

# The Beautiful Skies for ALL

National Astronomical Observatory of Japan  
Masatoshi Ohishi  
masatoshi.ohishi@nao.ac.jp

National Institutes of Natural Sciences

National Astronomical Observatory of Japan

国立天文台

National Astronomical Observatory of Japan

NINS

大学共同利用機関法人  
自然科学研究機構

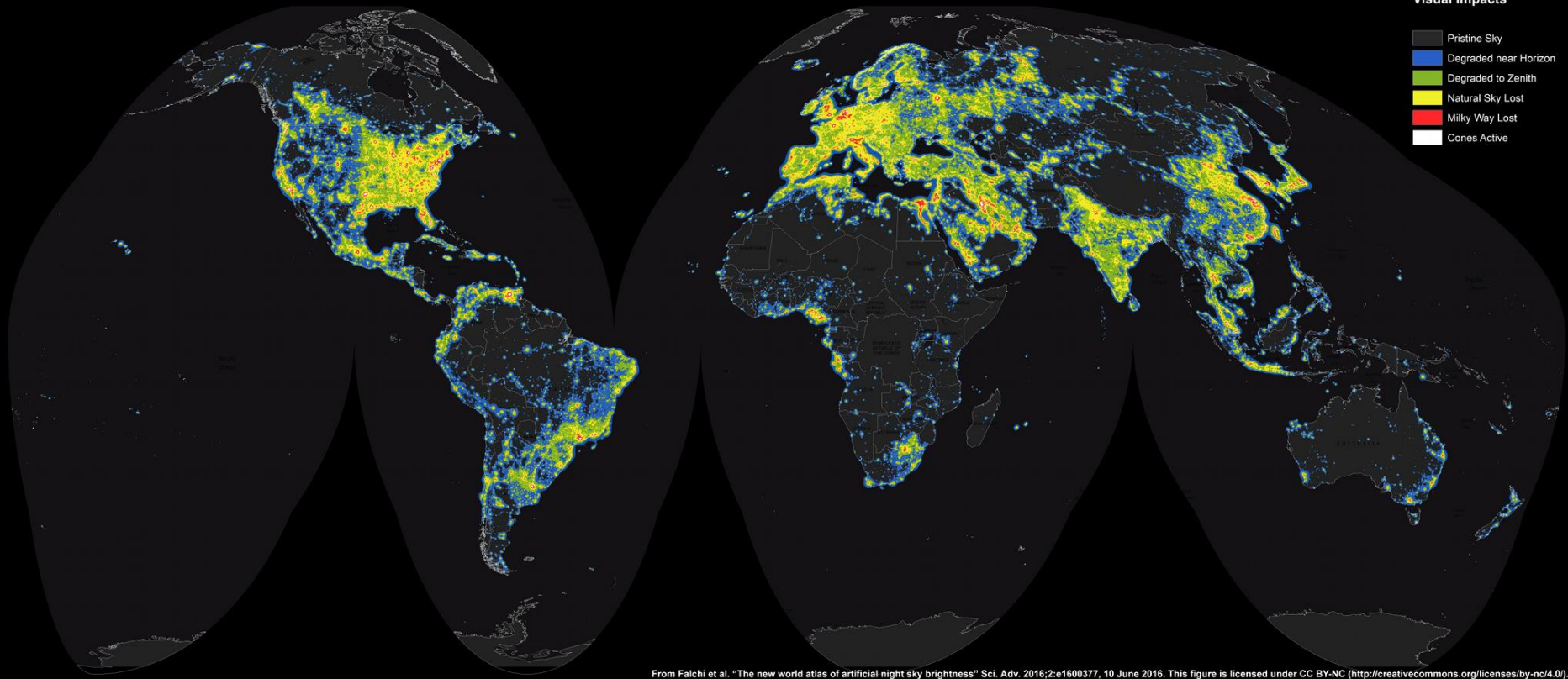


14th UNISEC Global

© Alex Tudorică

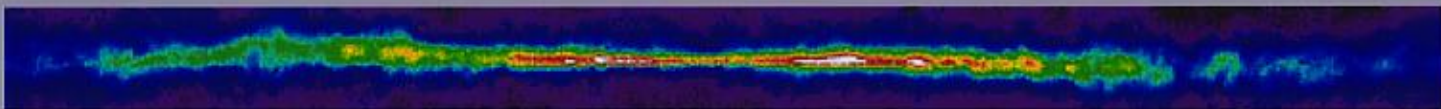




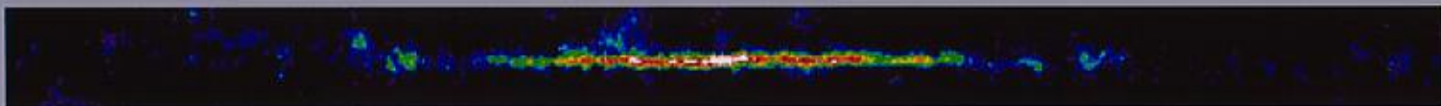


From Falchi et al. "The new world atlas of artificial night sky brightness" *Sci. Adv.* 2016;2:e1600377, 10 June 2016. This figure is licensed under CC BY-NC (<http://creativecommons.org/licenses/by-nc/4.0/>).

