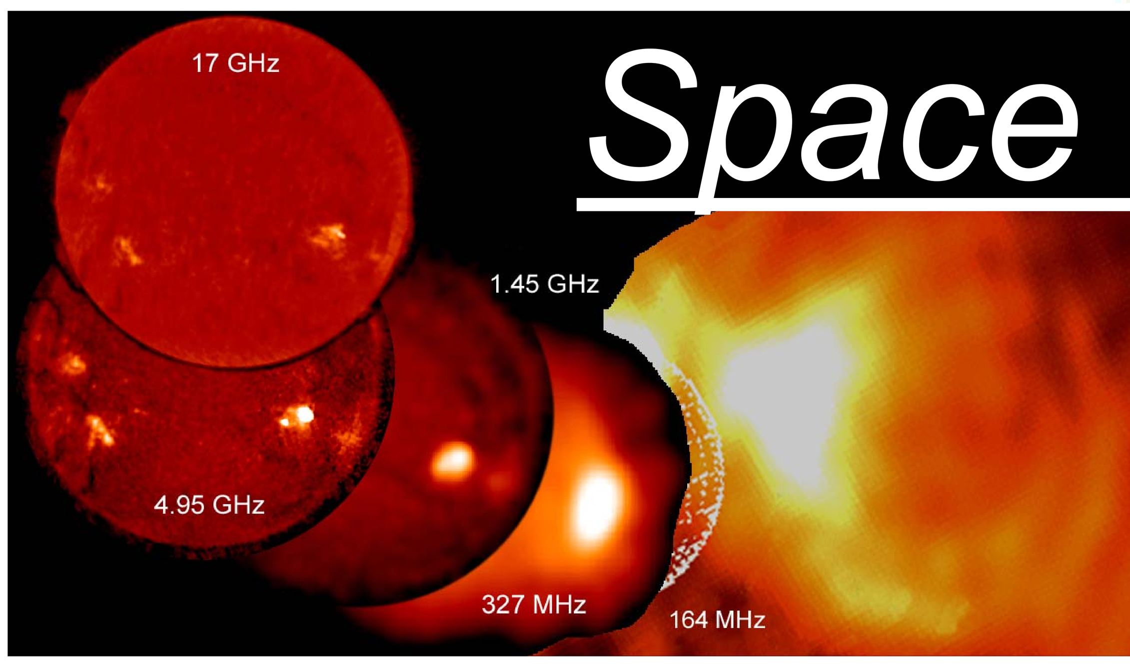
FASR
FREQUENCY-AGILE SOLAR RADIOTELESCOPE



