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PLANNED IMPROVEMENTS
TO THE
OWENS VALLEY FREQUENCY-AGILE INTERFEROMETER
FOR MAX'91

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SCIENTIFIC MOTIVATION FOR MICROWAVE SPECTROSCOPY

* MEASUREMENT OF CORONAL MAGNETIC FIELDS

Gyroresonance opacity creates spectral features that can be used to accurately measure the strength of magnetic fields at the base of the corona. (Figure 1) This provides the basis for a practical coronal magnetograph.

* DIAGNOSTICS OF SOLAR ENERGETIC ELECTRONS

Theoretical models of brightness temperature spectra show that microwaves can cleanly distinguish between thermal and nonthermal gyrosynchrotron emission on the basis of shape of the spectra. The peak brightness temperature and peak frequency then define the plasma and particle parameters. (Figure 2)

WHY HASN'T THIS BEEN DONE BEFORE ??

The diagnostic content of microwaves is in terms of their brightness temperature spectra (surface brightness).

To measure brightness temperature at any frequency, it is necessary to spatially resolve the source.

The physics of gyroresonance emission and the character of burst spectra imply that spectral resolution of about 10% is required over several octaves of frequency.

THERE IS NO EXISTING FACILITY THAT COMBINES BOTH ADEQUATE SPECTRAL COVERAGE AND HIGH SPATIAL RESOLUTION IMAGING.

(The VLA does not have the spectral coverage; the present Owens Valley interferometer does not have enough baselines to image complex sources.)

WHAT'S THE PLAN ??

To add 3 small antennas to the OVRO interferometer to form a 5-element SOLAR-DEDICATED array.

This would provide up to 7 or 10 baselines (compared to the present 1 or 3). This would be sufficient to apply microwave diagnostics to most active region and burst sources.

By using frequency-synthesis it would also provide an imaging capability comparable to that of a ~100 baseline interferometer for morphological observations.
(See Figures.)

WHAT'S INVOLVED IN EXPANDING THE ARRAY ??

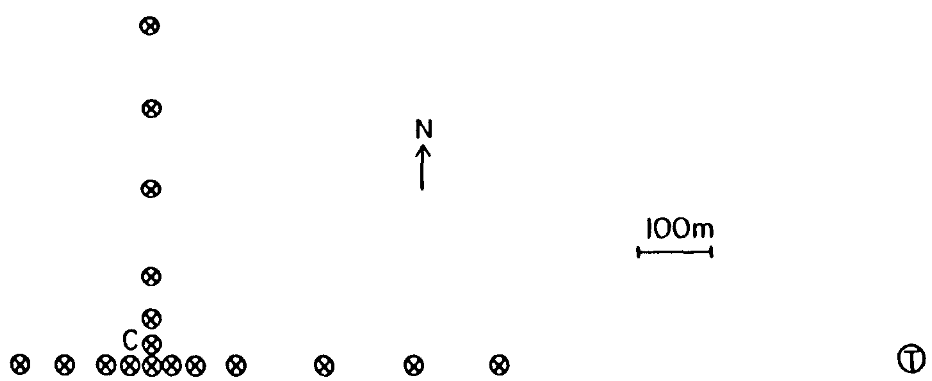
* The present system is based on a pair of 27-meter parabolic antennas, equipped with frequency-agile receivers. By rapidly cycling in frequency the system functions effectively as a microwave spectrometer over the range 1 to 18 GHz. Baselines up to 1.25 km are available so that burst and active region sources can be resolved at all frequencies.

* To expand the array, we will add 3 small (2 m diameter) antennas, equipped with frequency-agile receivers of essentially the current design.

* Large antennas are not necessary because by doing interferometry between 2 meter and 27 meter diameter antennas, the effective sensitivity is the same as that with a pair of 7 meter antennas (geometric mean of 2 and 27). This is quite satisfactory.

* Although antennas of this diameter are readily available, commercially available antenna mounts do not combine adequate sky coverage with reasonable cost. Therefore we will build the antenna mount in-house, using a simpler design well-matched to our requirements. (See 1/4 scale model.)

* To avoid the expense of new cabling, the small antennas will be located at existing antenna stations. (See below.)



Interferometer configuration, showing the possible locations of the 27 m antennas (×) relative to the 40 m telescope (T) and the control room (C).

* Normally a significant expense in N-antenna arrays is the need for N x N correlators and associated systems.

* This expense will be avoided by constructing a 5-to-3 line multiplexer and then time-multiplexing existing delay lines, amplifiers, correlators and data system.

