Discovery Space
An Underrated Key Science Project?

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SKA History
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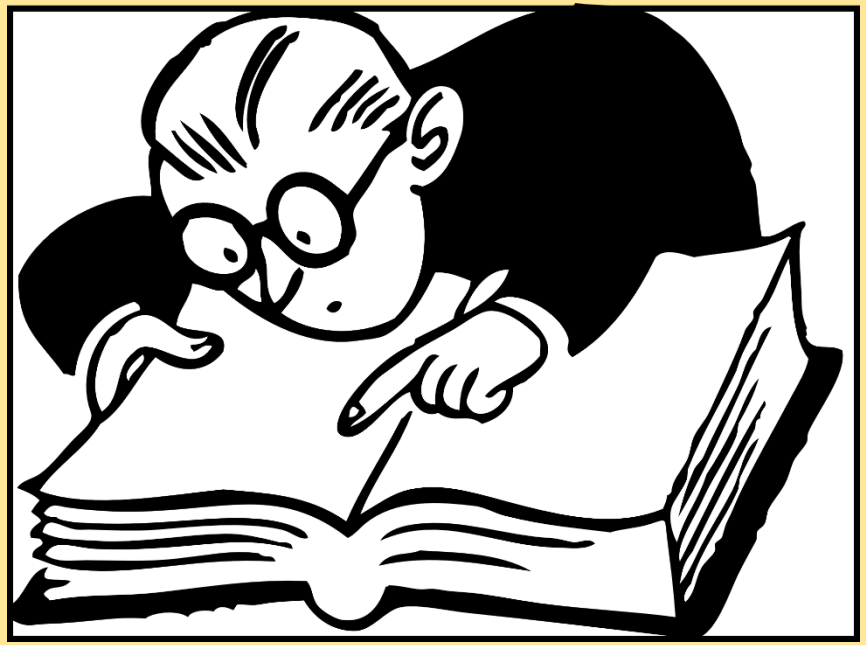


Why do we build new large and expensive scientific instruments like the SKA?

Government Official or Science Policy Leader

- National Prestige
- Support of National Industry- Help boost economy
- Get to Play with the Big Kids (Small Country – e.g., New Zealand)
- International Leadership Economic/Sociologic Influence (Big country)

Engineer -- Get to play with new toys

Philosopher - Promote a cause, born global; world's biggest radio telescope

Scientist

- Check a theory or idea
- Study specific problem areas
- Discover something new – unknown unknowns

Major Unexpected Ground Based Radio Astronomy Discoveries

Year	Discovery
1933	Cosmic radio emission
1938	Non thermal radiation
1942	Solar radio emission
1943	Solar radio bursts
1949	Radio galaxies
1951	HI
1955	Jupiter radio bursts
1955	Evolving Universe
1962	Radio Recombination Lines
1962	Venus rotation/temperature
1963	Quasars

Year	Discovery
1964	Mercury Rotation/temperature
1964	Interplanetary Scintillations/solar wind
1965	Interstellar molecules
1965	CMB
1965	Water masers
1968	Pulsars - neutron stars
1970	CO and Giant Molecular Clouds
1971	Superluminal motion
1979	Gravitational lensing
1974	Gravitational radiation
1991	Exoplanets
2007	Fast Radio Bursts

Ground Based Radio Astronomy Discoveries

Discovery	Sensitivity	δθ	δν	δτ
Radio Galaxies		X		
Quasars		X		
Pulsars				X
Cosmic Masers			X	X
Extra Solar Planets	X			X
Solar Radio Bursts				X
Cosmic Evolution	X	X		
Radio Recombination Lines	X		X	
Jupiter Bursts				X
HI	X			
Molecules	X		X	

