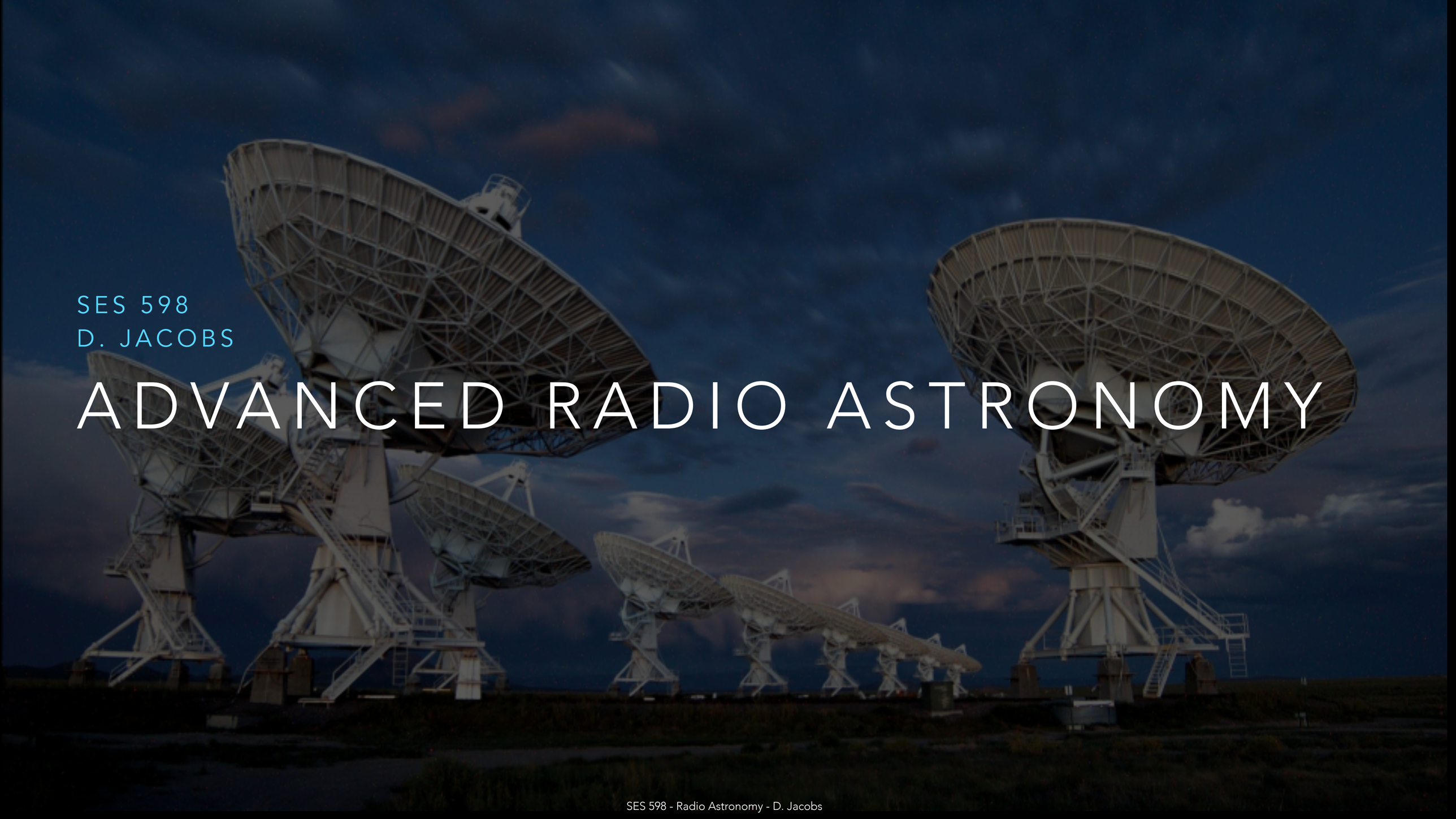


SES 598

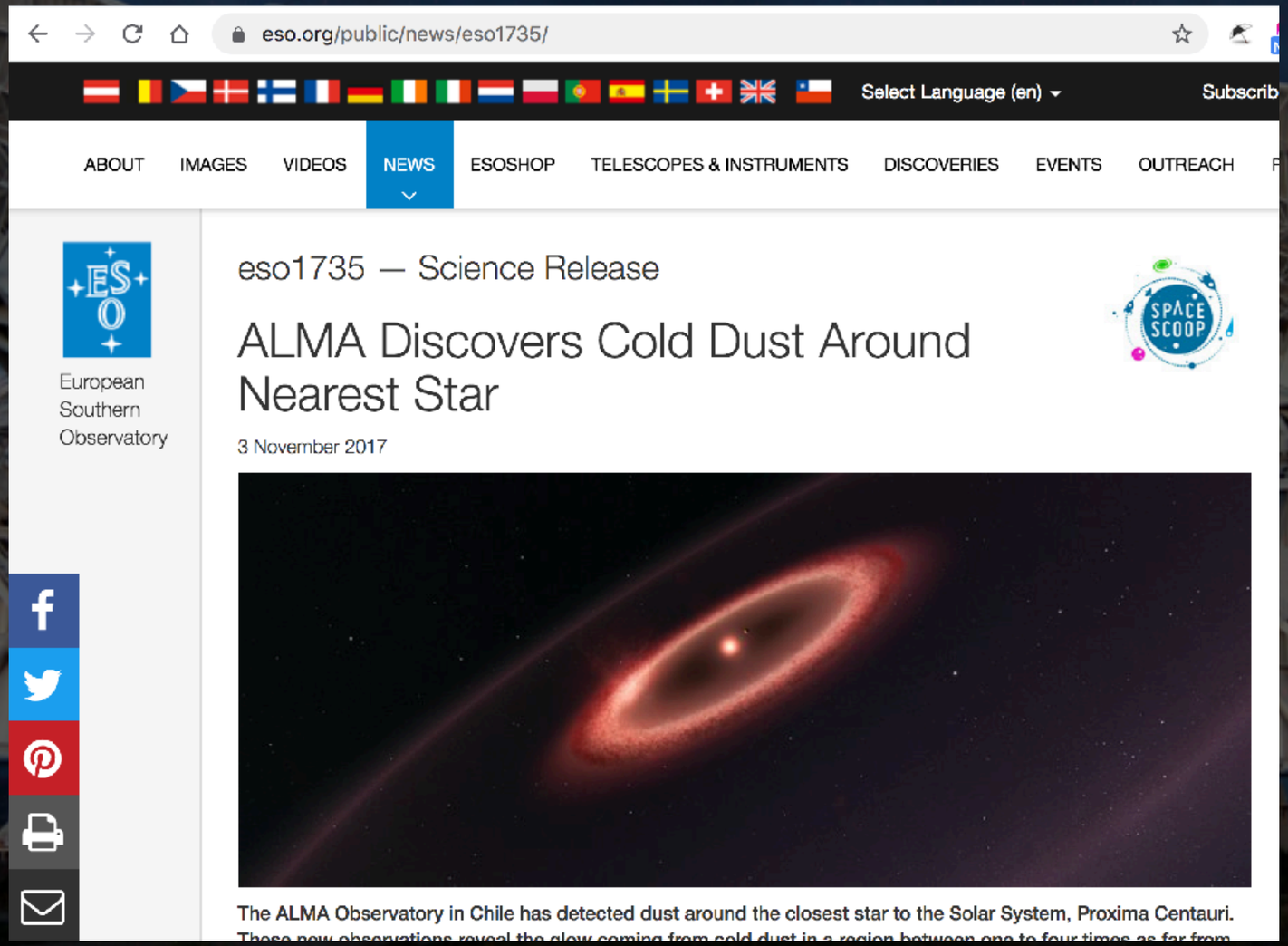
D. JACOBS

ADVANCED RADIO ASTRONOMY

CLASS GOALS

- Conversational in breadth of radio astronomical applications
- Technical Competency in radio astronomy data analysis
- Understanding of astrophysical processes causing radio emission
- Work with real radio data from JVLA, ALMA, and our own instrument.
- Know some history.

