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Govind Swarup and Genesis of Radio Astronomy in India

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Abstract: At present, India is one of the leading countries in the world in radio astronomical researches. Prof. Govind Swarup, who has left us forever in September 2020, was the driving force behind the progress of our country in this field. In the present review article, growing up of Swarup as a world class radio astronomer and his role for the birth of radio astronomy in India have been discussed with special emphasis on his contributions for the establishment of two major radio telescopes in our soil.

1 Introduction

Modernisation of radar technology just before and during World War II paved the way for the birth of radio astronomy, the second window of astronomical observation, more than 300 years after the first use of optical telescope. Naturally, when Govind Swarup (23.03.1929—07.09.2020), after obtaining M. Sc. Degree from Allahabad University in 1950, joined the National Physical Laboratory (NPL) as a research scholar of K. S. Krishnan FRS

(1898—1961), in most of the countries of the world radio astronomy was either in a nascent stage or completely unknown. Our country was also no exception from this situation. However, apart from USA, Australia also made remarkable progress in radio astronomy within a very short period. So, when Prof. Krishnan attended the 10th General Assembly of the International Union of Radio Science held at Sydney University in 1952, he was deeply moved by the advancement in radio astronomy made by Australia under the able leadership of J.L. Pawsey (1908—1962) who created a group of talented radio astronomers, viz. B.Y. Mills (1920—2011), J.P. Wild (1923—2008), W.N. Christiansen, commonly known as Chris (1913—2007), J. G. Bolton (1922—1993), R. Payne-Scott (1912—1981), R. N. Bracewell

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(1921—2007) etc. A number of indigenous radio telescopes were built in that country. It may be mentioned here that Pawsey and Payne-Scott made a radio observation at 11 cm. as early as March, 1944[1, 2]. Anyway, Krishnan narrated his experience in Australia in a colloquium at the NPL which attracted young scholar Govind Swarup who was then, under Krishnan's instruction, working on the development of a device for investigating electronic paramagnetic resonance at 3 cm[3]. After receiving the above mentioned information from Krishnan, reacting sharply, Swarup read as many as thirty research papers on radio astronomy (published in *Australian Journal of Physics* and *Nature*) by radio astronomers of Radio Physics (RP) division of Sydney. This made him inclined towards the new field of radio astronomy. Krishnan was also looking for starting radio astronomical research at the NPL. So, he recommended Govind Swarup's name[3]for a two-year Fellowship (under the Colombo Plan) which was accepted and in March, 1953, Swarup and R. Parthasarathy of Kodaikanal Observatory left for Australia for working under the supervision of Pawsey.

2 Formative Years

(a) Australian Chapter

After interacting with Swarup, Pawsey could realise that the former was more interested in observational astronomy rather than theoretical work. So he advised Swarup to work with different groups of radio astronomers of Australia for gaining knowledge about various techniques related to radio astronomy. Accordingly, Swarup spent first three months with W. N. Christiansen (1913—2007) and J. A. Warburton at Potts Hill field station for assisting them in the preparation of a two dimensional map of the quiet Sun at 21 cm[3]. In that work, Swarup had to Fourier transform the scans manually using only an electronic calculator.This tedious job with Christiansen had a lasting effect on Swarup and he commented – "*I learned the powerful technique of radio interferometry from Chris in 1953 and have not looked back*''[2,4]. Moreover, Swarup devised an alternative technique for preparation of a two dimensional map without using the laborious job of Fourier transformation[3, 5]. This method of Swarup is still used in medical science for X-ray imaging and tomography.

During next three months Swarup and J. A. Roberts worked at Dapto field station under the guidance of J. P. Wild for constructing a 45 MHz receiver for daily observation of Cygnas A and for determining the velocity of turbulence in ionosphere[3, 5]. In the next three months, Swarup was engaged at Pots-Hill with B. Y. Mills and Alec Little for building a phase shifter for the prototype Mills Cross antenna[3]. In the last three months of his first year stay in Australia, Swarup worked in a group with J. G. Bolton as its leader, for making a highly stable D. C. power supply of 2000 volts[5].

