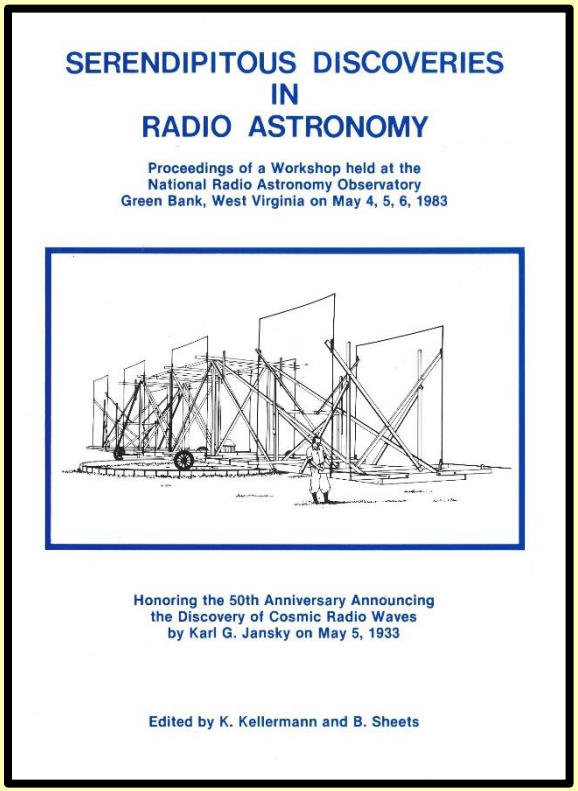
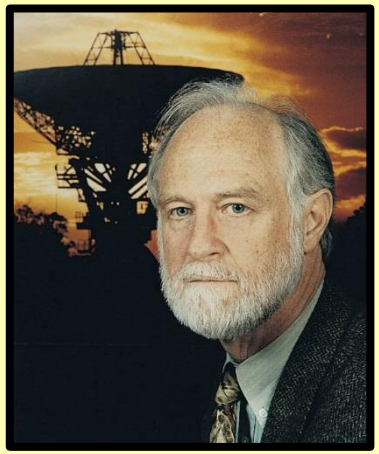
Serendipitous Discoveries in Radio Astronomy:

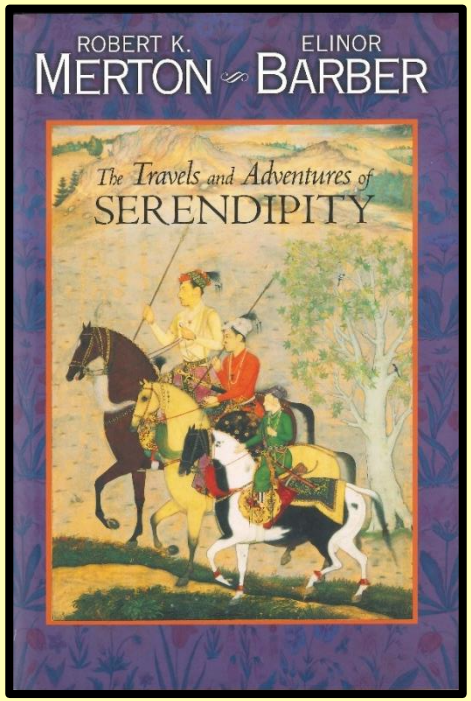
How? Why?



Ken Kellermann

NRAO





The faculty of making happy and unexpected discoveries by accident.

