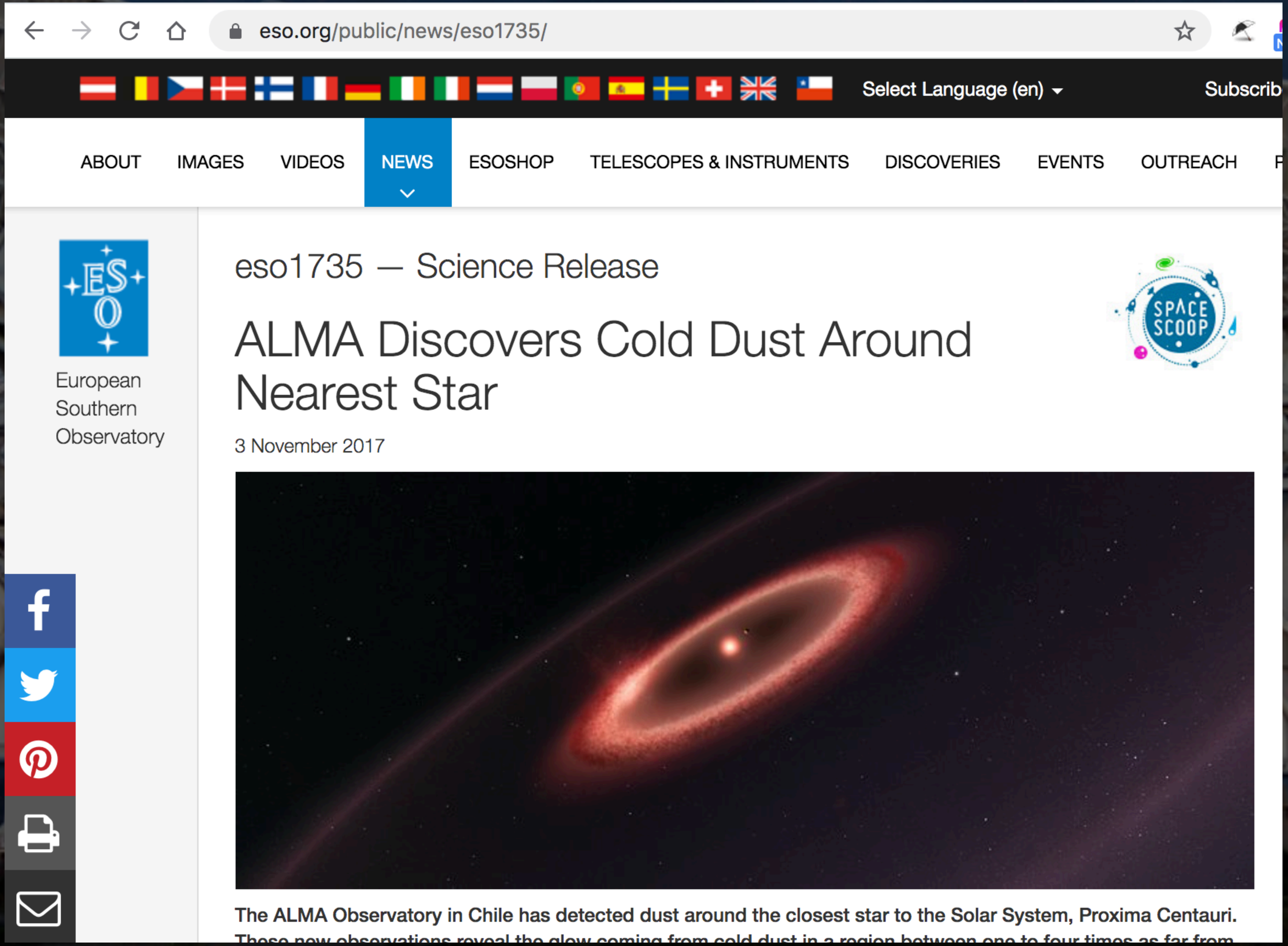
SES 598
D. JACOBS

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

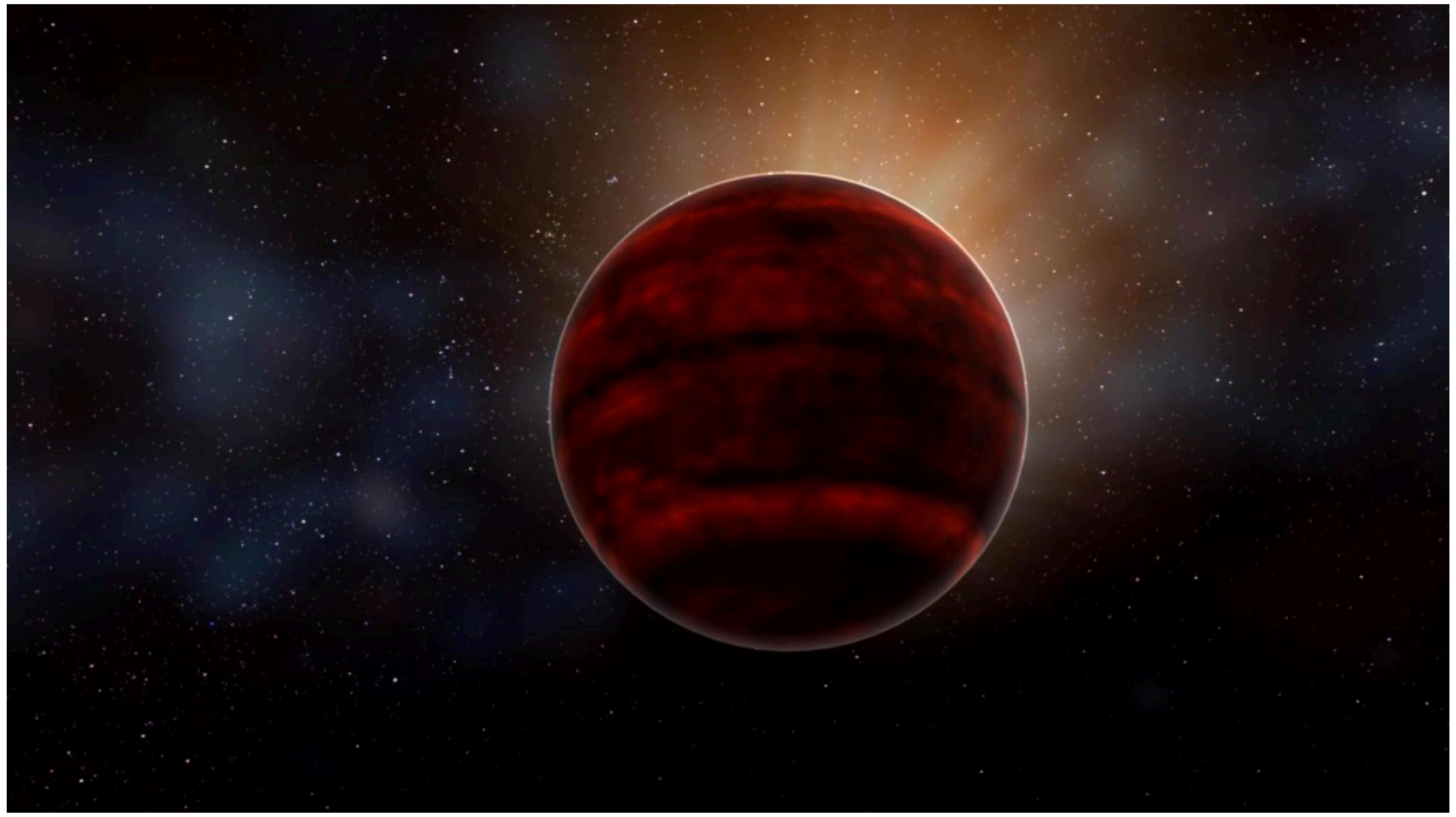


IMAGE: ARTIST IMPRESSION OF A RED DWARF STAR LIKE PROXIMA CENTAURI, THE NEAREST STAR TO OUR

CLASS SETUP

- **Students:** Graduate and Senior Undergraduates
- **Assumed Background:** Physics Degree + Basic astronomy
- **Space:** ISTB4 492
- **Time:** MW 1:30-2:50
- **Class Details:** danielcjacobs.com/edu/raclass/

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

- Two main class components
  - 1) the relevant tools from math, physics, astronomy
    - Traditional lectures + homework in WRH
  - 2) projects
- Materials posted on danielcjacobs.com/edu/raclass/
  Lecture slides, recordings
- All homework problems in handwriting due Monday in class

GRADING

- Cumulative point system
- Grade = **points awarded** / total assigned
- With extra credit this can be > 100%
- Final letter grade awarded according to this scale.
- Default values (unless otherwise specified):
  - Assignments: 1pt/question
  - Tests: 5pts/question
  - Projects: 10pts/milestone
  - I will attempt to balance these so no part becomes pointless
  - Estimated course point total: 150 +/- 25

A >95%
B >85%
C >75%
D >50%
F

Data Project:
Detect a flare at Prox. Cen

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

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.

Puts habitability of nearby system into question

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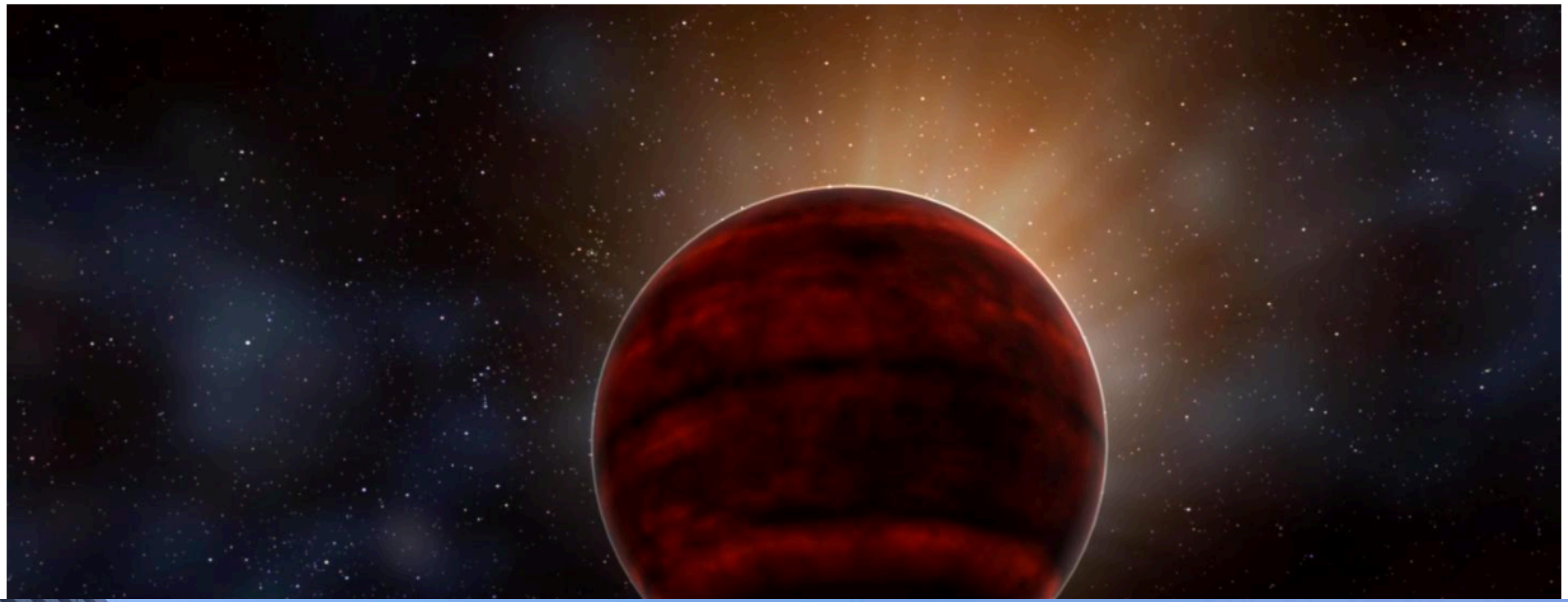

CLASS WORK

- **Homework** from Tools. Due next Monday occurring after a weeks time has elapsed.
- **Class projects**
  Documentation of incremental progress.
  Teamwork encouraged, but your contribution must be clearly identified.
- **First month:** Background physics, instrument principles. Homework
- **Second month:** Radiation and synthesis imaging. Synthesis tutorials and ALMA project
- **Third month:** Spectral lines, pulsars. Start 21cm project
- **Fourth Month:**. Other cool objects, finish 21cm project. Extra credit.
- Final oral reports last week of class, written report due on final date.