RADIO DATA ARE A LITTLE TRICKIER THAN OTHER ASTRONOMY MODES



eurekalert.org/pub_releases/2018-02/nrao-pff022618.php

PUBLIC RELEASE: 26-FEB-2018

Powerful flare from star Proxima Centauri detected with ALMA

Puts habitability of nearby system into question

NATIONAL RADIO ASTRONOMY OBSERVATORY

SHARE PRINT E-MAIL

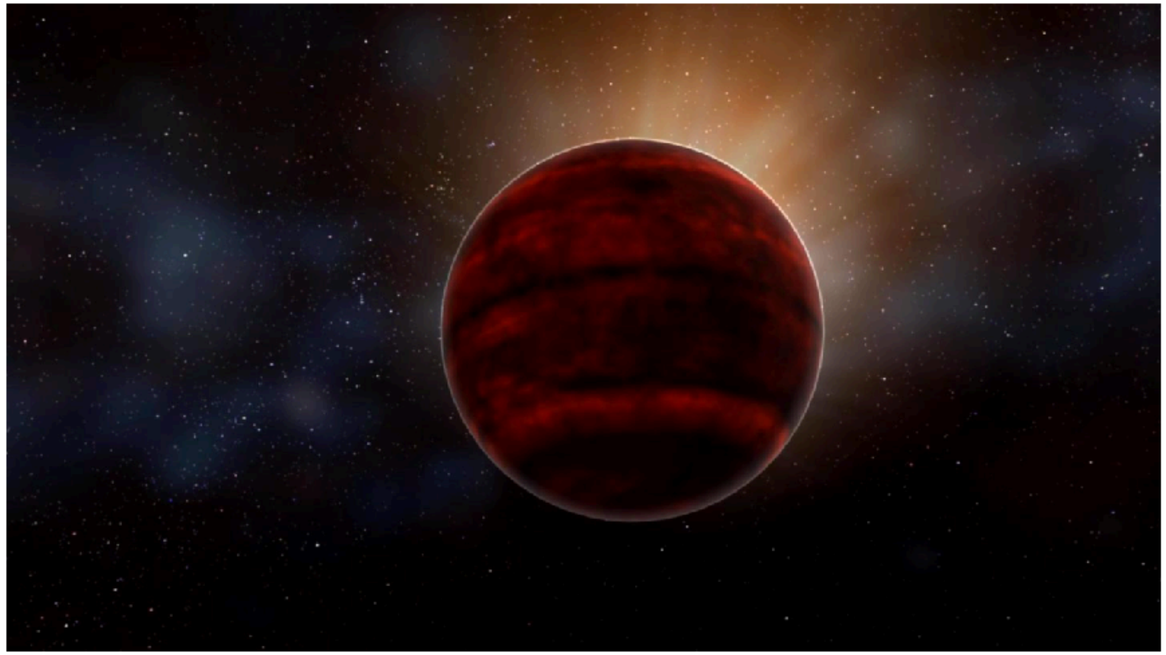


IMAGE: ARTIST IMPRESSION OF A RED DWARF STAR LIKE PROXIMA CENTAURI, THE NEAREST STAR TO OUR

CLASS SETUP

- **Students:** Graduate and Senior Undergraduates
- **Assumed Background:** Electromagnetism, Calculus, Undergrad level Astronomy, Thermodynamics
- **Location:** asu.zoom.us/j/6282829966
- **Schedule:** MW 10:30-11:45
- **Book:** Taylor er al 1999
  available in good pdf - http://www.phys.unm.edu/~gbtaylor/astr423/s98book.pdf
- **Other books that I use:**
  Thompson Moran and Swenson
  Krause
  Wilson, Rholfs, and Huttenmeister
- Useful References
  CASAGuides imaging tutorials -(casa.nrao.edu)

COURSE OUTLINE

- The Wonderful World of Wadio
- The Why of the Radio Sky
  Emission mechanisms and wave propagation
- Receivers
- Antennas
- Interferometers
- Imaging
- Tricky Techniques to Track Transients

COURSE BUSINESS

- Focus of the class will be on producing some high quality projects -> Next Slide
- **Grading:** 50% engagement, 50% quality of work
- Materials posted on danielcjacobs.com/raclass/
  Lecture slides, recordings
- Homework will be in the form of tutorials and then reports on progress
  Any assignments due Mondays at Class

Data Project:

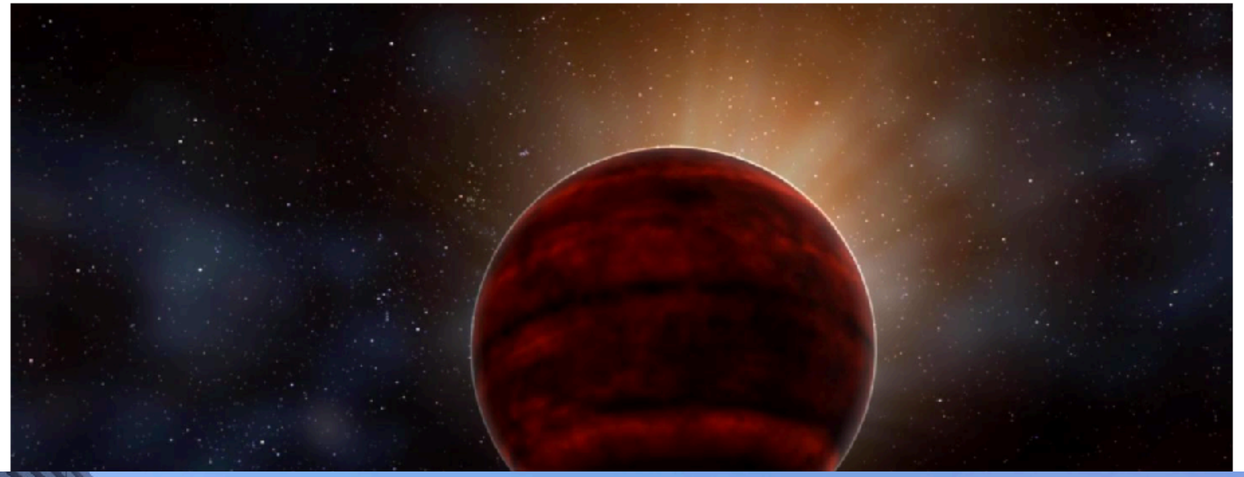
Detect a flare at Prox. Cen

Analyze the archive ALMA data.
One of the authors rates this analysis: hard, but not unreasonable

Puts habitability of nearby system into question

NATIONAL RADIO ASTRONOMY OBSERVATORY

SHARE PRINT E-MAIL



Instrument Project

Rooftop 21cm Horn

Build a more robust version of this instrument.
We have a steel horn and lots of SDRs.
Goal: map the rotation curve of the galaxy.

CLASS PROJECTS

- **No:** homework or tests.
  Yes: Output you can be proud of.

- **Your work**
  Documentation of incremental progress.
  Teamwork required, but your contribution must be clearly identified.
  Something due every Monday, details discussed in class. Turn in via email.

- **First month:** Discussion and background, parts requests, Tutorials

- **Second month:** Progress logs aiming for first draft attempt by wk 8, oral update

- **Third month:** *Spring Break March 8 and 10*, Review plan for last quarter

- **Fourth Month:** Drafts and parts of final report.

- Final oral reports last week of class, written report due on final date.

