



# The Radio Synoptic Survey Telescope (RSST)

Steven T. Myers

*National Radio Astronomy Observatory*

*Socorro, NM*

# 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  $10^4 \text{ deg}^2$  with  $1 \text{ deg}^2$  FOV
  - can do so in 1 day with 2-8<sup>s</sup> 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

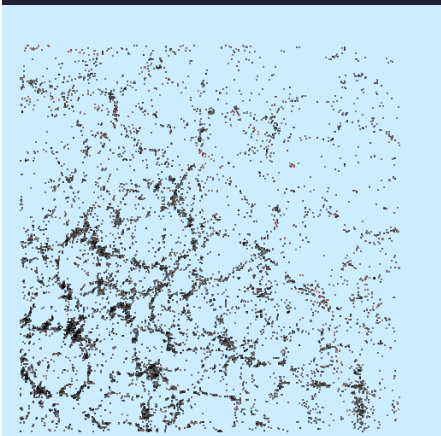
1. Eisenstein et al 2005 (spectro-z)  
3D map from SDSS 3%  
46,000 galaxies in  $0.72 (h^{-1}\text{Gpc})^3$
2. Cole et al 2005 (spectro-z)  
3D map from 2dFGRS at AAO 5%  
221,000 galaxies in  $0.2 (h^{-1}\text{Gpc})^3$
3. Padmanabhan et al 2007 (photo-z)  
Set of 2D maps from SDSS 5%  
600,000 galaxies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