WORK EXPECTATIONS

- Homework

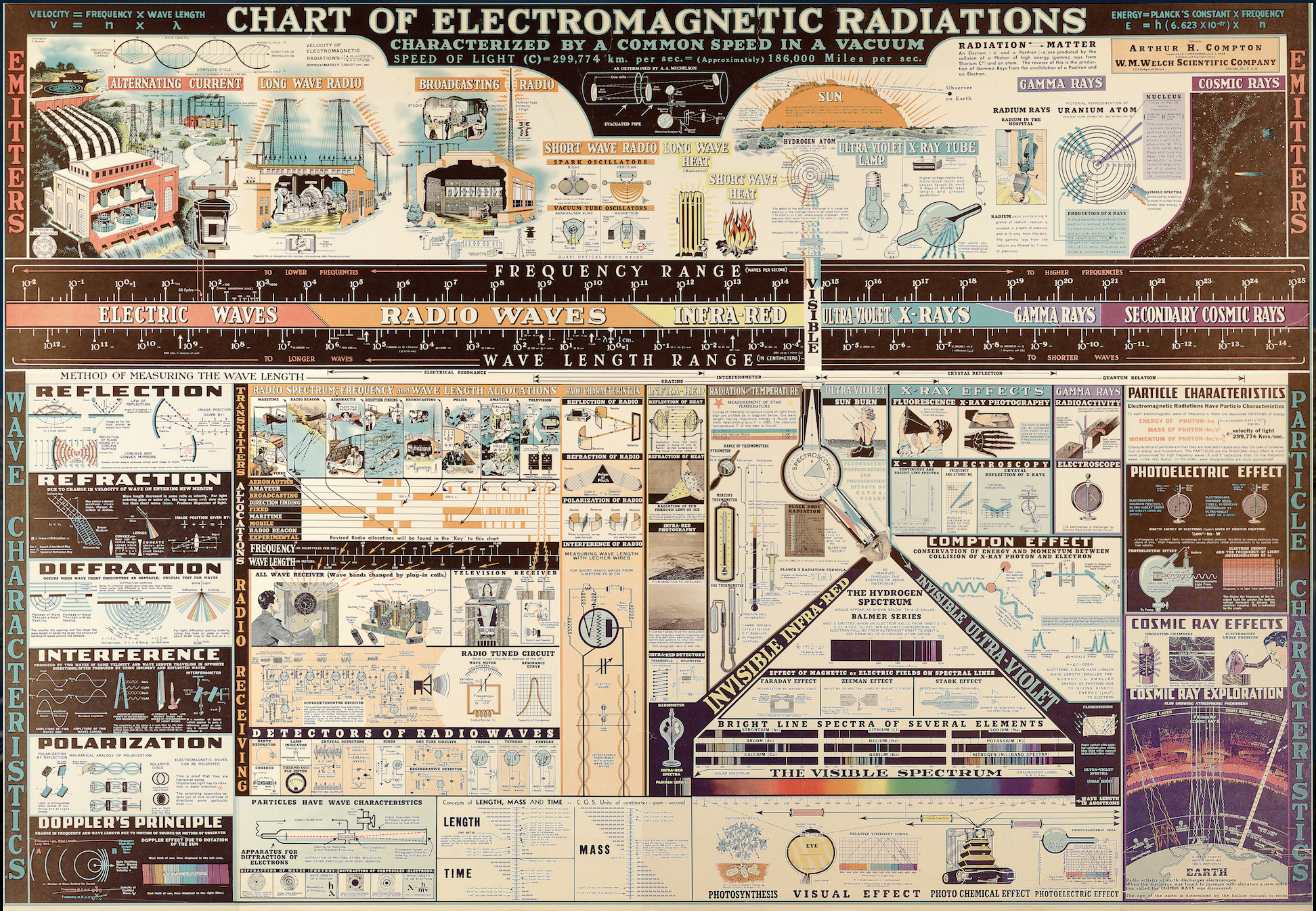
CHART OF ELECTROMAGNETIC RADIATIONS
CHARACTERIZED BY A COMMON SPEED IN A VACUUM
SPEED OF LIGHT (C)=299,774 km. per sec.= (Approximately) 186,000 Miles per sec.
VELOCITY = FREQUENCY X WAVE LENGTH
V = n x λ
ENERGY=PLANCK'S CONSTANT X FREQUENCY
ARTHUR H. COMPTON
W.M.WELCH SCIENTIFIC COMPANY
EMITTERS
ALTERNATING CURRENT
LONG WAVE RADIO
BROADCASTING RADIO
SHORT WAVE RADIO
LONG WAVE HEAT
SHORT WAVE HEAT
SUN
ULTRA-VIOLET LAMP
X-RAY TUBE
GAMMA RAYS
COSMIC RAYS
FREQUENCY RANGE
ELECTRIC WAVES
RADIO WAVES
INFRA-RED
VISIBLE
ULTRA-VIOLET
X-RAYS
GAMMA RAYS
SECONDARY COSMIC RAYS
WAVE LENGTH RANGE
METHOD OF MEASURING THE WAVE LENGTH
WAVE CHARACTERISTICS
REFLECTION
REFRACTION
DIFFRACTION
INTERFERENCE
POLARIZATION
DOPPLER'S PRINCIPLE
TRANSMITTERS
ALLOCATIONS
RADIO RECEIVING
RADIO SPECTRUM; FREQUENCY and WAVE LENGTH ALLOCATIONS
DETECTORS OF RADIO WAVES
RADIO TUNED CIRCUIT
SPECTROSCOPE
INVISIBLE INFRA-RED
INVISIBLE ULTRA-VIOLET
COMPTON EFFECT
THE HYDROGEN SPECTRUM
BALMER SERIES
BRIGHT LINE SPECTRA OF SEVERAL ELEMENTS
THE VISIBLE SPECTRUM
PARTICLE CHARACTERISTICS
PHOTOELECTRIC EFFECT
COSMIC RAY EFFECTS
COSMIC RAY EXPLORATION
EARTH
PARTICLE CHARACTERISTICS
PARTICLES HAVE WAVE CHARACTERISTICS
LENGTH
MASS
TIME
PHOTOSYNTHESIS
VISUAL EFFECT
PHOTO CHEMICAL EFFECT
PHOTOELECTRIC EFFECT

