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 $A/T_{sys} \approx 2 \times 10^4 \text{ m}^2 \text{ K}^{-1}$
    • 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 $10^4 \text{ deg}^2 = \frac{1}{4} \text{ sky}$
    • 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 $1\deg^2$ FOV
  – can do so in 1 day with 2-8s 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, it's an international facility, but a 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~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 – freeloding!

• 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}Gpc)^3

2. Cole et al 2005
   3D map from 2dFGRS at AAO  (spectro-z)  5%
   221,000 galaxies in 0.2 (h^{-1}Gpc)^3

   Set of 2D maps from SDSS  (photo-z)  5%
   600,000 galaxies in 1.5 (h^{-1}Gpc)^3

   (Same data as above)

HI surveys are woefully behind in numbers of detections

Thanks to Pat McDonald (CITA)

SDSS 2.5-m telescope, Apache Point, NM

AAO 4-m telescope at Siding Spring, Australia
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**
  - 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…