In 1954, when Christiansen switched over to Meudon Observatory in France for a year, Swarup and Parthasarathy, under the guidance of Pawsey, converted the Potts-Hill EW grating from 21 cm. to 60 cm. for observing the quiet Sun at 500 MHz. Their observational results[6, 7, 8, 5, 2] clearly showed limb brightening in the equatorial region of quiet Sun which supported the observation of Smerd,[9, 3, 5] but contradicted that of Stanier[10, 3, 5]. Radio emissions associated with sun spots were also studied[8]. In early 1955 Swarup, under instructions from Christiansen, built Chris Cross at Fleurs field station near Sydney which consisted of two mutually perpendicular arrangements (like a cross) of antennas for making daily solar maps at 21 cm. wavelength[11, 3, 5]. After construction of this array, the necessity for the 32 dishes in Potts-Hill was over. So Swarup approached Pawsey for donating those 32 dishes to India for radio astronomical research. Pawsey as well as E. G. Bowen, Chief of the Division of Radio-physics, agreed instantly. Krishnan was also ready to accept that gift. After making this arrangement, Swarup returned to India for starting radio astronomical research at the NPL. He was ready to initiate radio astronomy research in India. However, due to some problems, the donation of the 32 dishes didn't materialise at that time. So Govind Swarup, being invited by Donald Menzel (1901-1976), the Director of the Harvard College Observatory, left India to join Fort Davis Radio Astronomy Station of the Harvard Observatory in August 1956 [2, 5].

(b) USA Chapter

In USA, Swarup started working with Alan Maxwell (1926-2021) for studying dynamic spectra of solar bursts in the frequency range 100-600 MHz using the recently installed 8.5 metre radio telescope. During his stay there, in December, 1956, Swarup discovered a new type of solar burst known as U burst[12, 2, 3, 5]. In the meantime, in early 1957, Swarup decided to work for a Ph.D. and, being advised by Pawsey, joined Stanford University in September 1957 to work under the supervision of R. N. Bracewell[3]. As a part of his Ph. D. work, Swarup studied quiet Sun at 9.2 cm. using the newly constructed Stanford Microwave Spectroheliograph. He detected a north-south asymmetry in the emission by the quiet Sun at that particular wavelength[13, 3, 2]. In December 1960, Swarup was awarded Ph. D. by Stanford University for his thesis entitled *Studies of solar microwave emission using a highly directional antenna*. Being elated by the observations of north-south asymmetry detected by Swarup, Pawsey wrote to him on 18 April, 1861 – "*I am most interested in your ....report. I am hoping it is the essentials of a PhD thesis. I thought it was a most interesting report and I congratulate you on the outcome of your Stanford work. Your report now will be my authoritative source on the features of 10 cm observations*"[2]. Swarup joined Stanford University as an Assistant Professor on 1 January 1961.

3 Back to Motherland

In spite of being included in the Faculty of Stanford University, Swarup had always a desire for working on Indian soil. So he and three other same minded radio astronomers, viz. T. K. Menon, M. R. Kundu and T. Krishnan decided to come back to India. In September 1961, they sent a proposal to five leading scientific institutions in India for creating a radio astronomy group. At the same time the same proposal was sent to five renowned astronomers, viz. Harlow Shapley (1885—1972) of Harvard, USA, Jan Oort (1900—1992) of Leiden, Netherlands, Bart J. Bok (1906—1983) of Mt. Stomlo, Australia, J. L. Pawsey of CSIRO, Australia and J. F. Denisse (1915—2014) of Observatoire de Paris, France their for opinion. The foreign experts sent their comments to Bhava. On 6 October, 1961 Pawsey wrote – "*I have a very high opinion of the scientific talent in this group…, a group chosen from among them should have an excellent chance of building up a first class scientific institution… I regard this spontaneous movement among the young Indians who have initiated this proposal as a most encouraging sign and strongly urge you, in the interests of science in India, to try to assist them in their efforts to work out something worthwhile*"[1]. Bok's encouraging comments (23 October 1961) were – "*Here is a case of four young, but renowned, Indian Radio Astronomers, all thoroughly trained and with good research records…. hardly equalled by any group that one might assemble anywhere in the world… It seems to me that their offer to return to India as a group is a unique one and one that should by all means be accepted and acted upon promptly. An offer like the present one comes only rarely in the history of scientific development of a nation which, scientifically is obviously coming of age*"[1]. Oort commented (23 October 1961) – "*Their plans are reasonable and balanced and appear extremely suitable, starting an active centre of radio-astronomical research in your country; I should therefore like to support their proposal whole-heartedly. You are fortunate in having a group of young Indians who appear to be so well-equipped to start a research centre in a subject that is at present in the centre of interest. There is no doubt in my mind that your country …. would profit if you could succeed in realising their plans…*"[1].