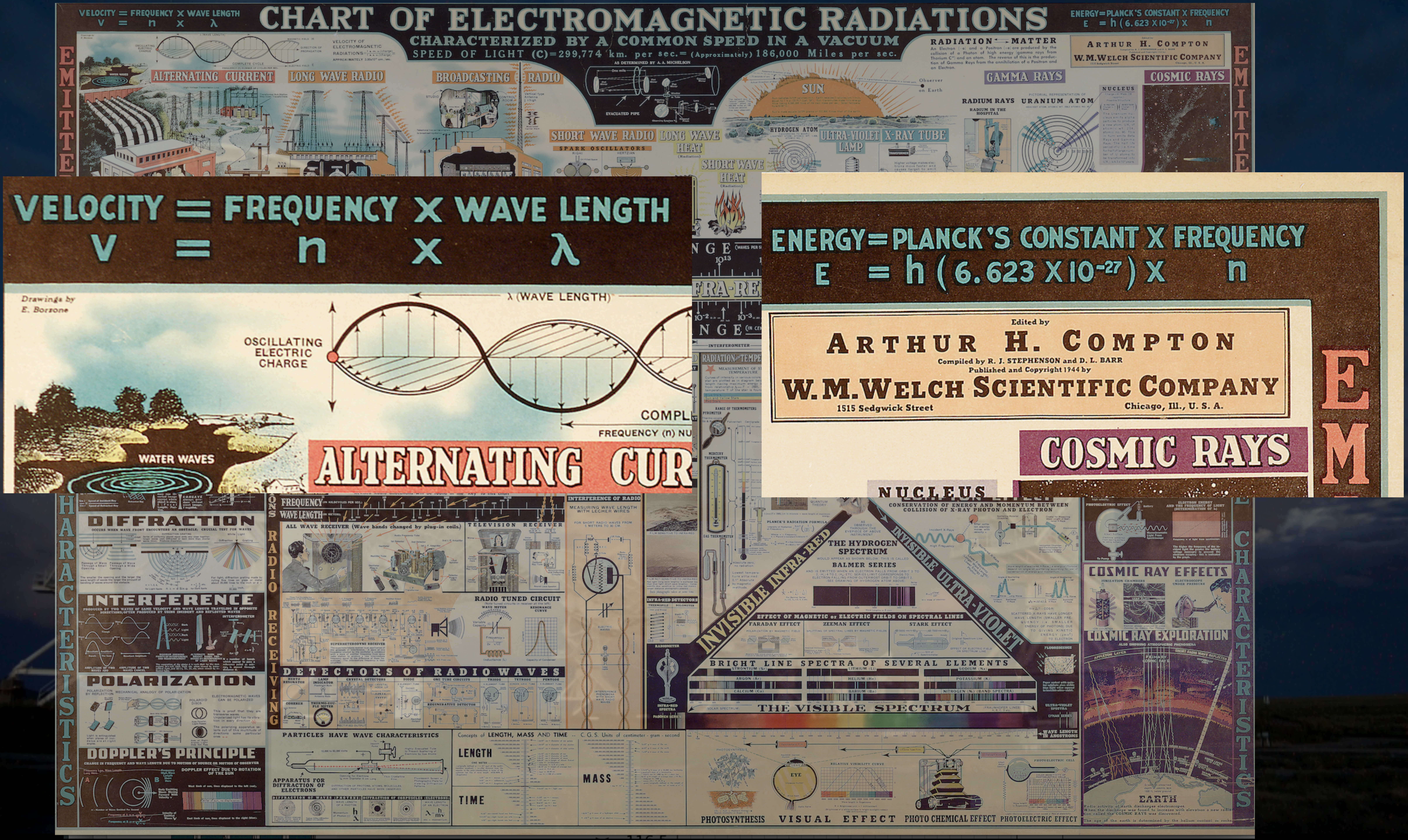
CHART OF ELECTROMAGNETIC RADIATIONS
CHARACTERIZED BY A COMMON SPEED IN A VACUUM
VELOCITY = FREQUENCY X WAVE LENGTH
v = n x λ
Drawings by E. Borzone
OSCILLATING ELECTRIC CHARGE
λ (WAVE LENGTH)
WATER WAVES
ALTERNATING CUR
ENERGY=PLANCK'S CONSTANT X FREQUENCY
E = h (6.623 X 10-27) X n
Edited by
ARTHUR H. COMPTON
Compiled by R. J. STEPHENSON and D. L. BARR
