%)	4(11%)	7(18%)	38
Total	27(21%)	12(10%)	51(41%)	9(7%)	27(21%)	126

Relative contributions of different countries:

Going by the criteria of the first author's affiliation, we have presented in Table 4 the papers of the different *categories* originating from various countries, for the 3-year period. The top contributors are: USA (with 116 papers), followed by UK (26), Germany (13), Japan (12), France (11), Australia (9) and The Netherlands (7). In the matter of review articles, too, USA emerges at the top (4 reviews), followed by Germany, Japan and U.K. with one review article each. Note that, as per Nature's editorial policy, review articles are normally invited contributions. Lastly, we note that Indian contribution during the 3-year period amounts to 2 papers, both being *Letters* in the *theoretical* category.

Table 4. Number of papers originating from different countries$.

Country	Observational			Theoretical			Analysis			Others			Total
	93	94	95	93	94	95	93	94	95	93	94	95	Total
Australia	5	-	3	-	1	-	-	-	-	-	-	-	9
Canada	1	2	-	-	-	-	-	-	-	-	-	-	3
Chile	-	1	-	-	-	-	-	-	-	-	-	-	1
China	-	1	-	-	-	-	-	-	-	-	-	-	1
France	3	3	-	3	-	1	-	-	-	-	-	1	11
Germany	3	3	2	-	1	1	-	1	-	R	-	1	13
India	-	-	-	1	1	-	-	-	-	-	-	-	2
Ireland	1	-	-	-	-	-	-	-	-	-	-	-	1
Italy	1	-	2	-	1	-	-	1	-	-	-	-	5
Japan	1	4	3	1	1	-	-	-	-	R	-	1	12
Netherlands	3	3	1	-	-	-	-	-	-	-	-	-	7
Russia	1	-	-	1	-	-	-	-	-	-	-	-	2
South Africa	-	-	-	-	-	-	-	1	-	-	-	-	1
Spain	1	-	4	-	1	-	-	-	-	-	-	-	6
Switzerland	-	-	1	-	-	-	-	-	-	1	-	-	2
U. K.	8	4	4	2	1	-	4	2	-	-	R	-	26
USA	19	20	18	12	9	11	7	2	2	R+4	R+5	2R+3	116
Total		126			49			20			23		218

$ Going by the first author's affiliation (Sect. 2). 'R' stands for review article.

Comments on the 'size' of the author-list :

The distribution of this parameter for the *Observational, Theoretical, Analysis* and *Others* categories is shown in Fig.1. As expected, the distribution for the *Observational* category has the longest tail. Another interesting feature is the striking lack of single-author *observational* papers (just one such paper during the 3 years). Three-author papers are the most common in the *Observational* category, while two-author papers are the most common in the *Theoretical* category. As an indicator of international collaboration, we also show with shaded area the papers whose first two authors are affiliated to different countries (Fig.1).

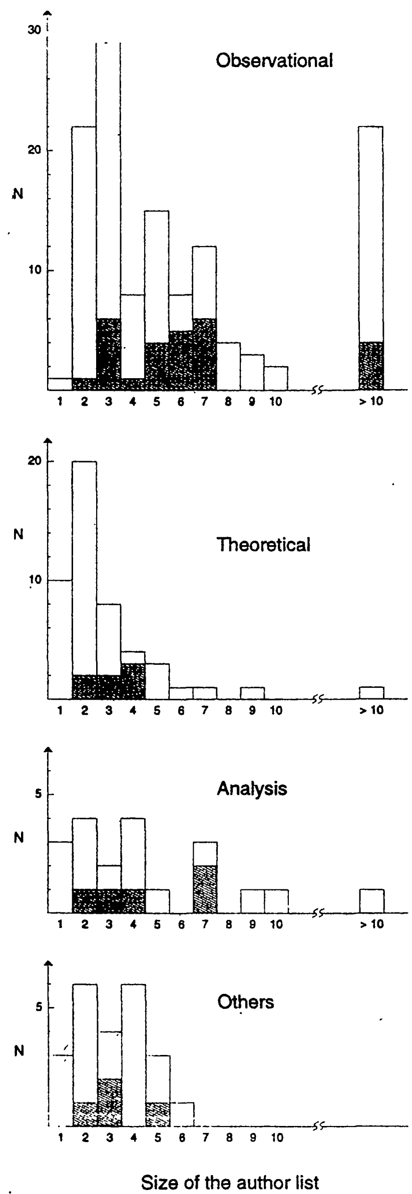

Figure 1. Size of the author list.

3. The role of small and medium-size telescopes

In the present era of intense competition, are small / medium-size telescopes capable of producing results meriting publication in front-ranking journals, like *Nature* ? One important objective of our study is to examine this key question, as it may have important bearing on the establishment of astronomy facilities in developing countries and in the university sector (where funds are usually scarce even in industrially advanced nations). In our analysis we have identified, for each paper in the *observational* category, the *'principal'* telescope, namely the telescope which played the leading role in arriving at the main result reported in that paper (almost always, this selection turned out to be fairly unambiguous).

Table 5. Lists of the 'Principal' telescopes used for the observational papers (1993-95) $.