* The resulting system will be capable of fully sampling 5 antennas while changing frequencies up to 10 times per second.

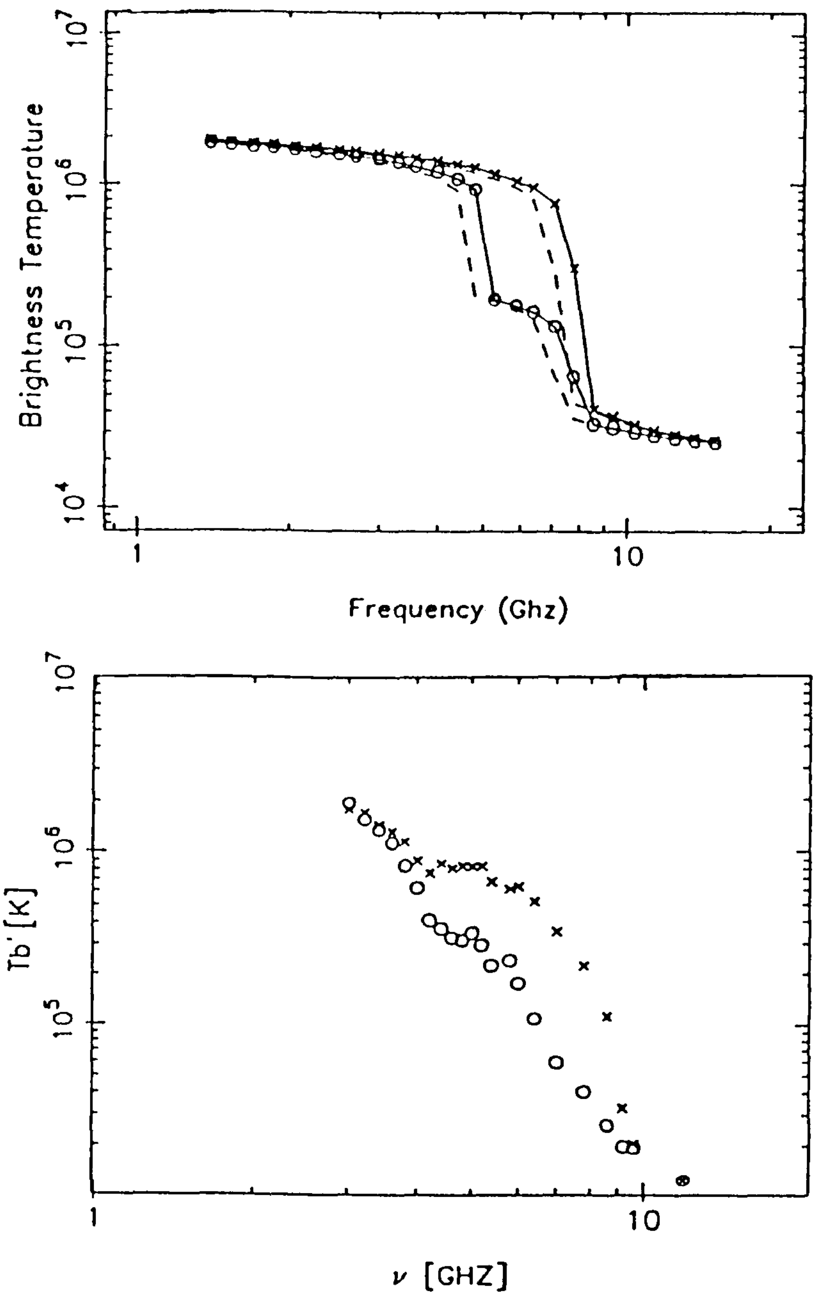


Figure 1. The upper panel shows model line-of-sight spectrum calculated using a three-dimensional potential field model of sunspot magnetic fields in a constant conductive flux modelled atmosphere. The discontinuities are a result of the interplay of gyroresonance opacity (at the 2nd and 3rd harmonics) with the sharp temperature gradient at the transition zone. x and o represent emission in the extraordinary and ordinary modes respectively. The dashed line shows the effect of increasing the model magnetic field by 10%.

The lower panel shows a typical observed line-of-sight spectrum near an isolated sunspot. As suggested by the model, the frequencies at which the spectral breaks occur (particularly in the extraordinary mode) can be readily interpreted in terms of the magnetic field where the line of sight intersects the base of the corona. For this line of sight (4000 km displaced from the center of the sunspot), at 300,000 K the 3rd harmonic of gyrofrequency corresponds to 7.6 GHz, implying a field of 900 gauss (ref Hurford and Gary, NASA-CP-2442, p317).