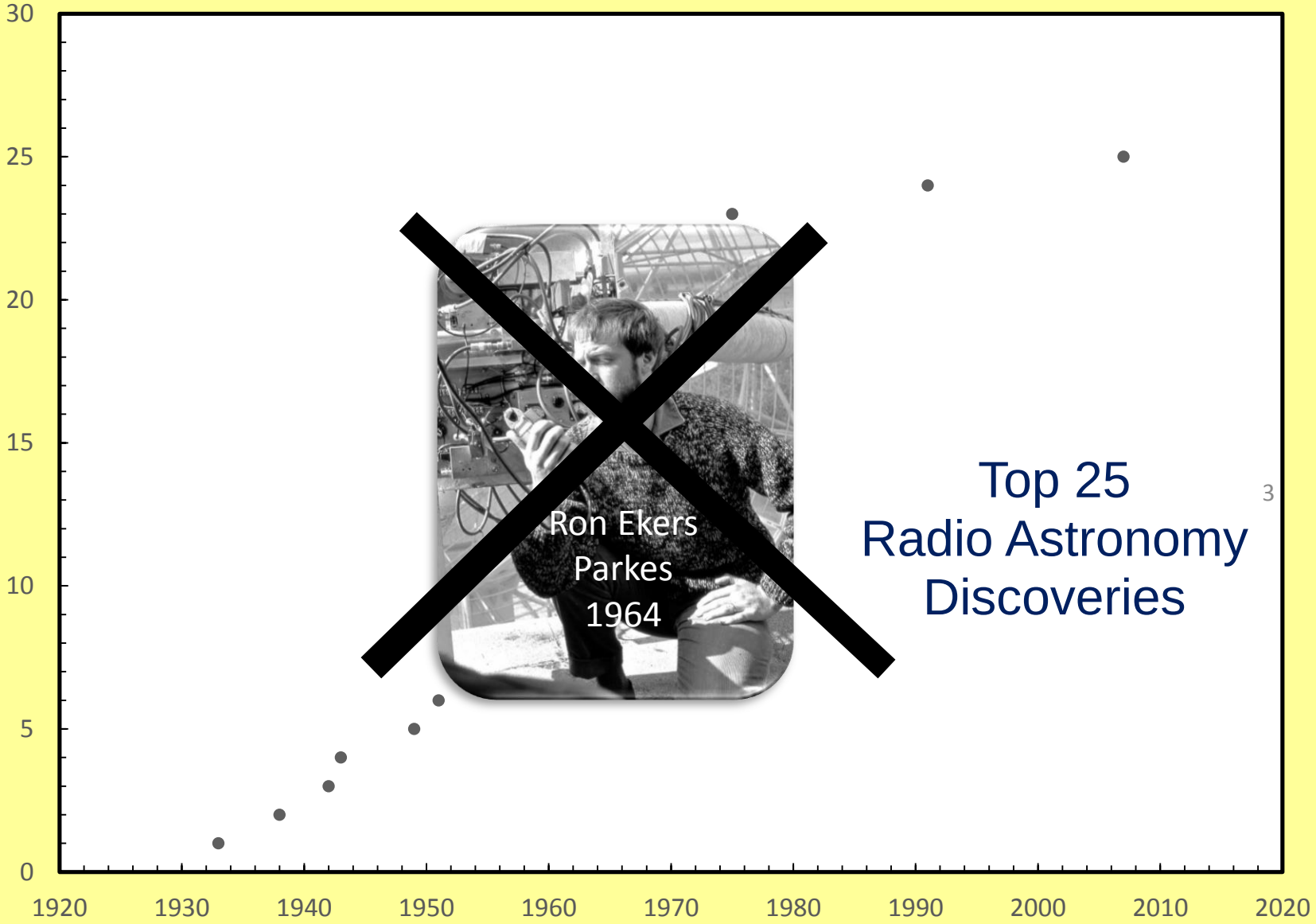
Innovation and Discovery in Radio Astronomy

A celebration of the career of Ron Ekers

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
1964	4th test of GR

Year	Discovery
1964	Mercury Rotation/temperature
1964	Interplanetary Scintillations/solar wind
1964	Interstellar molecules
1965	CMB
1965	Cosmic masers
1968	Pulsars - neutron stars
1970	CO and Giant Molecular Clouds
1971	Superluminal motion
1974	Gravitational lensing
1974	Gravitational radiation
1975	Solar deflection confirming GR
1991	Exoplanets
2007	Fast Radio Bursts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Ron Ekers
Parkes
1964
Top 25
Radio Astronomy
Discoveries

Steven Chiu
NRAO Summer Student, 1972
1997 Nobel Prize in Physics for the
"Development of methods to cool and trap atoms with laser light"
US Secretary of Energy 2009-2013

"If you are the first person to look under a rock with a new set of tools, you don't even have to be that smart to discover something new."

