We cannot foresee what may happen before we meet again in Zurich (three years from now). On the astronomical side we can make some guesses. The 200" reflector will be completed.... But on the international side no one dares to prophesy. If in international politics the sky seems heavy with clouds, such a meeting as this at Stockholm is as when the Sun comes forth from behind the clouds. Here we have formed and renewed bonds of friendship which will resist the forces of disruption.

With the outbreak of the war in the following year, all formal activities of the IAU came to an abrupt end. But Oort kept the IAU alive and carried on as the General Secretary during the difficult war years when Holland and many other European countries were occupied. It is a great tribute to Oort that three years after the war ended the IAU met in Zurich as planned. The war had left its scars and bitter feelings. However, Oort and others made sure that the German astronomers were invited to Zurich on a personal basis. To quote Otto Struve:

His efficiency and impartial conduct of the work of the Union during the difficult years of the war and especially during the past three years of reconstruction has not only won him the admiration, respect and affection of the vast majority of astronomers of all nations, but has created a lasting monument in the history of international science.

Oort served as the General Secretary of the IAU for 13 years. He was elected the President of the IAU in 1958. As the President of IAU he played an important role in many international projects such as the International Geophysical Year, and the Committee on Space Research. One of his most important contributions during this period—and whose importance is ever-growing—is the establishment of the International Union Committee on the Allocation of Frequencies (IUCAF). There was a crucial three-month long meeting in Geneva in 1959 in which important frequency bands for scientific research were reserved and significant allocations made. Oort made sure that either he or one of the senior members of the IAU was present in Geneva during this entire three-month period.

Yes, Oort was an 'institution' in more than one way. He will be missed. His friends and colleagues will miss him most in the weekly colloquia. For almost 70 years one could take it for granted that Oort would be present at the Thursday 4 O'clock Colloquia in the Leiden Observatory.

Oort was undoubtedly the most prolific astronomer of this century. Bengt Stromgren said this of Oort on his 80th birthday:

Imagine a situation of a historian of natural science, working sometime during the 21st century, on a monograph describing Jan Oort's scientific importance. If successful, this historian would have covered in his monograph a very substantial portion of the history of astronomy in our century.

And imagine a historian of natural science, not a person working in the 21st century but someone working at a much later time. Suppose that he had first studied the development of mathematics in the 20th century, and that during these studies he would have discovered that the mathematician 'Bourbaki' was not a real person but a name covering a whole group of mathematicians. Working on the development of astronomy in the 20th century, and faced with the extent and importance of Jan Oort's contributions, this historian might well be tempted to advance a theory inspired by the 'Bourbaki' story!

Yes, Jan Oort was undoubtedly one of the most creative scientists of this century. Very few can look forward to a life of such undiminished creativity till the age of 90. As his eldest son said at Jan Oort's funeral, he was truly a fortunate man.

Jan Oort and radio astronomy

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To appreciate the very special role that Jan Oort played in the history and development of radio astronomy, one must go back to the very beginnings of this field. The subject was launched by two Americans with very non-Anglo-Saxon names, Karl Jansky and Grote Reber. Jansky is long gone and at peace. Reber is still with us, and in a way, in the same boat as today's speakers! Our editor tracked him down to his lair in Tasmania very recently, and Reber too is presumably worrying about a manuscript that *Current Science* is waiting for.

Reber built a 36-foot-diameter paraboloid in his backyard with his own hands and money, and published the first 'radio map' of the galaxy in the *Astrophysical Journal* in 1940. The trauma involved in getting a radio amateur's nocturnal exercises accepted for publication in the holiest of the establishment's journals is a saga in itself, but belongs to Reber's story and not Oort's. What is relevant here is the effect this paper had on Jan Oort when a copy of the *Astrophysical Journal* containing it managed to get to Holland in what must have been one of the worst years of the war. To appreciate this, a little more history is needed.

Following the work of the two American pioneers, physicists and engineers who had been involved in radar development in England, Australia and the US turned their skills and efforts to radio astronomy after the end of the war. The reactions of the establishment types (optical astronomers and astrophysicists) if they did react, were generally condescending. I cannot resist quoting as an example, the unsolicited comment by the Commonwealth Astronomer in Australia that 'even if the (radio) sources did exist, they could be of no possible interest to astronomers'[1]. Three of the six sources in the list produced by Bolton which provoked this remark were the Crab, Virgo A and Centaurus A (!). This attitude was possible even in 1948 by which time many reasonably intelligent people had realized that radio astronomy was a separate window to the universe which was bound to bring great new things into view.