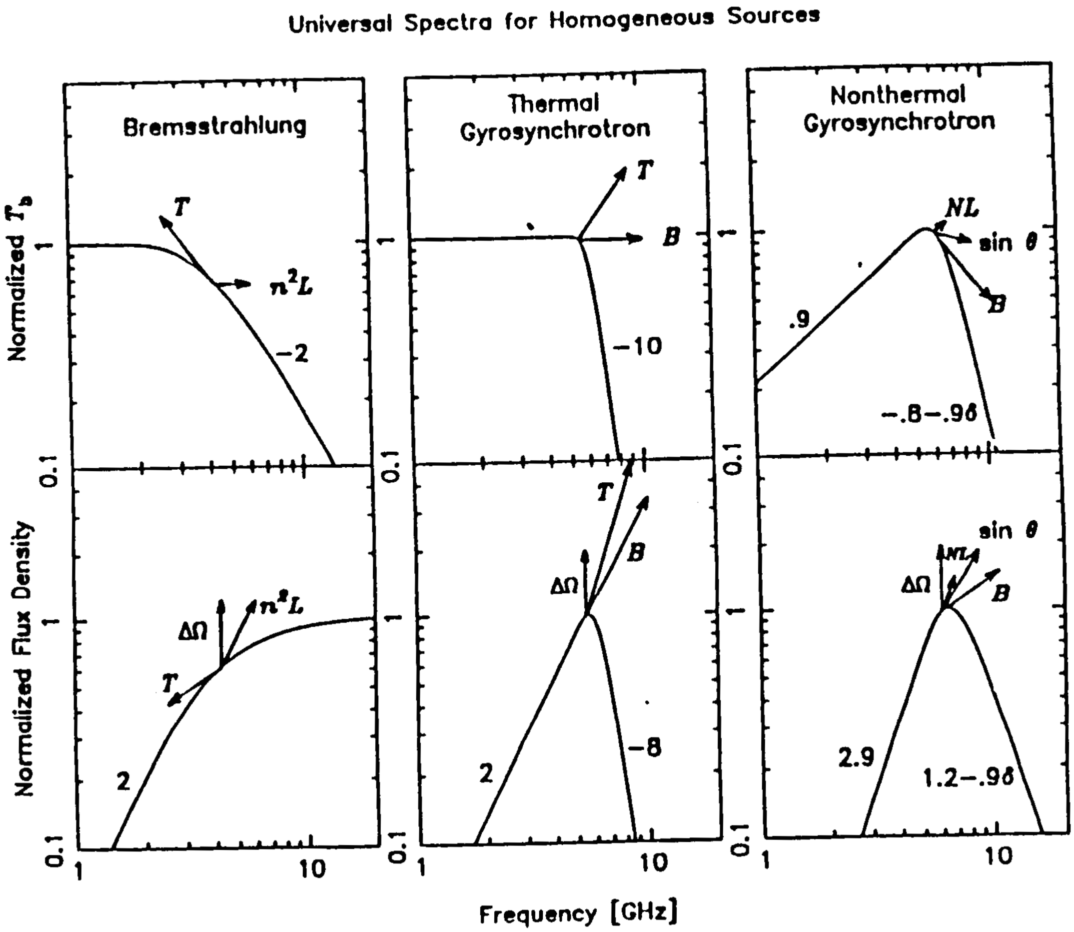


Figure 2. Universal curves, from theory, for emissions by various mechanisms from a homogeneous source. The arrows indicate the magnitude and direction in which the spectrum would shift for a factor of 2 increase of the indicated parameter. The top panels show brightness temperature spectra (requiring measurements with spatial resolution) and the bottom panels show the corresponding flux density spectra for a source of fixed size. The arrow labelled B in the thermal gyroresonance spectrum actually represents the quantity, B $(nL)^{0.11}$ $\sin(\eta)^{0.66}$. Theta, the angle between the field line and line of sight, can be independently determined from circular polarization.

