The Optical Identification of the Hercules X-1 System

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The first optical identification of an X-ray pulsar—a neutron star—in a binary system was made in the summer of 1972 at the Wise Observatory. We describe some of the circumstances of this discovery that stand out in our memories a decade later.

The Observatory was built under the direction of Uri Feldman who designed an observatory that was both beautiful and functional. He displayed, in order to complete the design and construction all in one year, a disarming honesty, a fierce stubbornness, and an unlimited capacity for work. Uri would shout at contractors and soothe scientific egos, sometimes in the same sentence. Throughout the first summer in which we lived at Mitzpe Ramon, Uri supervised the technical work and inspired all of us associated with the Observatory with his enthusiasm for creating something new in Israel.

We arrived naïvely at the Wise Observatory armed with twelve carefully planned scientific programs involving spectroscopy, photometry, and photography. Observations of the newly-discovered pulsating X-ray source, Hercules X-1, was one of these programs, but was not our highest priority project. We quickly found out that the only operating instrument was the wide field direct camera and that even the darkroom for this instrument was not yet built. About half of our effort for the rest of the summer was spent, together with Uri and Shmuel Stolero (the senior night assistant), in designing and testing the new darkroom equipment and in improving the setup for taking direct photographs. None of the advanced instrumentation that Mike Lecar later brought to Israel with the aid of Smithsonian funds was available for our use.

The months before the construction of the Wise Observatory were one of the most exciting epochs in X-ray astronomy. During this period, the first X-ray satellite, Uhuru, opened up a field of study that dominated much of astronomical research for the next ten years. Riccardo Giacconi, Ethan Schreier, and their colleagues discovered the first known pulsating X-ray source, Centaurus X-3, and showed that it was a member of a binary system of stars. This object was not accessible from the Wise Observatory because it was in the southern hemisphere. However, shortly before we came to Israel, the second pulsating X-ray source, Hercules X-1, was discovered by Harvey Tananbaum, Riccardo, Ethan, and their collaborators. Fortunately for us, Hercules was conveniently placed in the northern sky where we could study it on our summer observing run in Israel.

Of the twelve previously planned projects, one of the few that we could do with the direct camera was to take repeated exposures of the entire error box in which the Hercules X-ray source was known to be located. There was some reason to believe that this might be informative, based on a recently completed theoretical paper by Jonathan Arons and John Bahcall. Most of the other optical groups around the world were trying to detect photometrically the optical counterpart of the X-ray pulses, a procedure which (fortunately for us) proved to be much more difficult than observing the unpulsed variations by photographic means.

We were promised by Yuval Ne’eman as much observing time as we wanted during the first summer in exchange for our help in getting the Observatory started. Yuval—the father of both astronomy and astrophysics in Israel—believed that we could most efficiently turn the Observatory into a general user facility by staying there one summer and doing science. He was right, although it was much more work—and fun—than any of us anticipated.

The first few nights were frustrating. The telescope drive malfunctioned; the dome was
hard to open and close; the camera was not stable; the guide scope could not be focussed; the seeing was poor; we could not develop the plates; and we lacked the scientific instruments that were necessary for most of our projects. But Shmuel could fix anything and often did—always cheerfully. He would work all night as an observing assistant and then spend much of the next day improvising a new way to move the dome, to hold the camera in place, or to stabilize the tracking. Without the strong administrative backing of Yuval and the superlative technical support of Uri and Shmuel, no scientific work at all would have been possible during the first summer. Somehow, with their help, everything essential got done.

We began each evening by bringing our two boys, Safi (age 3 1/2) and Dan (age 1 year), to the Observatory and let them play. In the night assistant’s room until they fell asleep. Safi slept in a borrowed crib and Dan slept on a towel in one of the desk drawers. After a night’s observing, we would wrap the sleeping boys in blankets and carry them to the tender with which we drove back to Mitzpe Ramon as the bright desert sun rose in the early morning. Somewhat surprisingly, our boys never woke up on those trips back to our apartment.

We accumulated—while learning how to use the telescope—several plates of the Hercules X-1 field taken during the period of July 6 and July 15. John did most of the observing and Neta did most of the analysis, although we did switch jobs occasionally. After the first few plates were developed, Neta inspected them carefully by eye and noticed that one of the stars in the X-ray error box, HZ Hercules, was highly variable. She plotted crude eye estimates of the intensity versus time and guessed, from the initial graph of a few points, that the optical star might have the same period of 1.7 days as the UHURU Coup found for the X-ray source.

About this time, Arno Penzias came down for a visit with his family to see how the Observatory was working and to enjoy the public swimming pool to which we all retreated in the hot Negev mornings. Arno was skeptical of the reality of the periodicity that Neta guessed, but interested. He did take “just for the experience” one plate of the field. (He swore that it would be his last optical observation until the Observatory obtained an automatic guider. So far, it hasn’t gotten a guider and he hasn’t done any more optical observations.)

We increased our efforts to observe variations in HZ Hercules and took many plates each night. At the end of a couple of weeks of observations, Neta could predict with reasonable accuracy what would be the magnitude of HZ Hercules at the beginning and end of each observing night. She would make eye estimates by comparing intensities on plates we took of the Hercules field with plates we took of the globular cluster M13, for which many photometric standards were available. We would even observe changes in the brightness of HZ Hercules in the expected direction during the course of an evening’s observations.
Figure 1: Note from J. Bahcall to Y. Ne’eman informing him of the discovery of optical periodicity in HZ Hercules.

When we were certain that HZ Hercules had the same period as the X-ray pulsar, we sent a cable announcing the optical identification to the IAU center for astronomical cables at Harvard University. We celebrated by going out to eat at the only restaurant in Mitzpe Ramon (subsequently closed by the health authorities) before returning for more observations. The identification was quickly confirmed by Bill Liller at Harvard (who sent us a generous congratulatory message via Mike Lecar) using preexisting material in the Harvard collection of plates and by workers at several other observatories. The note, in elementary Hebrew, in which John informed Yuval of the discovery is reproduced here as Figure 1 (from framed note in Yuval’s office).