ASTRONOMY IN JAPAN*

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Abstract. The research activity in Japanese astronomy is described, taking into account the social and historical background. A trend in the last two decades is shown by the numbers of papers in 13 branches of astronomy. Major research facilities and international collaboration programs are summerized. Future programs under consideration are briefly discussed.

1. Introduction

The history of astronomy in Japan is relatively young compared with that in other Asian countries which pioneered in the advancement of world civilization. Although some astronomical records were found in diaries of intellectuals, few professional astronomers existed before Japan was exposed to modern civilization in 1870's. Even in 1950's there were only three universities which had departments of astronomy and accepted only a little more than ten students each year.

In contrast to a small community of astronomical science, astronomy is very popular among Japanese people. A number of planetaria in many big cities are crowded by visitors, particularly by school children, many articles of astronomy appear in popular scientific journals, and astronomy is one of the most popular TV programs. Among about 2000 members of the Astronomical Society of Japan nearly $\frac{3}{4}$ are amateurs who often contribute to astronomy by the discoveries of comets and novae, as frequently reported in the IAU Circular.

In comparison with the great enthusiasm in astronomy, the progress in astronomy as science is not so sound as it ought to be. In schools astronomy is taught as minor part of earth science. As a consequence, most teachers are not well educated in astronomy, and schools absorb few astronomy graduates as teachers. Funding for astronomical research has been poor in comparison with that for other branches of science. Hence, the number of telescopes available for astronomical research is extremely short compared with the number of astronomers, although Japan is producing many good telescopes for amateurs.

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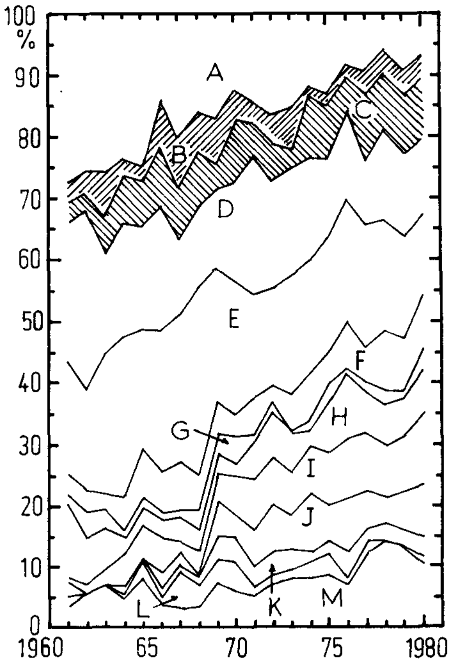

Fig. 1. Relative numbers of papers in 13 branches presented at Astronomical Society meetings. Branches to which the papers belong are indicated by alphabets as explained in Table I.

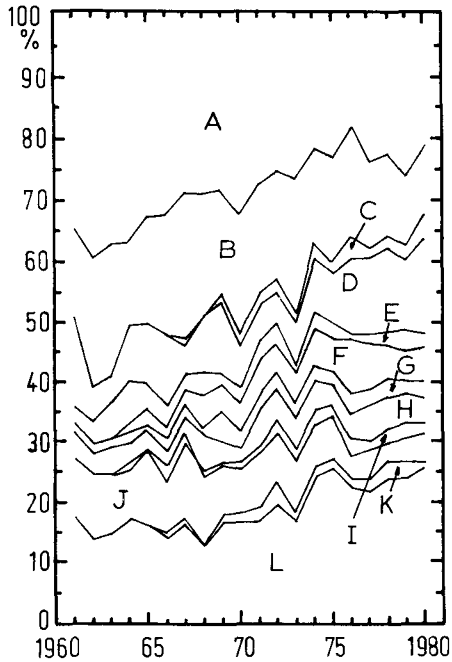

Fig. 2. Relative numbers of speakers of various institutions at Astronomical Society meetings. Affiliated institutions are indicated by the following alphabets. A: TAO, B: University of Tokyo excluding TAO, C: ISAS, D: Kyoto University excluding HAO (KAO), E: HAO (KAO), F: Nagoya University excluding RIA, G: RIA, H: Tohoku University, I: Hokkaido University, J: ILO, K: Radio Research Laboratory, and L: others.