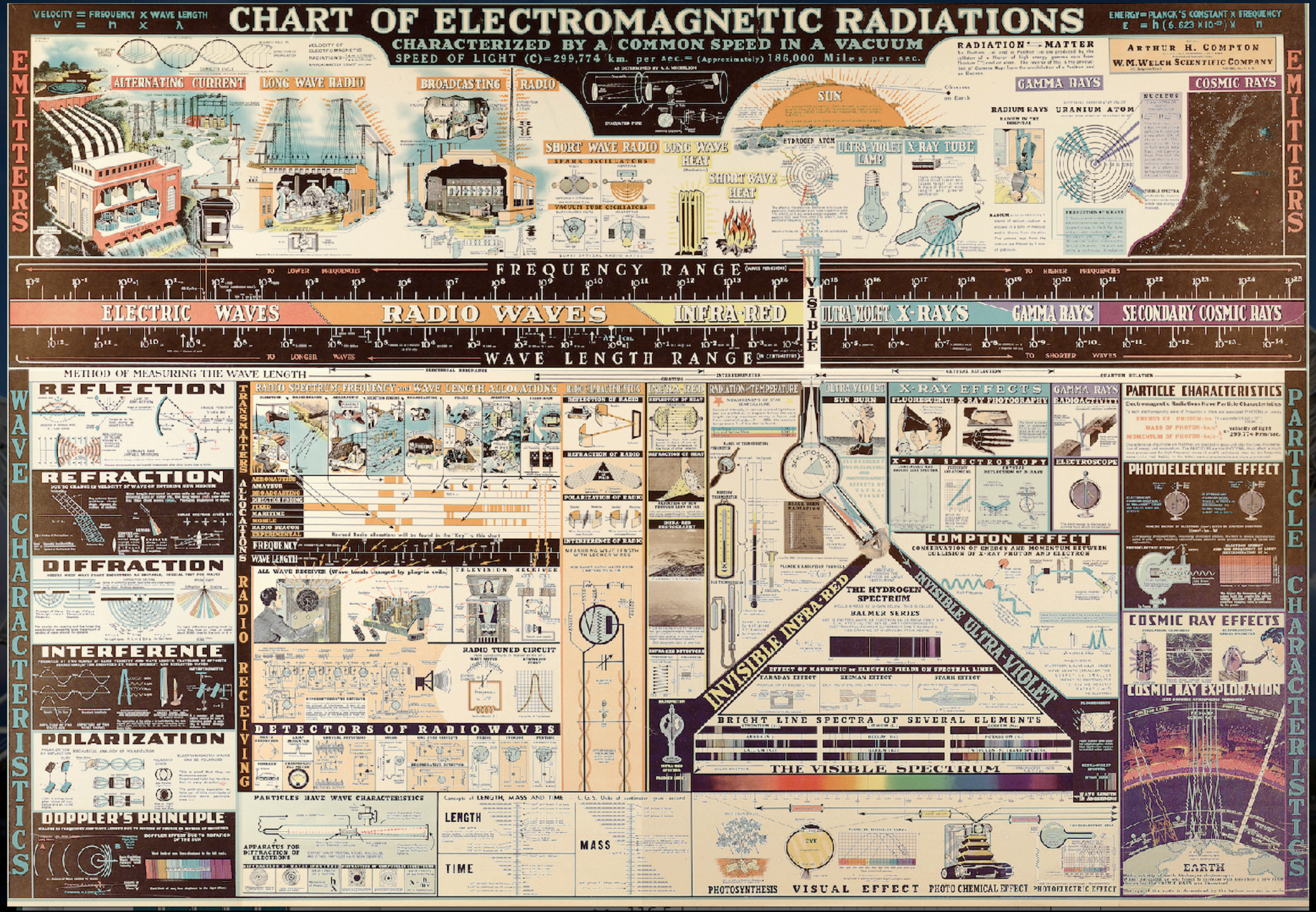
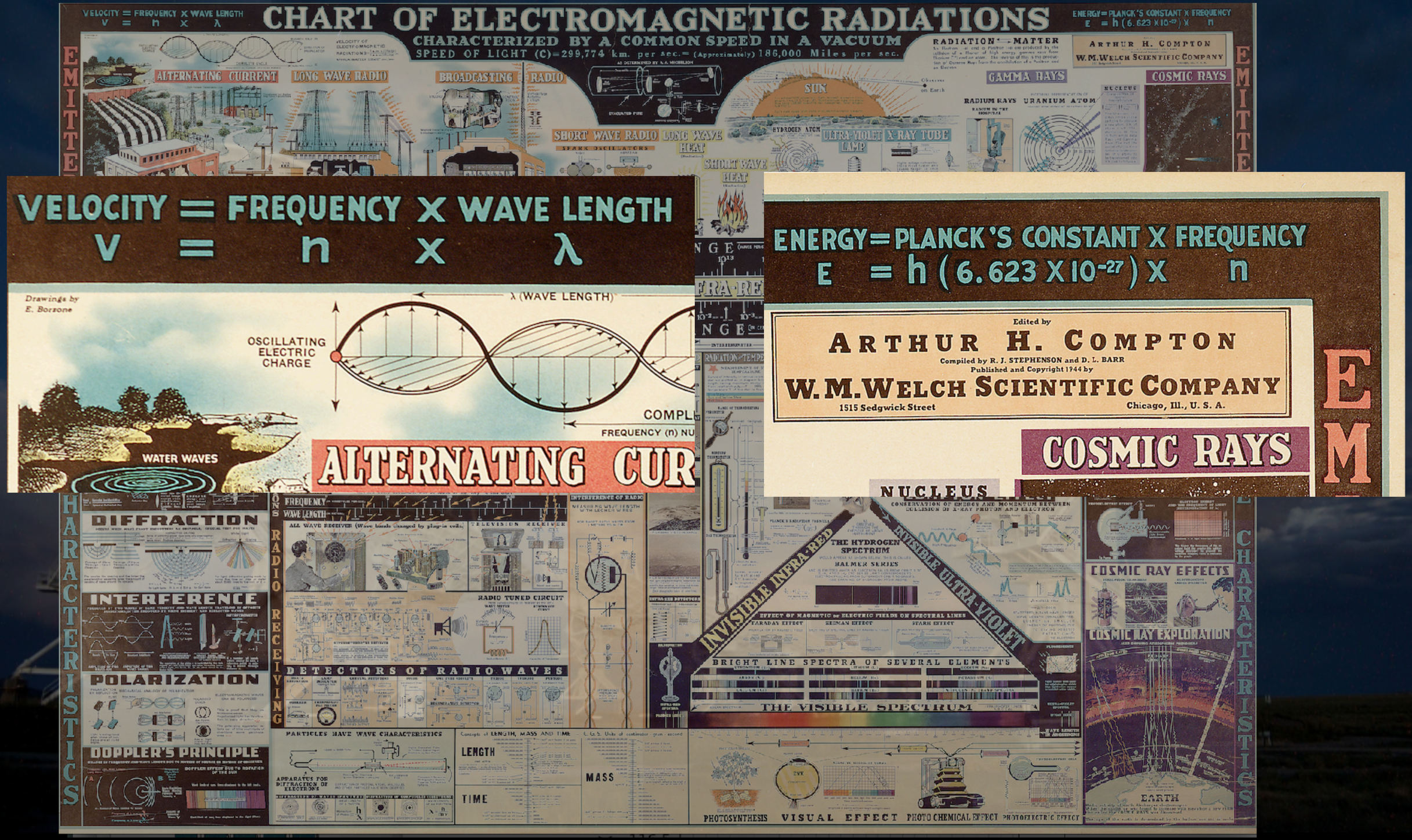


