When Earth Songs Filled the Void of Space
A story about how science works and about real people...

When Earth Songs Filled the Void of Space
The time of the story runs from 1894 to 2001, but may include today…

When Earth Songs Filled the Void of Space
Space [Merriam-Webster]: “the region beyond Earth’s atmosphere or beyond the solar system”
Void [Merriam-Webster]: “containing nothing 
<void space>”
So space or what we think about space is the topic

When Earth Songs Filled the Void of Space
“Science is best defined as a careful, disciplined, logical search for knowledge about any and all aspects of the universe, obtained by examination of the best available evidence and always subject to correction and improvement upon discovery of better evidence. What's left is magic. And it doesn't work.”

James Randi
The Scientific Method

- Observe
- Hypothesis
- Predict
- Fix
- Test
- Works
- Theory
The Scientific Method

1. Observe
2. Hypothesis
3. Predict
4. Test
5. Fix

Works

Theory
So Let’s Observe a Little
Ionosphere
Birkeland’s
Terella Experiments in the 1890s
Earth’s Magnetic Dipole
The Sun is a Copious Source of Plasma
A Shell of Solar Electrons is Formed by Earth’s B-field
The 1950 Picture of Space Near Earth

- Exosphere
- Heavyside layer
- Shell of Solar Electrons
So What’s Next?
Are there observations that don’t fit the theory?
Legitimized Observations!

1894

Llanfair

Haverfordwest

Lowestoft
World War I

Amplifier
Burton and Boardman Introduced the Sound Spectrograph in 1930
Frequency Dispersion

\[ f^{-1/2} = \frac{t}{D} \]

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<th>D</th>
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1952
L. R. Owen Storey
Cavendish Laboratory
University of Cambridge
Whistlers with Atmospherics

Whistlers without Atmospherics

Figure 5. Measurements, through two nights, of the dispersions of the whistlers.
**Figure 4.** Short and long whistler overlapping.

**Figure 6.** Short whistler with triply dispersed 'echo'.

**Figure 8.** Multiple-flash type group of short whistlers.

**Figure 9.** Whistler pair.
## Frequency Dispersion

\[ f^{-1/2} = \frac{t}{D} \]

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![Graph showing frequency dispersion](image-url)
Dispersive & anisotropic ionospheric plasma guides waves along the Earth’s magnetic field.
BUT THERE IS A PROBLEM!

Ionosphere can typically only produce $D \sim 2 \, s^{1/2}$ while dispersions of $D \sim 60 \, s^{1/2}$ are measured.

WORSE: H. J. A. Ratcliffe, Owen’s thesis adviser, presents his results at the 1952 URSI meeting in Sydney, but notes Owen’s theoretical interpretation is probably wrong.
mid – 1950’s

Robert Helliwell

“The Father of Whistler Research”

Unalaska, AK

Seattle, WA

Stanford, CA

Byrd Station, Antarctica
Donald Carpenter, 1963

Discovers the Plasmapause from ground whistlers
Konstantin Gringauz, 1959

Makes the first in-space measurements of the plasmasphere from Luna 2

URSI 1963
Schumann Resonances

Extremely low frequencies (ELF) around 7.83 (fundamental), 14.3, 20.8, 27.3 and 33.8 Hz
Animation of ELF wave propagation
Explorer 1
January 31, 1958

van Allen
Pickering
Von Braun

Radiation Belts Discovered
IMAGE Mission

Launched March 25, 2000

“Seeing With New Eyes”
The Plasmasphere We can See!

- Aurora
- Fingers
- Crenulations
- Channel
- Notch*
- Plume
- Plasmapause
- Shoulder
- Shadow

● = SUN
The Plasmasphere is reborn with our new eyes.
Upstream of Bow Shock
Bow Shock-Magnetosheath
Lion Roars - Magnetosheath
Whistlers – The Plasmasphere
Auroral Kilometric Radiation
Plasmaspheric Hiss
Magnetospheric Chorus
Voyager 1 – Saturn’s Ring Plane
Are We There Yet?

Observe → Hypothesis → Predict → Test → Fix → Works → Theory → Observe

http://icecast.msfc.nasa.gov:8000/inspire.mp3