Atomic Hydrogen



Molecular Hydrogen



Infrared



Near Infrared



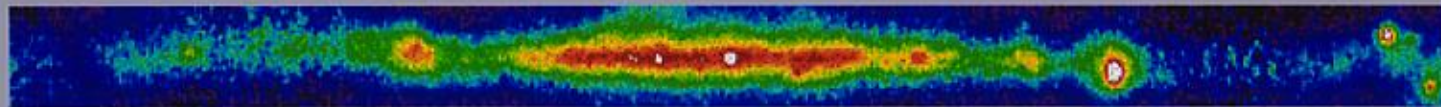
Optical



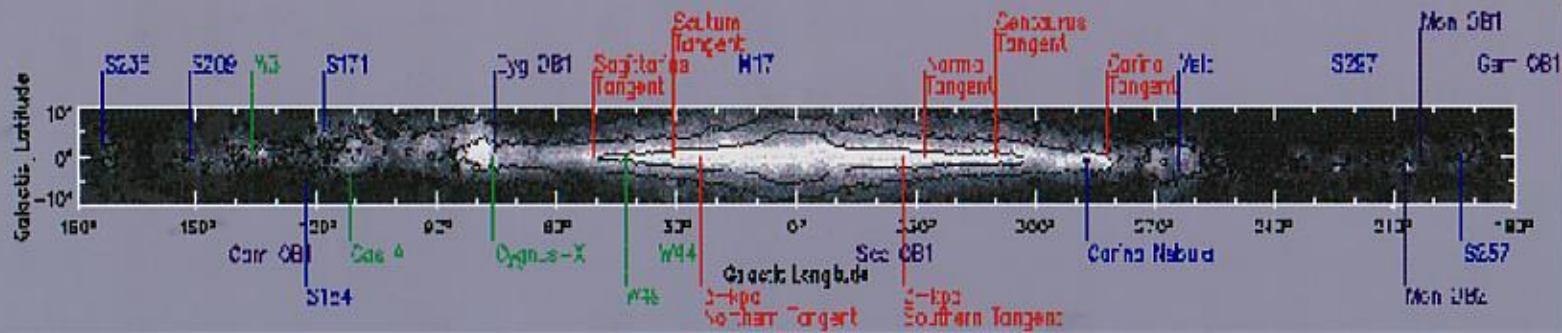