Space Weather Through Radio Imaging Spectroscopy

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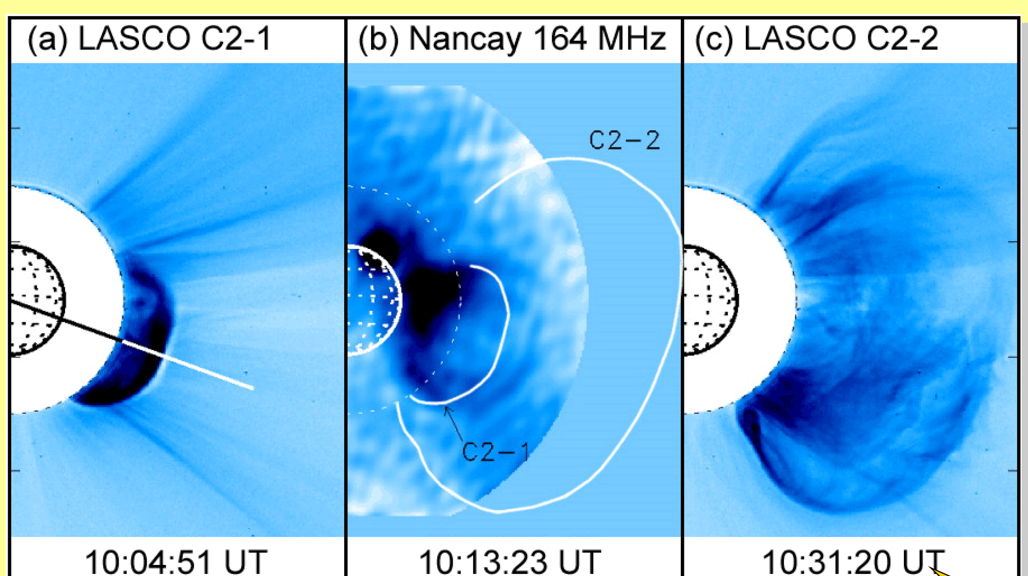
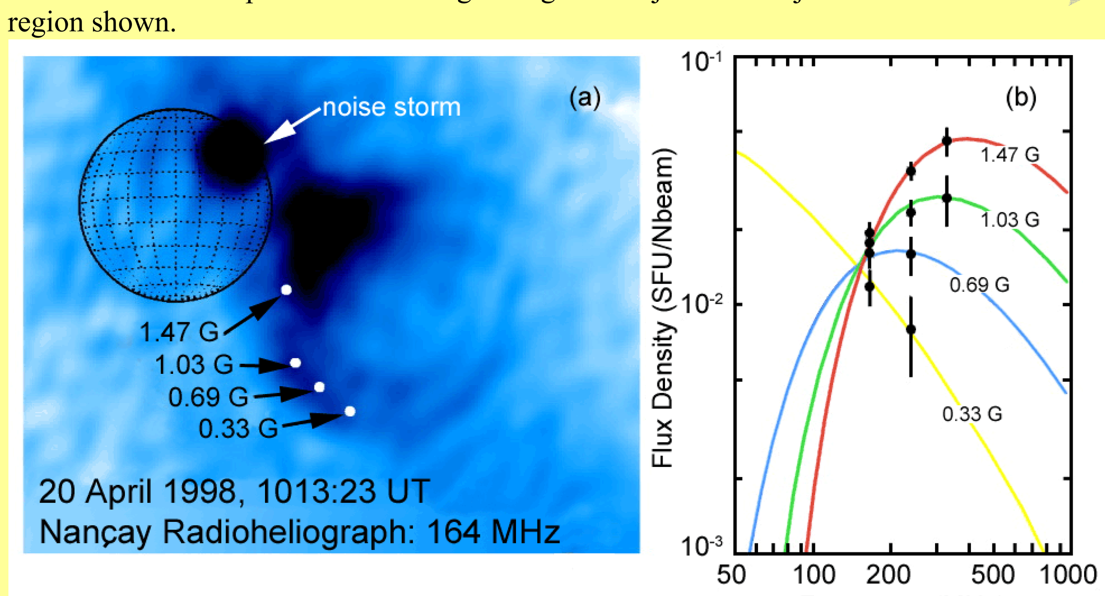
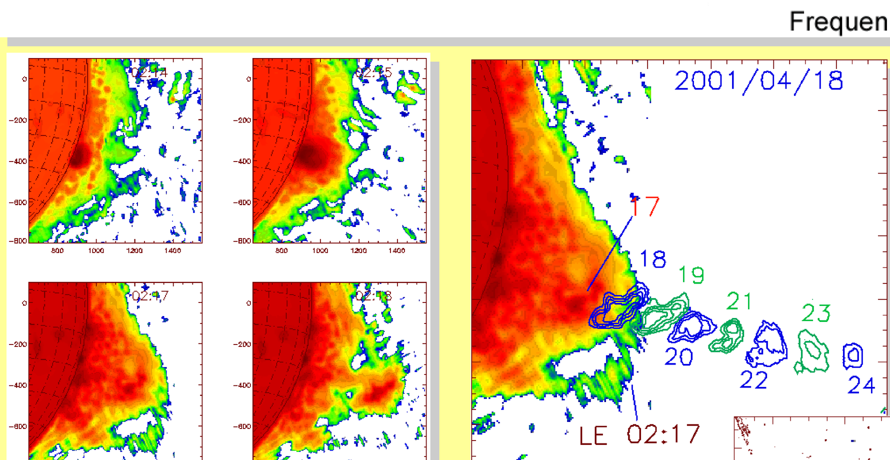
Radio Imaging Today