CHART OF ELECTROMAGNETIC RADIATIONS
CHARACTERIZED BY A COMMON SPEED IN A VACUUM
SPEED OF LIGHT (C)=299,774 km. per sec.= (Approximately) 186,000 Miles per sec.
VELOCITY = FREQUENCY X WAVE LENGTH
v = n x λ
ENERGY=PLANCK'S CONSTANT X FREQUENCY
ε = h (6.623 X10⁻²⁷) X n
ARTHUR H. COMPTON
W. M. WELCH SCIENTIFIC COMPANY
EMITTERS
ALTERNATING CURRENT
LONG WAVE RADIO
BROADCASTING RADIO
SHORT WAVE RADIO
SPARK OSCILLATORS
VACUUM TUBE OSCILLATORS
LONG WAVE HEAT
SHORT WAVE HEAT
SUN
HYDROGEN ATOM
ULTRA-VIOLET LAMP
X-RAY TUBE
GAMMA RAYS
RADIUM RAYS
URANIUM ATOM
COSMIC RAYS
FREQUENCY RANGE
TO LOWER FREQUENCIES
TO HIGHER FREQUENCIES
ELECTRIC WAVES
RADIO WAVES
INFRA-RED
VISIBLE
ULTRA-VIOLET
X-RAYS
GAMMA RAYS
SECONDARY COSMIC RAYS
WAVE LENGTH RANGE
TO LONGER WAVES
TO SHORTER WAVES
METHOD OF MEASURING THE WAVE LENGTH
WAVE CHARACTERISTICS
REFLECTION
REFRACTION
DIFFRACTION
INTERFERENCE
POLARIZATION
DOPPLER'S PRINCIPLE
TRANSMITTERS
RADIO SPECTRUM FREQUENCY and WAVE LENGTH ALLOCATIONS
AERONAUTICS
AMATEUR
BROADCASTING
DIRECTION FINDING
FIXED
MARITIME
MOBILE
RADIO BEACON
EXPERIMENTAL
FREQUENCY
WAVE LENGTH
RADIO RECEIVING
ALL WAVE RECEIVER (Wave bands changed by plug-in coils)
TELEVISION RECEIVER
RADIO TUNED CIRCUIT
DETECTORS OF RADIO WAVES
RADIO CHARACTERISTICS
REFLECTION OF RADIO
REFRACTION OF RADIO
POLARIZATION OF RADIO
INTERFERENCE OF RADIO
INFRA-RED
REFLECTION OF HEAT
REFRACTION OF HEAT
INFRA-RED PHOTOGRAPHY
INFRA-RED DETECTORS
RADIATION TEMPERATURE
SPECTROSCOPE
BLACK BODY RADIATION
INVISIBLE INFRA-RED
INVISIBLE ULTRA-VIOLET
THE HYDROGEN SPECTRUM
BALMER SERIES
EFFECT OF MAGNETIC or ELECTRIC FIELDS ON SPECTRAL LINES