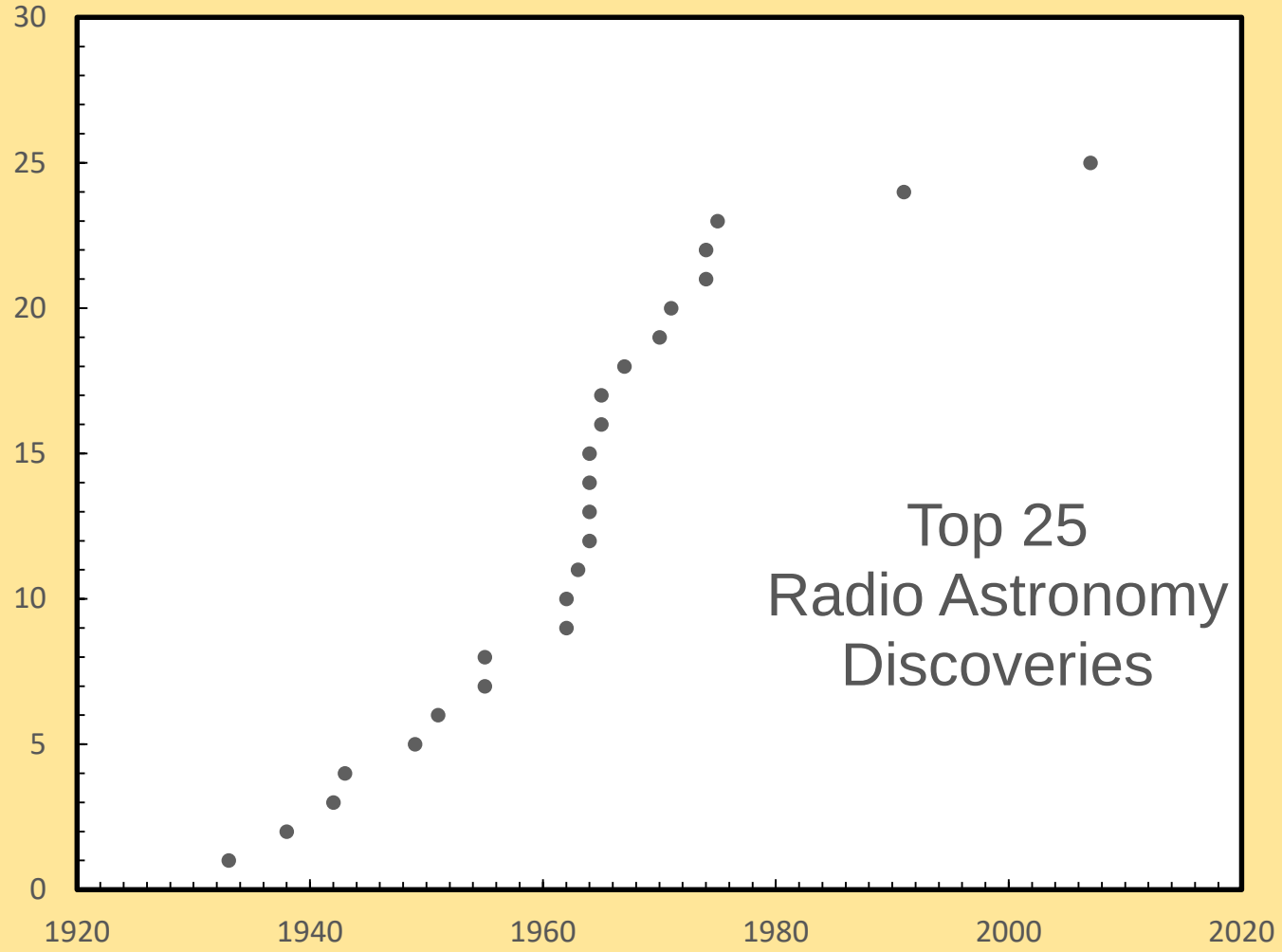
Surveys

Targeted observations

What was the role of theory?

