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CURRENT STATUS OF FASR, AND COLLABORATION WITH BDA

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ABSTRACT

The Frequency Agile Solar Radiotelescope (FASR) design is now firmly established, and the project has been formally proposed to U.S. funding agencies. The broad range of science to be done with this major solar-dedicated radio facility is discussed. The details of the design and current status of the project are also given. The proposed site near Big Pine, California means that there should be excellent overlap in daily observing between the Brazilian Decimetric Array and FASR. Observations by the BDA below 2.5 GHz should be especially useful for collaborative studies.

INTRODUCTION

The Frequency Agile Solar Radiotelescope (FASR—Bastian, 2003; Gary, 2003) has now been formally proposed to US funding agencies (National Science Foundation), and its design has been finalized to the extent that its operation can now be envisioned in some detail. The original plan for the array called for of order 60-100 antennas in each of three arrays, each dedicated to different parts of the 0.05-21 GHz frequency range to be covered by FASR. The estimated cost of the full project was about $50 M. The funding opportunity that we have proposed for carries a lower funding cap of $25 M, which has forced a significant re-scope of the project. I give a brief history of the trade-offs that were necessary to reach the current design within the cost cap of $25 M. Having established the current design, I then revisit the science goals and list the expected performance of the re-scoped array for realization of these goals. All of the main science goals will be achieved with the rescoped array, and we are enthusiastic about FASR's impact on our understanding of the main problems in solar physics.

One of the impacts of the funding constraint is the decision to focus resources on the high-frequency (2-21 GHz) frequency range. The result is that the proposed FASR instrument calls for 15, rather than the original 80, antennas in the decimetric (300-3000 MHz) frequency range. This makes the Brazilian Decimetric Array (BDA) even more crucial to the success of FASR, by providing additional information about solar bursts observed by both instruments simultaneously. Such observations are made possible by the large overlap in observing time range for the two instruments.

ORIGINAL FASR DESIGN

The original FASR design called for three overlapping frequency ranges (0.05-0.35 GHz, 0.3-3 GHz, and 2-21 GHz) to be covered by three different receiving element designs, called FASR C, B and A, respectively. The numbers of antennas envisioned for each array were 60, 80 and 100 in the three arrays C, B and A, with the FASR C elements being log-periodic dipoles, fat dipoles, or similar, FASR B consisting of 6 m dishes, and FASR A consisting of 2 m dishes. The total cost of the instrument was expected to be around $50 M, and included a 100-antenna correlator that would be time shared among the three arrays.

RE-SCOPED FASR DESIGN

The funding opportunity that we have responded to has a funding cap of $25 M for the entire project, with a funding profile of roughly $5 M/year. An assumed start in early 2009 will result in completion of the facility in 2013. The factor-of-two decrease from the originally assumed funding means that a re-scope of the instrument is necessary. By judicious choice of re-scope options, the FASR team has ensured that FASR will address all of its original science goals with an acceptable reduction in range of measurable quantities and speed of measurement. Table 1 lists the parameters of the re-scoped design, where the main change from the original design is in the number of antennas and in the number of simultaneously correlated antennas, with a small subsequent hit on the time required to complete a frequency-correlation cycle. The cost savings is realized partially by decreasing the number of antennas, which of course scales as N, but even more by the decrease in the size of the correlator, which scales roughly as N^2.

Table 1 - FASR Parameters.

Angular resolution	20/νGHz arcsec
Frequency range	50 MHz – 21 GHz
Number data channels	2 (RCP + LCP)
Total instantaneous BW	2 x 500 MHz
Frequency resolution	1% or 5 MHz
Time resolution	**A** (2-21 GHz): [snapshot 1 s] **B** (0.3-2.8 GHz): 1 s **C** (50-350 MHz): 0.2 s
Polarization parameters	IQ/UV
Number antennas	**A** (2-21 GHz): **B** (0.3-3 GHz): **C** (50-350 MHz): 15
Antennas correlated per integration cycle	30
Size antennas	**A** (2-21 GHz): 2 m **B** (0.3-3 GHz): 6 m **C** (50-350 MHz): LPDA
Array size	2.9 km EW x 3.8 km NS
Absolute positions	1 arcsec
Absolute flux calibration	<10%

As shown in Table 1, the re-scoped design calls for 45 FASR A antennas, and 15 each of FASR B and C elements. The correlator will be designed to correlate 30 antennas at once, doing three correlation cycles of the FASR A antennas, and using a fourth correlation cycle to correlate both FASR B and C arrays simultaneously. For example, if we separate the 45 FASR A antennas into 3 groups of 15 antennas, referred to as A1, A2 and A3, then the four correlation cycles will correlate group A1 with A2, group A1 with A3, group A2 with A3, and then B and C simultaneously. Since the correlator handles 500 MHz at one time, to cover the FASR B 0.3-3 GHz range requires 6 separate tunings. To cover the FASR A range (2-21 GHz) requires 38 tunings. The design calls for 20 ms data samples, for which the entire set of frequency- correlation cycles can be done in 3 s, although full-spectrum imaging in A array can be done in 1 s, and in B array in 0.5 s, while C array is fully sampled once every 0.1 s. In this way, a solar- science-relevant temporal cadence is maintained for all three frequency ranges so that the science goals are satisfied.