X-Ray



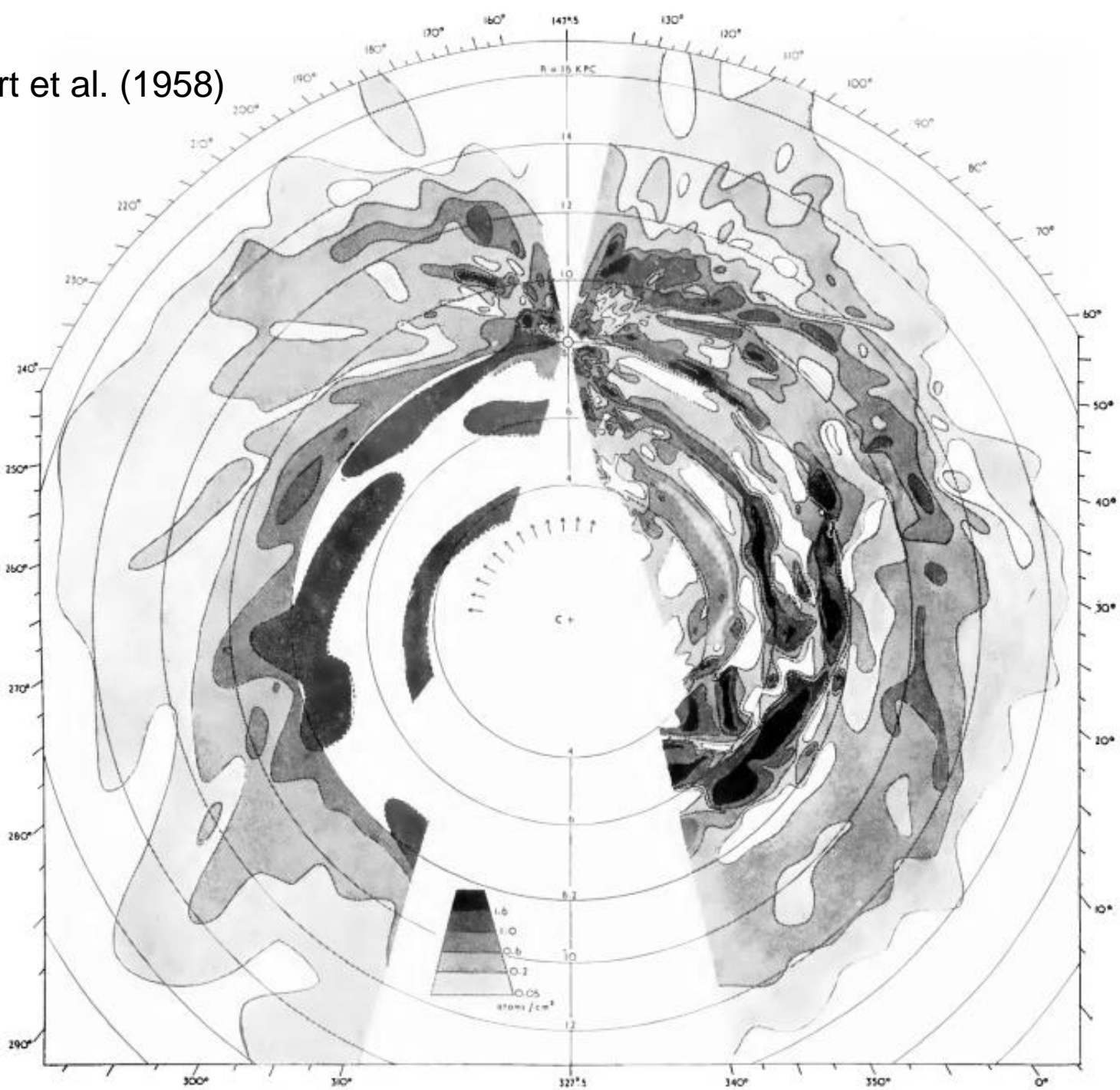
Gamma Ray

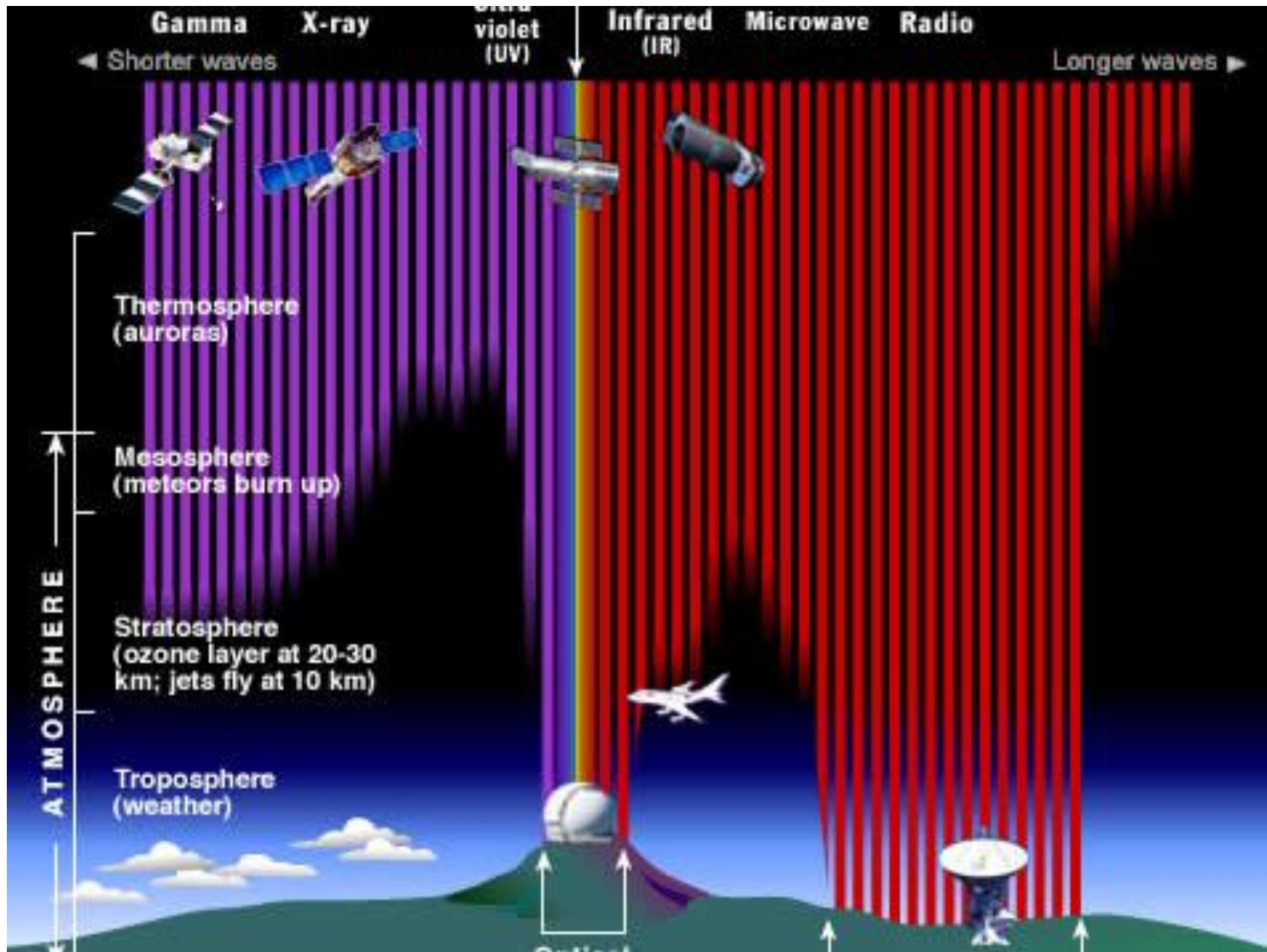


Finder



Credit: Oort et al. (1958)