Professor Mark Oliphant (1901—2000), Director of the Research School of Physical Sciences at the Australian National Laboratory and a friend of Bart Bok, was also aware of the above mentioned proceedings and he himself correspondence with Prof. Bhava during late 1961 to early 1962. In his letter to Bhava on 6 October, 1961, Oliphant remarked – "We find the presence in Australia of strong groups in radio astronomy to be most stimulating to us all and very attractive to research students. I feel sure that Indian science would be richer if some means can be found to establish radio astronomy as a vigorous branch of research and teaching. We in Australia would welcome the presence of colleagues in this field in neighbouring India and would be happy to help and collaborate in every possible way"[1]. The most inspiring reply in India came from H.J. Bhava (1909—1966). In his telegram to all the four of the Swarup's group on 20 January, 1962, Bhava wrote – "*We have decided to form a radio astronomy group. Letter follows with offer*"[14, 5]. After acceptance of the offer by Swarup on 8 February, 1962, Bhava wrote to him (3 April, 1962) – "… *If your group fulfils the expectation we have of it, this could lead to some very big equipment and work in radio astronomy in India than we foresee at present…*" So, Swarup resigned from Stanford University in March 1963 and returned to India on 31 March 1963 to join TIFR[3]. In the meantime, all the 32 dishes of Potts Hill (which couldn't be procured earlier) were received by Govt. of India. Some talented young scientists like V.K. Kapahi (1944—1999), J.D. Isloor, D.S. Bagri, M.N. Joshi, N.V.G. Sarmaand, R. P. Sinha joined TIFR nearly at the same time.

While contemplating about a suitable project, in August 1963, Swarup came across two papers – one by Cyril Hazard (born 1928) et al. and the other one by Martin Schmidt (born 1929), both published in *Nature*, describing the discovery of the first Quasi-stellar object or Quasar (termed by Schmidt) 3C 273 using lunar occultation method. On the other hand, by 1960 Martin Ryle (1918—1984) detected as many as 300 radio galaxies using Cambridge interferometer and assumed that many other weaker radio sources could be detected at large distances. On reading the above two papers, it suddenly occurred to Swarup that lunar occultation could be used for finding the exact location and angular size of numerous uncatalogued weaker radio sources also[5]. However, observations of a large number of weak radio sources with arcsecond resolutions would require a radio telescope whose collecting area should be very large, at least four times that of the Jodrell bank (76 m) or Parkes (64 m) radio telescope which was totally impracticable. So, Swarup thought of a large (500 m long and 30 m wide) parabolic cylindrical radio telescope which would enable to track the Moon each day for several hours and observe radio sources with arcsecond resolution. Swarup discussed his idea elaborately with Professor M. G. K. Menon, the Dean of the Physics Faculty of TIFR, who agreed enthusiastically. Swarup's long discussion with Bhava was also fruitful. But before construction of the abovementioned radio telescope, Swarup and his colleagues decided to build the first radio telescope of India at Kalyan.

4 Foundation of Radio Astronomical Research in India

(a) Kalyan Radio Telescope

As the leader of a group of radio astronomers, Swarup first decided to set up a grating type radio interferometer at Kalyan, Maharashtra for solar study using the 32 dishes of Potts Hill each with diameter 1.7 m. 24 of those dishes were placed along 630 m. East-West baseline while the remaining 8 were arranged along 256 m North-South direction. The construction of Kalyan radio telescope was completed in April 1965[16, 5]. During 1965-1968, this grating type interferometer was used for observing the sun in both quiet and active phase at 610 MHz. The study showed pronounced limb brightening and the temperature of the solar corona was found to be $\sim 10^6$K[16, 5].