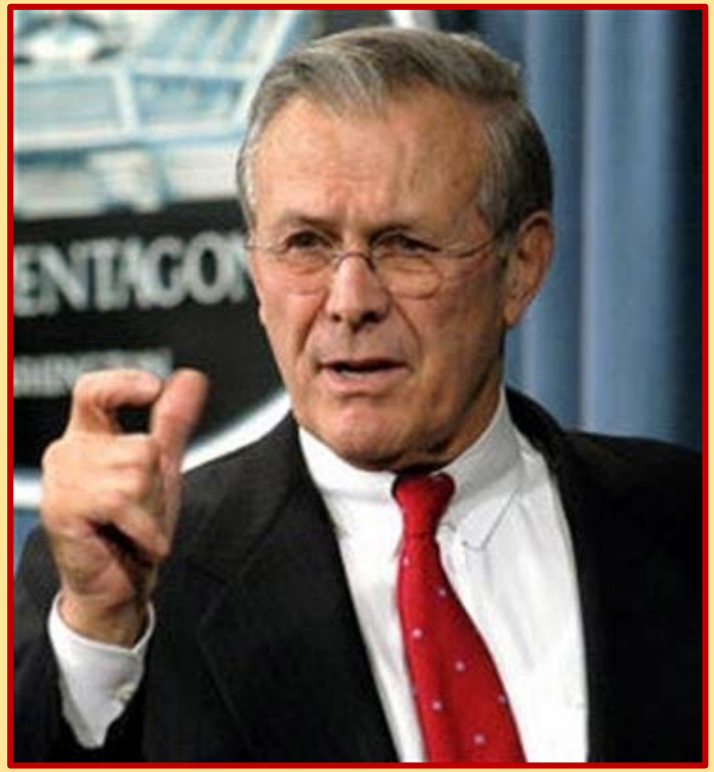
- Prediction led to discovery
  - HI, Interstellar Molecules
- Predicted but played no role
  - Solar Corona, CMB, Superluminal Motion, Exoplanets, Grav. Lensing
- Incorrect theory - delayed discovery
  - Non-thermal radiation, RRL, Mercury Rotation, CO, OH/H_2O Masers
- Looking for something else
  - Quasars, Pulsars, Cosmic Masers, FRBs, Gravitational Radiation Exoplanets
- Just looking - surveys
  - Jupiter Bursts, Venus Rotation, Radio Galaxies, SNR
- Non Astronomical Discoveries
  - Cosmic radio emission, CMB, Solar Bursts, Pulsars

