



The Radio Synoptic Survey Telescope (RSST)

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Background



- At Chicago-2 in August 2006, it was proposed that the EOR (SKA-lo) and HI-Machine (SKA-mid) concepts were sufficiently advanced that “White Papers” should be written with the goal of presenting the cases to the upcoming Decadal Review.
- As an example of an HI-Machine proposal, I have written a draft of a case for the Radio Synoptic Survey Telescope.
- Here it is...



What is the RSST?

The Radio Synoptic Survey Telescope



- The RSST concept is for a “SKA-mid” facility
 - it is proposed here as the “SKA-mid” from a US science perspective
- Primary Science Goals
 - Cosmological HI
 - Deep continuum imaging
 - Transient detection and monitoring
- Also
 - other redshifted lines (e.g. OH mega-masers)
 - pulsars, SETI, etc.

The RSST is ...



- NOT my idea
 - came out of discussions at Chicago 2
- NOT a new concept
 - pretty much what is proposed in SKA Science Book
 - is what appears in the DETF report as the “SKA”
- NOT a technology development project
 - pathfinders and technical demonstrators are underway
 - including a TDP in the US
- NOT unconnected to the rest of Astrophysics
 - complementary to big multiwavelength surveys
 - e.g. LSST, PanSTARRS, SDSS-3, JDEM, ...

The RSST is ...



- Radio?
 - core frequency range 0.4-1.4 GHz ($z < 2.5$) “HSST”
 - some science cases may want 0.3-3 GHz (must justify \$\$)
- A Square Kilometer Array
 - square kilometer of something (not white papers)
 - high gain/low noise $A/T_{\text{sys}} \approx 2 \times 10^4 \text{ m}^2 \text{ K}^{-1}$
 - don't throw away all that collecting area!
 - wide field-of-view, target 1 square degree
 - $A\Omega/T \approx 2 \times 10^4 \text{ m}^2 \text{ K}^{-1} \text{ deg}^2 \sim n_a n_b / T$ “megapix”
- A Survey Telescope
 - cover large areas of sky $10^4 \text{ deg}^2 = 1/4 \text{ sky}$
 - survey speed $(A\Omega/T)(A/T)\Delta\nu = n_a n_b A/T^2 \Delta\nu$

The Synoptic Part



- Revisit the sky regularly
 - if you want to cover 10^4 deg^2 with 1 deg^2 FOV
 - can do so in 1 day with 2-8^s per point
 - different parts of survey can have different depths (and thus cadences)
- What cadence? Depends on the science
 - many short visits or fewer longer ones?
 - looking for individual “bursts” or “pulses”?
 - looking for groups or trains of pulses?
 - classical variability curves (e.g. microlensing)?
 - also remember, many compact radio sources are variable (both intrinsic and scintillation)

Is the RSST a ...



- National Facility?
 - well, its an international facility, but an National resource for US astronomers
- targeted experiment?
 - the primary science goals & key projects are big surveys
- general observer facility?
 - probably not primarily, but perhaps 10% of time could be made available for proposers (and for TOO)
- an exclusive club?
 - No! RSST must involve and support a large part of the US astronomy community

RSST Key Science Surveys



- Key Projects (example)
 - Cosmological HI Large Deep Survey (CHILDS)
 - billion galaxies to $z \sim 1.5$ (and beyond)
 - HI redshift survey for cosmology
 - galaxy evolution
 - Deep Continuum Survey (DeCoS)
 - radio photometric and polarimetric survey (static sky)
 - commensal with CHILDS, extracted from spectral data
 - Transient Monitoring Program (TraMP)
 - bursts, variability, pulsars, etc.
 - commensal with other RSST surveys – freeloading!
- These are part of one big survey (Big Sur)



RSST Science

Science Precursors



- The case for precursor science
 - do not just “stop everything” to build new stuff
 - need science output throughout decade
- Use “current” facilities
 - Arecibo, EVLA, GBT, VLBA, ATA
 - e.g. ALFALFA HI survey, large EVLA surveys
 - also mm/sub-mm : ALMA, CARMA, CSO, etc.
 - also other wavebands : O/IR, Xray, Gamma Ray, etc.
- Use in new (and complementary) ways
 - pilot surveys and special targets
 - also science with SKA demonstrators (ASKAP, MeerKAT)

RSST Science Example: HI Cosmology



- “billion galaxy” HI survey
 - redshifts for gas-rich galaxies out to $z=1.5$ (and beyond)
 - Baryon Acoustic Oscillations (BAO)
 - cosmography of Universe $d(z)$, $V(z) \Leftrightarrow H(z)$
 - growth of structure and Cosmic Web
 - HI is critical window on galaxy formation and evolution
- complementarity with “Dark Energy” surveys
 - e.g. JDEM, LSST, DES, SDSS, DES, LSST, PanSTARRS
 - mutual interest with the DOE community (JDEM)
 - engage O/IR extragalactic and cosmology communities
 - NASA missions (JDEM, Planck, JWST, GLAST, etc.)