Published and Copyright 1944 by
W.M.WELCH SCIENTIFIC COMPANY
1515 Sedgwick Street
Chicago, Ill., U. S. A.
COSMIC RAYS
NUCLEUS
ALTERNATING CURRENT
LONG WAVE RADIO
BROADCASTING
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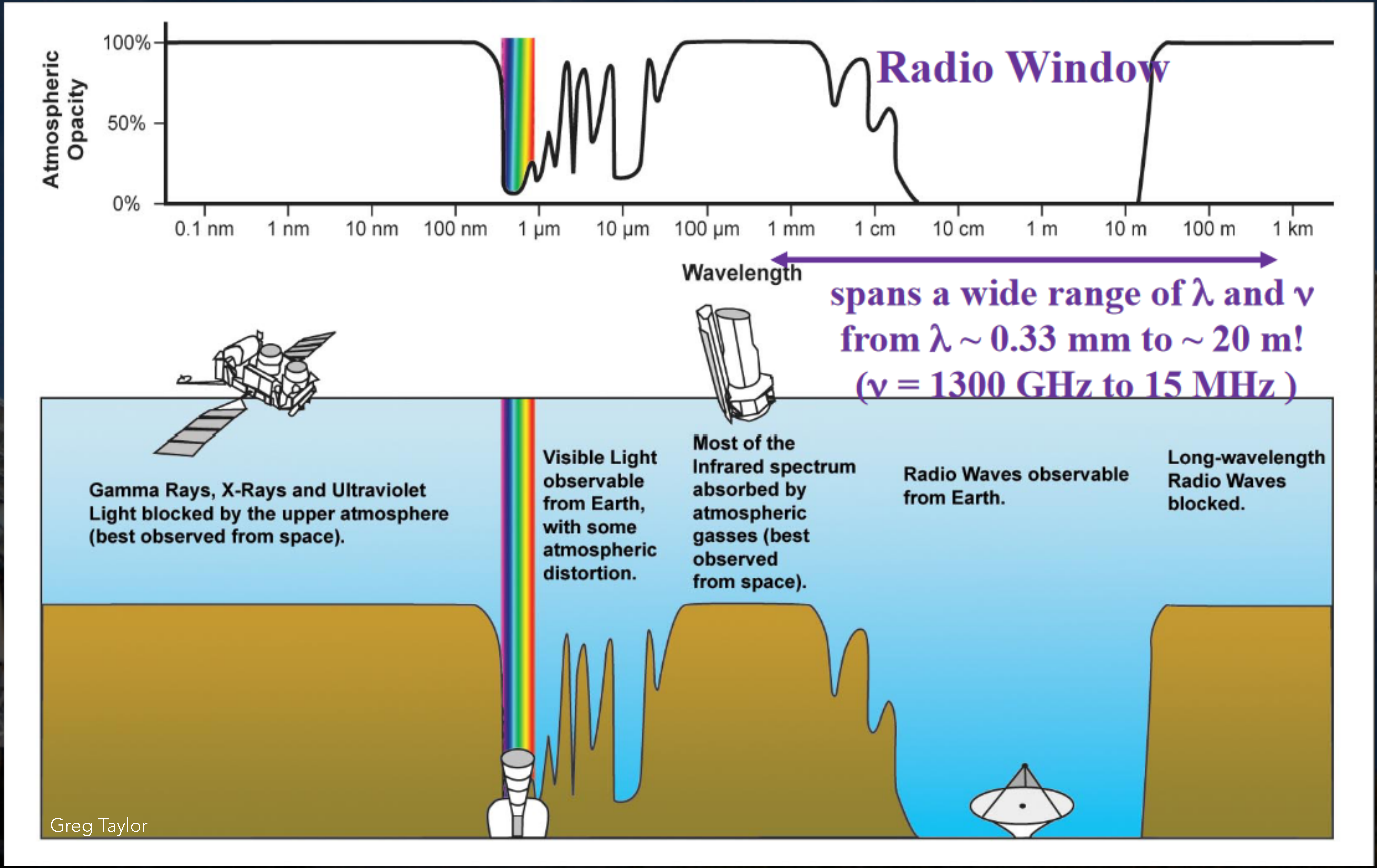
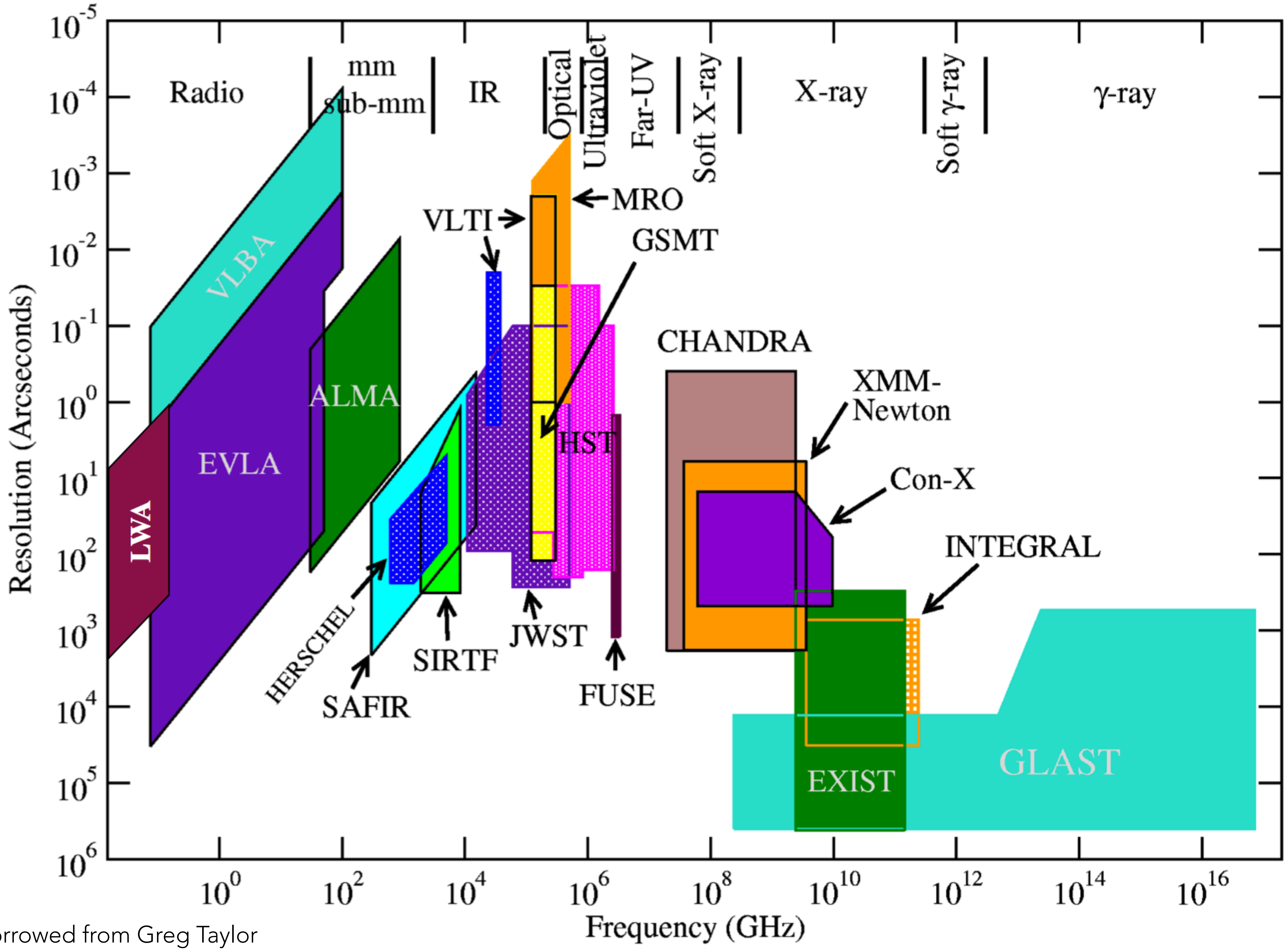
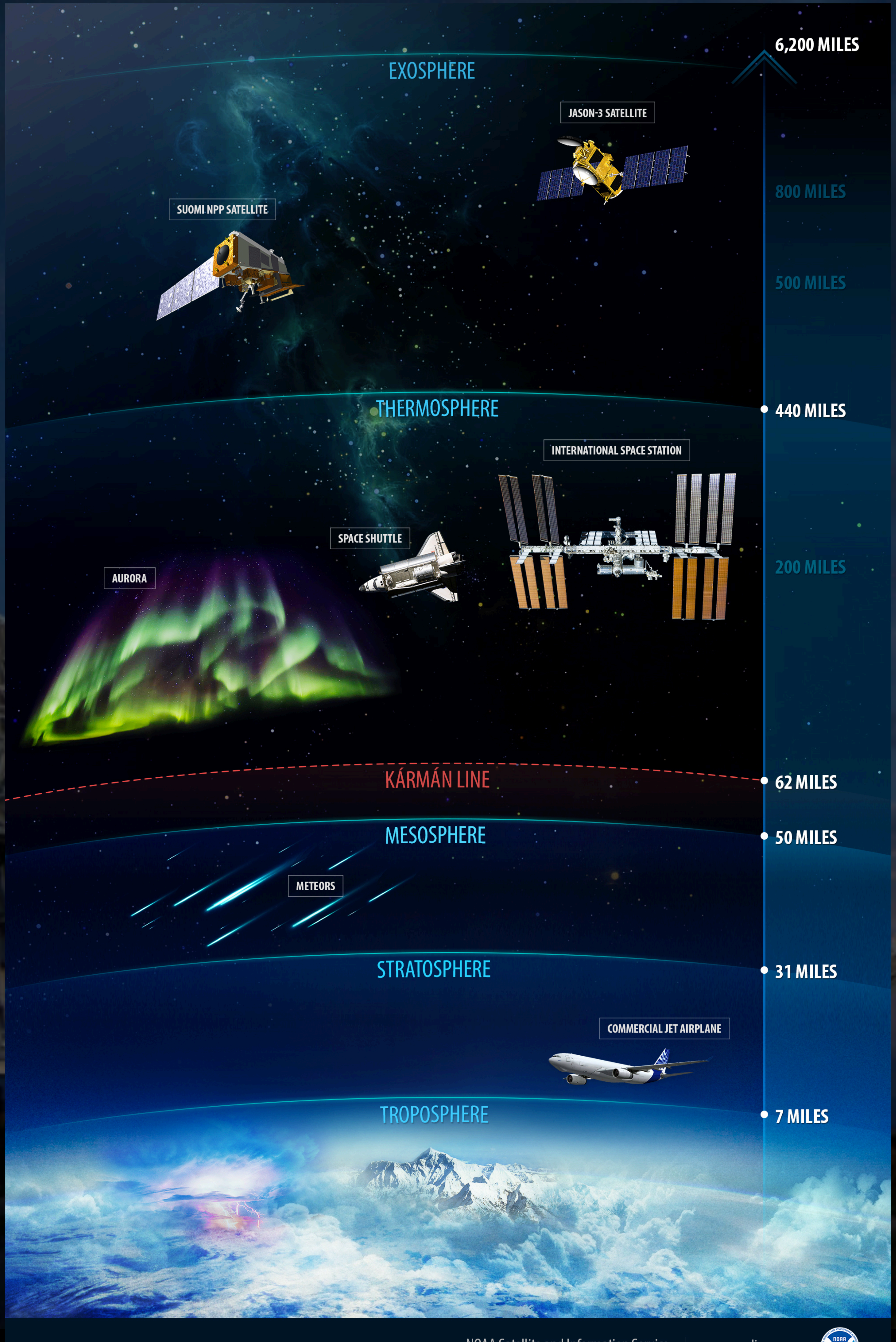
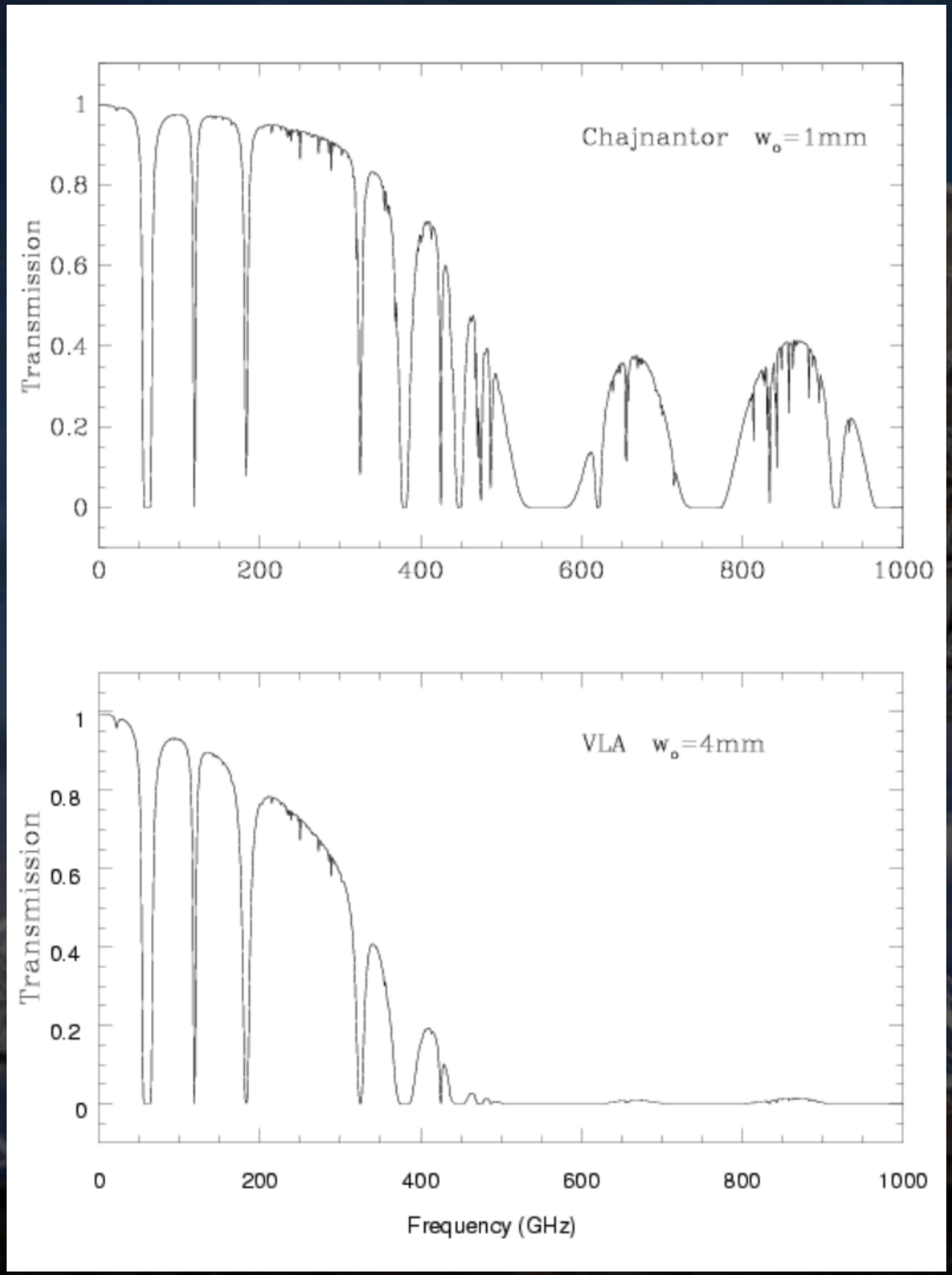

Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Radio Window
spans a wide range of λ and ν
from λ ~ 0.33 mm to ~ 20 m!
(ν = 1300 GHz to 15 MHz)
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed 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

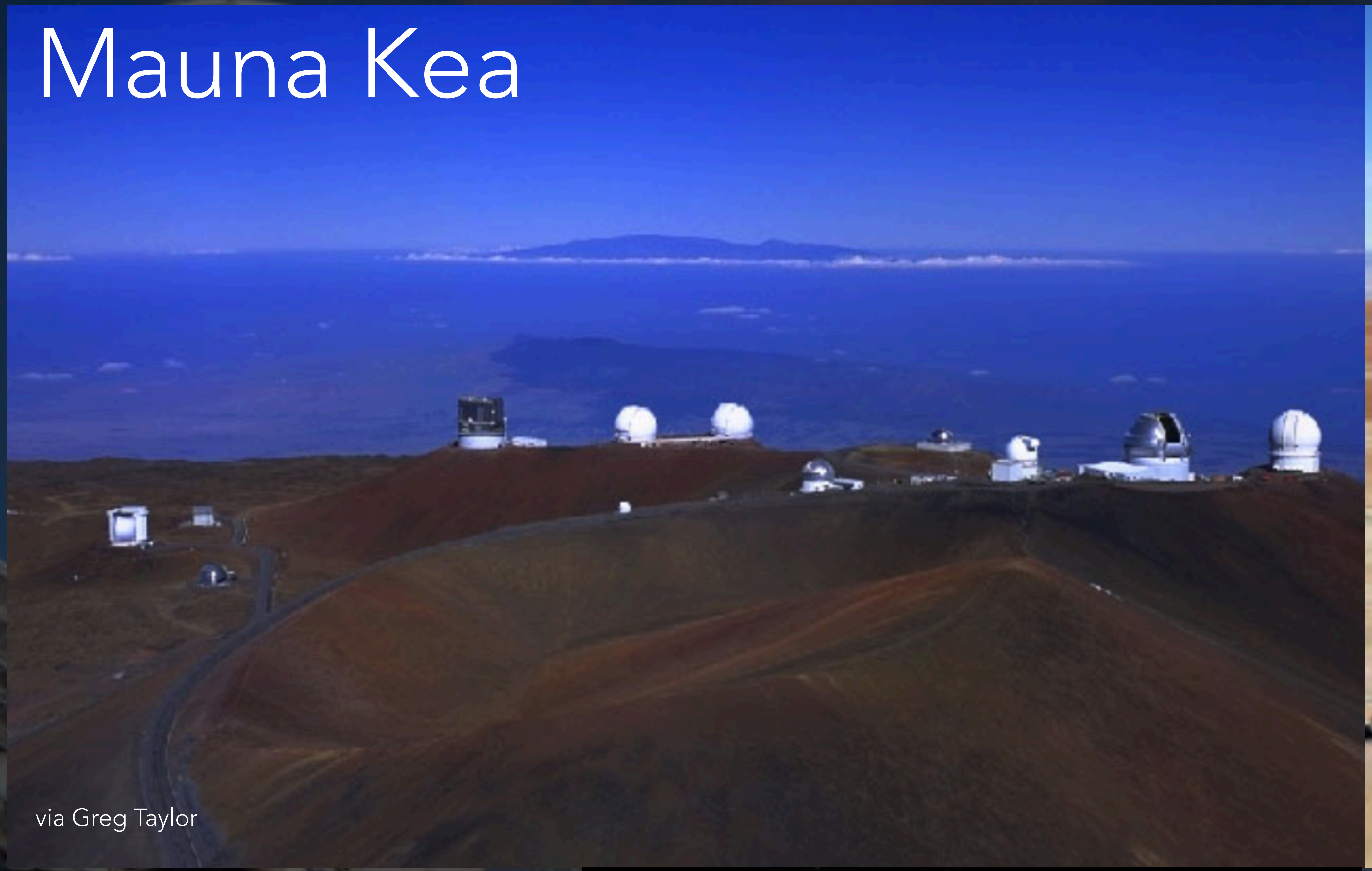


WATER
22.2 GHz, 183Ghz

O2
60GHz, 119GHz

HIGH AND DRY SITES

Mauna Kea



via Greg Taylor

Atacama Desert

ALMA Observatory

Space

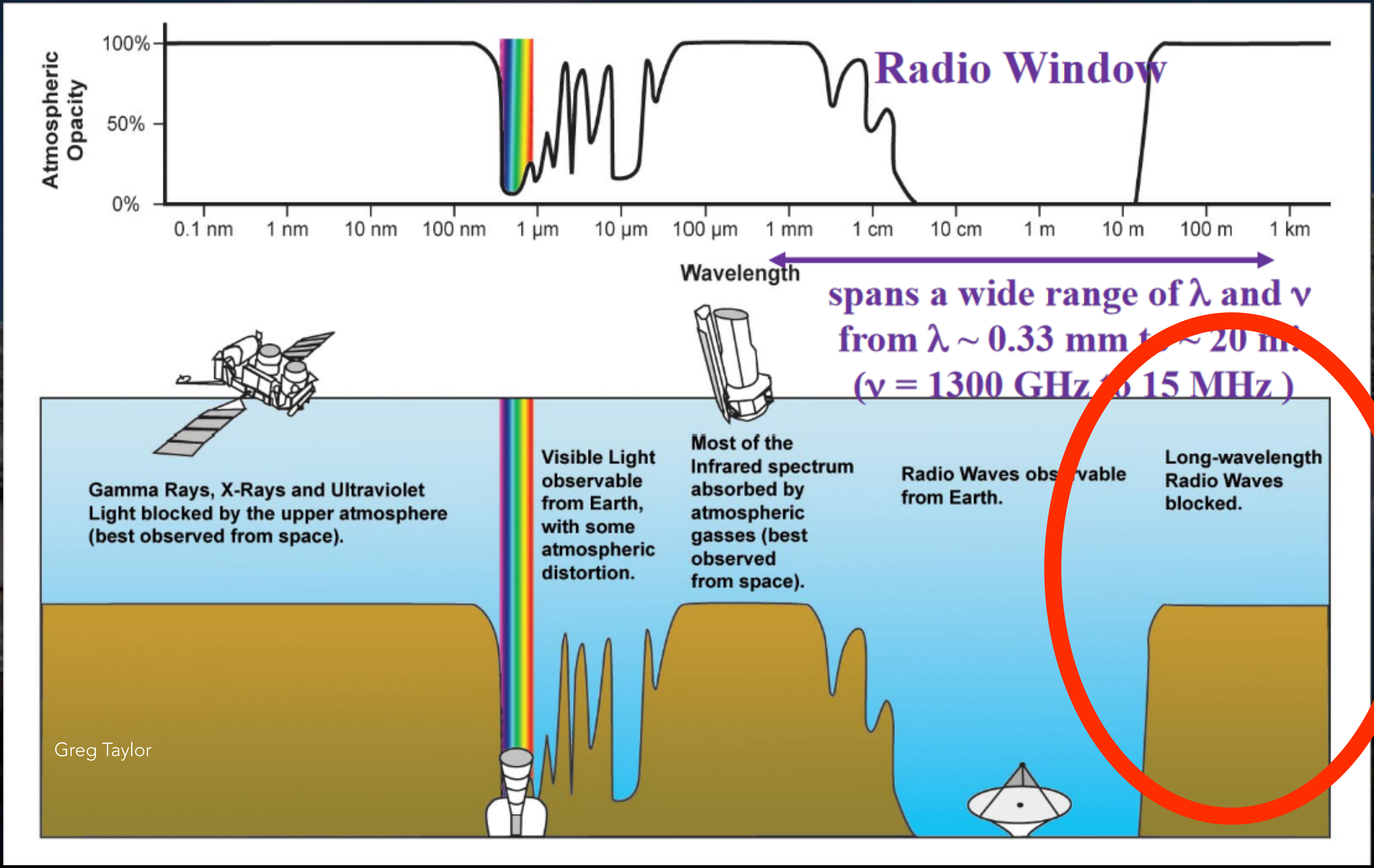
ESA

Antarctica

Dome C shown here

Xue-Fei Gong/Purple Mountain Observatory

THE LOW END



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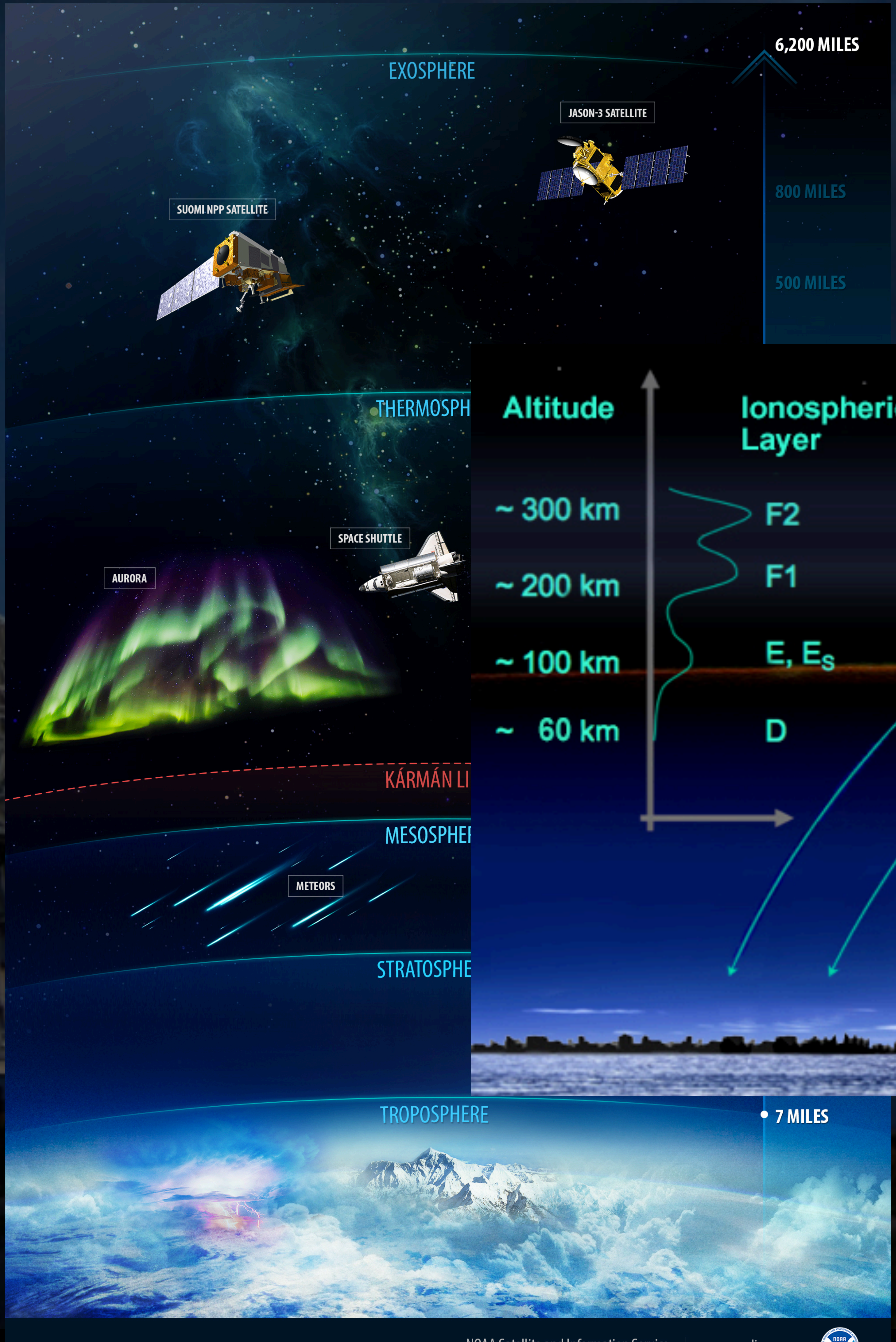
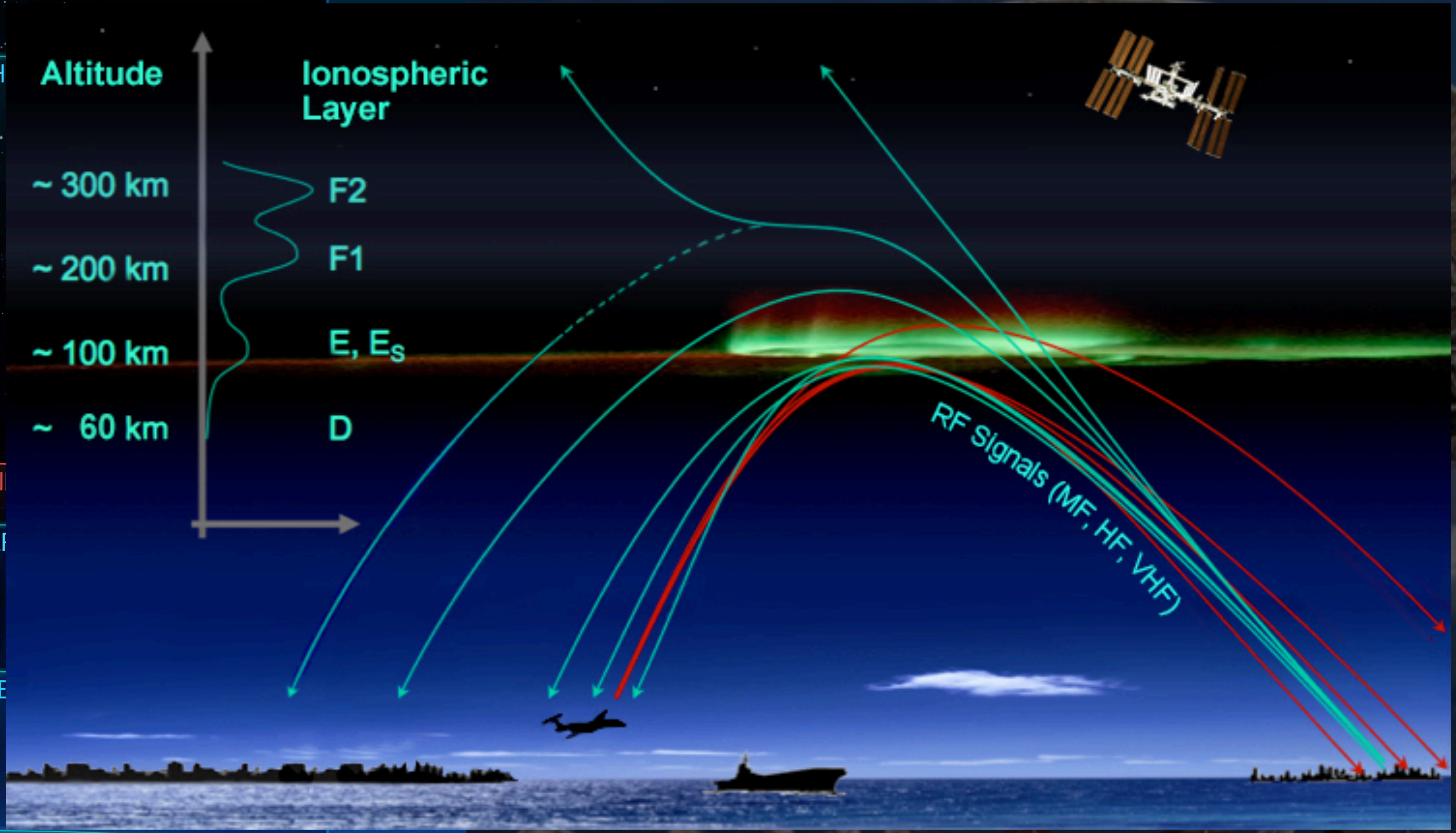
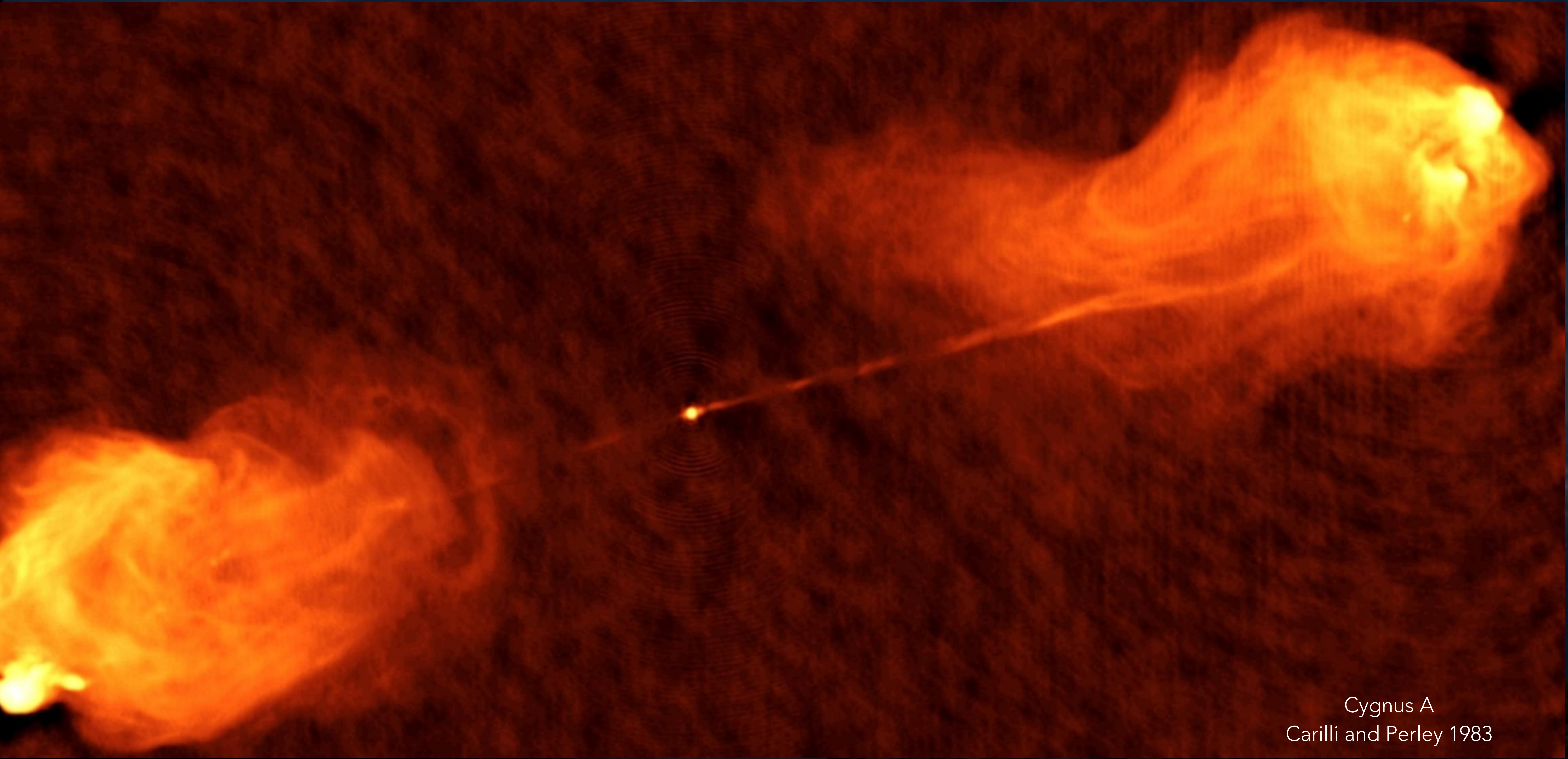
LOW FREQUENCY EDGE