History of Radio Astronomy Discoveries



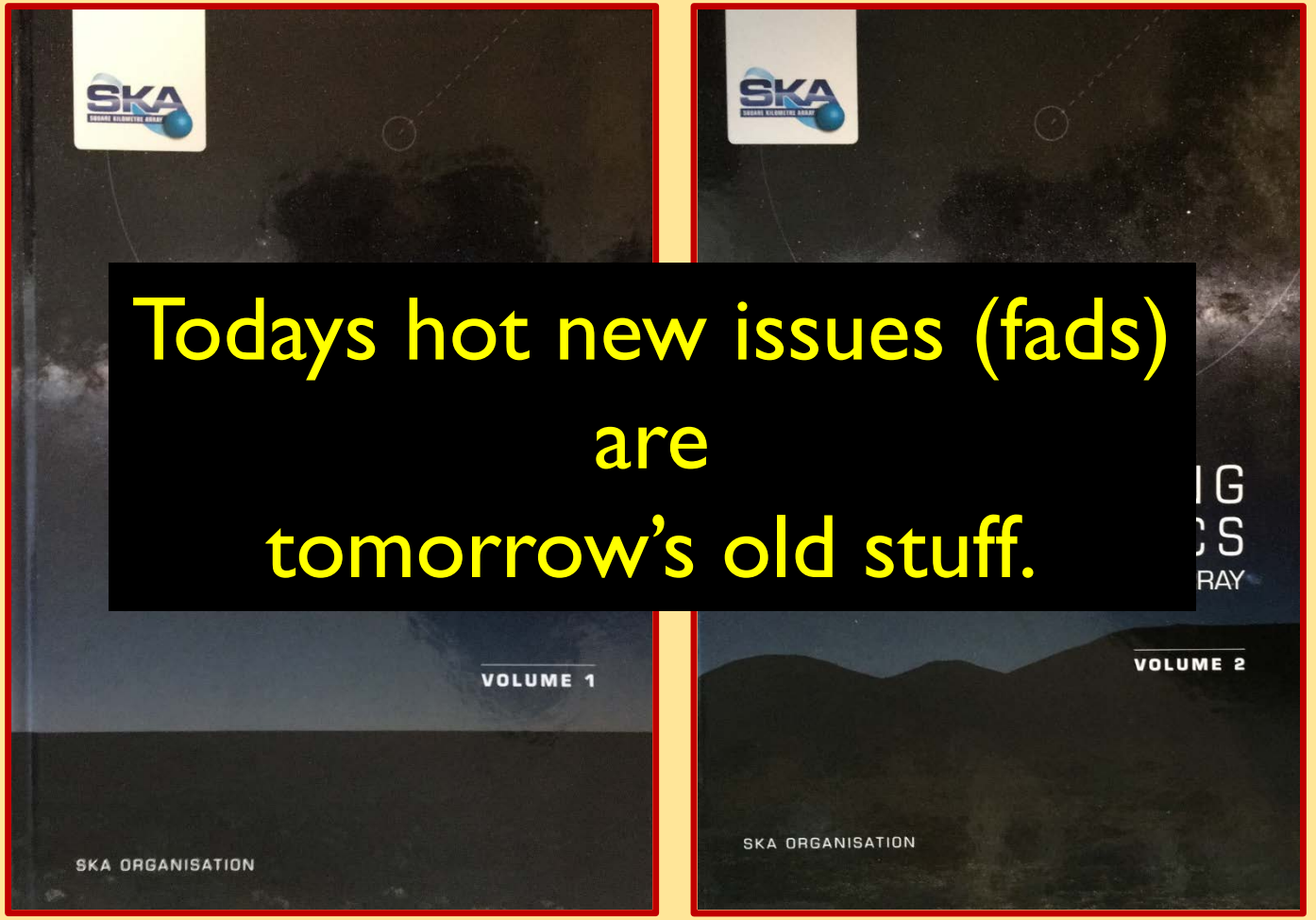
What's left to Discover

- Known Unknowns
  - FRBs
  - EoR
  - Unidentified radio sources
  - Gravity Waves
  - Jupiter-like Exoplanets
  - SETI
- Unknown Unknowns



Why does “Discovery Space” get so little attention?

- Proposal Gamesmanship
  - Individual Research Grants
  - Funding to build telescopes
  - Observing time
- Buzz words
  - Key Science Projects
  - Level 0/Level 1 Science
  - Legacy Projects
  - Design Reference Mission
- 1/135 Papers – discovery space



Todays hot new issues (fads)
are
tomorrow’s old stuff.

Question to the USSKA Consortium from the US Decade Review RMS Panel

Q. In order to justify this amount of money, there had better be some BIG science coming our of this. What is the top question that SKA-mid will answer before any other instrument can?

Telescopes are not used for what they were built for*

Telescope	Year	Built for	Used for
Jodrell Bank MK I	1957	Cosmic ray detection, HI	HI, **Pulsars, Grav. Lens, Lunar Imaging, Interferometry**
Arecibo 1000 foot	1963	Ionosphere, planetary radar	**Pulsars, SETI, Grav Rad, Large scale struct.**
Parkes 210 foot	1962	General	HI, **Pulsars, Quasars, FRBs**
NRAO 140 foot	1965	Radio source positions	**Astrochemistry, VLBI, Spacecraft communication**
NRAO 36 foot	1967	??????	**Astrochemistry**
ASKAP	2012	General	**FRB positioning**
Effelsberg 100 m	1972	General	**VLBI, Pulsars, Astrochemistry**
VLA	1980	Radio galaxies, cosmology	**Stars, Molecular Spectroscopy**
VLBA	1994	SLM	**Astrometry,** SLM
GBT	2000	HI, MM Spectroscopy, VLBI	HI, Astrochemistry, **Pulsars**
CHIME	2018	Hydrogen Intensity Mapping	**FRBs**

* Wilkinson, 19??

RadioAstron

Summary

- *Beware of Theorists*
- *Astronomy is an observational science. We cannot do experiments. We can only observe, and we should not be afraid of discovering something new.*
- *If everyone else is looking down, look up! Grote Reber*
- *If you look under a rock with a new tool, you don't have to be too smart to discover something new. Stephen Chu*
- *Today's hot new issues (fads) are tomorrow's old stuff.*
- *The excitement of the SKA will be not in the old questions it will answer but in the new questions it will raise. Wilkinson et al. 2004*
- *Telescopes are not used for what they were built for. Peter Wilkinson*