EARLY PARKES OBSERVATIONS OF PLANETS AND COSMIC RADIO SOURCES

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ABSTRACT

We discuss early Parkes observations of the radio emission from the planets Mercury, Venus, Mars, Saturn, and Uranus. The sensitive Parkes 11 cm system was used to detect a surprisingly high observed nighttime temperature on Mercury, the first, but unrecognized, hint that the Mercury actually rotates with respect to the Sun, as well as detecting the faint radio emission from Uranus. We also discuss the anomalous spectrum of PKS 1934-63, the first recognized GPS source.

Subject headings: planets: general — planets: individual (Mercury) — Radio continuum: galaxies: individual (1934-63)

1. INTRODUCTION

When the Parkes radio telescope went into operation, it was so much more powerful than any thing else that existed at the time, that one did not need to be an expert about anything to just point the telescope and make new discoveries.

I came to the Radiophysics Lab (RP) in 1963 with the intention of using the Parkes radio telescope to continue the work I did for my PhD thesis on radio source spectra. After a few months, I moved to Parkes, since that is where all the action was. John Bolton was the Director and ran the observatory with an iron hand. He made all the rules, and there was no room for argument or negotiation. One of his rules was that the telescope could be used for observing only at night, and the days were reserved for maintenance and testing. Often, I noticed that there was no maintenance or testing going on, but the telescope was sitting idle. It really bothered me to see this fantastic instrument just sitting there unused. But as much as I pleaded, John would not compromise his principles.

It wasn’t just a matter of finding a telescope operator, or driver, as they were called, since I was a licensed driver myself, having been suitably trained and tested by John himself. The only exception to his “nighttime only” policy, he explained, was to observe something that could not be observed in the night sky. After careful thought, I concluded that this meant the occasional supernova, the Sun, and Mercury. I wasn’t prepared to wait around a few hundred years for the next supernova, and I wasn’t interested in the Sun. Beside the Sun was too complex with all those different types of bursts, and anyway there was a whole solar division at RP that studied the Sun. That left just Mercury.

2. THE PLANETS

I didn’t know very much about the planets, but I learned that they are heated by the Sun, and that their surface temperature depends mostly on their distance from the Sun, but also their albedo (how much energy is reflected rather than absorbed), and the rate that the planet rotates (absorbs and radiates heat).

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2.1. Mercury

All the astronomy text books of the time said that since the rotation period of Mercury is the same as its period of revolution around the Sun, that there was perpetual day time on one hemisphere, and perpetual night on the other. This generally accepted idea apparently dated from the 1888 work of Giovanni Schiaparelli (Holden 1890; Lowell 1902) on the basis of a few observations and his line drawings of surface features that he imagined seeing.

Typically, Celia-Payne Gaposhkin’s 1954 text book, Introduction to Astronomy, reported The sun beats fiercely on the face of Mercury; ... Mercury always turns the same face to the sun, ... and so one side of the planet is in continual sunlight; the other is in perpetual shadow. Under the suns rays the surface of Mercury is kept at a temperature near 350 C .... But the other side of the planet is in eternal darkness, and its temperature cannot be far from absolute zero (Payne-Gaposchkin 1954).

So, I knew if I wanted to study Mercury at Parkes, I would need to observe when the planet was at superior conjunction on the other side of the Sun when the hot day lit side would be facing the Earth. I expected that the signal would be weak, and that it would be necessary to average many scans to detect any radio emission from Mercury. To complicate the situation, Mercury is always near the Sun, so that the side lobes of the strong solar emission can easily be stronger than the weak thermal emission from Mercury.

There had been only one previous measurement of the radio emission from Mercury, by Howard et al. (1962) which was made when approximately half of the illuminated planet faced the Earth. Howard et al. (1962) measured a surprisingly high average disk temperature of about 400 K. Assuming the nighttime temperature was close to absolute zero, they calculated a subsolar (noon time) temperature of 1100 ± 300 K, considerably higher than expected from solar heating.