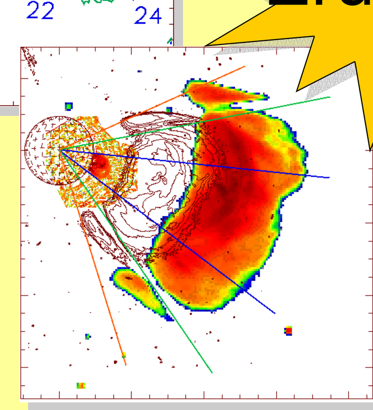
Above: Radio image [3] of a Coronal Mass Ejection (CME) compared with LASCO. The radio CME became visible after the image in (*a*), and faded before the image in (*c*).

Below: Use of imaging spectroscopy to derive the magnetic field strength [3] within the CME loop. The field strength ranges from just over to just under 1 G in the region shown.

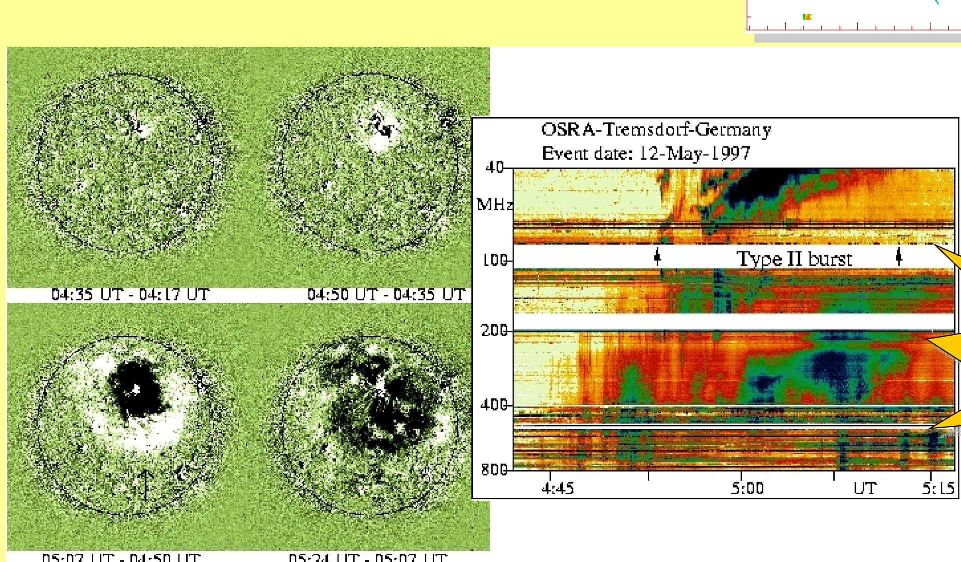




Above: A small loop prominence, seen here at 17 GHz [8], erupts at >1500 km s^{-1}. Such features can be seen to much greater heights than Hα, especially at lower radio frequencies.

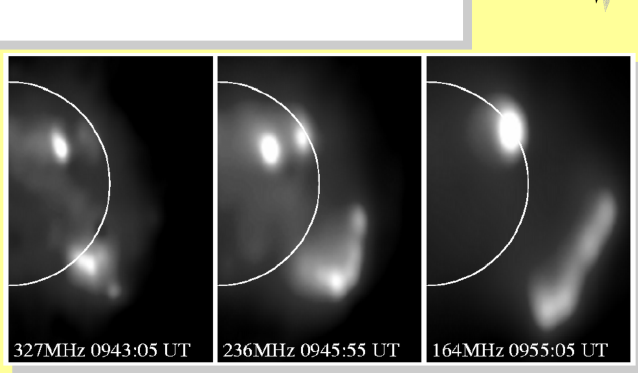


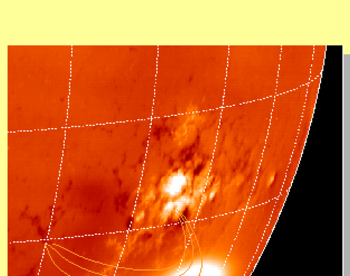
Right: The prominence material eventually becomes part of a major CME.