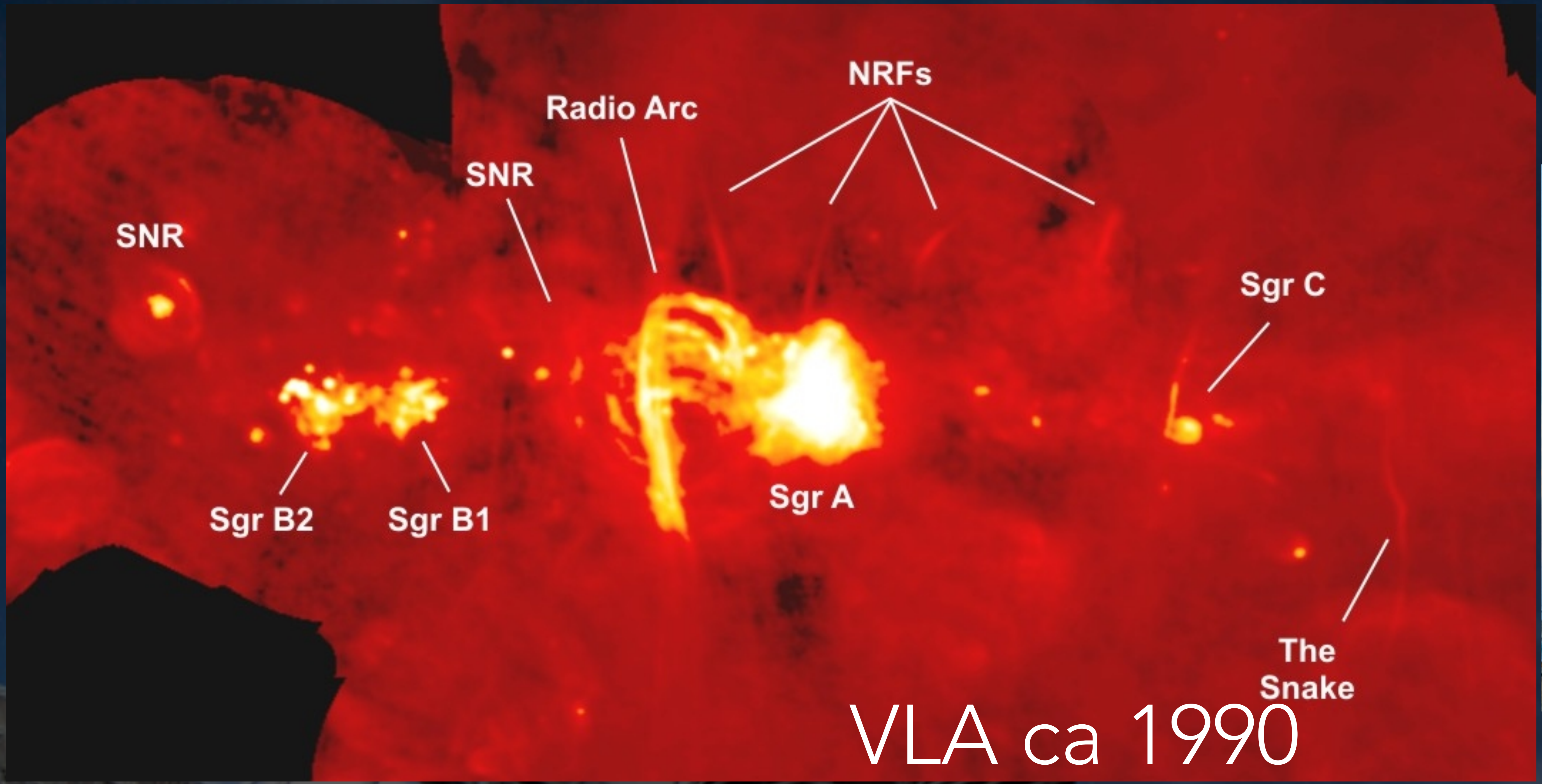


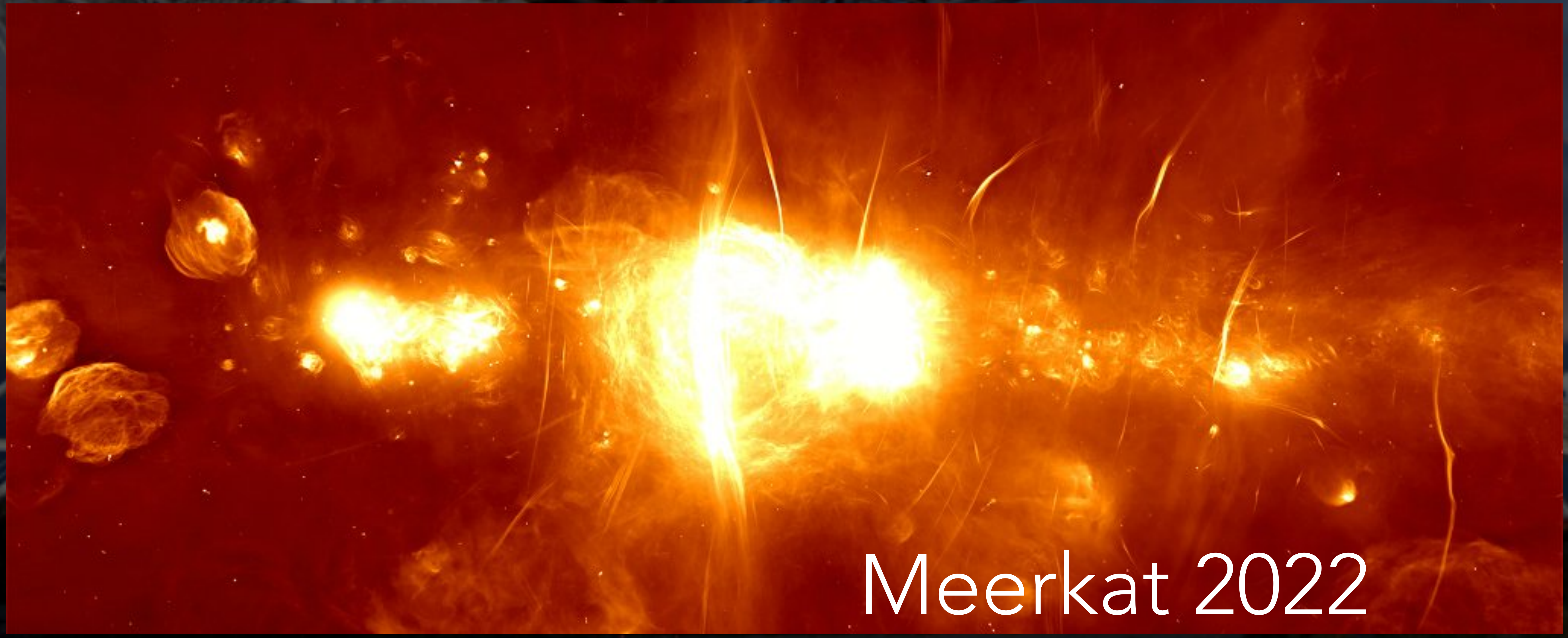

The Very Large Array



Cygnus A
Carilli and Perley 1983


Webb (infrared)


NRFs
Radio Arc
SNR
SNR
Sgr C
Sgr B2
Sgr B1
Sgr A
The Snake
VLA ca 1990


Meerkat 2022

NASA, ESA, CSA, STScI, SARAO, Samuel Crowe (UVA), John Bally (CU), Ruben Fedriani (IAA-CSIC), Ian Heywood (Oxford)

Cosmic Microwave Background

Background temperature fluctuations at 300GHz

Planck 2015

NEXT

- Derivation of Intensity and Brightness temp
- More objects.

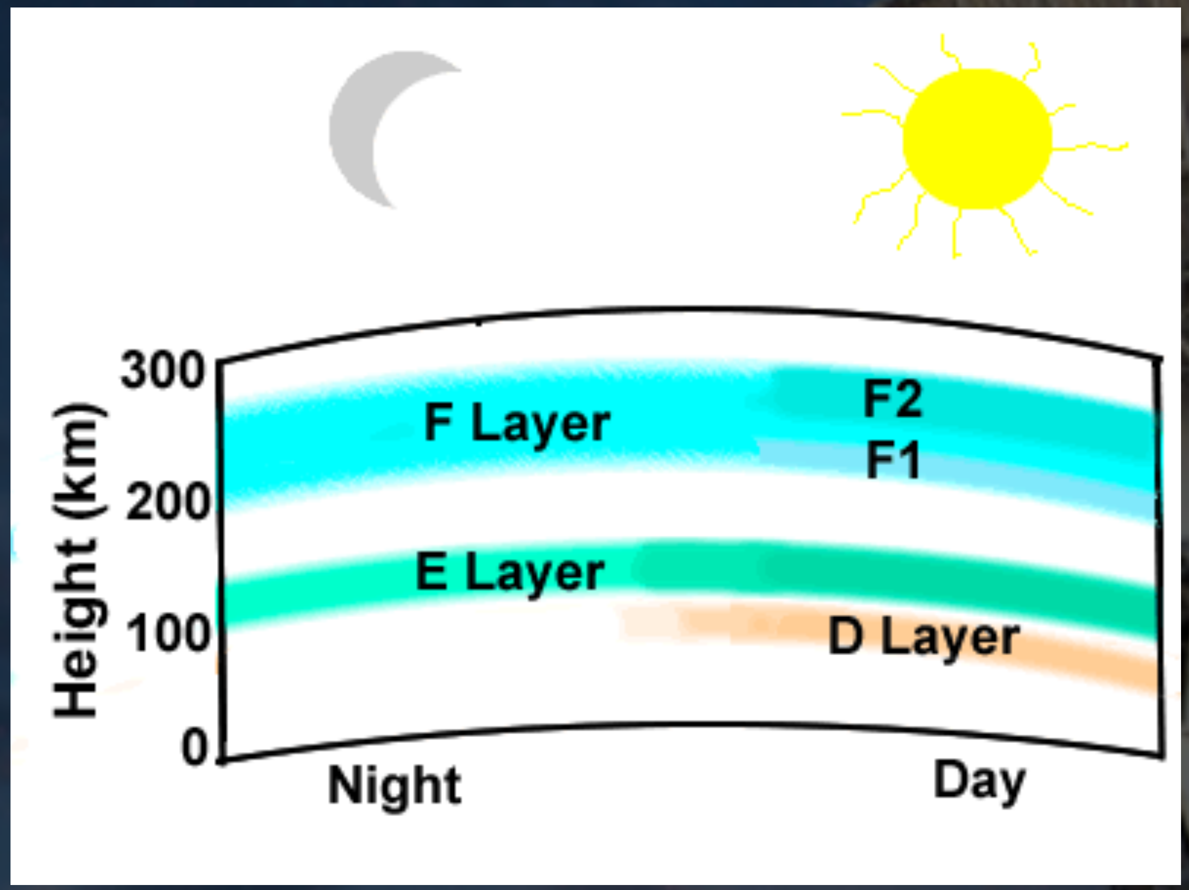
IONOSPHERE WEATHER MATTERS A LOT

lower cutoff frequency depends on density (n_0)