FARADAY EFFECT
ZEEMAN EFFECT
STARK EFFECT
BRIGHT LINE SPECTRA OF SEVERAL ELEMENTS
THE VISIBLE SPECTRUM
ULTRA-VIOLET
SUN BURN
X-RAY EFFECTS
FLUORESCENCE
X-RAY PHOTOGRAPHY
X-RAY SPECTROSCOPY
CRYSTAL REFLECTION OF X-RAYS
GAMMA RAYS
RADIOACTIVITY
ELECTROSCOPE
COMPTON EFFECT
CONSERVATION OF ENERGY AND MOMENTUM BETWEEN COLLISION OF X-RAY PHOTON AND ELECTRON
PARTICLE CHARACTERISTICS
Electromagnetic Radiations Have Particle Characteristics
ENERGY OF PHOTON
MASS OF PHOTON
MOMENTUM OF PHOTON
PHOTOELECTRIC EFFECT
COSMIC RAY EFFECTS
COSMIC RAY EXPLORATION
EARTH
PARTICLES HAVE WAVE CHARACTERISTICS
APPARATUS FOR DIFFRACTION OF ELECTRONS
Concepts of LENGTH, MASS AND TIME
C.G.S. Units of centimeter - gram - second
LENGTH
TIME
MASS
PHOTOSYNTHESIS
VISUAL EFFECT
PHOTO CHEMICAL EFFECT
PHOTOELECTRIC EFFECT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GAMMA RAYS
RADIUM RAYS
URANIUM ATOM
NUCLEUS
COSMIC RAYS
VELOCITY = FREQUENCY X WAVE LENGTH
v = n x λ
Drawings by E. Borsone
λ (WAVE LENGTH)
OSCILLATING ELECTRIC CHARGE
WATER WAVES
ALTERNATING CUR
ENERGY=PLANCK'S CONSTANT X FREQUENCY
E = h (6.623 X 10⁻²⁷) X n
Edited by
ARTHUR H. COMPTON
Compiled by R. J. STEPHENSON and D. L. BARR
Published and Copyright 1944 by
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1515 Sedgwick Street
Chicago, Ill., U. S. A.
COSMIC RAYS
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FREQUENCY
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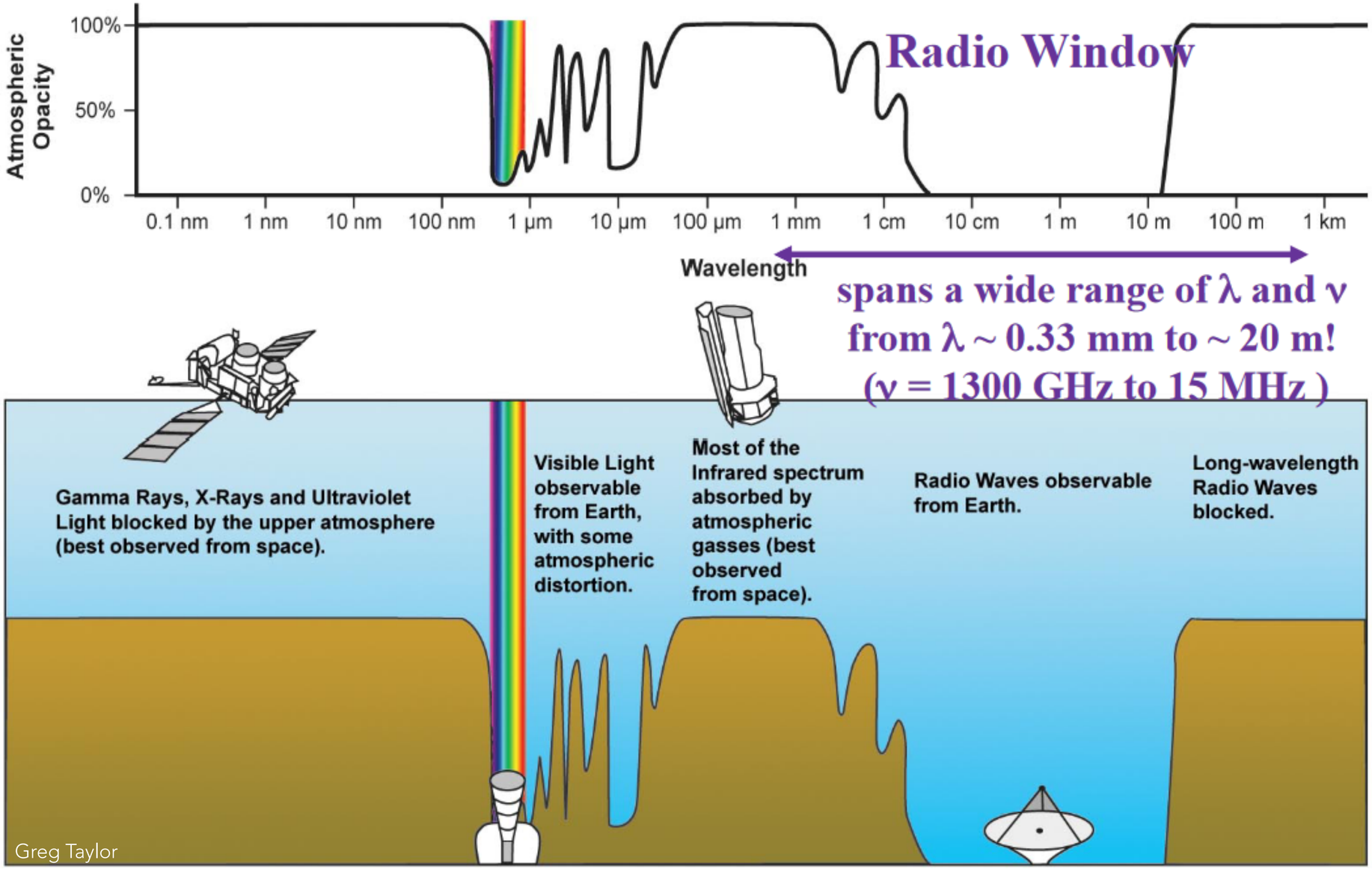
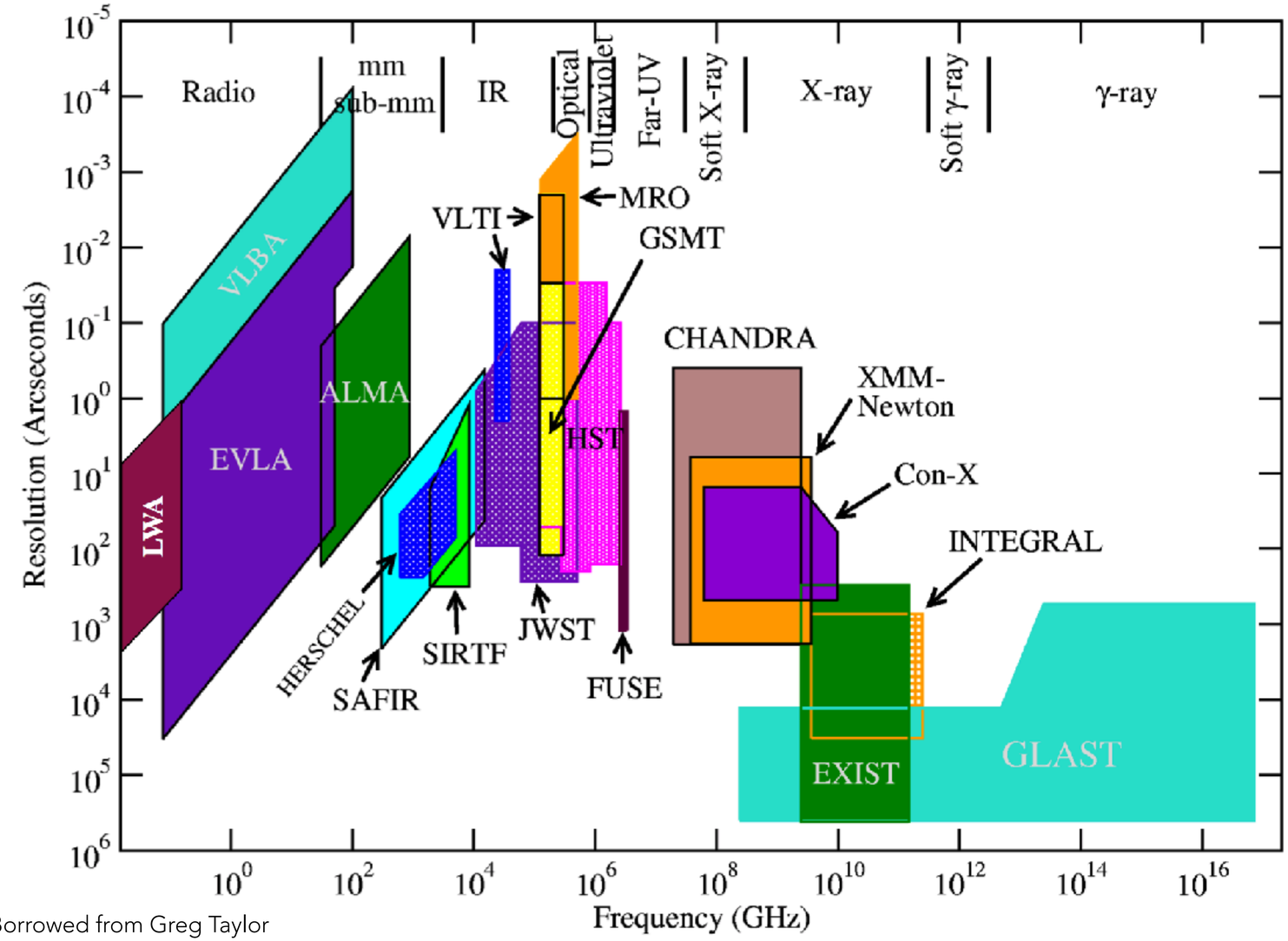
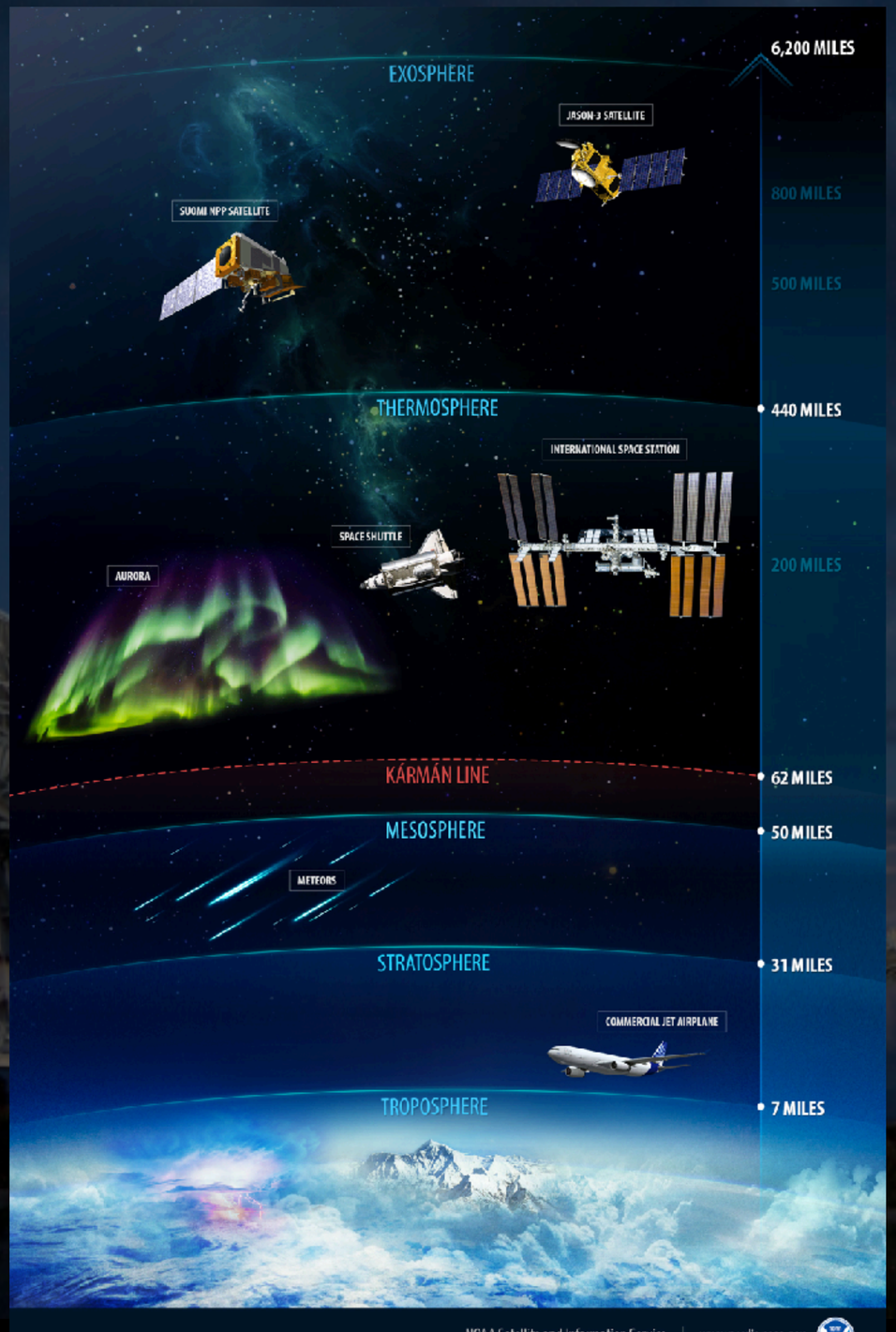
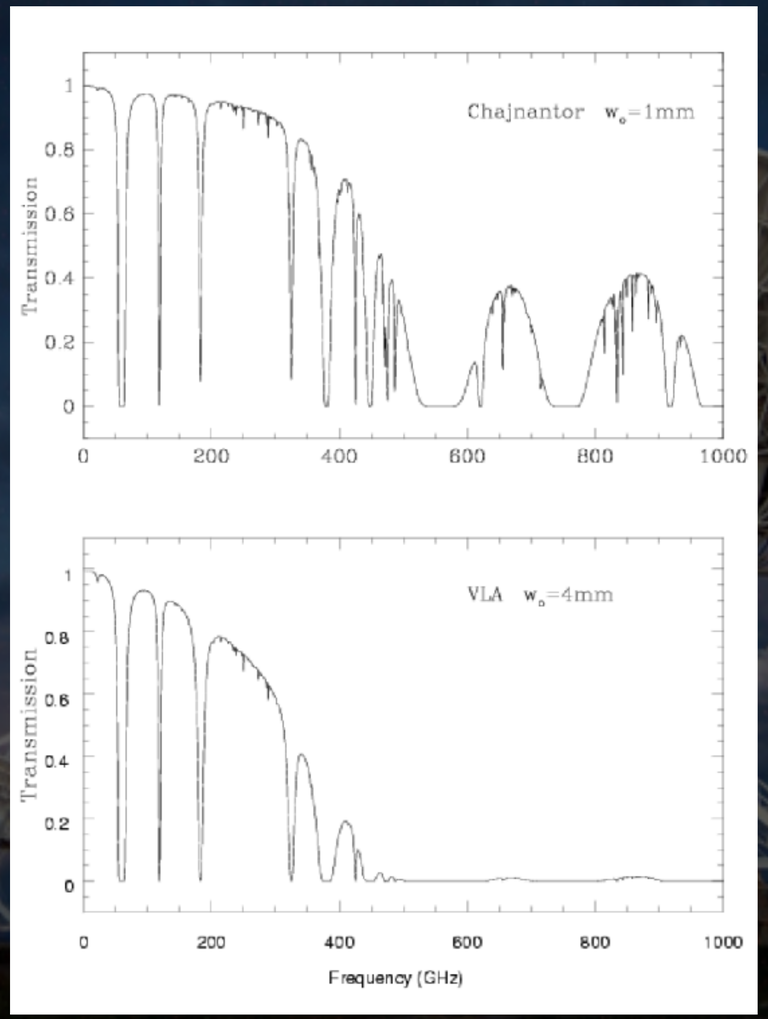

Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 μm
10 μm
100 μm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Radio Window
spans a wide range of λ and ν
from λ ~ 0.33 mm to ~ 20 m!
(ν = 1300 GHz to 15 MHz)
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.
Greg Taylor



Borrowed from Greg Taylor

THE HIGH FREQUENCY EDGE

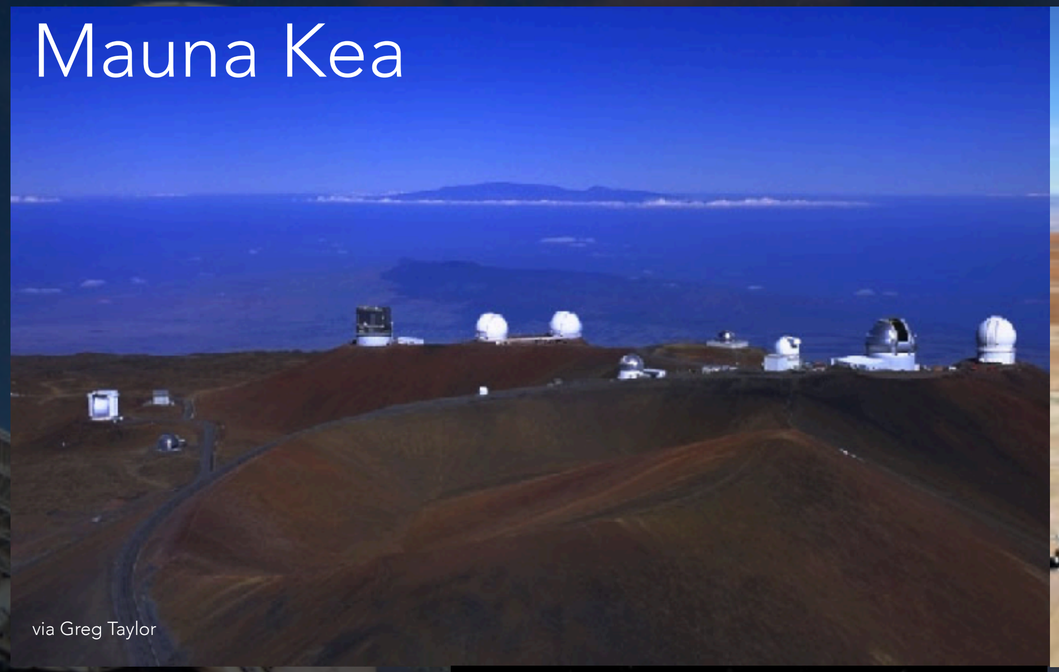




WATER
22.2 GHz, 183Ghz

O2
60GHz, 119GHz

HIGH AND DRY SITES



via Greg Taylor

ALMA Observatory

Space

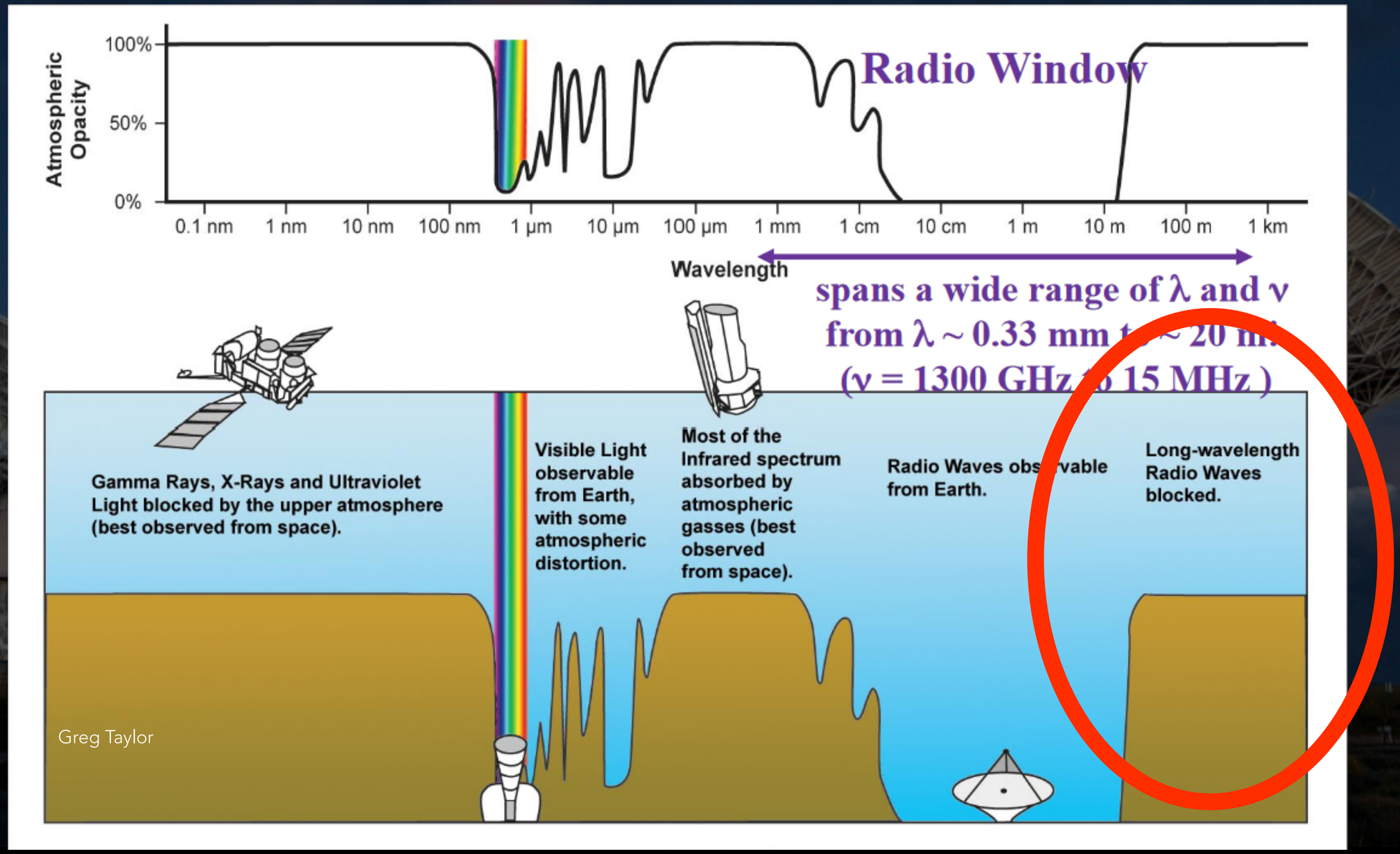
ESA

Antarctica

Dome C shown here

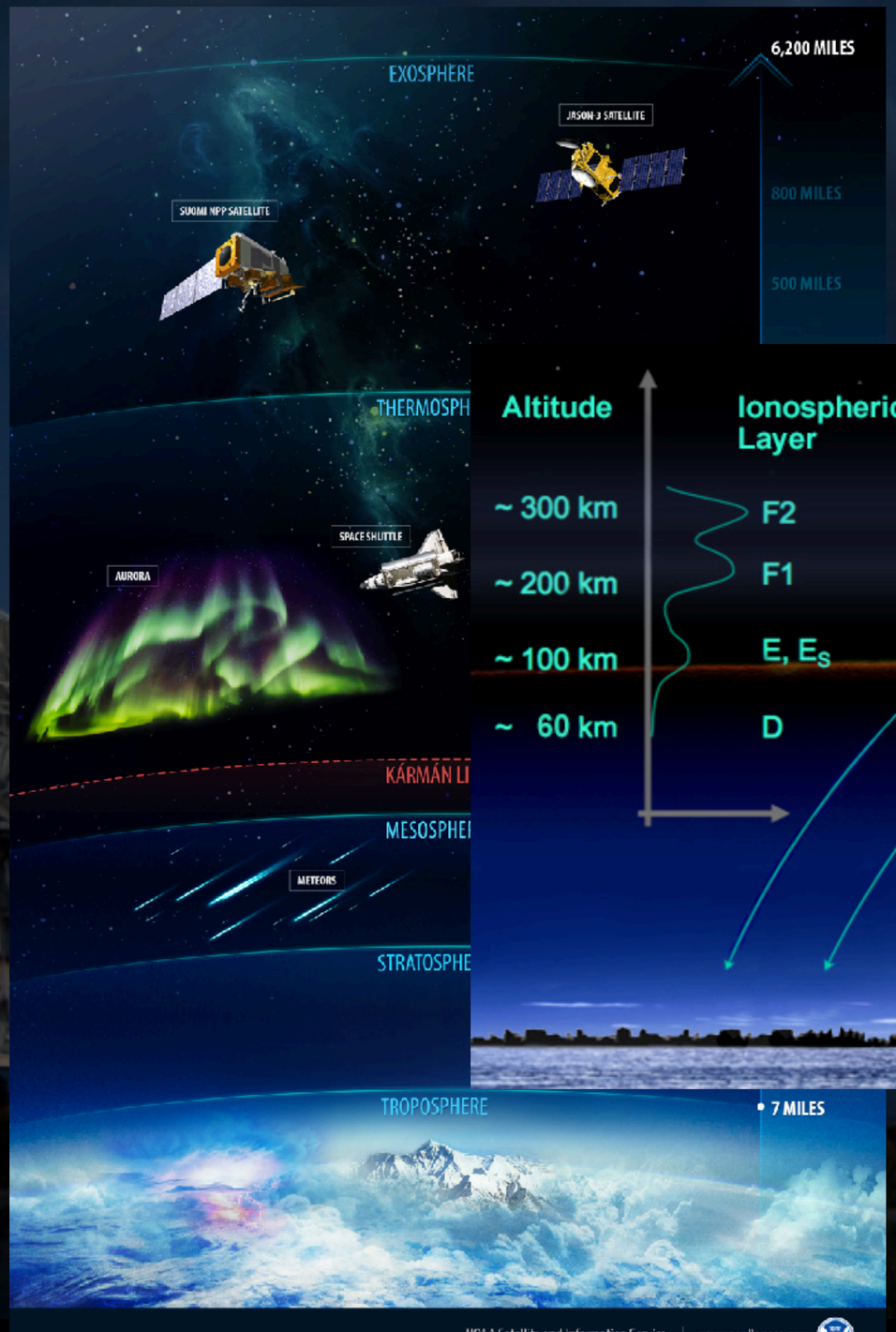
Xue-Fei Gong/Purple Mountain Observatory