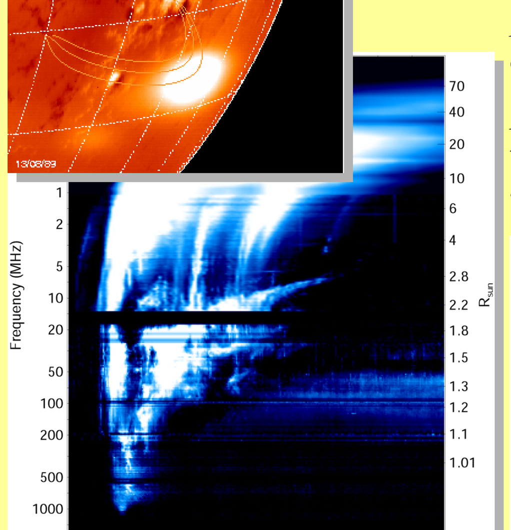


Above: An EIT wave, associated with a radio type II burst (shock wave) seen in a spectrograph.

Right: Multi-frequency radio images [6] of a shock headed for IP space.



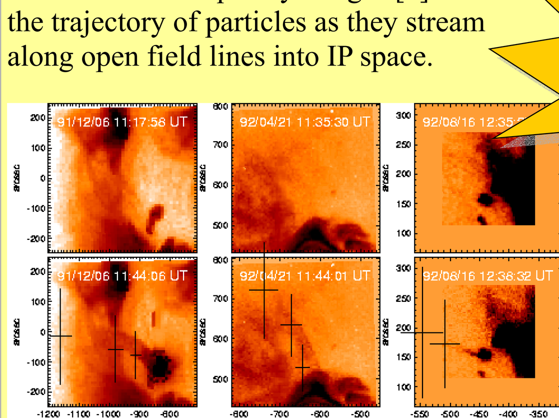




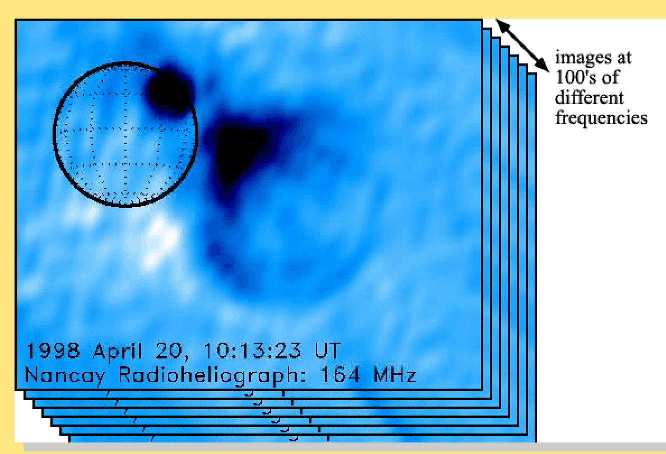
Below Left: A flare and shock wave spew particles into IP space that generate radio emission across a wide band of radio frequencies.