Now go back eight years to 1940, when Oort was in hiding in Holland because of his protests against the dismissals of Jewish Professors in that country. He just sees Reber's paper and unbelievably thinks, my god, if we could find a radio spectral line that comes from interstellar hydrogen, observations of its Doppler shift would enable us to map the motions in the galaxy which we simply cannot see now because of the dust in the way! He puts the problem to Henk van de Hulst in 1944 and as is well known the prediction was made in 1945 that there should be a signal at 21 cm. What is not well known, but something I find very revealing about his attitude to science, is that Oort sent van de Hulst to talk to this radio amateur in Illinois, to ask about how to build a receiver to work at 21 cm. Reber said it was difficult, later gave it a half-hearted try but never finished the job.

It was not just radar engineers who went over to radio astronomy after the war. A lot of radar equipment (even the enemy's) played an important role. The western coast of Europe was littered with German radar dishes of 7.5 m diameter (called Wurzburg antennas) all the way from Spain to Norway (Figure 1). Several of these dishes found their way to radio observatories that were being set up after the war in Europe, and one even went across the Atlantic to Washington DC. Oort too had to settle for just one of these war relics, having failed to persuade the Netherlands' Academy immediately after the end of the war to fund a 25 metre (!) paraboloid to do radio astronomy (what's that?). He was too far ahead of the times.

It was for his Wurzburg antenna situated at Kootwijk that a sensitive receiver (by the standards of the day) was being built to detect interstellar hydrogen. And as is well known, an unfortunate fire totally destroyed the receiver, setting the Dutch back far enough to lose the credit for the first detection which went to Purcell and his student Ewen working with a relatively simple receiver connected to a horn stuck out of the window! Such was Purcell's greatness of character, and such was the respect Oort already commanded in the world of astronomy, that the Harvard result was held back till both the Dutch and Australian (lucky guys) groups had also detected the radiation to allow a joint publication in *Nature* in 1951. Try to imagine this happening anywhere in today's rat-race research atmosphere.

Figure 1. A Wurzburg 7.5 metre diameter paraboloid similar to the one installed at Kootwijk to observe the 21 cm line from interstellar hydrogen.

Tiny as it may have been, Oort's first radio telescope made fundamental contributions in the years following the 'detection' of the 21 cm line. Survey I (1952–53) covered all of the galactic plane that could be seen from Holland and Survey II (1953–55) mapped a band of width $\pm 20°$ containing the plane. The differential rotation of the galaxy, the coordinates of its poles and its centre were determined from H-line observations for the first time with the Kootwijk 7.5 metre telescope between 1951 and 1955. These observations combined with those from Australia by Frank Kerr and colleagues produced the first map of the spiral pattern of our Galaxy going out to distances ten times or more beyond the limits imposed by dust on optical observations. Radio astronomers of today should stop and ponder for a moment that all this was done with a telescope that had to be moved by hand every few minutes during observations!

The moment the 21 cm line was observed in 1951, Oort went back with the proposal he had made in 1945 for a 'large' radio telescope which would have adequate resolution to provide answers to many important questions about the galaxy that he worried about incessantly. This time he got the money and the telescope arrived in 1956. For a short while after its commissioning, the Dwingeloo 25 meter telescope (Figure 2) was the largest paraboloid in the world, but remained effectively so for a much longer period. The 250 ft Jodrell Bank telescope was completed in 1957, but it had not been designed for operation at wavelengths as short as 21 cm, nor did it have Oort driving its research programmes. This was evident at the famous URSI/IAU symposium on radio astronomy held in Paris in 1958, where there were any number of important results from the Dwingeloo telescope, but only one paper on moon radar from the Jodrell Bank 250 footer.

The major discoveries to come from the Dwingeloo 25 metre antenna, Oort's 2nd radio telescope, were HI (the spectroscopists' symbol for neutral atomic hydrogen) radiation from external galaxies, the 3 kpc arm and expanding rotating gas near the galactic centre, the first high quality HI absorption measurements, an HII (ionized hydrogen) region survey of the galactic plane, the discovery of galactic background polarization and, of course, the high velocity clouds. Blaauw[2] recalls an incident that truly illustrates both Oort's foresight and his role in the development of radio astronomy, which is the subject of this article. Just after the Dwingeloo telescope became operational and a period of 'gathering the fruits' was ahead, there was a meeting of the Board of the Netherlands Foundation for Radio Astronomy at which Oort could not be present as he was travelling abroad. But he had left a letter telling the Board that the time had come for the next step with much higher angular resolution!