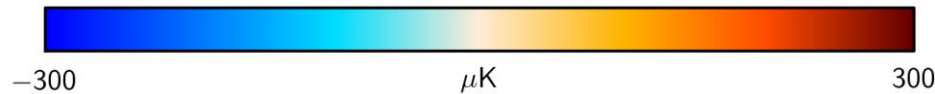
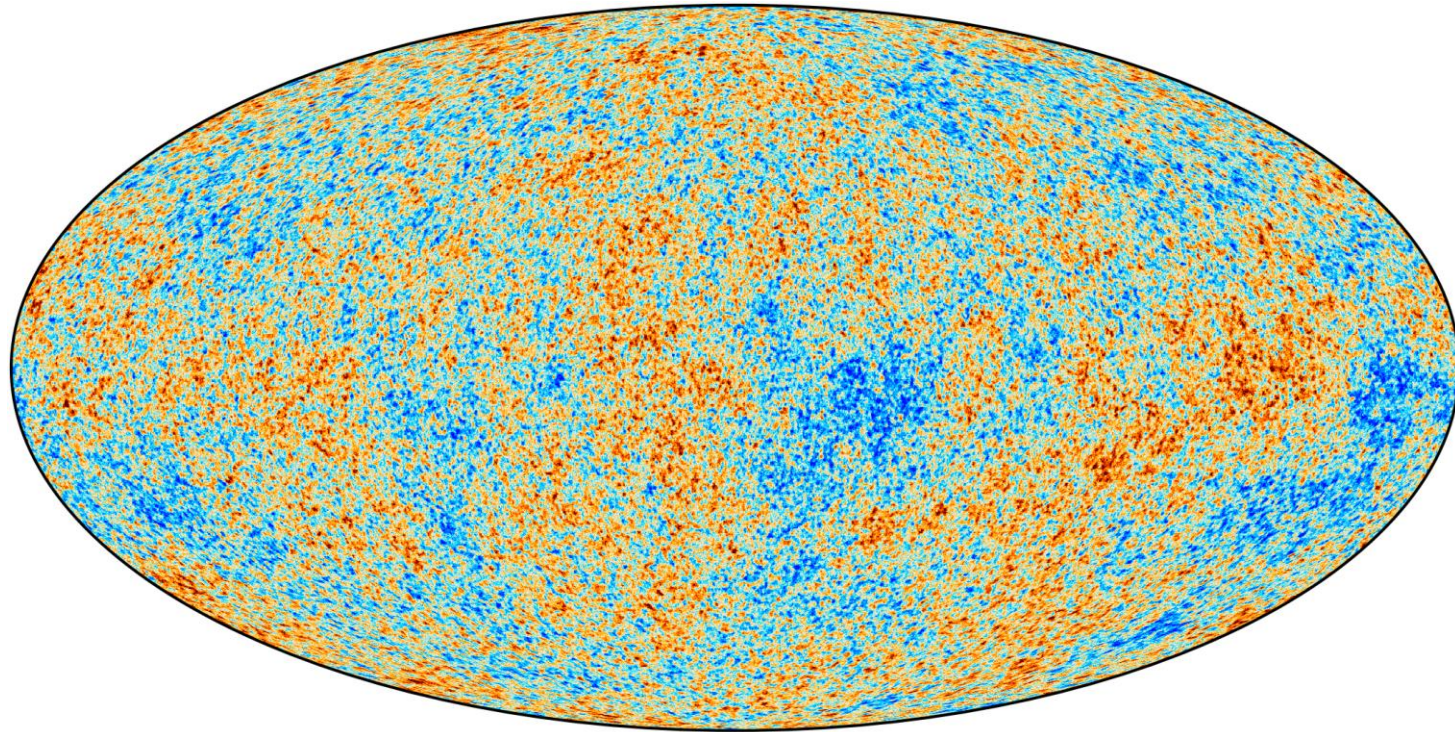


