The P's and Q's of Modern Astronomy[1]

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You have all heard the expression: MIND YOUR P's and Q's. Well, the P's and Q's of modern astronomy are the PULSARS and the QUASARS. The other P's and Q's in the well known expression are left as an exercise for the listener (or the reader) because I don't know what they are. One of my friends suggested "Pints and Quarts". A punster suggested "Pros and Quons". If any of you should know the answer, please enlighten me.

The pulsars and the quasars are both discoveries of a relatively new field of astronomy, namely RADIO ASTRONOMY, so I would like to start by giving you a brief history of radio astronomy so that you can see how it fits in with modern astronomical research.

A century ago (1872) Maxwell proposed the concept of the electromagnetic spectrum, and in 1887 Hertz detected radio waves. In 1890 Thomas A. Edison suggested an attempt to detect solar electromagnetic disturbances, and Sir Oliver Lodge tried in 1894. There was too much interference from the city of Liverpool, and he failed.

Karl Jansky was an engineer employed by the Bell Telephone Laboratories. In the early 30's the first transatlantic ratio-telephone communications were attempted, and static not of a random character was troublesome. Jansky was given the job to "find the source of the static and do something about it". He built a directional antenna mounted on a turntable (using Model T Ford wheels), and started to work. He soon discovered that the source of the static reached the same direction 4 minutes earlier each day. Then came a day when it was an hour and 4 minutes early. The puzzle was resolved when someone told Jansky that the local area had gone on daylight saving time and the clocks had been set ahead during the night. At any rate, the 4 minutes per day meant that the origin of the static was not on the earth, but was in the universe outside the solar system. The motion of the earth around the sun causes the stars to rise and set 4 minutes earlier each day compared with the sun. Jansky concluded that the static was coming from the constallation of Sagittarius, the direction of the center of our galaxy, the Milky Way. Jansky's bosses at Bell Labs concluded that Bell Labs couldn't do anything about the Milky Way, and they assigned Jansky to other work. And so the "Galileo of Radio Astronomy" was not able to follow up his important discovery, made in 1931.

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[1] The Indiana Academy of Science established in 1971 a Science Communication Award of $500., funded through the Science and Society Committee from its National Science Foundation grant. The award is presented at the general session of the fall meeting, when the recipient is called upon to give an address. The recipient is also scheduled for visits to Indiana college campuses, to bring somewhat similar material to students, faculties and townspeople. Printed here is Dr. Edmondson's summary of his address given at the Saint Mary's College meeting of the Academy on November 3, 1972. His complete address was later given at five Indiana colleges.

The next important worker was Grote Reber of Wheaton, Illinois (1932-46). He earned a living in the daytime as an electronics engineer, and stayed up all night (when man-made interference, such as automobile ignitions, was a minimum) working with a 31 foot paraboloid that he built himself. He produced the first radio map of the sky. In 1944 he published a map with 12° resolution at 1.85 meters. Then he was with the National Bureau of Standards for a while, and later worked in Hawaii and Tasmania supported by grants from the Research Corporation. He is now a Senior Research Associate at Ohio State.

During World War II radar workers in England detected the Sun and many other celestial radio sources, but this information was all classified until the war ended. Following the war great progress was made in Australia, England and Holland, but very little in the United States. A great step forward was made in 1956 when Congress appropriated $4,000,000 in the budget of the National Science Foundation to construct the National Radio Astronomy Observatory near Green Bank, West Virginia. I was a temporary bureaucrat in 1956-57, and my initials on November 19, 1956 started the Grant and Contract Record through the NSF channels. The major NRAO instruments now are the 140-foot precision steerable telescope and the 300-foot meridian transit. There is also a 36-foot microwave dish on Kitt Peak in Arizona. Work in radio astronomy has developed in a number of universities, in the midwest notably at Ohio State, Michigan, and Illinois.

Mention should also be made of the first detection of the 21 cm Hydrogen line by Ewen at Harvard. However, it was the Dutch and the Australians who cashed in on this discovery in the 5 years after it was made, because adequate radio telescopes did not exist in the United States.

A radio telescope is an antenna to collect the radiation, plus a receiver-amplifier and a recorder to record the data. Resolving power has been a serious problem in radio astronomy, and various techniques have been developed to improve resolving power. Brute force, that is very large dishes, is one way. Interferometry is another. The Green Bank Interferometer is a good example. The Very Large Array, the start of which has been authorized in the NSF budget will be a major step forward. Global interferometry using tape recorders has been successful, but does not eliminate the need for the VLA and other high resolution facilities.

The largest dish in the world, which is not steerable, is the 1000-foot dish at Arecibo in Puerto Rico. I have saved mention of this until the end of my radio astronomy survey because it is the principal U.S. instrument for studying the *pulsars,* the p's of modern astronomy. (16 slides were used to illustrate the lecture up to this point.)

The pulsars were discovered by radio astronomers in England just after the Prague meeting of the International Astronomical Union in 1967. The first 2 or 3 were facetiously called the LGM's (for little green men), but it soon became clear we were dealing with a natural phenomenon. The radio astronomers detected radio sources emitting flashes, or pulses, of radiation in periods of a few seconds down to 1/30 of a second. The one with the very short period has been identified as a star in the "Crab Nebula" and its variation has been detected optically by very sophisticated electronic and optical techniques. The "Crab Nebula" is the remnant of a supernova recorded by the Chinese in 1054, and the pulsar is believed to be the supernova itself. It is now generally believed that the pulsars are rapidly rotating NEUTRON STARS which send out a beam of radiation. The pulses would be analogous to the flashes of a lighthouse or an airport beacon, (10 slides were used to illustrate these comments on the pulsars).

The first quasar (meaning quasi stellar object) was discovered in 1960. It was a strong radio source, and the optical counterpart looked like a stellar object on plates taken with the 200-inch telescope. However, ordinary stars (except for the nearby Sun) do not send out detectable radio frequency radiation. Moreover, the spectra of quasars did not look like any known stellar spectrum. The mystery was solved when Maarten Schmidt suggested that the quasar spectra might be the result of large red shifts, with familiar features shifted to the infra-red, and unfamiliar features shifted from the ultra-violet to the visible. This suggestion paid off, and led to the discovery that some quasars have red shifts corresponding to about 90% of the speed of light.

It had been known for many years that galaxies have red shifts corresponding to speeds up to about 20% of the speed of light, and that these velocities are directly proportional to the distances of the galaxies. This is the observational basis for the theory of the expanding universe. If the quasar red shifts are "cosmological", meaning that they result from the expansion of the universe, then the quasars are the most distant objects known. If they are this far away, the intrinsic luminosities are at least 1000 times as bright as our galaxy, and we have the problem of explaining how so much energy can be produced. If we assume they have normal luminosities, they must be relatively nearby, and then we have to find a way to explain the large red shifts. The quasars are probably the major unsolved problem of present-day astronomy. (36 slides were used to illustrate these comments on the quasars).

We must also keep in mind that as the astronomer looks out to large distances in space, he is also looking backward in time. We see the Andromeda galaxy not as it is now, but as it was 2 million years ago. The light that is leaving it today will not reach the earth until 2 million years from now. If the quasar red shifts are cosmological, then we are seeing the quasars as they were 10 billion years ago, a time very close to the origin of the universe itself.