The Westerbork Synthesis Radio Telescope (WSRT), Oort's third instrument (Figure 3), had a chequered history. Aware of what had been achieved with dilute

Figure 2. The 25 metre reflector at Dwingeloo in the Netherlands, completed in 1955, at which time it was the largest in the world. This telescope, light in weight (only 127 tonnes) and therefore of modest cost, was deliberately designed to study the interstellar (21 cm) hydrogen line.

Figure 3. The radio telescope array at Westerbork, Holland. One telescope, at the end of the array, can be moved on rails to give eleven sets of different separations simultaneously.

apertures like the Mills cross, Chris cross, etc., in Australia, Oort invited Christiansen, one of the pioneers of radio astronomy, and several others to Leiden to design a telescope that would truly be at the forefront. On the premise that two countries together can afford more than one, the original exercise was for a Benelux telescope. However, after a great deal of work had been done over many years, Belgium pulled out. A lesser man might have been crushed with disappointment, but Oort just took this as an opportunity to see if one could come up with a better design since Holland would have to go it alone, which meant with less funds. This design was provided by Martin Ryle's Nobel Prize winning technique of earth rotation synthesis with an east-west baseline.

And, as always, Oort succeeded. WSRT came into operation in 1970 or so when he had formally retired. But as everyone knows, he was the driving force and the guiding spirit behind the whole series of extraordinary advances made with this superb synthesis telescope in the next decade. An excellent account of what this telescope achieved in its first ten years is provided by Allen and Ekers[3] in the book presented to Oort on his 80th birthday. Of the 36 or so items mentioned in their article, already a selection, I list below a dozen or so just to provide a feeling for the range and importance of the contributions. They are: a first map of M51 showing the nuclear source and the spiral arms in the continuum (1971); a map of the continuum arms of NGC 4258 (1972); the first map of a trail of radio