TABLE I

Trend of the papers in 13 branches[a] of astronomy

Fractional number	Real number		
	Increased	Unchanged	Decreased
Increased	I, J, K, M		
Unchanged	C, F	G, H, L	
Decreased	D, E	B	A

[a] A: Postion astronomy, B: Celestial mechanics, C: Solar system, D: Solar physics, E: Stellar physics, F: Nebulae and interstellar matter, G: Stellar systems, H: The Galaxy, I: Galaxies, J: High energy astronomy, K: Cosmology, L: Physical processes and theory, M: Instrumentation and data processing.

Recently, however, the research in astronomy has developed with a wide step and will, we hope, develop further, if the future programs under planing come into being. We will briefly describe a change in our astronomical community in the last quarter century and present our future prospect.

2. Recent Trend in Astronomy

We begin with introducing an interesting analysis of papers presented at bi-annual meetings of the Astronomical Society of Japan (Tsubaki and Nakano, 1982). A total of 4338 papers presented in 1961–1980 are classified into 13 branches. The number of papers per year has increased as

$$N = 9.88(t - 1960) + 113.2\,,$$

according to the least square fitting. The percentages of papers in 13 branches have changed as shown in Figure 1. The result is qualitatively summarized in Table I.

Before 1961 position astronomy and solar physics are most popular branches. In Tokyo Astronomical Observatory, to which about 40% of speakers are affiliated, the largest majority of astronomers worked in position astronomy and the next in solar physics. Radioastronomy which started in 1950's at Tokyo Astronomical Observational (TAO), University of Tokyo and at Research Institute of Atmospherics (RIA), Nagoya University had been dedicated to solar radio astronomy, until a 6 m telescope for mm waves was constructed at TAO in early 1970's. In order to encourage astrophysics, 188 cm and 91 cm reflectors were constructed at Okayama Astrophysical Observatory of TAO in 1960 and have been available for nation-wide astronomers. The relative numbers of papers in Figure 1 reflect that such a change occurred in 1960's.

A jump in the trend occurred when space astronomy started in 1960's, owing to the availability of sounding rockets and balloons operated by Institute of Space and Aeronautical Science (ISAS), University of Tokyo, which is now named as Institute of Space and Astronautical Science separated from University of Tokyo. Observations of X-rays, ultraviolet radiation and infrared radiation were first performed by a group at Nagoya University in mid-1960's. This explains a sudden increase in the numbers of papers in high-energy astronomy. ISAS has launched 9 satellites, of which three have been dedicated to astronomy.

The studies of galaxies have been encouraged by the availability of a Schmidt telescope at Kiso Observatory of TAO in 1970's. Non-solar radio astronomy is rapidly expanding since Nobeyama Radio Observatory started to operate a 45 m dish in 1982. A number of astronomical facilities of high quality have been available since late 1970's. Among them we mention a solar telescope at Hida Astronomical Observatory (HAO) of Kyoto University, an expanded institution of Kasan Astronomical Observatory (KAO), and new facilities for position astronomy at International Latitude Observatory at Mizusawa (ILO).

It is important to note the role played by Research Institute of Fundamental Physics (RIFP) of Kyoto University. Director, H. Yukawa, who was once an adjoint professor of astrophysics and encouraged C. Hayashi to work in astrophysics and cosmology right after the World War II, M. Taketani and one of the authors (S.H.) planned to organize a Workshop to discuss astrophysical problems which were supposed to be closely related to fundamental physics. The first meeting in 1956 was held by active participation by J. Hitotsuyanagi, T. Hatanaka and a number of enthusiastic physicists. Workshops continued by the leadership of M. Taketani and created activities in theoretical astrophysics. Some of observational and experimental activities were also born out of a series of workshops, see Hayakawa (1981).

One of the outcomes of the Workshops was the establishment of astrophysics groups in physics departments of several universities such as Hokkaido University, Nagoya University and Kyoto University. These groups have not only conducted theoretical research but also observational and experimental works. The contributions of the physics community to astronomical research may be seen by a trend of the relative numbers of speakers at Astronomical Society meetings, as shown in Figure 2. In 1961 speakers were affiliated to 19 institutions, mostly to astronomical observatories and departments of astronomy and astrophysics, while in 1970 they were affiliated to 80 institutions. Space astronomy is dominated by physics graduates, and the leaders moved mainly from cosmic-ray research.

3. Background of Future Programs

Despite the rapid progress in recent years, there are several serious problems to overcome. Planning of future astronomy programs has to take these problems into account.