What enabled radio astronomy discoveries

- Predicted from theory
- Predicted but played no role
- Incorrect theory - delayed discovery
- Looking for something else
- Just looking (e.g., surveys)
- User facility or observer built telescope or instrument
- Training: Physics, Astronomy, Engineering
- Organization: University, Industry, Observatory, Military
- Age of discoverer
- Number of authors

Prediction led to discovery

H I

Interstellar molecules

Solar bending

4th Test of GR

Predicted but played no role

Solar Corona

CMB

Superluminal Motion

Exoplanets

Gravitational radiation

Theory incorrect

Non-thermal radiation

RRL

Mercury rotation

CO – GMCs

OH/H_2O masers

Looking for Something else

Quasars

IPS

Pulsars

Cosmic Masers

FRBs

Gravitational radiation

Exoplanets

Just Looking

Reber-solar bursts

Jupiter bursts

Venus rotation

Non Astronomical Discovery

Cosmic Radio Emission
Solar radiation
Solar Bursts
Pulsars

Could have been discovered earlier

Jupiter bursts

Quasars

Pulsars

H I

Molecular masers (OH –H_20)

Carbon Monoxide

CMB

Public User or Private facility?

Private Facility

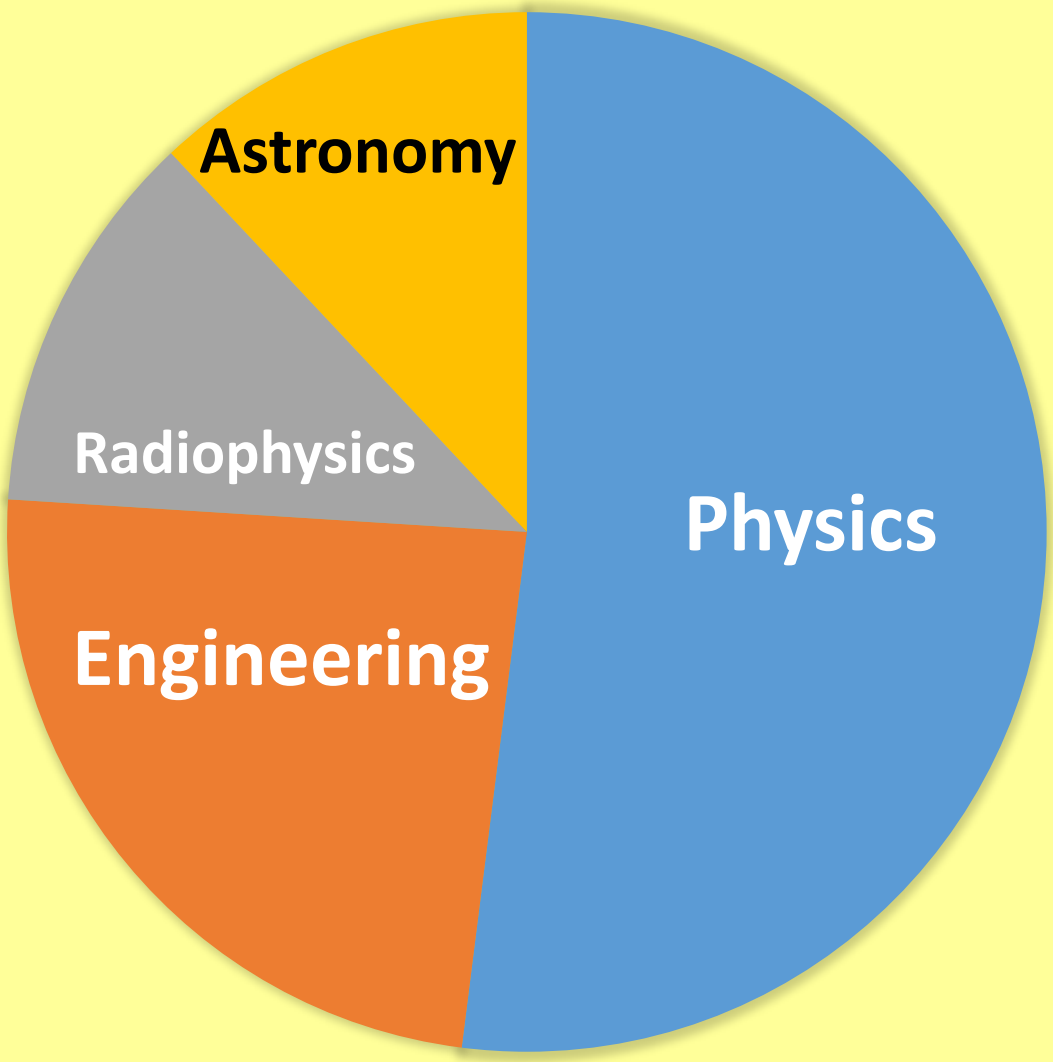
- Cosmic radio emission
- Non thermal emission
- Solar radio emission
- Radio galaxies
- H I
- Jupiter Bursts
- Cosmic evolution
- Masers
- RRLs
- IPS
- Pulsars
- 4th Test of GR