(b) Ooty Radio Telescope

Just before the construction of Kalyan radio telescope, in January 1965, Swarup and Ramesh Sinha started searching a favourable site for a much larger radio telescope. Swarup could realise that South India, due to its proximity to the equator, would be an ideal place for setting up a radio telescope. After searching nearly 30 hills in South India, the suitable site was selected near Muthorai village situated 5 km. away from Ooty in the Nilgiri Hills at an altitude of 2100 m (11°23′00′′N, 76°39′58′′E). Taking advantage of about 11°inclination of the mountain (which is also the latitude of the place), the 530 m long and 30 m wide parabolic cylindrical antenna of Ooty Radio Telescope (ORT) was constructed on the North-South slope of the Nilgiri Hills so that the long axis of the telescope and earth's rotational axis become parallel. As a result, by rotating only the long axis of the telescope, celestial radio sources can be tracked daily for at most 9 hours 30 minutes. After visiting the location in May 1965 and again in December 1965, Bhava

Fig. 1: The Ooty Radio Telescope

approved the site. However, since the site was within the periphery of a reserve forest, Bhava had to request the Tamil Nadu Government for getting permission. After the green signal came from the government, Swarup started his work. In the meantime, a number of rising radio astronomers like S. Anathakrishnan, V. Balasubramanian, Gopal Krishna, M.N. Joshi, V.K. Kulkarni, D.K. Mohanty, A Pramesh Rao etc. joined TIFR making the radio astronomy group of that institution much stronger. The reflecting surface of the ORT was made of 1100 stainless wires. The structural and mechanical parts of the fully indigenous ORT were designed by Tata Ebasco (named afterwards as Tata Consulting Engineers) while M/s Bridge and Roof of Kolkata were given the responsibility for constructing the structural and mechanical parts. N.V.G. Sharma, M.N. Joshi, D.S. Bagri, S. Ananthakrishnan and others designed the electronic system[3, 5]. ORT started functioning on 18 February, 1970 by observing a 4C radio source and two other uncatalogued sources through lunar occultation. The telescope operates in 322-328 MHz range which is an internationally protected frequency for radio observations. By 1978, angular size of nearly 900 catalogued (3C and 4C) as well as uncatalogued radio sources were determined with resolution 0.5 – 10 arc sec which was till then the best resolution achieved in the entire world. Some of the major discoveries made with the ORT are as follows[5]:

1. In 1972, Gopal Krishna et al.[17, 5] discovered a nearly 20 pc. diameter non-thermal radio halo around the centre of the Galaxy by lunar occultation of the Galactic centre source Sagittarius A at 327 MHz.
2. Observations of the interplanetary scintillation of radio sources revealed a significant amount of emission from compact sources of angular diameter less than 0.5 arc sec[18, 19, 5].

3. The gravitational lensing of the very bright radio source 1830-211 was discovered [20, 21, 5] which was later identified as Einstein ring lens[22, 5].
4. An upper limit of HI mass in super clusters was set by Subrahmanyan and Swarup [23] through observations at 327 MHz.
5. The data obtained from ORT indirectly supported Big Bang model of the universe[24, 25, 3].

In the 1980's, Ooty Synthesis Radio Telescope (OSRT) was built for making two dimensional images of celestial radio sources by observing at 327 MHz[5]. Apart from the ORT antenna, OSRT has seven other parabolic cylindrical antennas which are placed at distances up to 4 km. During first twenty five years (1964—1989), the data collected by the Kalyan Radio Telescope, ORT and OSRT resulted in publications of 285 papers in refereed journals including 20 in *Nature*[5].