Current State of the Art in BAO



Four published results

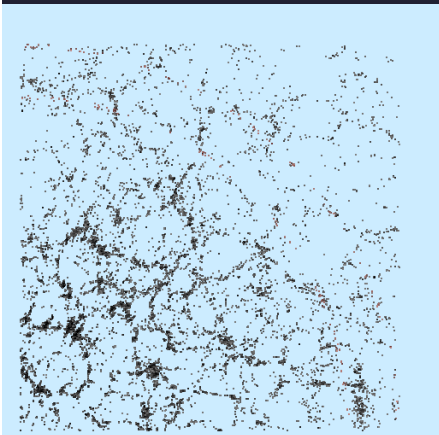
1. Eisenstein et al 2005 (spectro-z)
3D map from SDSS 3%
46,000 galaxies in $0.72 (h^{-1}\text{Gpc})^3$
2. Cole et al 2005 (spectro-z)
3D map from 2dFGRS at AAO 5%
221,000 galaxies in $0.2 (h^{-1}\text{Gpc})^3$
3. Padmanabhan et al 2007 (photo-z)
Set of 2D maps from SDSS 5%
600,000 galaxies in $1.5 (h^{-1}\text{Gpc})^3$
4. Blake et al 2007
(Same data as above)



SDSS 2.5-m telescope, Apache Point, NM



AAO 4-m telescope at Siding Spring, Australia



HI surveys are woefully behind in numbers of detections

Thanks to Pat McDonald (CITA)

RSST Science: A Broad Community



- More on the DOE connection
 - RSST “SKA” is a Phase IV project in the DETF report
 - addresses “Connecting Quarks to the Cosmos” questions
 - active astrophysics and cosmology groups in labs
 - Fermilab (SDSS), LBL+Livermore (Snap,&c), LANL (SDSS,LWA)
 - interest from LANL on LWA & RSST (AstroInformatics)
 - data mining and high-performance computing a lab mission
- Obvious connections to LST & DE projects
 - many of the same galaxies as LSST, PanSTARRS, DES
 - RSST can provide HI redshifts
 - complementary to galaxies seen in O/IR (e.g. HETDEX)
 - complete view of the Universe
 - “whole Universe telescope” sees gas and stars and dark matter

RSST Science Example: Continuum



- Extremely deep (10 nJy) continuum survey
 - “billion” extragalactic radio sources
 - AGN
 - star-forming galaxies
 - SNR and HII regions in galaxies
- Census of “rare” phenomena
 - Gravitational Lenses (e.g. CLASS)
- Polarimetry
 - Rotation Measure (RM) survey
 - galactic and extragalactic magnetic fields

RSST Science Example: Transients



- Bursty phenomena
 - giant pulsar pulses out to Virgo
 - brown dwarf flares
- Variability
 - compact radio sources (IDV, scintillation, etc.)
 - GRB afterglows
- Exotica
 - UHE particles in lunar regolith
 - SETI
- Pulsars
 - provide spigot Pulsar Machine attachment



RSST Roadmap

What really needs to happen



- Need to write a White Paper for DR
 - assemble small “blue team” to write the case
 - need punchy science case
 - solidify numbers (simulations?)
 - remaining technical development? choices?
 - need “Phase A” level costing
 - put in front of “red team” next year
 - present to Decadal Review
- This is time critical – if the community wants to participate in a “RSST” project, then must get this into the Decadal Review

Why this really needs to happen



- This is for the future of US Radio Astronomy
 - it is up to us to present our case to the DR
 - the International SKA cannot do this for us
- Must get buy-in
 - from a cross-section of US astronomy community
 - from physics and astrophysics communities
 - from multiple interested agencies (DOE, NASA)
- Not just radio astronomy
 - other galaxy survey projects in same time frame
 - natural partnerships (LSST, JDEM)

Not just another Giga-Dollar Project



- Comprehensive RSST Science Program
 - the road from our current facilities to the RSST frontier
 - science along the way (staged implementation)
 - should be part of the White Paper
- Bring our community along
 - grow the scientific community along with the project
 - find inclusive model for development, construction, ops
 - will need “all hands on board” to handle data
 - data products are for community
- The International Aspect
 - larger community around the world

The Time for Some Hard Questions



- The International Aspect
 - relation to Intl-SKA? do we agree on the concept?
 - are we minor or major partner? timescales? budget?
 - do we have a site preference?
- Technology Issues
 - are we happy with current SKA design decisions?
 - need more technology development?
 - a software telescope: data management focus?
- Operational Models
 - who runs the RSST project? Science Center?
 - what model for inclusive operations?

Final Word



- had enough meetings yet?

WTFP !

- countdown to 2009-2010...

For more information...



- RSST Proto-White Paper (draft)
 - on the Arecibo Frontiers conference website:
<http://www.naic.edu/~astro/frontiers/RSST-Whitepaper-20070910.txt>
- SKA Info
 - <http://www.skatelescope.org>
 - particularly see the “Science Book”
 - “The Dynamic Radio Sky” by Cordes, Lazio & McLaughlin
 - “Galaxy Evolution, Cosmology, and Dark Energy with the SKA” by Rawlings et al.
 - others...