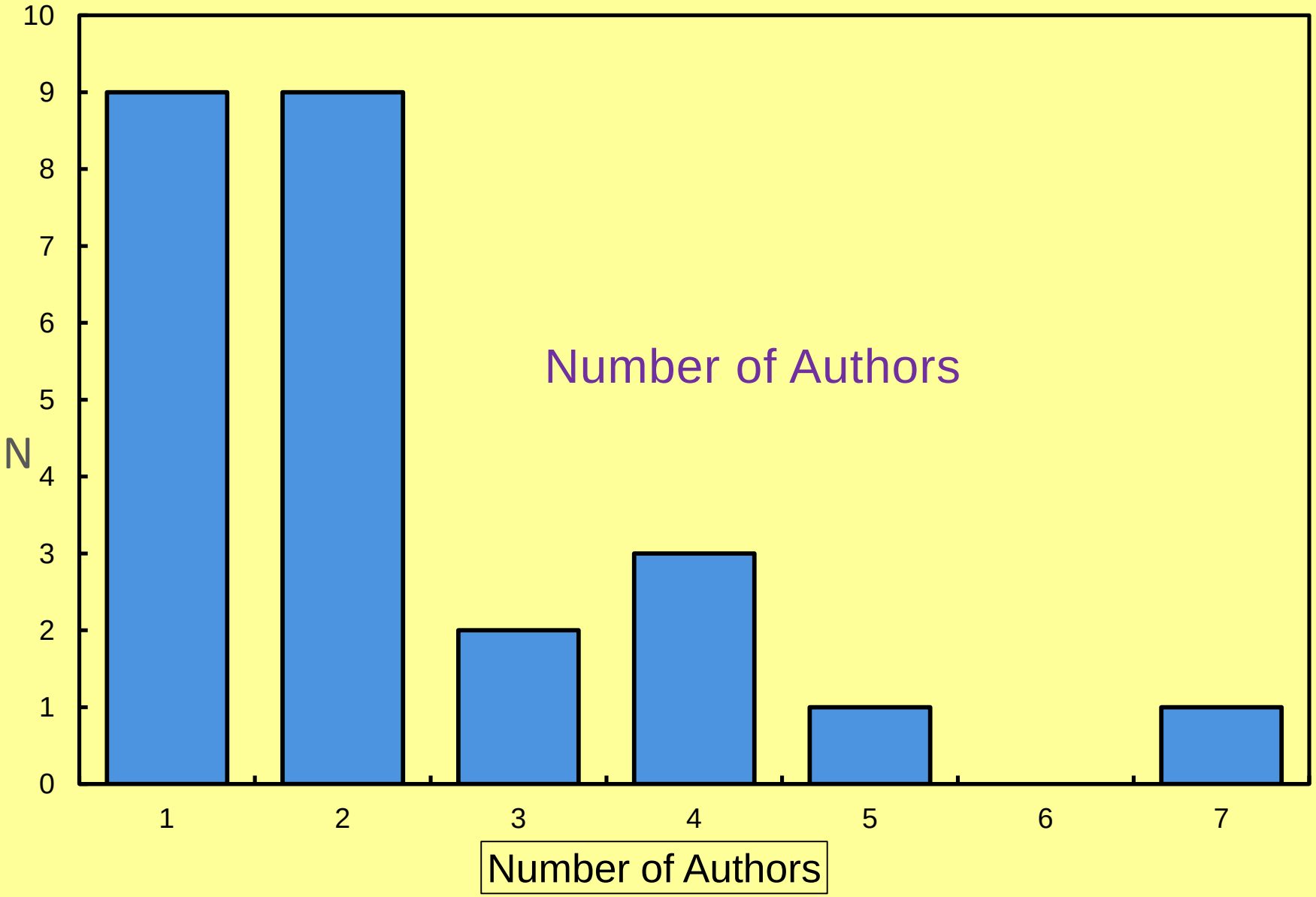
Public User facility

- Venus rotation
- Mercury rotation
- Quasars
- Interstellar molecules
- CO and GMCs
- Superluminal Motion
- Gravitational lensing
- Exoplanets
- FRBs