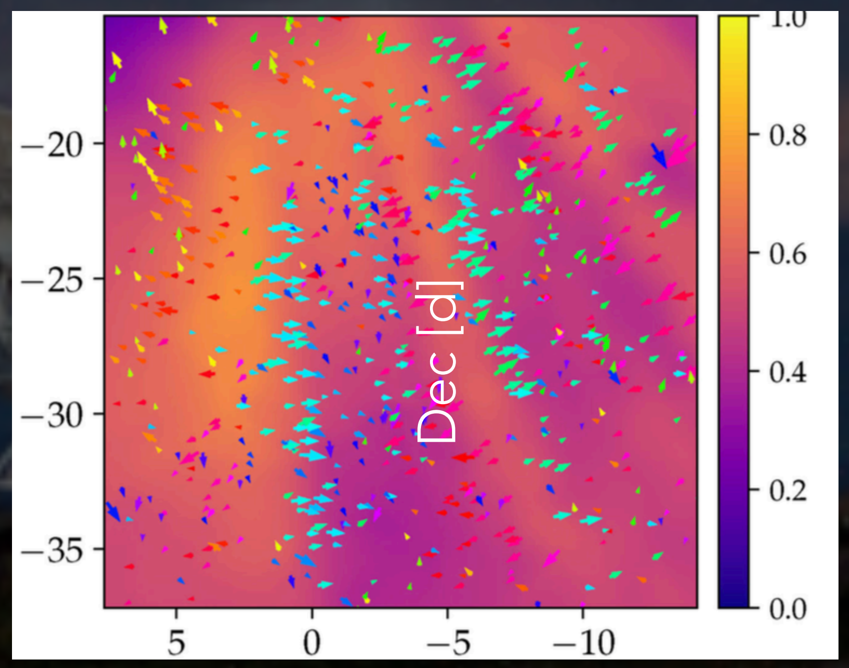
$$\omega_{pe} \triangleq \left(\frac{n_0 e^2}{\varepsilon_0 m_e} \right)^{1/2}$$

Daytime ~11MHz
Night time ~ 4.5 MHz

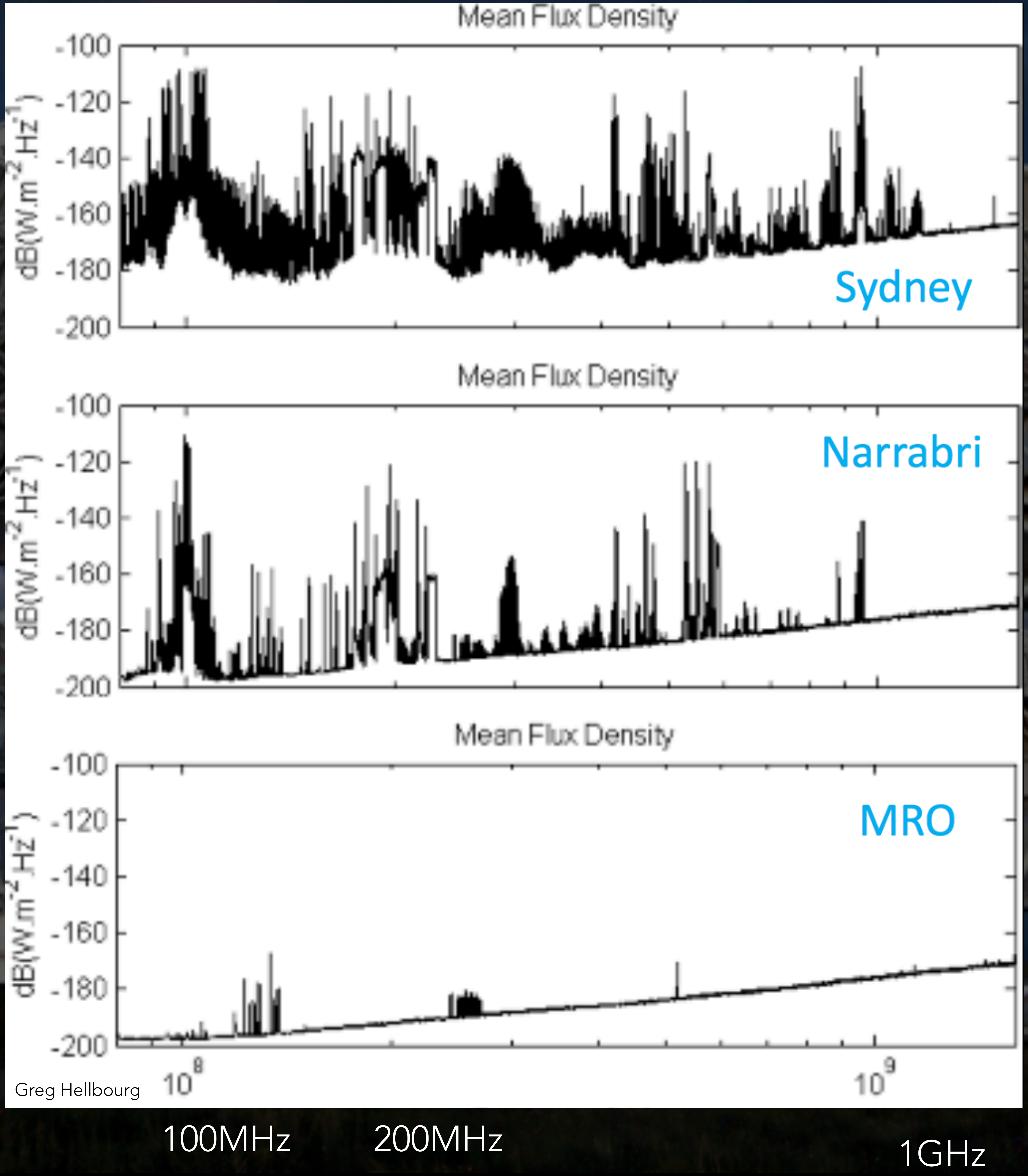
Denser in the sun!