## Electromagnetic waves

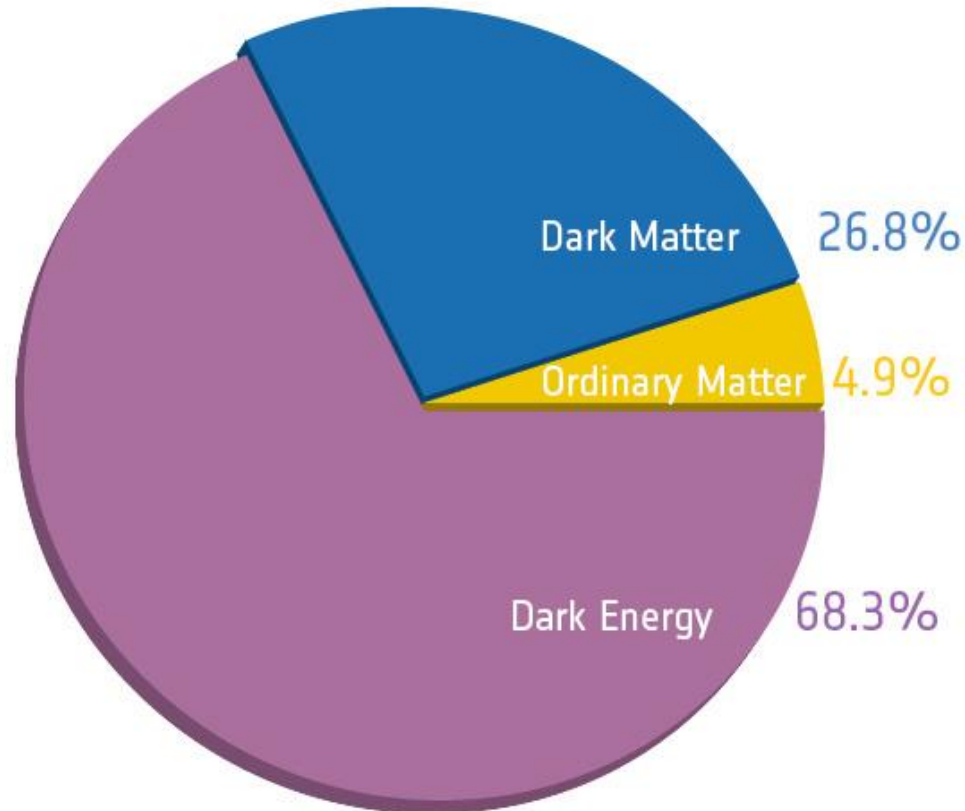
(Credit: STSci/JHU/NASA)