- Gravitational radiation
- Solar bending

Type of Organization where work occured

TRAINING/BACKGROUND

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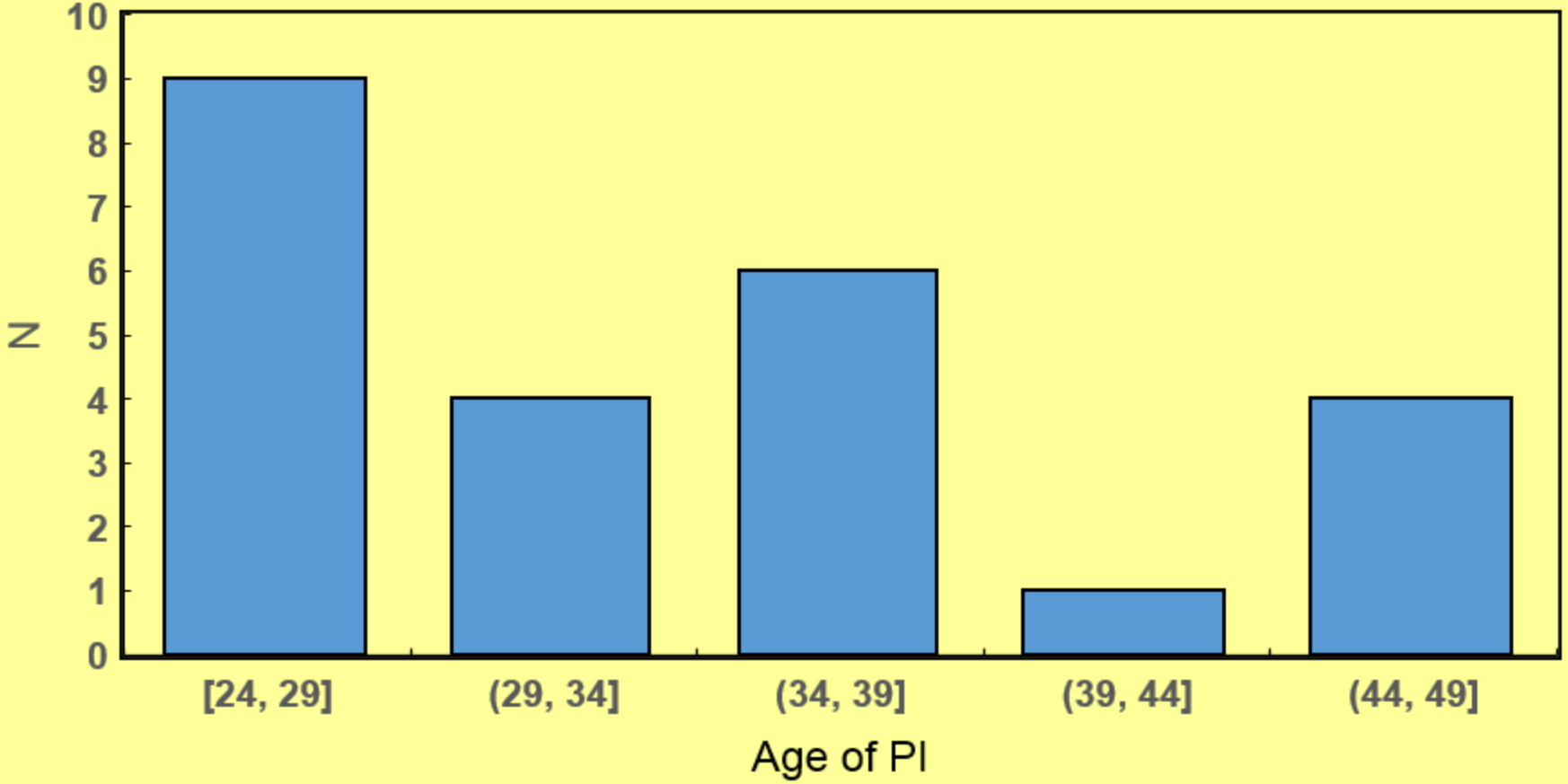
Number of Authors

