The Future of Single Dish Radio Astronomy

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Dish Radio Astronomy 2003

"FUTURE"

Year 2001 Vision*

1. Determine the large-scale properties of the universe: its age, the nature (amount and distribution) of matter and energy that make it up, and the history of its expansion.
2. Study the dawn of the modern universe, when the first stars and galaxies formed.
3. Understand the formation and evolution of black holes of all sizes.
4. Study the formation of stars and their planetary systems, and the birth and evolution of giant and terrestrial planets
5. Understand the effects of the astronomical environment on Earth.

**Astronomy and Astrophysics in the New Millennium,* Astronomy and Astrophysics Survey Committee, Board on Physics and Astronomy, U.S. National Research Council ("Taylor-McKee Report"), 2001.

"Future"

Year 2003 Vision*

1. What is Dark Matter?
2. What is the nature of Dark Energy?
3. How did the universe begin?
4. Did Einstein have the last word on Gravity?
5. What are the masses of neutrinos, and how have they shaped the evolution of the universe?
6. How do cosmic accelerators work and what are they accelerating?

**Connecting Quarks with the Cosmos, Eleven Science Questions for the New Century,* Committee on the Physics of the Universe, National Research Council, ("Turner Report"), 2003.

"Future"

Year 2003 Vision*

7. Are protons unstable?
8. What are the new states of matter at exceedingly high density and temperature?
9. Are there additional space-time dimensions?
10. How were the elements from Iron to uranium made?
11. Is a new theory of matter and light needed at the highest energies?

*_Connecting Quarks with the Cosmos, Eleven Science Questions for the New Century,_ Committee on the Physics of the Universe, National Research Council, ("Turner Report"), 2003.

“Single Dish”

One physically-contiguous, light-gathering, structure.

- May have response (light-gathering power) in more than one direction
- May have beam-forming network at the focal point (i.e. can form a telescope beam electronically not optically).

“Radio Astronomy”

The study of celestial objects at wavelengths from the ground-based ionospheric cutoff (~10 MHz) to the ground-based atmospheric cutoff (~1000 GHz).

- Definition is a practical one, not a physical one
- Excellent ground-based sites count for the definition
- This is a factor of ~10^5 in wavelength--one should expect a change in telescope technology across this wavelength span.

A Science-Driven Future of Single Dish Radio Astronomy

1. EOR

- Map HI sky brightness as a function of source turn-on time (redshift): 50(?) – 200(?) MHz

2. Star/planet Formation

- Characterization of star/planet formation environment (chemistry, excitation, magnetic field)

3. Solar System-Earth effects

- Chemistry of comets, planetary atmospheres, radar characterization of NEAs

A Science-Driven Future of Single Dish Radio Astronomy

4. Dark Matter
- Dynamics of galaxies and groups of galaxies (large-scale HI and CO surveys)

5. Origin of the Universe
- Gravity waves (precision pulsar timing)

6. Gravity, theory of
- Large scale: kinematics of galaxies and clusters of galaxies
- Small scale: Precision timing of binary pulsar systems

A Science-Driven Future of Single Dish Radio Astronomy

7. Masses of neutrinos
- Spatial distribution of matter as a function of redshift for comparison with models

8. New States of Matter
- Precision pulsar timing—maximum spin rate related to the equation of state of a neutron star (“quark star”?)

9. New Theories of Matter and Light
- Extreme environment: pulsar emission mechanisms

Requirements for the Future of Single Dish Radio Astronomy

1. Survey Capability—Large Field of View
- EOR
- HI, CO
- Pulsars
- “Discovery Space”

2. Dedicated Access

3. Flexibility
- Spectral coverage, multiple simultaneous users, RFI mitigation techniques

Technology for Future of Single Dish Radio Astronomy

1. Multibeaming with Array Detectors to increase the instantaneous field of view
   - Made possible now by low cost HFET and MMIC receivers

2. Fixed antenna designs of large aperture
   - Maximizes collecting area for given cost at the expense of sky coverage

3. "Commensual" observing
   - Wideband IF signal processing for multiple, simultaneous scientific users with different science objectives
   - Made possible now by low cost digital hardware and processing

(Near) Future Single Dish Radio Telescopes

1. LMT
- CO spectroscopy of high redshift galaxies

2. FAST
- HI Spectroscopy
- Pulsar timing

3. APEX, AT
- CO spectroscopy of high redshift galaxies
- Spatial distribution of ULIRG as a function of redshift

(Longer Term) Future of Single Dish Radio Astronomy [Speculation]

1. Telescopes designed and built for a specific scientific objective

2. Emphasis on large-as-possible instantaneous field of view—heavy emphasis on multibeaming

3. Scientific partnerships in telescope design and construction (international, institutional) are the rule, not the exception