(1) Shortage of research and teaching positions. There are 10 graduate courses for astronomy and astrophysics, and about 20 are graduated therefrom each year. Only a few of them are lucky enough to get research and/or teaching jobs, about one-third get fellowships of short (1–2 yr) terms, and the rest of them (about 5% at present) support themselves for continuing research. There are at least three reasons for the accumulation of about 70 jobless astronomers of reasonable capability. First teaching jobs of the undergraduate and high-school levels are limited because of the educational system as mentioned in Section 2. Second, industry is reluctant to take astronomy graduates. Third, the government keeps policy to reduce the number of public servants which include the staff of national universities and research institutions. For example, the number of staff (including administration staff) of Nobeyama Radio Observatory is only about 20, compared with about 200 at Max-Planck Institut für Radiophysik. The shortage of positions is very serious, since many of scientists who will be responsible for future development would be lost.

(2) Shortage of optical telescopes. The nation's largest optical telescope is the 188 cm reflector at Okayama Astrophysical Observatory of TAO. The observation time is chopped into 4–7 night units, and are allocated for 60–70 groups in 45 weeks a year. The 91 cm telescope is as crowded as the 188 cm telescope, and the solar telescope is used at night for stellar spectroscopy by several groups. If the observation time allocated

is compared with about 150 clear nights, one can understand how many astronomers miss the chance of observation.

The future programs are discussed at Committee of Astronomy, Science Council of Japan which represents the voices of astronomers in various branches. The space astronomy is planned by ISAS, the national institute for space science, which has a solid program in 1980's. Other programs are not yet matured, so that only our hope in the future can be described.

4. Space Astronomy

Space science in Japan started with the participation in IGY by launching sounding rockets for geophysical research. Balloon launching developed by cosmic-ray physicists in 1950's was also adopted as a part of activities of ISAS in early 1960's. Satellite launching began in 1970's and now is the central activity of ISAS. Astronomical satellites which were launched and will be launched are listed in Table II.

TABLE II

List of astronomical satellites

Year of launch	Name	Objectives
Feb. 1979	Hakucho	Galactic X-rays
Feb. 1981	Hinotori	Solar X-rays and γ-rays
Feb. 1983	Tenma	Galactic and extragalactic X-rays
1987	ASTRO-C	Galactic and extragalactic X-rays, γ-ray bursts

X-ray astronomy is strongly emphasized because of the following reasons. First, this is an important field to be pushed forward. Second, our space astronomy began with X-ray astronomy, and there had been quite a few experienced scientists in this field. Third, Japanese space astronomers have considered themselves to be responsible for the observation of X-ray sources during the shortage of other X-ray astronomy satellites. The third point has been found important, since Hakucho detected several X-ray burst sources which were rarely active and recorded pulsation periods of several X-ray pulsars, for which both periods and the rates of period change varied.

Several satellites are planned to be launched in 1990's, though not approved yet. They include satellites for ultraviolet observation (UVSAT), for high-energy solar physics (HESP) at the next solar maximum, for cosmic X-rays and γ-rays (CXGT) and so forth. Their details will have to be defined. A shuttle infrared telescope (IRTS) was planned but has been given up because of funding difficulty. However, infrared astronomers are looking for a chance of having an orbiting telescope of much lower cost.

Because of the busy satellite schedule, neither balloons nor rockets have been used by X-ray astronomers in recent years, although they were active users in 1970's. Instead, infrared astronomers are actively using balloons and rockets, and attitude controlled rockets are mostly used for ultraviolet observations.

It should be emphasized that the international collaboration has been important for rockets and balloons. Rocket launching at Thumba, India, in collaboration with Indian X-ray astronomers, was conducted while the Japanese rocket range was closed in 1967 and 1968. A series of soft X-ray observations were performed by rockets launched from Hawaii in collaboration with a Dutch group. Another collaboration with Indian X-ray astronomers were successfully carried out with balloons launched from Hyderabad in 1969–1975. The X-ray structure of the Crab nebula was observed jointly with the UCSD group by balloons launched from Texas. Several balloons for near-infrared observations were launched from Mildura and Alice Springs, Australia in collaboration with Melbourne astronomers. Since the recovery of balloons is not easy in Japan, balloong flights in foreign countries are beneficial. A balloon infrared telescope (BIRT) is looking for launch sites of easy recovery.