Age Distribution



What's left to Discover

FRBs

EoR

Unidentified radio sources

Gravity Waves

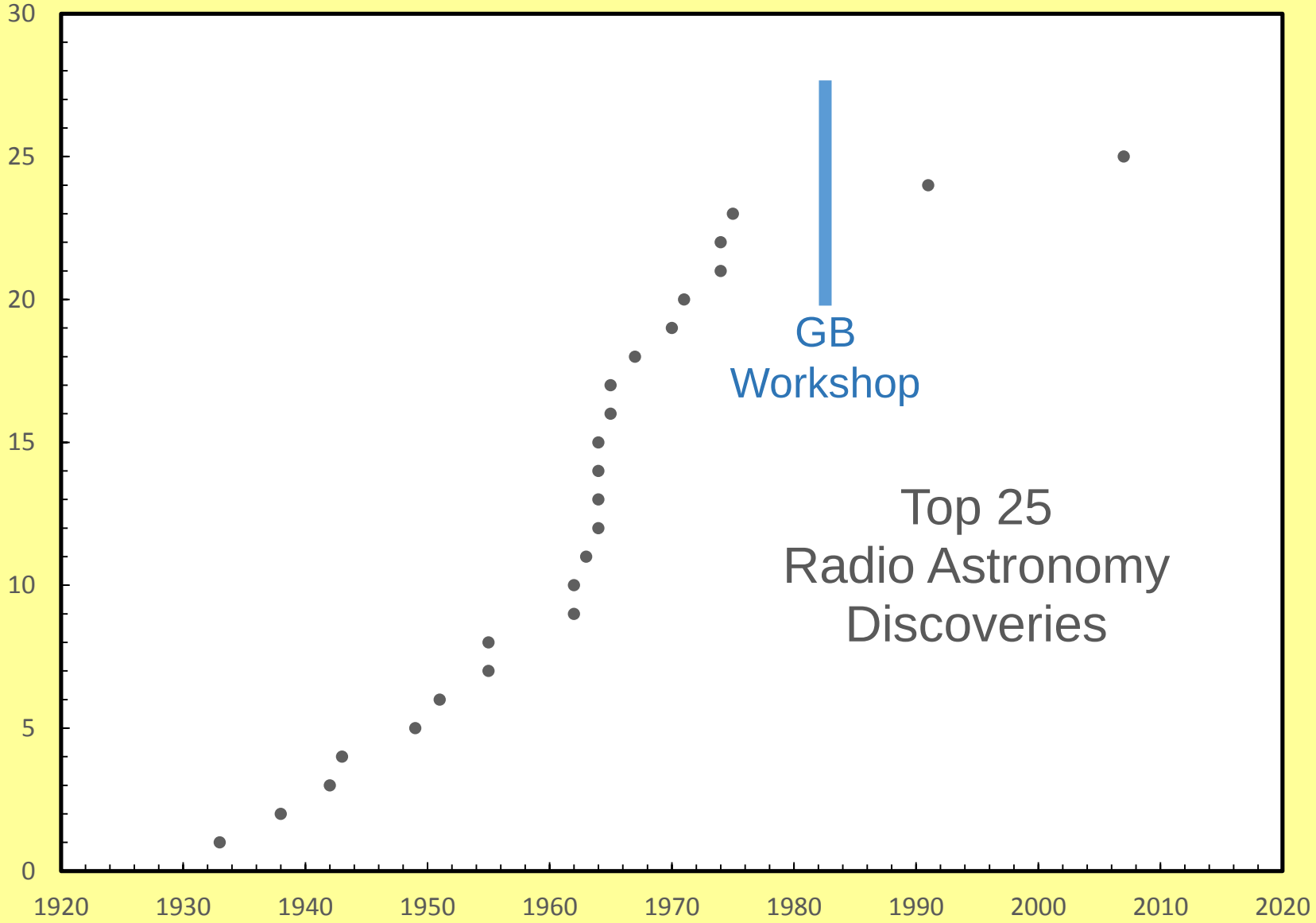
Pulsar arrays

LIGO Radio counterpart

Jupiter-like Exoplanets

SETI

?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GB
Workshop
Top 25
Radio Astronomy
Discoveries

Potential for new discoveries

- Maybe we have reaped all the low hanging fruit?
- Maybe there are no new tools
- Maybe we are using new tools that are counter-productive & inhibit rather than enable new discoveries
  - Advances in computer technology
  - Science Ready Data Products
  - Hands off astronomy
  - Astronomy for the masses

If you make your observations by writing a set of instructions for a telescope operator to carry out, and then write a set of instructions for a computer to extract some data from the results, then it is rather unlikely that you are going to find anything other than what you are looking for.

John Bolton to Taffy Bowen
December 1, 1964

data

Lessons learned

- Beware of theoreticians
- Avoid megaprojects (n>3)
- Stay young (<50)
- If you have access to a new tool–**USE It!**
- Avoid computers & science ready data products
  - Look at your data.

I thank Ron

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1962	Radio Recombination Lines
1962	Venus rotation
1963	Quasars
1964	4th test of GR

Year	Discovery
1964	Mercury Rotation
1964	Interplanetary Scintillations/solar wind
1964	Interstellar molecules
1965	CMB
1965	cosmic masers
1967	Pulsars - neutron stars
1970	CO and Giant Molecular Clouds
1971	Superluminal motion
1974	Gravitational lensing
1974	Gravitational radiation