Since the signal from Mercury was expected to be weak, I rigged up a system that John Bolton had developed to digitize the telescope output which was sampled every few seconds, and then written on paper by an electric typewriter. To reduce the noise, I planned to...
average the numbers at each point from multiple scans using an electric adding machine. In order to gain experience in dealing with the solar side lobes, I started to observe just as Mercury was passing inferior conjunction when only the presumably cold dark side of the planet would be available. Much to my surprise Mercury came up loud and clear on a single scan. The apparent disk temperature was about 300 K, close to room temperature. I followed the planet as it revolved around the sun so that the sunlit side became more and more exposed. I wasn’t sure what to expect. Would the sunlit side also be hotter than the night side? No, the apparent disk temperature remained nearly constant, meaning that the day and night sides must have about the same surface temperature.

How could this be? The text books were clear on two things. Mercury doesn’t rotate and doesn’t have an atmosphere to circulate heat from the sunlit to the dark side. The evidence for non rotation appeared to me to be stronger than the evidence for no atmosphere. In fact, George Field (1962, 1964) had earlier suggested that Mercury might, in fact, contain a thin Argon atmosphere and predicted a dark side temperature between 50 K and 250 K. So I interpreted my anomalous temperature observations in terms of an atmosphere that could sustain the propagation of warm air from the daytime to the nighttime side.

The true interpretation was understood just a few months later, when radar measurements showed unambiguously that Mercury in fact did rotate with a 59 day period, precisely 2/3 of the rate of revolution around the sun (Pettengill & Dyce 1965). Characteristically, the theoreticians were quick to point out that this value was close to that expected on theoretical grounds (Colombo 1965; Peale & Gold 1965) although until the radar observations, they were apparently comfortable with an 88 day synchronous period. Apparently, Schaparelli, and others after him, had been fooled into believing that the rotation and revolution periods of Mercury were identical, because of the 3:2 spin-orbit resonance so that the synodic period is twice the rotation period; thus the same side of Mercury faces the Earth whenever Mercury is best observed in its very eccentric orbit at maximum distance from the Sun. Had I understood this, and had not been convinced by all the text books that Mercury doesn’t rotate, I might have been the first to understand that the warm nighttime temperature measured at 11 cm is due direct solar heating resulting from the rotation of the planet.

I learned from this experience that one should always go back to the original work, and not to trust text books or other secondary literature. Unfortunately I don’t read French, so I didn’t realize that Schaparelli’s data was so flaky, and apparently neither had any of the many text book writers for nearly the next hundred years.

2.2. Mars

At the 1964 IAU General Assembly in Hamburg, Rod Davies announced that he had measured a surprisingly high Martian temperature of 1,140±50K at 21 cm using the Jodrell Bank 250-ft MK I radio telescope (Davies 1964), although earlier observations had reported an apparent disk temperature of only 211±20K at 3.15 cm and 177±17K at 10 cm made at the Naval Research Labora-

tory (Mayer et al. 1958) and at NRAO (Heeschen 1963) respectively. These short wavelength values were close to that expected from solar heating, so Davies interpreted his observations in terms of intense non thermal radiation from charged particles circling the planet much like the Van Allen radiation belts observed a few years earlier around Jupiter by Radhakrishnan & Roberts (1960).

This was a serious matter, since NASA was about to send a spacecraft to Mars. If there really were belts of charged particles around Mars, they could affect the delicate instrumentation aboard the spacecraft. I was suspicious of the Jodrell Bank results since, the reported Martian flux density of only 0.2 Jy was comparable with the expected confusion noise of the MK I telescope at 21 cm. So I used the Parkes antenna to measure the disk temperature of Mars at 6, 11, and 21 cm. I pointed the antenna at the position of Mars on a number of successive days and measured the corresponding antenna temperature. Then after Mars had moved by more than a beamwidth, I re measured the antenna temperature at each of the same positions. The difference between the two measurements were then used to calculate the true antenna temperature due to Mars. Indeed, Mars turned out to have a perfectly reasonable disk temperature of 192 ± 26, 162 ± 18, and 169 ± 33 K at 6, 11, and 21 cm respectively (Kellermann 1965). The Jodrell Bank measurements, were, indeed, thoroughly confused at 21 cm.