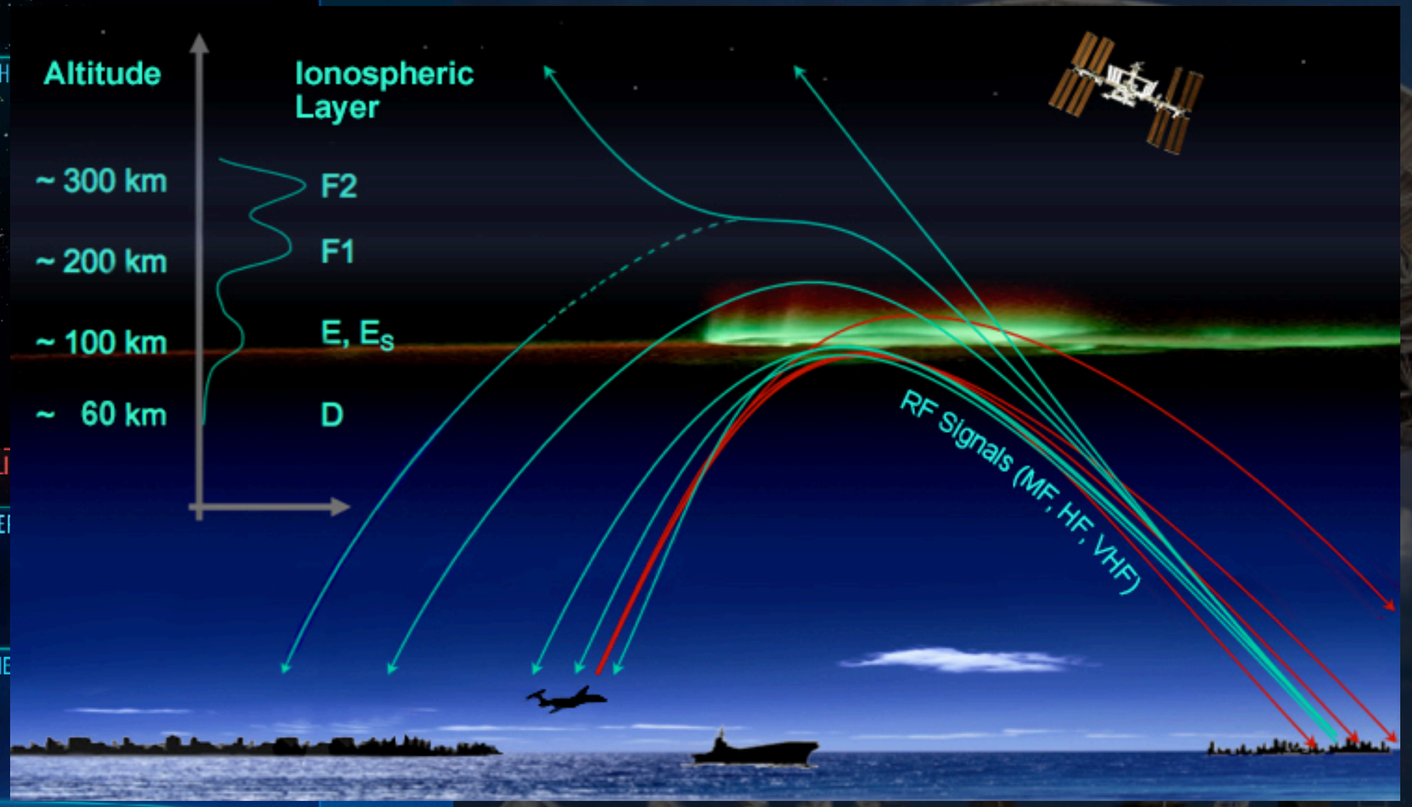
THE LOW END



Greg Taylor

LOW FREQUENCY EDGE





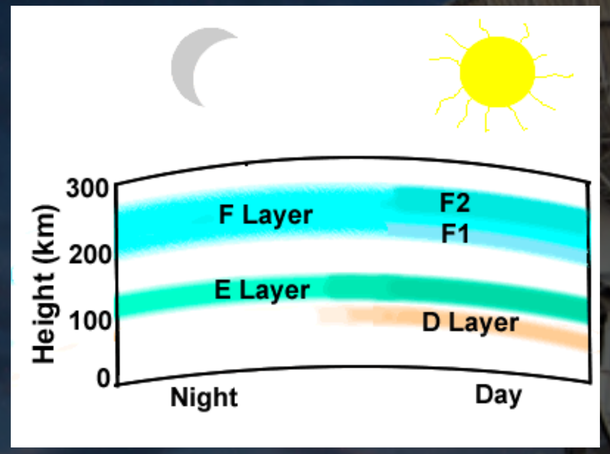
IONOSPHERE WEATHER MATTERS A LOT

lower cutoff frequency depends on density (n_0)

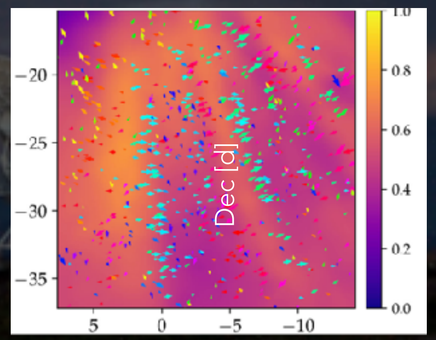
$$\omega_{pe} \triangleq \left(\frac{n_0 e^2}{\varepsilon_0 m_e} \right)^{1/2}$$

Daytime ~11MHz
Night time ~ 4.5 MHz

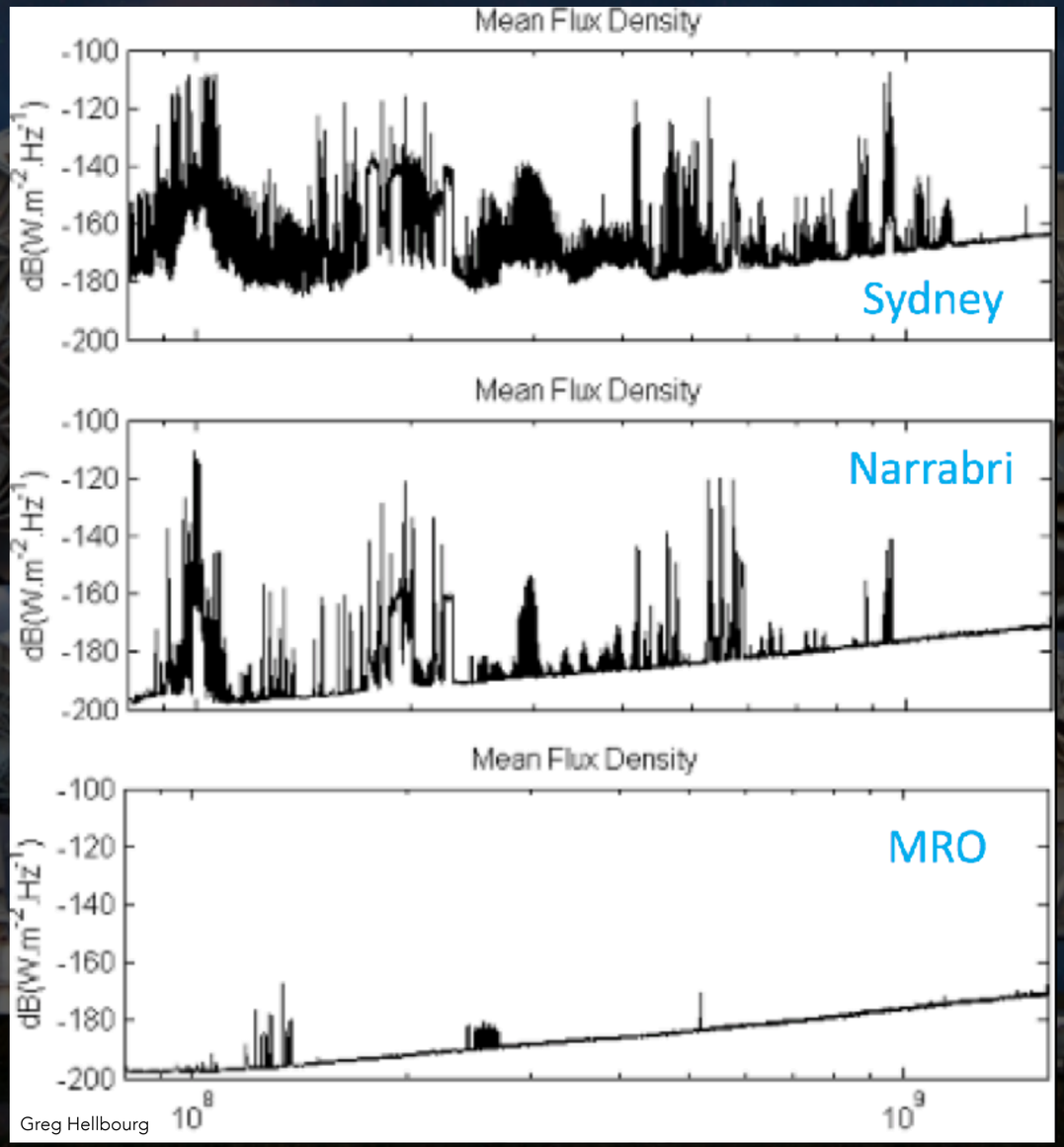
Denser in the sun!