SCIENCE WITH FASR

The FASR science goals are largely unchanged with the re-scoped array. The science case for FASR was made in the book *Solar and Space Weather Radiophysics* (Gary and Keller, 2004). Although some imaging capabilities are compromised or will be made less often, the image quality, spectral, and temporal resolutions are sufficient to answer the science questions. The four main science areas are

1. The Nature and Evolution of Coronal Magnetic Fields
2. The Physics of Flares
3. The Drivers of Space Weather
4. The Physics of the Quiet Sun

All of these science goals target measurement of magnetic fields in one form or another, as the heretofore largely invisible driver of the Sun's activity and atmospheric structure. FASR will for the first time provide sufficient spatial, spectral, and temporal resolution to allow the use of magnetic field diagnostics on a regular basis, and in a wide range of phenomena, including active regions, flares, CMEs and even quiet regions.

The FASR A array will provide the key observations for areas 1 and 2, above, and hence the re-scope ensures enough antennas (45) to retain all of the key science involving that area. Snapshot imaging with FASR A will be extremely good, to allow imaging of rapidly varying solar bursts. From inversion or forward modeling of the resulting spatially resolved spectra, magnetic fields will be determined precisely in and around flaring loops. These spectra also supply diagnostics of other plasma and particle parameters, such as temperature, density, numbers of high-energy electrons, electron energy spectra, and pitch angle.

With a small amount of Earth rotation synthesis (e.g. over 0.5-1 hour), active region magnetic fields will be measured in exquisite detail via their gyroresonance emission, making FASR into a coronal magnetograph. This will provide a standard data product for comparison and extension of photospheric field extrapolations.

FASR A will also image the CME precursor environment, eruption phenomena, and perhaps some CMEs themselves that emit at higher frequencies. FASR B, on the other hand, will be working in the same frequency range as BDA and will help to open this frequency range to imaging observations for the first time (e.g. review by Bastian et al., 1998). In this frequency range, solar bursts occur in a bewildering variety, and are expected to illuminate the very regions where magnetic reconnection takes place - the phenomenon that is responsible for explosive release of magnetic energy, and for restructuring the corona. Finally, FASR C will image bursts in the metric range, providing information on the location and propagation of electron beams and shocks.

Perhaps the most exciting aspect of FASR is that it provides images at all of these frequencies at once, to give a simultaneous, perfectly registered view of the flare, eruptive phenomena, associated bursts, and all of their consequences, with quantitative diagnostics. This panoramic view of solar activity will revolutionize our understanding of the Sun.

COLLABORATION WITH THE BRAZILIAN DECIMETRIC ARRAY

Within the frequency range covered by FASR, the decimetric range is perhaps the most exciting. This range has been almost completely unexplored with spatial resolution, while the many observations with spectrographs have shown an extremely rich and fertile ground for studying flare energy release and plasma physics. The BDA will also exploit this frequency range, and as such will be at the forefront of progress in this area of solar physics. Because of the FASR re-scope, the number of antennas (15) - and hence its imaging capability - will be limited. The BDA can fill in this gap by fielding a larger number of antennas, potentially providing a higher dynamic range for following the weaker and more complex emissions that would be invisible to FASR.

Given the fact that FASR and BDA will enjoy a significant amount of overlapping observation time (being at similar longitudes), there are ample possibilities for combining the strengths of the two instruments. This includes both observations and cross calibration. For example, a burst seen simultaneously by both instruments at the same frequency can be compared quantitatively to ensure that both instruments obtain consistent results. Any calibration differences will be readily apparent, and the cause can be discovered and corrected. At most times of the year, BDA will also extend FASR’s observation time, and vice versa, since BDA will acquire the Sun before it rises at the OVRO site, and FASR observations will continue for a time after the Sun sets for BDA. Thus, there are several ways in which BDA and FASR observations in the decimeter band will enrich each other.

CONCLUSION

The FASR project will soon be underway, with construction occurring in parallel with the BDA development. It is important that these two efforts be coordinated to some extent, to maximize the value of the future collaboration. FASR will revolutionize our understanding of the Sun by providing the most complete view of the radio window that we can design. BDA will extend FASR’s capability in the important decimetric part of that window, which has heretofore been largely unexplored. New discoveries await, and both instruments will be at the forefront of a new era in solar physics research.

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