1975	Solar deflection confirming GR
1992	Exoplanets
2007	Fast Radio Bursts

Number of Authors

No.	Discovery
1	Cosmic radio emission
1	Non thermal radiation
1	Solar radio emission
1	Solar radio bursts
3	Radio galaxies
2	HI
2	Jupiter radio bursts
1	Evolving Universe
2	Radio Recombination Lines
1	Venus rotation
1	Quasars
1	4th test of GR

No.	Discovery
2	Mercury Rotation
3	Interplanetary Scintillations/solar wind
4	Interstellar molecules
2	CMB
4	cosmic masers
5	Pulsars - neutron stars
2	CO and Giant Molecular Clouds
7	Superluminal motion
1	Gravitational lensing
2	Gravitational radiation
2	Solar deflection confirming GR
2	Exoplanets
5	Fast Radio Bursts

Enabled by new tools

New Tool	Discovery
✓	Cosmic radio emission
✓	Non thermal radiation
✓	Solar radio emission
✓	Solar radio bursts
✓	Radio galaxies
✓	HI
	Jupiter radio bursts
✓	Evolving Universe
✓	Radio Recombination Lines
✓	Venus rotation
✓	Quasars
✓	4th test of GR

New Tool	Discovery
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Age of discoverer

Age	Discovery
28	Cosmic radio emission
29	Non thermal radiation
33	Solar radio emission
33	Solar radio bursts
27	Radio galaxies
29	HI
27	Jupiter radio bursts
37	Evolving Universe
	Radio Recombination Lines
35	Venus rotation
34	Quasars
35	4th test of GR

	Discovery
39	Mercury Rotation
40	Interplanetary Scintillations/solar wind
28	Interstellar molecules
29	CMB
48	cosmic masers
24	Pulsars - neutron stars
34	CO and Giant Molecular Clouds
45	Superluminal motion
46	Gravitational lensing
24	Gravitational radiation
35	Solar deflection confirming GR
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39	Fast Radio Bursts