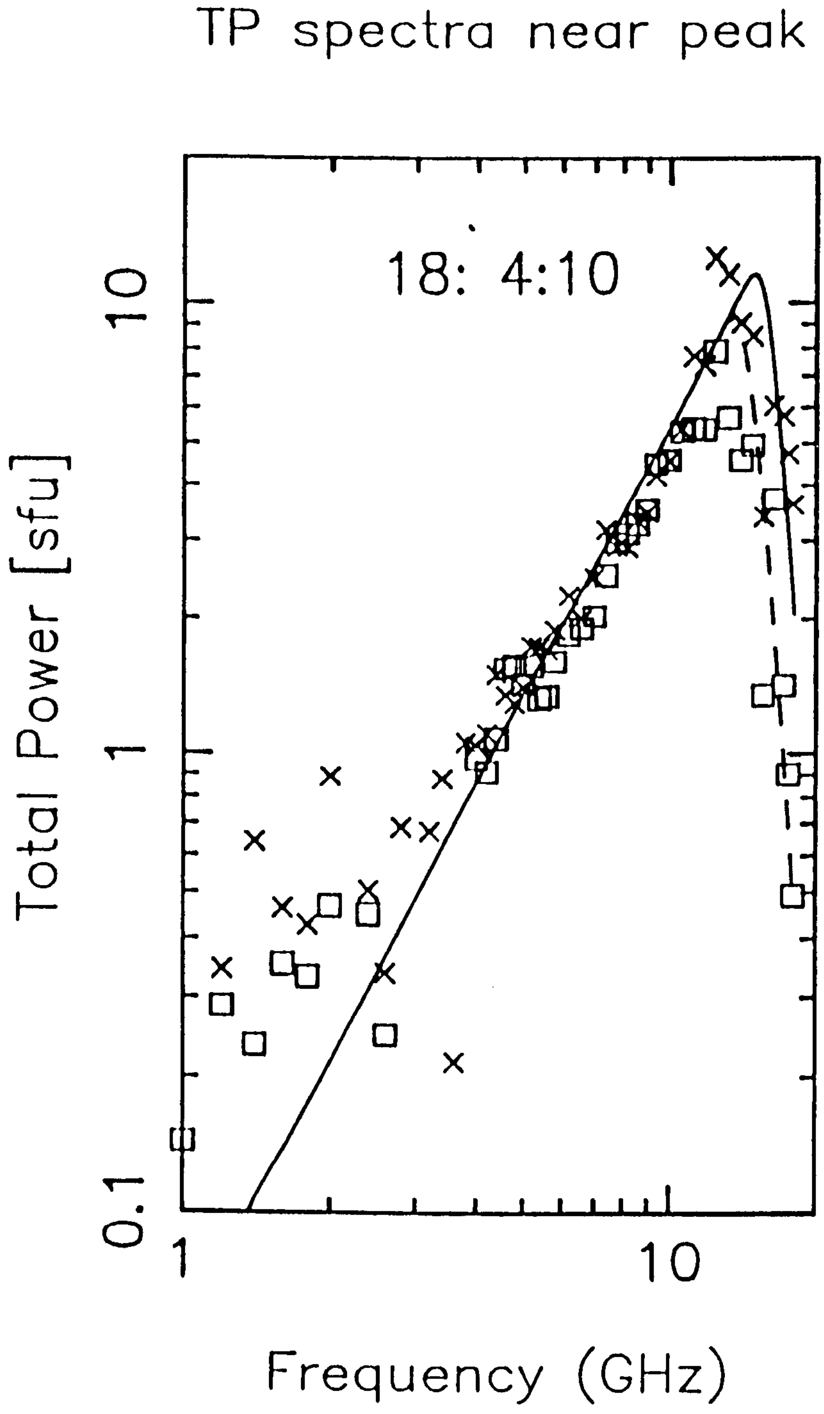


Figure 3. The microwave spectrum in right- and left-hand circular polarization for a burst with demonstrably simple spatial structure and interferometrically determined size of 8 arcseconds. The overlaid curves assume a homogeneous source with a thermal gyrosynchrotron spectrum. Thus the only degrees of freedom for the fits are the peak flux and frequency. Corresponding x-mode (solid) and o-mode (dashed) fits are shown.

FREQUENCY-SYNTHESIS IMAGING

* EXPLOITS THE FACT THAT THE SEPARATION OF ANTENNAS IN UNITS OF WAVELENGTH IS DIFFERENT AT EACH FREQUENCY.

* THEREFORE AN 86 FREQUENCY MEASUREMENT WITH 3 ANTENNAS CAN PROVIDE AS MANY U-V POINTS AS A 258 BASELINE INTERFEROMETER.

* FUNDAMENTAL CONCERN IS THE EFFECT OF FREQUENCY-DEPENDENCE IN THE SOURCE GEOMETRY.

