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Search for Near-Earth Asteroids With the Spacewatch Camera

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The Spacewatch program began as an engineering development for the discovery of near-Earth asteroids and comets, with the first observations starting in 1983 using an RCA CCD that has 320 × 512 pixels. We wrote extensive software to scan the sky and learned how to do astrometry for precise orbits of newly discovered objects. The merit of the concept was proven, with many observations reported in the *Minor Planet Circulars* and recovery of comets in the *Circulars of the International Astronomical Union*. We improved the precision of astrometric observations for comets and asteroids (T. Gehrels, B. G. Marsden, R. S. McMillan, and J. V. Scotti, "Astrometry With a Scanning CCD," *Astron. J.*, Vol. 91, pp. 1242-1243, 1986). For efficient scanning and discovery of new objects, however, one needs a larger CCD, for which we have obtained a Tektronix 2048 × 2048 CCD.

This type of pioneering work has not been done before with such a large CCD in the scanning mode. We have defined most of the problems: For instance, what is the best scanning routine to find near-Earth asteroids and comets? Which are the best scan regions for this goal? In addition to the automatic detection that we have done before with the computer system in Tucson, it may be possible to inspect the data already on the mountain in order to recognize fast-moving objects with the new computer equipment. How to recognize fast-moving objects on the screen already at the telescope? How to interpret the data on that screen, and next on the tapes for further analysis with our computer on the campus in Tucson? Should the data be partially pre-processed or compressed before being sent to Tucson, or should we attempt to concentrate all the data-reduction capability at one site?

Since 1981, we have obtained some of the answers to these questions through various exercises that usually resulted in the accomplishment of useful research on various objects, with publication of the results. This is all summarized in a paper entitled "Various Modes of Using Charge-Coupled Devices" that Gehrels, McMillan, Scotti, Perry, and Rabinowitz have submitted to the *Astrophysical Journal*. Its abstract reads:

> This paper describes a new discipline in astrophysics, "scannerscopy," of scanning the sky with charge-coupled detectors (CCD) and computerized reduction. Usually we turn the drive off, and the scanning motion of the sky is precisely followed by slaving the charge-transfer of the CCD to the sidereal drift rate. The CCD is read out during the observing, and flat-fielding corrections are not needed. In this paper, a comparison is made with photographic surveying of Schmidt telescopes,

> showing that the CCD-scanning is to be preferred, especially for the detection of fast-moving objects. With the "Spacewatch Telescope" of the Steward Observatory of The University of Arizona on Kitt Peak, we have developed new modes of using the CCD for searches of gamma-ray bursters, space debris, satellites, comets, cometesimals, the tenth planet, and various types of asteroids. Routine astrometry is done for moving objects, with a precision of ±0.6 arcsecs. We are presently using a Tektronix 2048 × 2048 CCD, which appears to be successful also in the discovery of near-Earth asteroids. The goal is to study magnitude-frequency relations of asteroids, comets, and satellites, as well as to develop new techniques for surveying; the need for a 1.8-m CCD-scanning reflector, and for surveying with CCD cameras on spacecraft that pass through the asteroid belt, is apparent.

The 2048 × 2048 CCD is now permanently on the Spacewatch Telescope. A Solbourne computer has arrived and is being programmed by Dr. David Rabinowitz, who joined us for postdoctoral study in September. It will take at least half a year to complete these programs, but every month we test the next step in this work with observations at the telescope. During one of these tests, Rabinowitz discovered the trail of a fast-moving asteroid, 1989 UP. Its perihelion distance is near 0.9 AU, which seems to indicate that it is dynmaically under the influence of the Earth and will eventually impact it. The aphelion distance is in the asteroid belt, which seems to indicate that it is a fragment of collisions there. A lightcurve obtained by Dr. Wieslaw Wisniewski yielded an amplitude near 1 magnitude, and this seems to confirm that it is an elongated fragment.

We have taken the first organizational steps towards a text and source book on Space Resources in the Space Science Series of The University of Arizona Press. The book will be based on an international conference to be held in Tucson in January 1991. The leading scientific editor is P. Lewis.