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A ROTATING SPACE INTERFEROMETER WITH VARIABLE BASELINES AND LOW POWER CONSUMPTION

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ABSTRACT

A new concept is presented here for a large, rotating space interferometer which would achieve full *u,v* plane coverage with reasonably uniform integration times, yet once set in motion no additional energy would be required to change collector separations, maintain constant baseline rotation rates, or to counteract centrifugal forces on the collectors.

1. INTRODUCTION:

A very large imaging astronomical interferometer presents many daunting technical challenges. When futuristic ideas for space interferometers are envisioned, the practical difficulties of making this kind of mission work are sometimes not appreciated. For successful imaging interferometry, *u,v* plane coverage should be complete (achieved by obtaining a full set of collector baselines and position angles on the sky), and uniform integration times should be obtained for all points in the *u,v* plane (achieved by keeping baseline scan rates and rotation rates within reasonable limits during the observations). But with conventional designs considerable energy could be required to maintain constant baseline rotation rates, change baseline spacing, counteract centrifugal forces on moving parts of the rotating structure, or for station keeping in a design with free-flying components. Power consumption must be reduced to levels that can be provided by stored or collected energy sources (flywheels, propellants, solar-electric power, etc.).

Unfortunately, changing the moments of massive collectors on a rotating interferometer structure can cause its angular velocity to change by orders of magnitude since angular momentum is conserved (a familiar example is the spinning figure skater). To maintain reasonably constant angular velocities with a conventional rotating interferometer design, it would be necessary to decelerate the structure each time the apertures were moved to the minimum baseline, and accelerate it again as they were extended to maximum separation. This procedure would have to be repeated continuously. Kinetic energy could be extracted from the rotating structure and used to control the angular velocity, but storing it and converting it into useful work would require very complex and massive mechanical systems (such as flywheels, generators, batteries, etc.).

Tethers could be used as simple, deployable structural elements to control the radial positions of the otherwise free-flying collectors. The mission concept for SPECS - Submillimeter Probe of Early Cosmic Structure - is now being studied at NASA/Goddard Space Flight Center (Leisawitz 1999). SPECS is envisioned as a very large (1000 meter class), rotating, variable baseline space interferometer with three 3-m collectors (telescopes or flats). In the initial SPECS concept, electric motors could be used to pull in the collectors with the tethers (Mather 1999). However, tethers have practical limitations (they act only in tension, for example), which can lead to major demands on spacecraft station keeping, stabilization and metrology systems.

The ideal space interferometer instrument would consume no additional power to scan and rotate the baselines at acceptable rates, or to work against centrifugal forces. However, as with any rotating interferometer design, energy would be required to change the angular momentum of the spacecraft (for example, to stop rotation of the interferometer so that it could be re-pointed to a new observing position, and then to restart rotation).

2. THE NEW LOW-POWER CONCEPT:

In the new concept, the interferometer structure would be made up of light trusses. The truss might be of a deployable design, as proposed by Brown (1999), which unrolls from a coil on orbit. A collector is mounted on one end of each rotating arm, and an instrument module which also acts as a counterweight is mounted on the other end. The module can contain optics, delay lines, electronics, etc. The counterweighted arms pivot about their centers of mass. As the arms rotate the distances between the collectors change, and the collector baselines scan and rotate continuously without any work being done, sampling the u,v plane with reasonably uniform integration times. Since the moments do not change, there are no changes in the angular velocity of the structure as the collectors move. The spacecraft could be configured either with three arms to mimic the current three-aperture tethered SPECS design, or with two rotating arms. Both designs rely on the same basic principles and technology, and have their respective advantages and disadvantages.

2.1. The Three-Armed Design:

The three-armed rotating interferometer (which mimics the geometry of the tethered three collector SPECS concept) consists of a central platform made up of three light radial masts braced with guy wires. A rotating arm with a collector on one end pivots on the end of each of the masts, like a propeller spinning on the blade of a three-bladed windmill. If the three arms rotate opposite to the rotation of the platform structure at the appropriate angular velocity and phase, the baseline scan rates and position angles in the rest frame can be kept within reasonable limits. When the angular velocity ω_i of an arm is much greater than the angular velocity ω_P of the central platform, the paths of the collectors are closely overlapping spirals, and u,v plane coverage can be completed in one revolution.A weakness of the three-armed design is that each of the rotating arms would be subject to centripedal force, resulting in periodic lateral loads and flexing of the long semi-rigid trusses against their pivot points. Other obvious disadvantages are complexity and total mass.