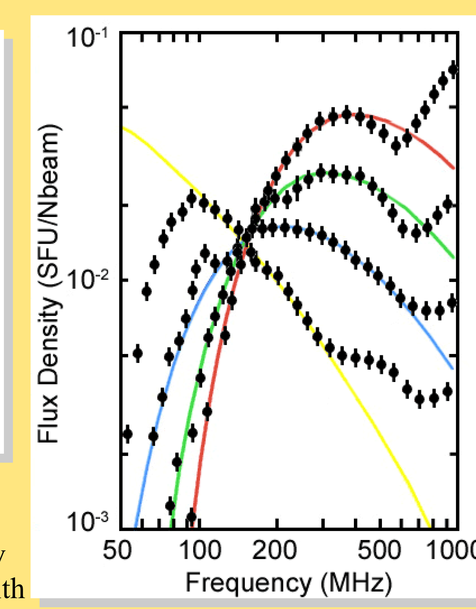
Left: Radio image [1] shows the location of particles as they stream along magnetic field lines.

Below: Multi-frequency images [5] show the trajectory of particles as they stream along open field lines into IP space.



What FASR Will Do





Rather than measure two or three spectral points along each line of sight, FASR will measure hundreds of frequencies (above), providing spectra of the quality shown schematically in the figure above right, with better spatial resolution and much better signal to noise than current instruments.

CMEs

FASR will measure CME magnetic fields.

The spectral resolution will be sufficient to distinguish multiple spectral components, providing better diagnostics that allow for different structures along the line of sight. Such diagnostics include temperature, density, and magnetic field strength.

Radio imaging of CMEs with existing instruments is very rare, with only a handful having been observed. The multifrequency imaging and sensitivity of FASR will allow it to observe many (perhaps most) CMEs for several reasons:

- FASR can avoid frequencies that are contaminated with high levels of nonthermal emission, allowing it to distinguish the weaker CME emission.
- FASR's high sensitivity to low surface brightness will make it far more sensitive to other instruments.
- FASR is unique in that it can observe in the decimetric frequency range where CME brightness contrast is predicted to be greatest.

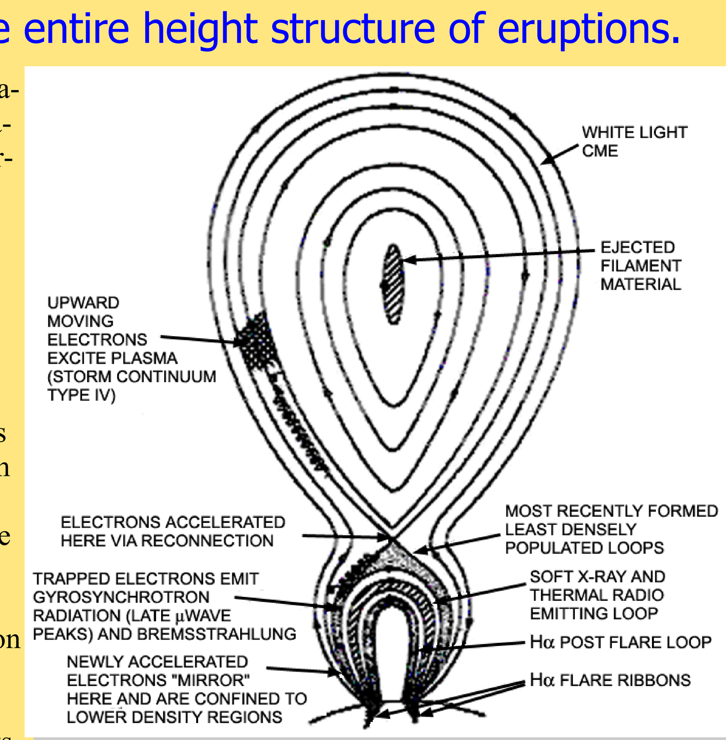
FASR will image the nascent stages of CME formation.

Most importantly, FASR will observe CMEs without an occulting disk, both on the disk and off the limb, so it will be able to image the nascent stages of CME formation, including Earth-directed CMEs, with the full diagnostic potential that radio spectral analysis provides.

FASR will image the entire height structure of eruptions.