2.3. The Other Planets

By this time, I considered myself an expert on planetary radio astronomy, and set out to use the Parkes antenna to measure the surface temperature of the other planets.

I observed Venus at 11, 21, 31, and 48 cm and was able to confirm the high temperature of Venus which had been previously measured at NRL (Mayer et al. 1958). This excess temperature of Venus is now understood in terms of a Green House effect due to the heavy cloud cover which envelops the entire planet. Although at the longer wavelengths, the effects of noise and confusion led to relatively large uncertainties, these new Parkes observations supported the somewhat lower disk temperature previously reported from observations at Arecibo (Hardebeck 1965) and Green Bank (Drake 1964).

Next I observed Saturn also at 6, 11, and 21 cm and measured disk temperatures of 179 ± 19, 196 ± 20, and 303 ± 50 K at 6, 11, and 21 cm respectively. The increase in apparent temperature at the longer wavelengths was also speculated to be due to a Jupiter-like non thermal radiation belt. However, subsequent high resolution observations showed no evidence for any radio emission beyond the planetary disk (Berge & Read 1968). More likely the high temperature measured at the longer wavelengths is due to the higher temperature lower down in the planet’s atmosphere which is probed by the longer wavelength radio emission.

Finally, I was able to use what was at the time, the most sensitive 11 cm system available anywhere to measure, for the first time, the thermal radiation from Uranus. As the observed flux density of 8 mJy is well below the 11 cm confusion level of the Parkes telescope, the observations were made at multiple positions of the planet, and corrected for confusion by subtracting the
observed flux density measured at each position after Uranus had moved outside of the antenna beam.

3. RADIO SOURCE SPECTRA

When John Bolton came to Caltech, he and Gordon Stanley designed and built the two element interferometer to measure accurate radio positions in order to enable the optical identification of radio sources. In order to prepare a finding list free of 3C lobe shifts, Dan Harris and Jim Roberts (Harris & Roberts 1960) observed all of the 3C sources using a single 90 foot element of the interferometer at a frequency of 960 MHz. They observed using drift curves, and apparently on several occasions Harris fell asleep at the controls and let the drift curve continue for long after the source passed through the beam. On two such occasions, Dan accidentally discovered a new source previously unrecognized in the lower frequency catalogs. He named these CTA 21 and CTA 102. As later shown by Kellermann et al. (1962) these were the first of the category of what we now call Giga-hertz Peaked Spectrum (GPS) Sources.

One of the first projects John Bolton initiated with the new Parkes radio telescope was a dual frequency survey of the available sky at 21 and 75 cm. John was aware of the unusual radio spectra of CTA 21 and CTA 102 and was on the lookout for similar type spectra. The Parkes Survey was divided into four declination zones and published in four installments. Paper I (Bolton et al. 1964) covered −20 to −60 degrees declination; Paper II (Price & Milne 1965) −60 to −90; Paper III (Day et al. 1966) 0 to +20; and Paper IV (Shimmins et al. 1966) 0 to −20. However, a careful inspection of the −20 to −60 catalog (Bolton et al. 1964) shows a surprising entry for the source 1934-63, which is located at −63 degrees declination and therefore properly belonging in the Price and Milne −60 to −90 degree catalog.

As told by John Bolton and Marc Price (private communications) what apparently happened was that Marc had just finished an all night 14 hour run and had left his chart records lying on the counter. John, knowing about CTA 21 and CTA 102 looked through Marc’s records and immediately noticed that 1934-63 was considerably stronger at 20 cm than at 75 cm. He asked Marc, “Are you finished with these?” Marc, being half asleep from his all night vigil, replied that he indeed was finished. “To teach him a lesson,” he responded.

Years later, I asked John Bolton why he had uncharacteristically published Marc’s data. ”To teach him a lesson,” he responded.

4. SUMMARY

I was privileged to have the opportunity to exploit the Parkes 210 foot radio telescope for studies ranging from solar system objects to distant radio galaxies and quasars. I was fortunate to have been tutored by the dish-masters, John Bolton and John Shimmins. It is to their credit that the Parkes dish has enjoyed 50 years of astronomical discovery and adventure including the exciting participation in the first manned lunar landing.

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Facilities: Parkes.

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