Refraction at 500MHz



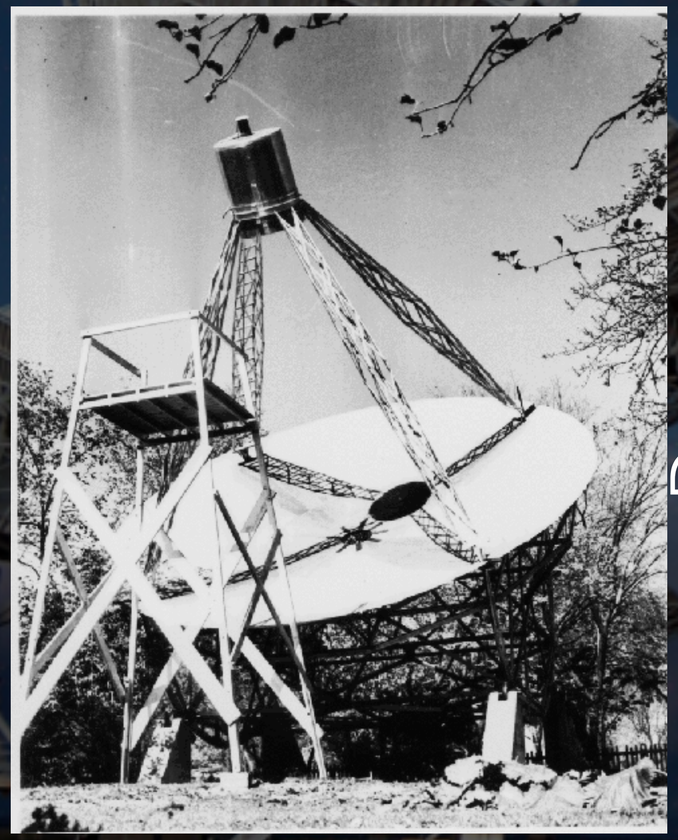
RADIO FREQUENCY INTERFERENCE



Greg Hellbourg

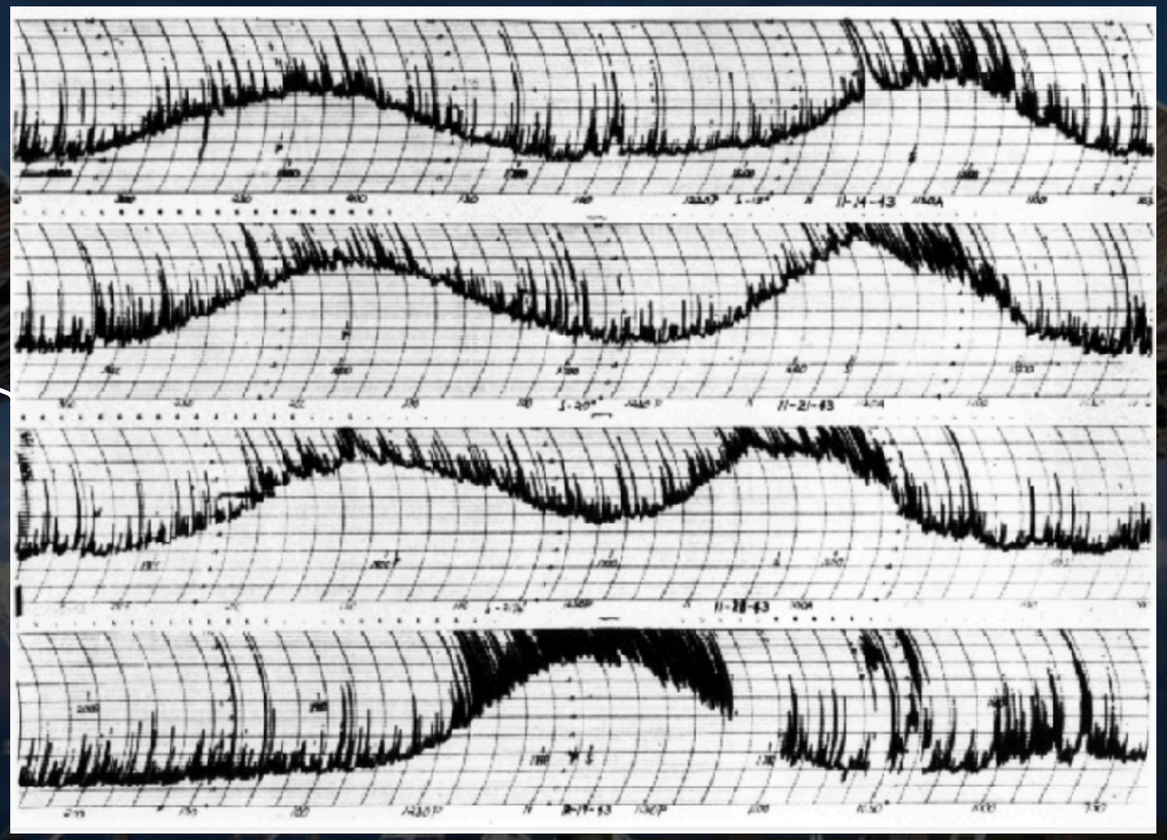
100MHz 200MHz 1GHz

INTERFERENCE IS NOT NEW!



Reber Dish 1937

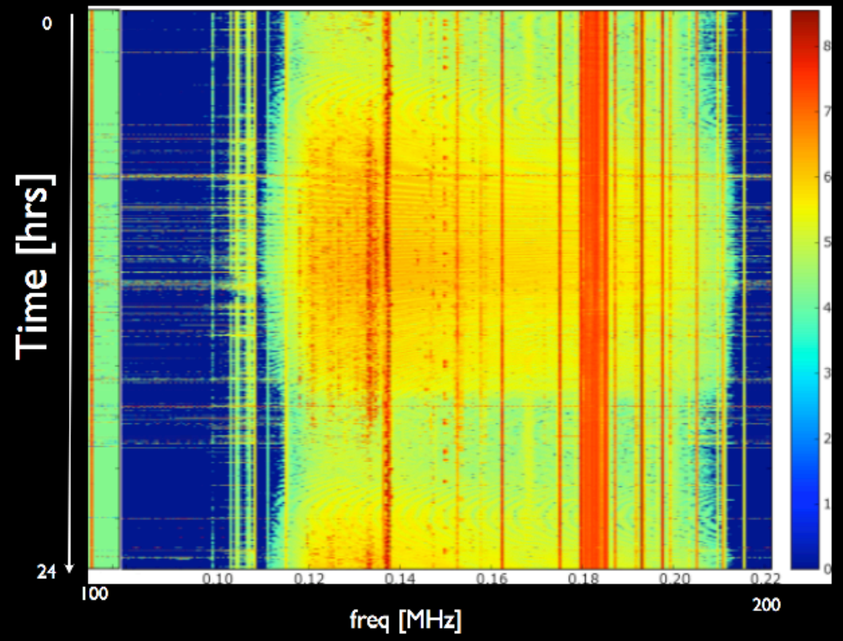
Days



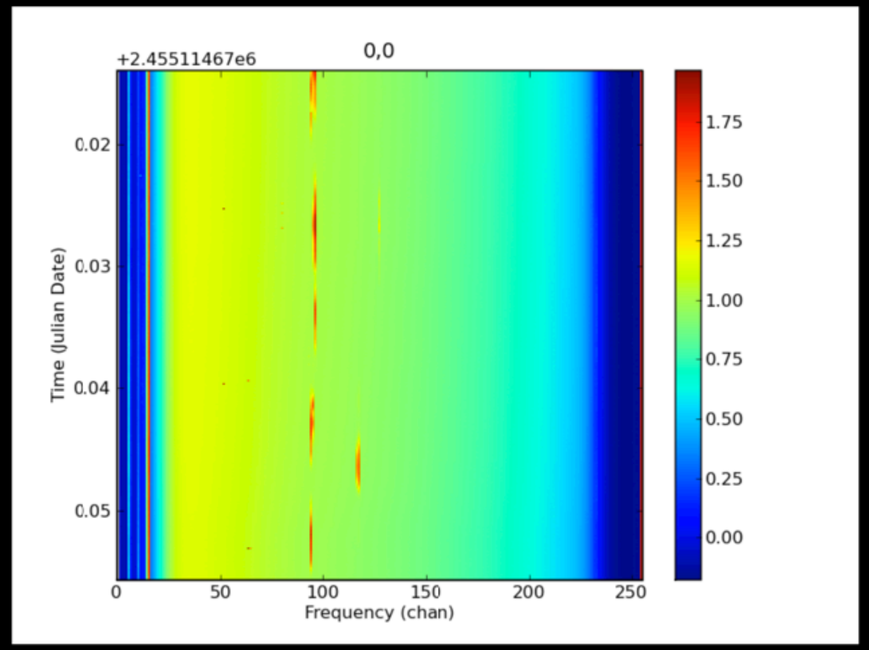
Power vs time

adapted from Greg Taylor

PAPER Green Bank



PAPER South Africa



NEXT TIME

- AGN
- Galaxies
- Pulsars
- Supernovae
- CMB
- The Sun
- Abundances

HOMEWORK

- For next Monday, read and comment on.
- Anglada et al 2017
  ui.adsabs.harvard.edu/abs/2017ApJ...850L...6A/
- Macgregor et al 2018
  ui.adsabs.harvard.edu/abs/2018ApJ...855L...2M/
- Topics: Planet formation and Space Weather