  - FOR SOURCES WHICH HAVE DIFFERENT MORPHOLOGY IN DIFFERENT FREQUENCY RANGES. THIS CAN RESTRICT THE RANGE OF FREQUENCIES USED IN A GIVEN MAP.

  - FOR SOURCES WHOSE SIZE OR FLUX VARIES SMOOTHLY WITH FREQUENCY, THE AMPLITUDES ARE WEIGHTED TO COMPENSATE FOR THE SPECTRUM, AND THEN THE SIZE VARIATION IS DETERMINED ITERATIVELY.

* IN PRACTICE, FREQUENCY-SYNTHESIS PROVIDES A COST-EFFECTIVE AND PRACTICAL TECHNIQUE FOR OBTAINING THE LOCATION AND MORPHOLOGY OF SOLAR MICROWAVE SOURCES.

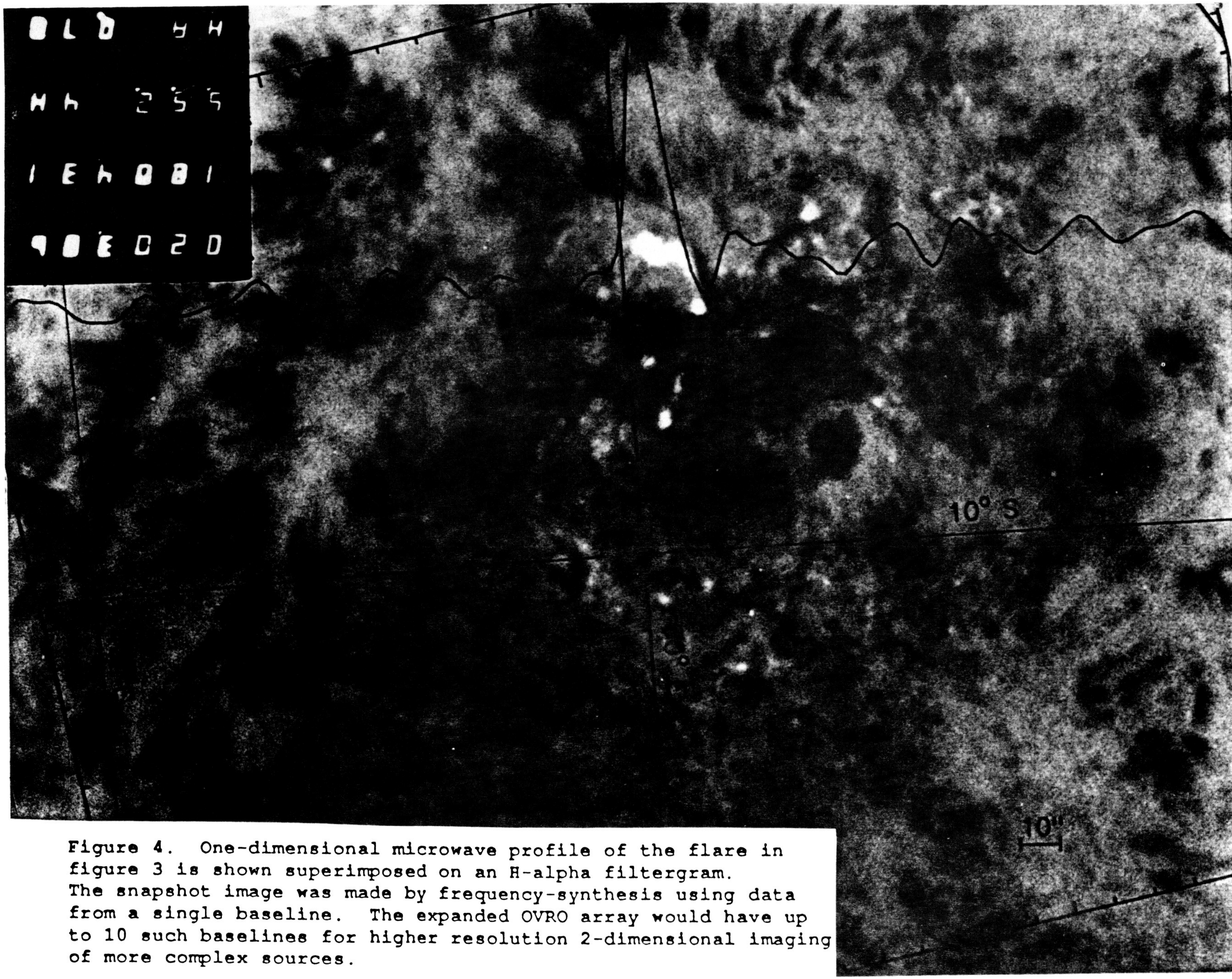


Figure 4. One-dimensional microwave profile of the flare in figure 3 is shown superimposed on an H-alpha filtergram. The snapshot image was made by frequency-synthesis using data from a single baseline. The expanded OVRO array would have up to 10 such baselines for higher resolution 2-dimensional imaging of more complex sources.