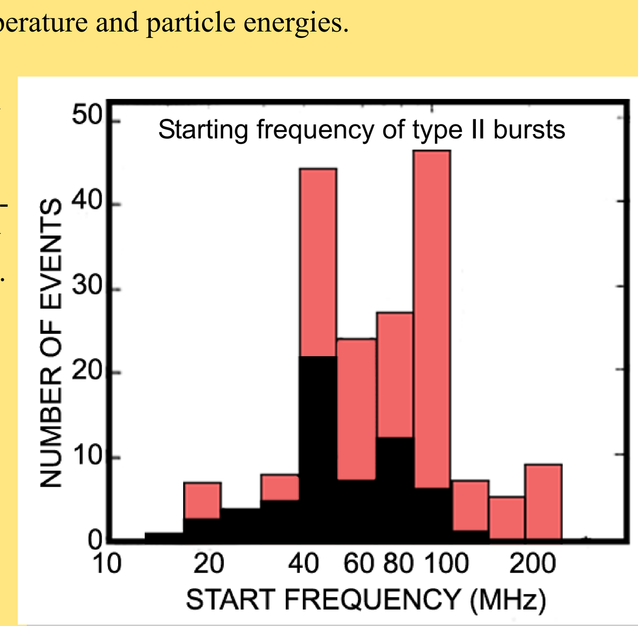
Eruptions

As a result of its multifrequency capability, and the sensitivity of radio to both thermal and nonthermal emission, FASR will image, and provide plasma diagnostics for, the entire height structure of eruptions over the range from the low chromosphere to more than 2 R_{sun}. This includes tracking the filament material from the surface, high-resolution imaging of the accelerated particles (see below), and high-resolution imaging of the density and temperature enhancements due to thermalization of the particles. In most regions, the radio spectrum will provide measurements or strong constraints on magnetic field strength, densities, temperature and particle energies.



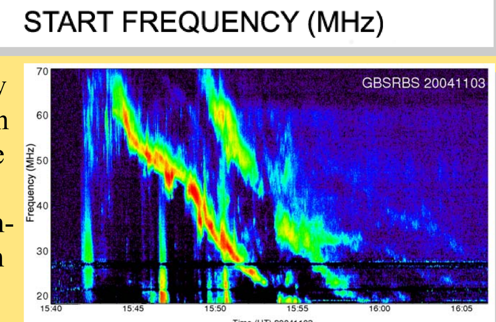
Shock Waves

As the figure at the right [5] shows, shock waves produce type II radio emission that most often starts below 100 MHz. Therefore, FASR will operate below 100 MHz, for which new antennas are being designed. The type II burst [7], below-right, was observed with a prototype antenna that is under consideration for FASR.



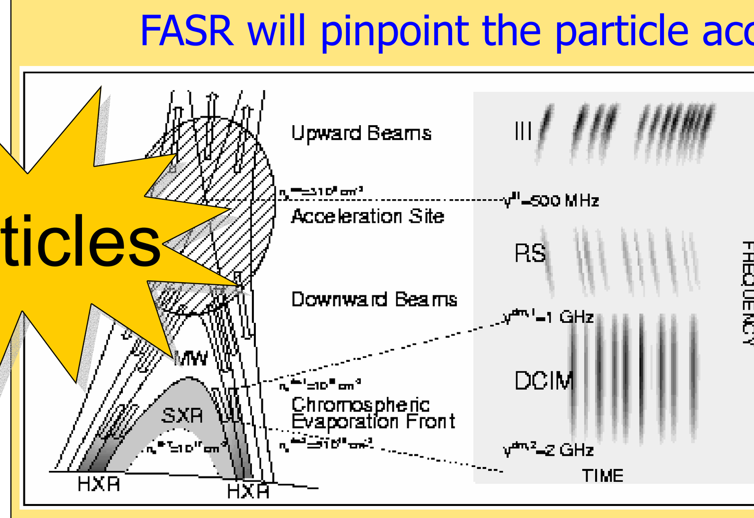
FASR will show the entire radio emitting region produced by the shock.

