TOWARDS THE DEFINITION OF A UNIFIED CELESTIAL OPTICAL/RADIO REFERENCE FRAME

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ABSTRACT. An almost inertial celestial reference frame based upon extragalactic sources is in the process of being established. This reference frame is to be global with a minimum density of one source per 100 square degrees. The source positions will be based upon radio observations and will allow optical reference frames to be related to this frame at the 0.03 arc second level.

1. INTRODUCTION

Reference frames are necessary to measure the positions and motions of objects. In astronomy we are concerned with the stellar reference frame of bright stars and the dynamical reference frame defined by planetary motions. These reference frames are defined by the accuracy of the observations of the objects making up the reference frame. The stellar reference frame is defined by the positions of the stars making up the FK5 reference frame.

Radio astrometry has made great progress in the past ten years in making accurate positional measurements over large angles. The accuracy of these measurements now appears to be approaching a milliarcsecond. Objects such as extragalactic radio sources make excellent reference points for establishing a reference frame as they should display little or no detectable proper motions. Observations by geodesists and astrometrists are in the process of measuring a grid of these sources in the northern hemisphere. Unfortunately these objects have very faint emission at optical wavelengths. Here we wish to discuss a program for establishing a unified celestial optical/radio reference frame based upon extragalactic radio sources.

2. THE PRESENT STATUS OF CELESTIAL REFERENCE FRAMES

The optical reference frame, the FK5, contains about fifteen hundred bright stars located over the celestial sphere and some three thousand fainter stars. The positions of the brightest stars are believed to be known to 0.03 arc seconds at the mean epoch which is about 1950 for most of the stars. The uncertainty in proper motion is estimated at 0.001

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arc second/year so that at 1987 the apparent positions should be accurate to 0.05 arc second.

The radio reference frame has yet to be established. There are various catalogs of from twenty-five to over one hundred extragalactic objects (Robertson et al. 1986; Ma et al. 1986; Fanselow et al. 1984) which report positional accuracies of less than a few milliarcseconds. The majority of the sources are located in the northern hemisphere with some objects having declinations as low as -40 degrees. Unfortunately these catalogs are based upon observations obtained over several years and it is difficult to estimate the epoch of the positions. This will not matter if the extragalactic objects display no proper motions. However there will be rotations between the catalogs as the earth's motions are not known to accuracies exceeding a milliarcsecond per year. This has been shown to be the case as these catalogs display small rotations of a few milliarcseconds between one another (de Vegt and Johnston 1986). One must base his reference frame on one of these catalogs.

3. PROGRAM PLAN

The program is aimed at establishing a reference frame of four hundred or more objects giving a density of at least one source per 100 square degrees. The objects will be extragalactic radio sources which display optical emission. The positions will be determined by the radio observations. These objects will be selected from the list of radio/optical candidates put forward by IAU Commission 24 (Argue et al. 1984) and supplemented by other flat spectrum objects chosen from the Parks and Green Bank-MPI surveys.

In the northern hemisphere, the radio positions of these objects can be determined very accurately as there are many facilities capable of making the observations. The positions of southern hemisphere objects cannot be determined as accurately, as there is a paucity of observatories equipped to make these observations. Observations will have to be carried out using the VLBI facilities in Australia, South Africa and Brazil. It is very important that observatories in these and other southern hemisphere countries be kept up or made capable of radio interferometric measurements.

Optical observations will be carried out using wide field astrograph cameras such as those located at Hamburger Sternwarte in Germany and Black Birch Astrometric Observatory in New Zealand and large 4 meter class prime focus photography. The astrographs will allow a large number of stars to be used to relate the position of the extragalactic radio source on the prime focus plate to the bright stars making up the optical reference frame. The accuracy of the relationship of the extragalactic radio source's position to the stars on the astrograph plate should be better than 0.03 arcsecond. For objects too faint for prime focus plates, CCD observations will be used as was the case for 1928+738 (de Vegt et al. 1987). In this way the positions of the extragalactic sources in the optical reference frame can be determined.

Observations will be obtained over a five year period beginning in July 1987. The radio observations from this campaign will be analyzed for self consistency with observations of all candidate objects obtained

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at least once a year in the northern hemisphere and observations obtained in the southern hemisphere when possible. The radio positions of sources down to declination of -40° should approach an accuracy of a milliarcsecond while those south of this declination may be degraded by factors of from 2 to 10. The optical observations will require a minimum of two prime focus plates per source and two wide field astrographic plates of the star field around the source. The optical observations should be on the optical reference frame to an accuracy exceeding 0.05 arcseconds globally.

The radio positions of the objects will be used to establish the reference frame and will be adopted as the positions of the objects. We are assuming that the optical and radio photocenters of the objects are coincident to the measurement accuracy, which will be a few milliarcseconds. The relationship of this reference frame to the FK5 (or any other optical system, e.g. HIPPARCOS) frame will be obtained to the accuracy of the optical plate transfer from the 4 meter prime focus plates to the astrograph reference stars (which will be of order less than 0.03 arcseconds). This should allow alignment of radio and optical images at this level which is about one half an Airy Disc of the Hubble Space Telescope.

4. CONCLUSIONS

Measurements are underway at optical and radio wavelengths to establish a global reference frame based upon extragalactic reference sources. If successful, a reference frame will be established which has a density of at least one source per 100 square degrees. This reference frame will be a radio based frame and will be capable of relating the radio defined reference frame to optical reference frames at accuracies of 0.03 arc seconds.

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