2.2. The Two-Armed Design:

The two-armed interferometer design (Figure 1) is equivalent in many ways to the three-armed design. It allows less flexibility in programming the observing scan pattern, but still may be preferable. The two-armed spacecraft resembles the hands of a clock. The hands rotate in opposite directions at slightly different angular velocities, so the "clock" effectively rotates with respect to the reference frame of the sky. The interferometer has three collectors obtain phase closure, two of which move along circular paths at the end of the rotating arms, and one which is mounted at the axis of rotation .

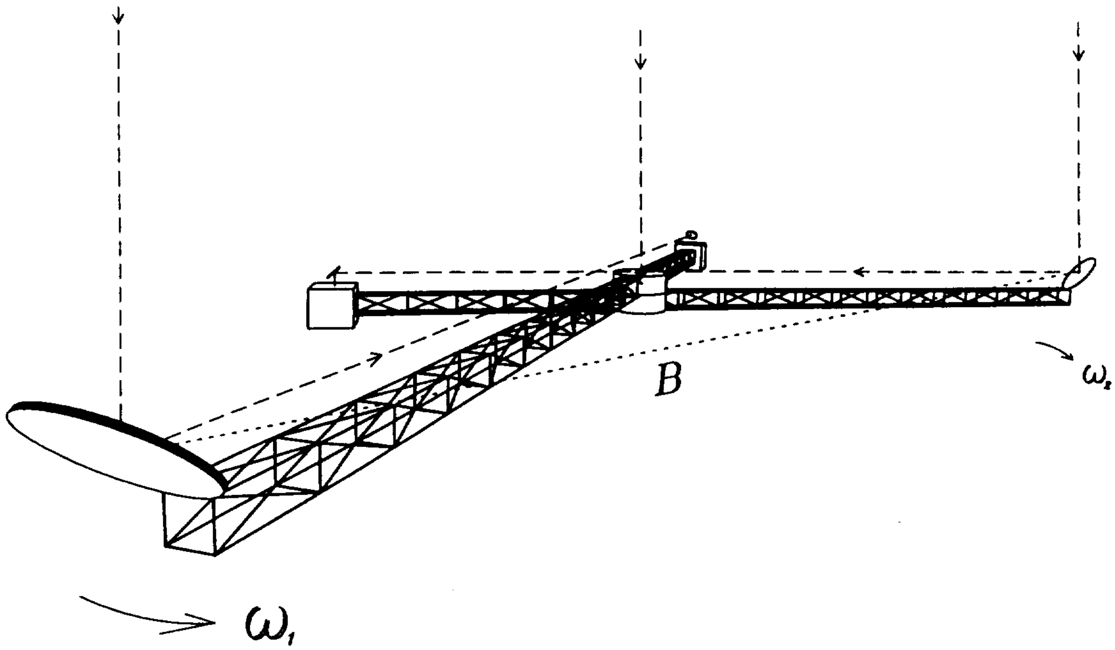

Figure 1: The two-armed interferometer spacecraft, resembling the hands of a clock. A collecting aperture is mounted on one end of each arm, and an instrument module which acts as a counterweight on the other. The arms rotate in opposite directions at constant but slightly different angular velocities ω_1 and ω_2. As the arms rotate the length of the baseline *B* between two moving collectors changes, and the "clock" itself effectively rotates with respect to the reference frame of the sky. Since the moments of the movable components remain constant there are no changes in the angular velocity of the structure as the baseline is scanned, and no energy is expended to position the collectors, or to maintain acceptable baseline scan and rotation rates.

Instrument modules opposite the collectors act as counterweights on each arm

In the configuration of the spacecraft shown in Figure 1, instrument module/counterweights are twice the mass of the collectors, with corresponding 2:1 ratio of moment arms. In this case the total mass of the interferometer would be roughly an order of magnitude greater than the mass of one of the collectors. However, the collectors could be light enough in construction that the total mass of the spacecraft would still be within practical limits. This version does not suffer from the problem of deflection of the rotating arms by centripedal forces effecting the three-armed design, since here the loads on the arms are only longitudinal. The two-armed design also has the significant advantages of relative simplicity and lower total mass.

Brown, M. 1999 *(Naval Research Laboratories, Washington, DC - internal report).*
Leisawitz, D. 1999, SPECS Website, *http://www.gsfc.nasa.gov/astro.specs*
Mather, J. 1999, *private communication.*