(c) Giant Metrewave Radio Telescope

On request of the TIFR Director Dr. B.V. Srikantan in May 1983, Swarup suggested in 1984 an innovative idea of constructing a radio telescope for operating at metre wavelength whose antennas would be placed over 25 km. region in a Y-shaped pattern. The site was chosen at Narayangaon (19°05′47′′N, 74°02′59′E), 80 km. from Pune in Maharashtra for placing the central array over an area of 1 square km. Swarup proposed the name of the telescope as the Giant Metrewave Radio Telescope (GMRT)[5]. He also created a cost effective design for supporting the wire-mesh panels of parabolic reflectors by using Stretched Mesh Attached to Rope (SMART). The diameter of each of the fully steerable dishes of GMRT is 45 m [26, 27, 5].

Fig. 2: The Giant Metrewave Radio Telescope

Under the supervision of Suresh Tapde and Swarup all thirty dishes were constructed by March 1996. A group of engineers of Bhava Atomic Research Centre designed the servo system while the entire antenna feeds in the frequency range 130-150, 230-235, 320-350 and 590-620 MHz. and the complex correlator system were designed by the Radio Astronomy Group of TIFR. The antenna feeds for 1000-1450 MHz. were done by Raman Research Institute, Bengaluru. GMRT started functioning in 1999. In 2001, it was opened for astronomers of India and abroad. Initially GMRT could operate at five frequency bands, viz. 130, 235, 325, 619 and 1430 MHz. with a band width of 32 MHz. Recently, installation of new antenna feeds and receivers at GMRT has enabled it to operate almost continuously from ~ 130 MHz. to ~ 1430 MHz. with much wider band width of 400 MHz. This upgradation of GMRT, renamed as uGMRT, has increased the sensitivity of the telescope by a factor of two[28, 5]. GMRT is the most powerful radiotelescope in the lower frequency range. It has been used for observing planets, exoplanets, the sun, pulsars, galaxy clusters, radio galaxies, quasars and various other sources of radio emission. On the basis of TIFR-GMRT Sky Survey conducted by the radio astronomers of NCRA-TIFR, Intema et al.[29] has published a catalogue of nearly 6 lakh radio sources[5]. GMRT has been used by astronomers of other countries also. Some of the results obtained with the GMRT can be summarised as follows[5]:

1. A double-double radio galaxy (J 1453+3304) was discovered by Saikia et al. (2006)[30].
2. Possibly the youngest supernova remnant in our Galaxy was discovered by Roy and Pal [31] at 330 MHz.
3. Saxena et al. [32] have discovered the farthest radio galaxy ($z = 5.72$).
4. Using the uGMRT, neutral hydrogen has been spotted at $z = 0.37$ (Bera et al. 2019)[33].
5. Chowdhury et al. (2020)[34] have detected HI at $z \sim 1$. It may be mentioned here that search for HI at large distances was one of the major objectives of GMRT[25, 26].

5 Concluding Remarks

It is clear from the above discussion that Prof. Govind Swarup was instrumental for initiating radio astronomical research in India and construction of three major radio telescopes in our country. In his school days, being inspired by the article *Akash Ganga* written by famous poet Mahadevi Verma, he quenched his thirst for astronomy by reading an astronomy book on this topic in his school library which was, in his own words - "…That was my first lesson in astronomy"[5]. Being a top class radio astronomer, Swarup could easily spend his life as a Faculty of world famous University or Research Institute. However, he was influenced by the idealism of M. K. Gandhi (1869—1948) and in his school days, supported the Quit India movement, joined in a procession daunting the firing of British soldier on their peaceful march. This ideology of serving his motherland prompted Swarup to resign from the lucrative professorship of Stanford University for building radio astronomy group at TIFR and initiating radio astronomical research in India. In the 1960s, when high level radio astronomical research started in only a few developed countries of the world, Swarup opened the second window of astronomy in our poverty stricken country merely eighteen years after independence in very cost effective way. For instance, under his advice thin steel wires were used for construction of the antennas of GMRT due to their light weight, small air resistance capacity, durability and lower cost than that estimated by Tata engineers[5]. For this reason, Prof. Somak Raychaudhuri, Director of IUCAA, has called Swarup as *Beacon of Frugal science*[35]. For his pioneering contributions in radio astronomy, Swarup received many awards, viz., Bhatnagar Award (1972), Padmashri (1973), INSA Vainubappu Memorial Award (1987), Harshel Medal (2005), Grote Reber Medal (2007), Homi Bhava Prize (2009) etc. He was also a Fellow of Royal Society, London. But, we should not judge the achievements of Swarup through number of prizes and accolades only. In its true sense, he was ***The Father of Indian Radio Astronomy***. Amidst the spectre of Covid-19 pandemic, Prof. Govind Swarup, has departed forever leaving behind a bright trail of his legacy.