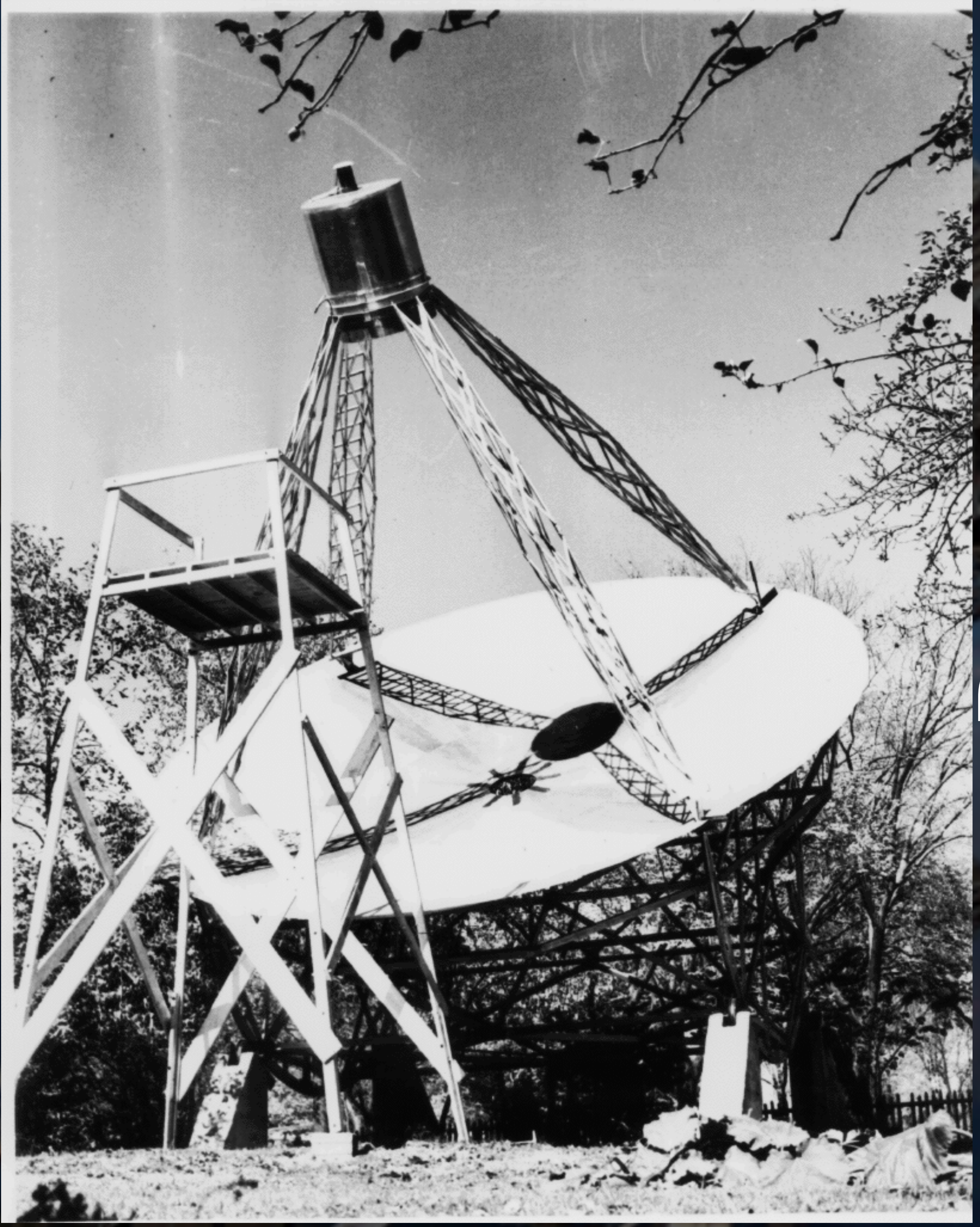
Refraction at 500MHz



RADIO FREQUENCY INTERFERENCE

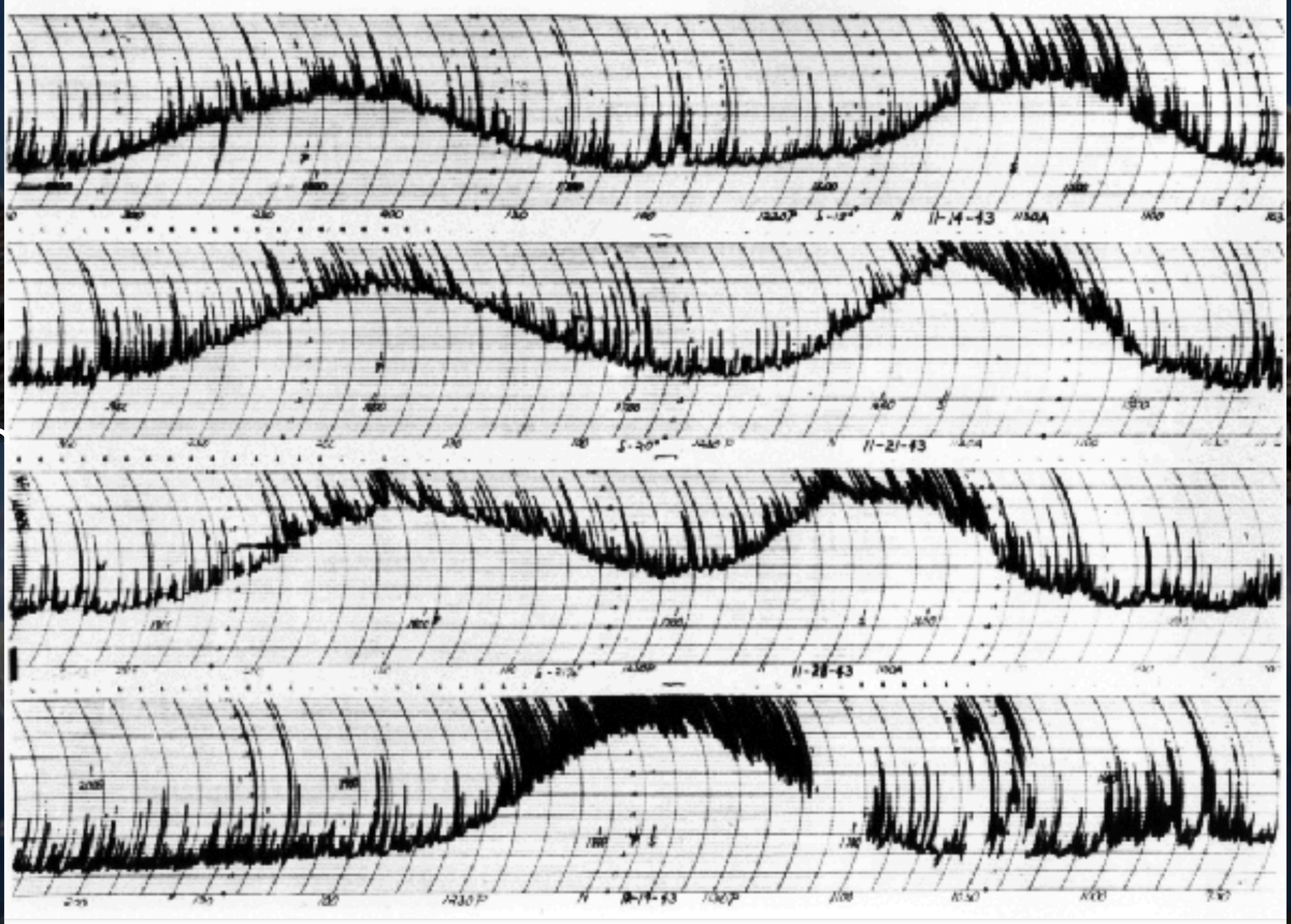


INTERFERENCE IS NOT NEW!



Reber Dish 1937

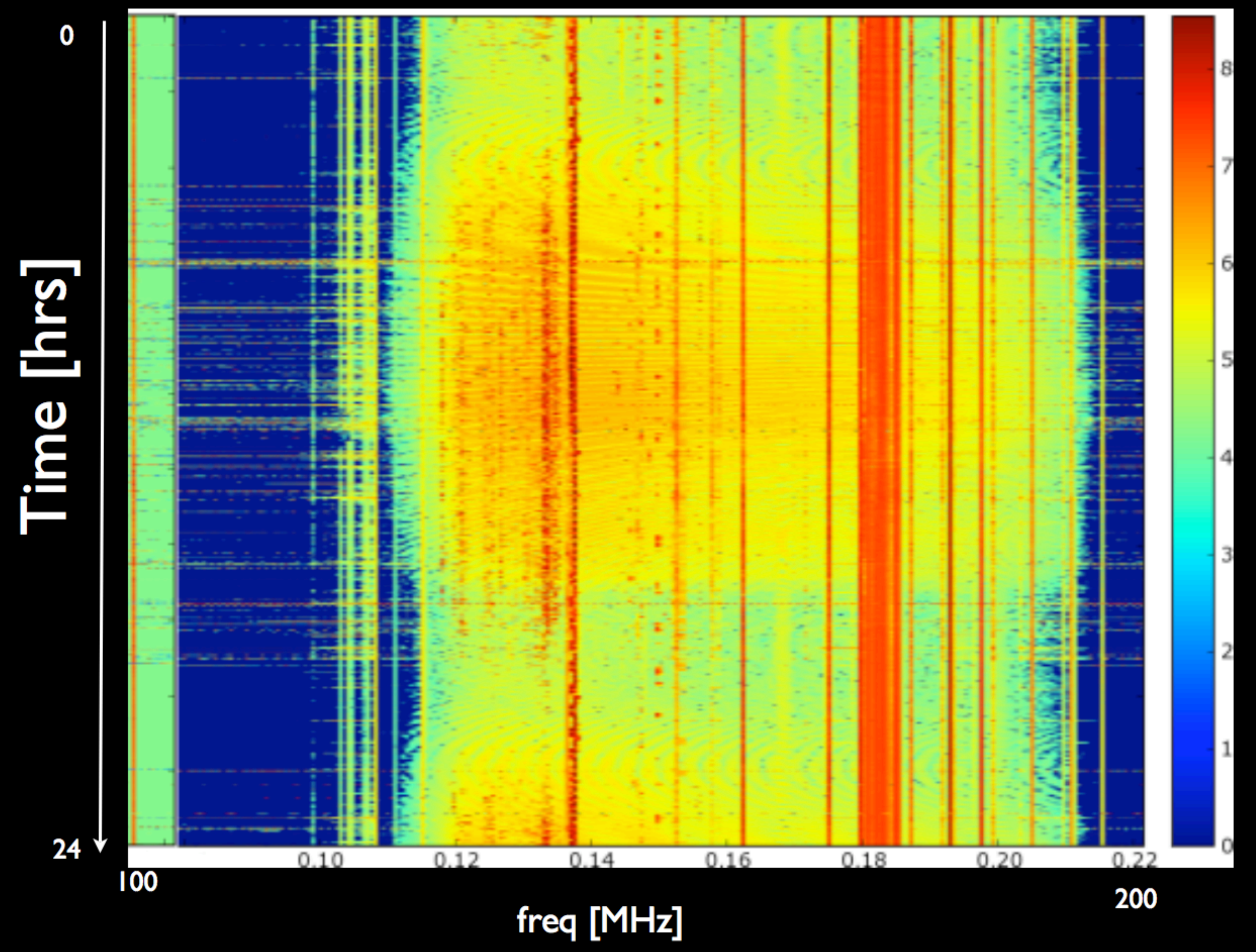
Days



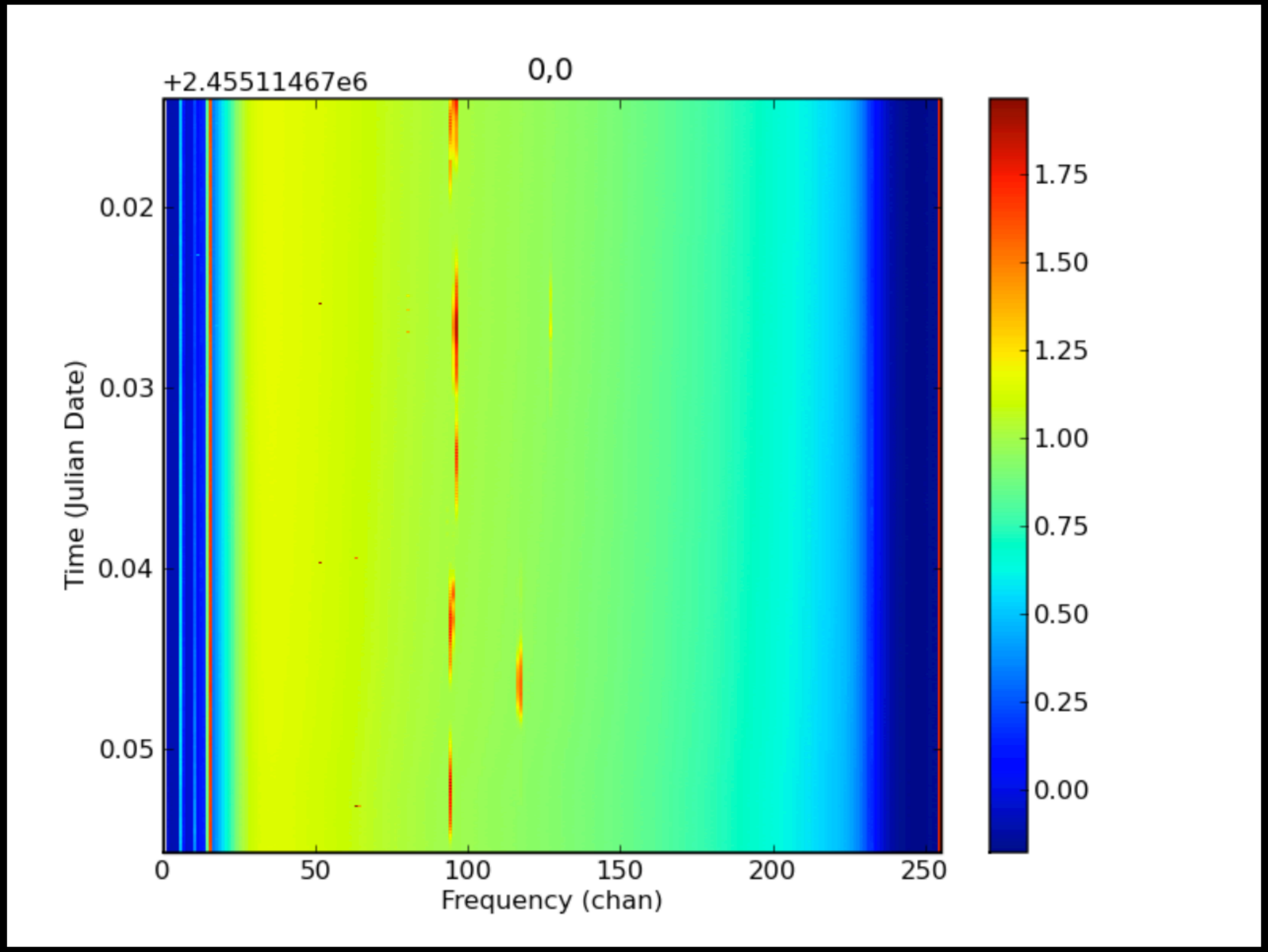
Power vs time

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