Space astronomy stimulates ground-based astronomy in several ways. The first successful achievement was the optical identification of Sco X-1, the brightest galactic X-ray source, with a variable star of about 13 magnitude in June 1966 at Okayama Astrophysical Observatory. Simultaneous optical and X-ray observations were attempted. Having noticed a small probability of success, ISAS constructed a 40 cm telescope in the rocket range for this specific purpose, and this yielded a continuous optical record of an X-ray/optical nova A0620–00 in 1975. Successful simultaneous observations of Sco X-1 were performed by a rocket and a telescope at Okayama in 1971 and by balloons launched from Hyderabad and a telescope at Nizamiah Observatory, Hyderabad in 1971 to support the Comptonization model. Simultaneous observations of X-ray bursts from XB 1636–536 by Hakucho and South American telescopes in 1979 and 1980 resulted in the understanding of properties of this low-mass binary system. During a high-activity period of the Rapid Burster in August 1979, the X-ray source was observed in infrared ranges in Hawaii, but no simultaneous infrared burst was detected, although prominent infrared bursts from the direction of the globular cluster containing the Rapid Burster were discovered in March 1979 by Indian astronomers.

In the course of near-infrared survey of the Galaxy, a hump was found at $l = 355°$, $b = -1°$ by the Kyoto and Nagoya groups. This region was surveyed at 2.2 μm at Bosscha Observatory and was found to be populated by red supergiants. In order to correlate the near-infrared surface brightness distribution of the Galaxy observed by balloons with the distribution of stars and H II regions, systematic surveys from the ground have been made at observatories in Indonesia, Hawaii, and Australia.

Intensive effort of coordination has been successfully carried out in connection with the Hinotori observation of solar X-rays. Several X-ray and γ-ray detectors on board Hinotori show various faces of solar flares. Ground-based facilities have devoted themselves to simultaneous observations of flares in the optical band at HAO, Mitaka of TAO, and Norikura of TAO as well as in the radio band at Toyokawa, Nobeyama, and Nagoya.

Hinotori stopped working in the middle of 1982 because of malfunctioning of the tape recorder control. Hakucho is still active but is not fully operated because of man power shortage, since X-ray astronomers who are also responsible for attitude control, data acquisition and data analysis are busy in the operation of Tenma.

5. Radio Astronomy

Solar radio emission is observed by radiometers and interferometers over a wide-frequency range. Facilities active at present are listed in Table III.

TABLE III

Solar radio telescopes

Location/Admin.	Frequency (GHz)	Description
Hiraiso/RRL[a]	0.1, 0.2, 0.6	cir. pol. radiometers
Toyokawa/RIA	1, 2, 3.75, 9.4	cir. pol. radiometers
	3.75, 9.4	EW and 2d interferometers
Nobeyama/TAO	17, 35[b], 80[b]	spectrometer, radiometers
	0.16, 17	EW + NS and EW grating interferometers
Nagoya/Nagoya Univ.	35	EW interferometer

[a] Radio Research Lab.
[b] Under construction.

Most of the telescopes are rather old and will have to be renewed in coming years. The construction of a solar imaging facility with resolution of 10″ is under investigation.

For the solar system RIA operates three dipole arrays at Toyokawa, Fujigane, and Sugadaira to observe the solar wind structure by quasar scintillation. Tohuku University operates antennae at Zaō near Sendai to observe decametric emission from Jupiter.

Non-solar radio astronomy is gradually coming up. A 45 m dish at Nobeyama is now available for all users. An interferometer which consists of the 45 m dish and five 10 m dishes is almost ready for operation. The 45 m dish is the world largest radio telescope in the mm range and has the spatial resolution of about 1500″/f (GHz). Effort is being made to improve the system temperatures and the pointing accuracy. In early observations a great number of molecular lines have been observed, and line profiles have been obtained with a resolution of 0.3 km s^{-1}.

TABLE IV

Non-solar radio telescopes

Location/Admin.	Diameter	Description
Kisarazu/KTC[a]	1.5 m	115 GHz CO survey
Nagoya/Nagoya Univ.	1.5 m	115 GHz CO survey
	4 m	80–120, 200–300 GHz
Mitaka/TAO	6 m	90, 115 GHz. Finding telescope for 45 m dish
Nobeyama/TAO	45 m	1.4, 5, 10, 22, 40, 120 GHz
	5 × 10 m	Interferometry

[a] Kisarazu Tech. College.

Complementary to large telescopes, small telescopes are useful for mapping extended sky regions. There are several small telescopes working in the mm range, as listed in Table IV. The most recent one is the 4 m dish at Nagoya University, which started operation a few months ago.