References:

1. W.M. Goss, *Making Waves, The Story of Ruby Payne-Scott: Australian Pioneer Radio Astronomer*, Springer-Verlag GmbH Berlin Heidelberg (2013).
2. W.M. Goss, *The Metrewavelength Sky*, ASI Conference Series (Eds. J.N. Chengalur & Y. Gupta) **13** (2014) 409.
3. G. Swarup, *J. Astron. Hist. Herit.* **9** (2006) 21.
4. G. Swarup, *J. Astron. Hist. Herit* **11** (2008) 194.
5. G. Swarup, *Ann. Rev. Astron. Astrophys*. **59** (2021) 1.
6. G. Swarup and R. Parthasarathy, *Aus. J. Phys*. **8** (1955a) 487.
7. G. Swarup and R. Parthasarathy, *Observatory* **75** (1955b) 8.
8. G. Swarup and R. Parthasarathy, *Aus. J. Phys*. 11 (1958) 338.
9. S.F. Smerd, *Aus. J. Scientific Res.* A **3** (1950) 34.
10. H.M. Stanier, *Nature* **165** (1950) 354.
11. W. Oschistron, In *Astronomical Instruments and Archives from the Asia-Pacific Region,* Seoul, Yonsei University Press (2004) 157.
12. A. Maxwell and G. Swarup, *Nature* **181** (1958) 36.
13. R. N. Bracewell and G. Swarup, *IRE Trans. On Antennas and Propagation* **19** (1961) 22.
14. H. J. Bhava, Western Union Telegram to T. Krishnan, M. R. Kundu, T. K. Menon and G. Swarup (1962a) 20 January 1962.
15. H. J. Bhava (1962b) Letter to G. Sawrup, 3 April 1962.
16. Swarup et al., *Nature* **212** (1966) 910.
17. Gopal-Krishna et al., *Nature* **239** (1972) 91.
18. S. Anathakrishnan et al., *Nat. Phys. Sci.* **235** (1972) 167.
19. S. M. Bhandari et al., *Aust. J. Phys.* **27** (1974) 121.
20. P. Rao A and R. Subrahmanyan, *Mon. Not. R. Astron. Soc.* **231** (1988).
21. R. Subrahmanyan et al., *Mon. Not. R. Astron. Soc.* **246** (1990) 263.
22. D. I. Jaunceyet al., *Nature* **352** (1991) 132.
23. R. Subrahmanyan, G. Swarup, *Astrophys. Astron.* **11** (1990) 237.
24. V. K. Kapahi, *Mon. Not. R. Astron. Soc.* **172** (1975) 513.
25. G. Swarup, *Mon. Not. R. Astron. Soc.* **172** (1975) 501.

26. G. Swarup, *Ind. J. Radio Space Phys.* **19** (1990) 493.
27. G. Swarup et al., *Curr. Sc.* **60** (1991) 95.
28. Y. Gupta et al., *Curr. Sc.* **113** (2017) 707.
29. H. T. Intema et al., *Astron. Astrophys.* **598** (2017) A 78.
30. D. J. Saikia et al., *Mon. Not. R. Astron. Soc.* **366** (2006) 1391.
31. S. Roy and S. Pal, *Astrophys. J.* **774** (2013) 150.
32. A. Saxena et al., *Mon. Not. R. Astron. Soc.* **480** (2018) 2733.
33. A. Bera et al., *Astrophys. J. Lett.* **882** (2019) L 7.
34. A. Chowdhury et al., *Nature* **586** (2020) 455.
35. S. Raychaudhuri, *Nature India* 9 September, 2020; doi 10.1038/nindia.2020.134.
36. Photographs are taken from internet sources.