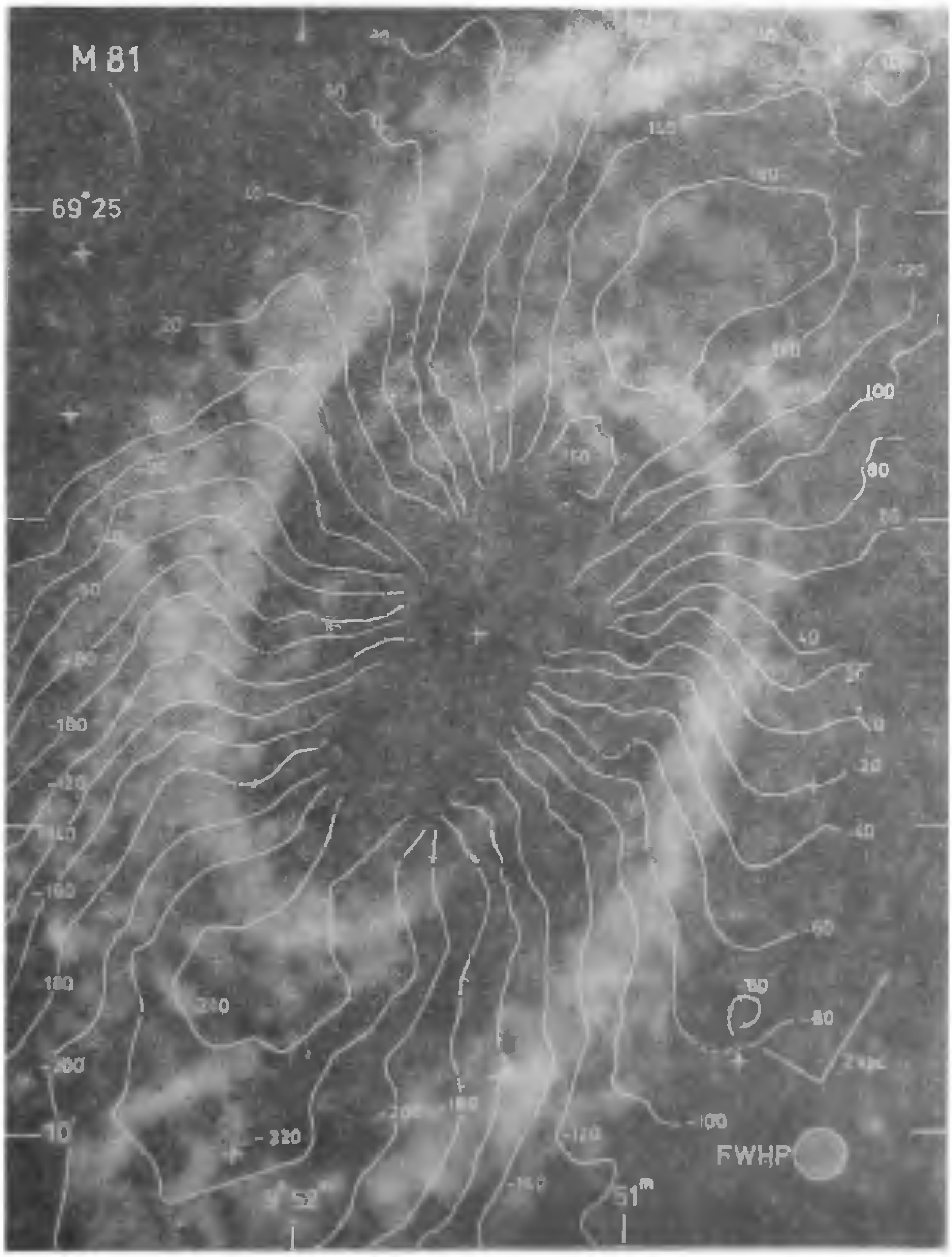

Figure 4. Measuring the dynamics of galaxies with the WSRT. This figure is from a thesis by H C D. Visser and shows the spiral galaxy M81. The contour lines in white represent the radial component of the motion of neutral hydrogen, as inferred from the Doppler effect. On a simple model of circular motion in a flat disc with a speed independent of radius, these contours would be straight lines through the centre. Striking deviations from this simple pattern near the spiral arms are seen, and these can be fitted by the 'density wave' theory.

emitting debris from the radio galaxy 3C129 (1972); comparison of the optical and HI spiral structure of M101 (1973); a map of a radio galaxy -NGC1265- showing the whole story from ejection of blobs to formation of diffuse tails (1973); discovery of the giant radio galaxies DA240 and 3C236 with megaparsec sizes (1974); measurement of the radial velocity field of M81 spectacularly confirming the predictions of the density wave theory (1974) (Figure 4); tests of general relativistic light bending close to the Sun (1975); a map of the galactic centre showing Sgr. A East & West (1975); observations of a galactic warp in NGC5097 similar to that suspected in our own galaxy (1976); a map of the continuum halo of the edge-on galaxy NGC 4631 (1977); radial velocity fields of 22 spiral galaxies (1978); a measurement of the *expansion* of Tycho's supernova in the eight years from 1971 to 1979; and maps of the hydrogen recombination line emission (1980).

There was no competition for WSRT in the decade mentioned above. The Very Large Array (VLA) in the USA came on line in 1980, and since then has had the No. 1 place amongst radio telescopes of the world. But I would like to point out that WSRT has continued to be useful and important and can still do some things better than the VLA. Also, the VLA benefitted immensely from the experience of WSRT in many ways, not least because both the first and present directors of the VLA came after years at WSRT. Oort followed everything that the VLA did as if it was his 4th telescope, and his views have greatly influenced even the development of GMRT in India, which at meter wavelengths will hopefully be to the nineties what the VLA was to the eighties and WSRT to the seventies.

I have already described Oort's reactions to Reber's work which showed his *instant* ability to recognize what would become of great importance in due course. Another example is a description in his own words: '... the epic of the first successful descent into the past of the Universe which was made by Ryle and coworkers at the Cavendish Laboratory. Radio astronomy clearly promised to become the *tool par excellence* for studying the universe'[4]. His mind remaining so much younger than his body, Oort had no difficulty in becoming an observational radio astronomer after 50 and pushing for the creation of new and bigger and better radio telescopes. In my view he contributed as much or more to the development of radio astronomy as any of the great telescope-building pioneers who came in from a different world, i.e. one where a great deal was known about radio but little or nothing about astronomy. It was only in Holland and only because of Oort that 'an astronomer from the start determined the observing programmes, the technical priorities and the next telescope's configuration'[5]. He knew what he was doing, so it is no wonder that the rest of us owe so much to him.

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Galactic rotation

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The discovery of galactic rotation—both, the global rotation and the local differential rotation in our Galaxy, will be discussed here. Oort made seminal contributions to this topic. A brief historical background is given first so as to place Oort's contribution in the proper perspective. This is important since the topic of galactic rotation was crucial in confirming the correct nature of our Galaxy.

Background

As late as 1920s, the nature of our Galaxy was not well-established[1–3]. There were two rival pictures for our Galaxy. One was the Kapteyn model based on the method of star counting. In this picture, the Sun lies at the centre of the Galaxy which has a roughly flattened ellipsoidal shape with planar and perpendicular sizes of about 2.8 kpc and 0.6 kpc respectively, corresponding to about 10% of the central density. In this picture, the other spiral nebulae were believed to be spiral galaxies similar to our Galaxy.

In sharp contrast to this was the picture of our Galaxy by Shapley, based on the distance measurements using the period-luminosity relation for RR Lyrae