Much effort is being made to keep NRO facilities running. It will take some more time until the whole facilities are completely ready for visitors of short stay at NRO. As in the case of satellite observations, scientists have to run around between the control panel and the computer, and rush between the telescope and the main building across a snowy field in winter.

6. Optical and Infrared Astronomy

Major telescopes available for solar, stellar, and galactic astronomy are listed in Table V. Among them three telescopes at Okayama and the Schmidt telescope at Kiso are open for all astronomers in Japan. Others may also be available for visitors of good will.

The 188 cm reflector was the largest in Asia when this was constructed in 1960 but is one of tens of medium-size telescopes at present; the world record is maintained only in its crowdedness. It is therefore natural to plan the construction of new, larger telescopes. This is the central issue of the future astronomy programs in Japan. However, the program is not yet materialized despite hot discussions in recent years. There are three ways of the future plan.

(1) A reflector with diameter larger than 3 m inside the country is favored on account of advantages of easy administration and access. Because of poor seeing attainable, stellar astronomy will be emphasized by some sacrifice of the observation of galaxies and infrared astronomy.

(2) A reflector with a little smaller size, say 2 m in diameter, constructed at a foreign site of good seeing is pushed forward by those who are interested in galaxies and infrared observations. However, a high barrier is expected because of the isolationistic attitude of Japanese government and difficult access.

TABLE V

Optical and infrared telescopes

Telescope	Location	Administration	Description
65 cm Coudé	Okayama	TAO	mainly solar
25 cm coronagraph	Norikura	TAO	
60 cm Coudé	Hida	HAO	solar
65 cm refractor	Hida	HAO	planetary
188 cm reflector	Okayama	TAO	
91 cm reflector	Okayama	TAO	
91 cm reflector	Dodaira	TAO	
50 cm Schmidt	Dodaira	TAO	comets
40 cm Schmidt	Ouda	Kyoto Univ.	
105 cm Schmidt	Kiso	TAO	
100 cm reflector	Agematsu	Kyoto Univ.	IR

(3) The participation in an international program NTT is anticipated in the near future, and technological studies for this purpose shall be encouraged.

These ideas are not mutually conflicting, but they cannot go on simultaneously because of man power and funding problems. It will not be too difficult to coordinate these ideas and to find out a pragmatic way.

7. Theory and Numerical Simulation

Theoretical activities have received a high reputation in the fields of celestial mechanics, stellar structure, and high-energy astrophysics since early days. These activities have recently been developed further by the use of fast computers. The numerical simulation has yielded interesting results in the stellar evolution in the very early and advanced stages, supernova explosions, gravitational collapses with relativistic effects, star formation, the formation of galactic arms and so forth. Computers at Mitaka, Nobeyama, ISAS, and Institute of Plasma Physics, Nagoya University as well as at respective universities are available also for visitors and are intensively used for numerical simulation.

The computer disease which is apt to spread out does not seem to become serious yet, owing to the clever guidance of theoretical astrophysicists who understand physics taking part in simulated phenomena.

It may be worth pointing out that theoretical astrophysicsts play active roles to make bridges to other fields of science. A group of solar system study involves geophysics, geology, and cosmochemistry. Close relations are maintained with plasma physics. Cosmology and particle physics are developed by mutual stimulation. Solar physics has had a long history of collaboration with solar-terrestrial physics. Celestial mechanis is an indispensable part of geodesy and planetology. Such active cooperation with neighboring fields by theory and observation increases the appreciation of astronomy and astrophysics in the whole community of science.

8. International Collaboration

Japanese science has faced a high barrier against international collaboration. This is rooted on our history that the nation was closed for about 300 years, our geography that our land is located at an edge of the world separated by the sea, and our language which is so different from other languages that most Japanese are poor speakers of foreign languages. Effort has been made in recent years to overcome these barriers.

In astronomy the international collaboration is indispensable, as already mentioned in connection with the site of a future telescope and simultaneous observations from the ground and space. One of the most successful international programs may be the collaboration between Indonesia and Japan. The collaboration consists not only of a temporal program for the present solar eclipse but also of a long-term program in 1979–1984 supported by the Directorate General for Higher Education, Indonesia and

the Japan Society for Promotion of Science. The details of the long-term program shall be described by Prof. Hidayat in this session. One of the authors (M.S.) is here under this collaboration program.

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