Single frequency images from current instruments show only where the shock crosses the plasma layer, and even images at three frequencies such as shown at left [6] are hard to interpret because only part of the shock is visible. FASR's multi-frequency imaging will show the entire radio emitting region produced by the shock at each instant. Simultaneous CME images will show the detailed relationship between CME and shock.



FASR will pinpoint the particle acceleration region.

Particles



One geometry for accelerating particles is at an X-type neutral point as shown in the figure at left [1]. Radio spectrographs indicate that drifting bursts, due to electrons propagating both upward and downward, tend to change their direction of drift in the decimeter frequency range. FASR's high frequency resolution imaging in this range will allow tracing of particle trajectories out of the region, to pinpoint the acceleration region. Radio spectral diagnostics of particle energies will provide strong constraints on the particle acceleration mechanisms.

How FASR Works

FASR is a large interferometric array, encompassing a 6 km circle, composed of up to 100 elements in each of three sizes. The figure above shows the inner part of one realization of the array, where the (white) 2 m antennas operate in the frequency range 3-30 GHz while the (gray) 6 m antennas operate over 0.3-3 GHz. A third array, not shown, will operate from 30-300 MHz and will be made of wire antennas similar to that shown at left, which is now under consideration [7] for FASR. The different size antennas are needed to maintain a full-Sun field of view and to image all of the Sun's spatial scales. The 100 antennas gives nearly 5000 measurements for superb image quality. *See the table of FASR Specifications, below.*

The frequency range, frequency resolution, time resolution, spatial scales and spatial resolution are all optimized for the Sun.

FASR will start operations in 2010.

The FASR project has received a thorough science review, and was the top ranked small project in the Solar and Space Physics Decadal Survey. It has finished its initial "Phase A" study, and will enter a one-year "Phase B" period of intense design and development in mid-2005. By mid-2006, the construction proposal will be submitted to NSF, with expected completion of the project by 2010, in time for the next solar maximum. Current plans are to administer FASR through a new observatory under management by AUI (Associated Universities, Inc.), which currently administers NRAO.

FASR Specifications	
Angular resolution	20"/ν_{GHz}
Frequency range	30 MHz—30 GHz
Number channel pairs	2—4
Total instantaneous BW	2 GHz
Frequency resolution	0.3—3 GHz: 0.1% <0.3 GHz, >3 GHz: 1%
Time resolution	0.3—3 GHz: 10 ms <0.3, >3 GHz: 100 ms
Polarization	I—V (Q, U)
Number of antennas	3—30 GHz: 100 0.3—3 GHz: 80 <0.3 GHz: 60
Size of antennas	3—30 GHz: 2 m 0.3—3 GHz: 6 m <0.3 GHz: wire
Maximum antenna spacing	6 km
Absolute positions	1"
Absolute flux calibration	<5%
Temperature contrast limit	1000 K

FASR will produce daily data products for Space Weather.

Space Weather is both research and application driven. FASR will do unexcelled research in a broad range of solar science areas, and it will also produce daily data products tailored to the needs of Space Weather users. Although FASR will produce as much as 10 TB of data per day, it will have pipeline data processing that automates most analysis tasks to produce key measurements at regular intervals during the observing day. Among the products currently planned are:

- Full-disk coronal magnetograms several times/day.
- Hourly (or better) F10.7 cm full-disk images.
- Coronal electron temperature maps.
- Coronal difference maps (highlighting evolving areas).
- Activity reports, with radio movies of selected events.

The science team seeks the advice and involvement of applications-oriented Space Weather community.

FASR will have an open data policy.

FASR will provide a completely new view of the radio Sun, and may be expected to make many discoveries, but to reach its full potential it must have a broad user base. Therefore, FASR will have a completely open data policy, with the research data bases open to all. Tools will be provided to make images, spectra, and movies from the archived data, and their use will require as little specialized expertise from the user as possible.

References

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