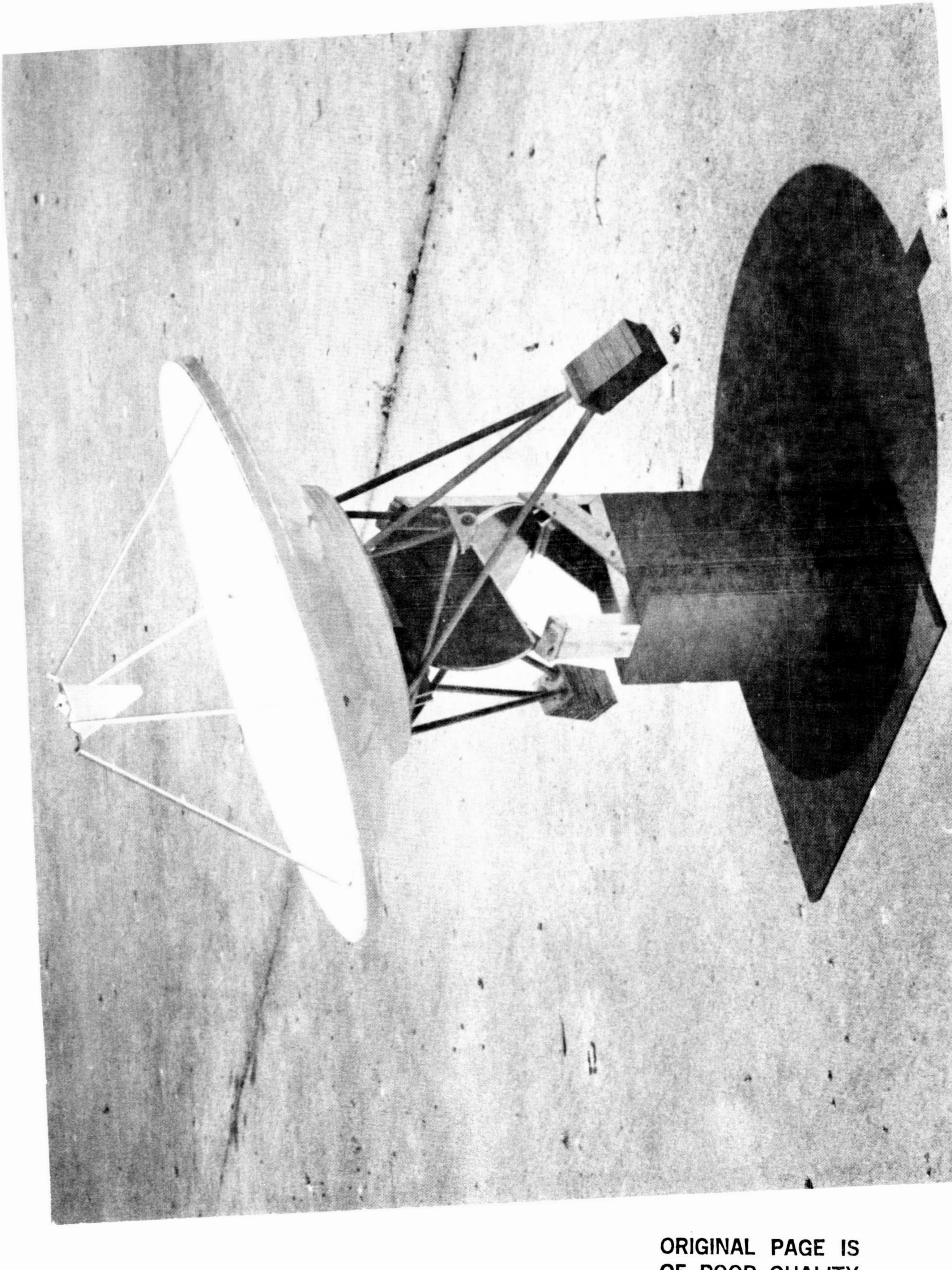


Figure 5. Quarter-scale model of the 2-m diameter telescope.

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