Radio telescopes		Infrared-MM telescopes		Optical telescopes	
Arecibo 305-m		(2) Cosmic Background Explorer (COBE)		(3) Anglo Australian 4-m	
Australia Telescope		ESO 3.6 - m		Asiago 1.8-m	*
Effelsberg 100-m		(4) IRAM 30-m		Big Bear Solar (<1-m)	*
EISCAT radar	*	(2) JCMT 15-m		Beijing 2.2-m	*
Goldstone 70-m		Nagoya 4-m	*	Calar Alto 3.5-m	
Kashima 34-m	*	Nobeyama 45-m		(2) CTIO (Cerro Tololo) 0.9-m	*
MERLIN(Jodrell Bank)		[Ulysses]		(2) CFHT 3.6-m	
MOST (Molonglo)				ESO 3.6-m	
Nancey	*			ESO 1-m	*
NRAO 42-m	*			(2) [Galileo Spacecraft]	*
Parkes 64-m				Haute Prov. 1.5-m	*
[Pioneer Spacecraft]				Haute Prov. 2-m	*
Ryle Telescope				Hale 5-m	
(6) VLA (NRAO)				(3) Hawaii Univ. 2.2-m	*
(3) VLBA (NRAO)				Heliostat Network	*
(4) VLBI (Multinational)				(8) [HST (Hubble) 2.4-m]	
WSRT (Westerbork)				INT (Isaac Newton) 2.5-m	*
				IRTF (IR Telescope) 3-m	
				KPNO (Kitt-Peak) 0.9-m	*
				KPNO (Kitt-Peak) 2.1-m	*
				(4) Keck 10-m	
				[Kuiper Observatory 0.9-m]	
				McDonald 0.8-m	*
				Mt. Wilson < 1-m	*
				MMT (Multiple Mirror) 4.5-m	
				NOT (Nordic) 2.5-m	*
				NTT (New Tech. Telescope) 3.5-m	
				Palomar 1.6-m	*
				Steward 2.3-m	*
				Stromlo 1.3-m	*
				UKIRT (UK IR Telescope) 3.8-m	
				UKST (UK Schmidt Telescope) -1.2-m	*
				WHT (William Herschel) 4-m	
				Video Camera	*

$ The space missions are shown inside square brackets.

In Table 5, we have listed separately for the three *wavebands* the various telescopes which made the dominant contribution to individual *observational* papers appearing in the 3 years (for each telescope, the count of papers that are principally based on that telescope is given in the parentheses, if the count exceeds one). The symbol star (*) indicates medium / small-size status of a given telescope, judged from its aperture size and the contemporary world status. Note that, irrespective of the aperture size, all space-borne telescopes are categorized as large telescopes, in order to underscore their large budgetary and technological implications. Thus, no small / medium-size telescope is represented in the X/γ - ray and the UV bands (the telescopes used for these two bands are: ASCA, CGRO, Giotto, GRANAT, HST, IUE, ROSAT and YOHKOH). For the remaining wavebands, the situation is as follows (Table 5):

Radio : Of the total 27 *observational* papers, only 4 (15 %) were contributed by medium / small-size radio telescopes.

Far / mid-infrared & Millimetre: Out of 12 *observational* papers published in this band, only one was principally based on a small / medium-size telescope (namely, the Nagoya 4-metre telescope).

Optical: Out of the total 51 (optical) *observational* papers, as many as 23 (45 %) were principally based on medium / small-size telescopes having a primary mirror of less than 2.5-metre diameter. Half of these papers actually came from the use of small telescopes (≤ 1.5 metre)! Note that of the 23 papers, 9 fall in the *extragalactic* and 8 in the *galactic* area; the remainder were on the solar system studies.

4. The special significance of the optical / near-infrared band

The foregoing discussion reveals a distinctive feature of the optical / near-infrared band, namely that even modest size telescopes can be effectively used to extract first-rate results. While a more extensive analysis of this feature will be presented elsewhere, a few points can be briefly recounted here. As already stated in Sect.1, the extraordinary concentration of spectral features in this narrow waveband constitutes such a potentially rich astrophysical diagnostic that even today, the basic characterization of most celestial objects derives largely from their optical properties. Thus, objects detected in practically any waveband need to be looked at with optical telescopes, as the first essential step in their detailed study. This demand on the optical band is often acute enough to keep even modest-size (but well instrumented) telescopes fully occupied.

Another contributing factor to the *'time squeeze'* on optical telescopes is the simple fact that ground-based optical observations are confined to night time (excepting rare events like solar eclipses) and even there, a good deal of time is lost due to clouds, or poor seeing conditions. In contrast, radio observations, for instance, are far less susceptible to such natural factors. A reflection of this contrast is the fact that so many 2-3 metre class optical telescopes that were set up a few decades ago (but have been upgraded with modern instrumentation) continue to be over-subscribed even today, despite their standing practically nowhere in the present world ranking. In short, the productive life-span of optical telescopes turns out to be remarkably long.

5. Conclusions

Taking the journal *Nature* as a prime chanel for reporting key findings, we have attempted to discern publication patterns in the field of astronomy during the recent three years (1993-95). In particular, by accounting for two-fifths of all observational papers reported in *Nature*, optical astronomy is found to occupy a pre-eminent position *vis-a-vis* all other branches of astronomy, despite these other branches being so much younger. Another striking result emerging from the present study is that in the optical band almost half of the first-rate results were obtained using modest telescopes which stand very far down in the contemporary world ranking. This phenomenon is hardly evident at other wavebands. Finally, India's contribution, measured in terms of the number of papers published during the 3-year period, stands at the 1 % level and is confined to theoretical work.

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