# Cosmic Microwave Background radiation by the Planck mission

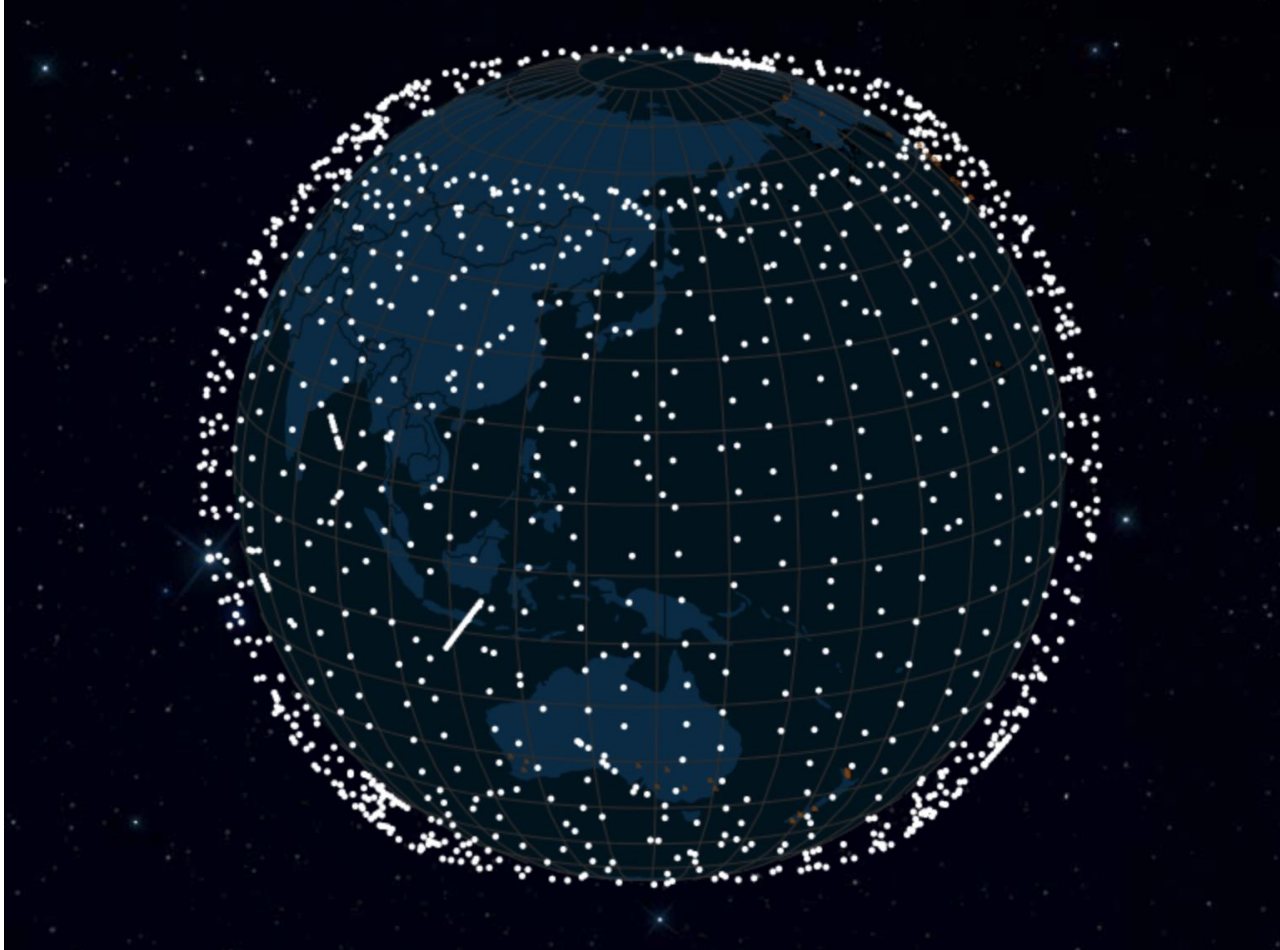


# We know a small portion only



Credit: ESA and the Planck collaboration

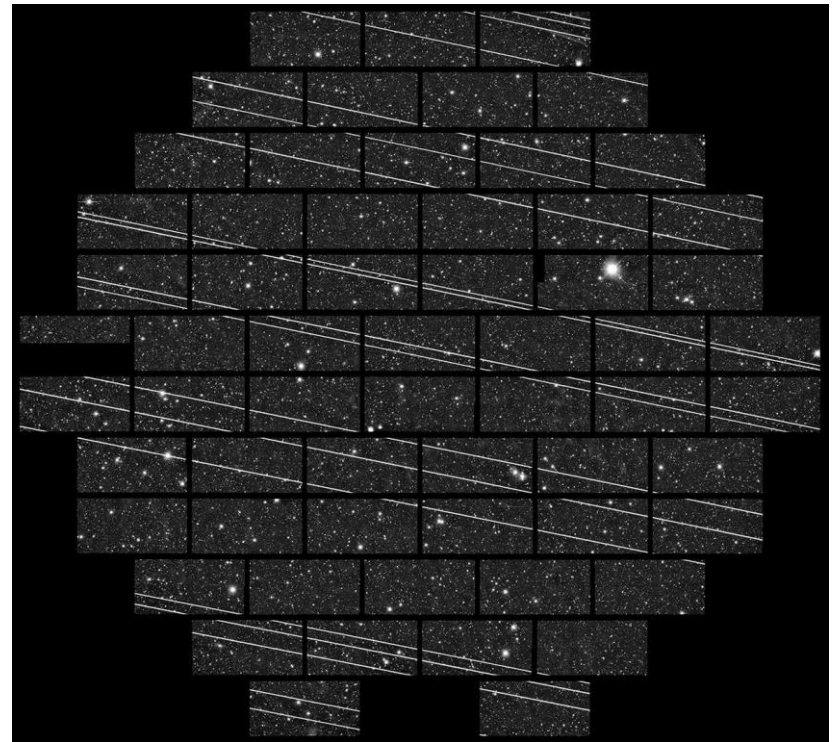
# Mega-constellations



<https://satellitemap.space>

# Mega-Constellations

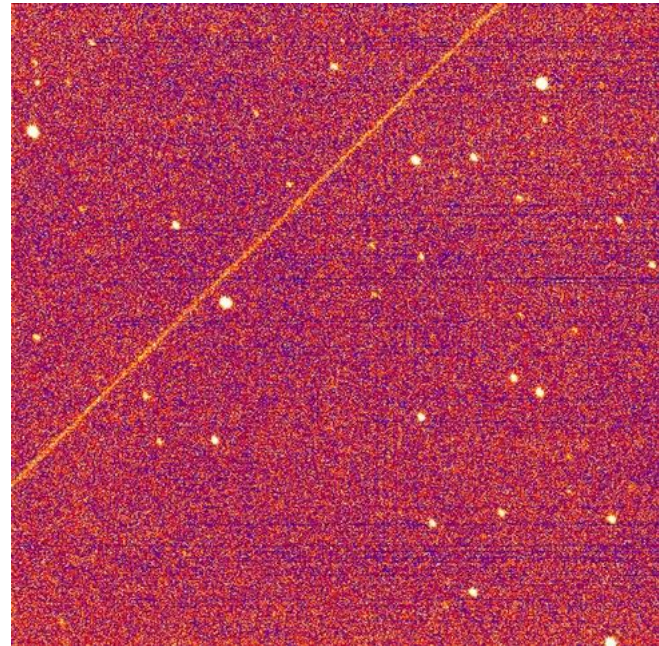
- Fast internet connection service via >10k satellites
- OneWeb, Starlink, ...
- Impair astronomical observations in optical/IR and radio
- Met with SpaceX for better future



Credit: NSF's National Optical-Infrared Astronomy Research Laboratory/CTIO/AURA/DELVE

# Brightness measurements

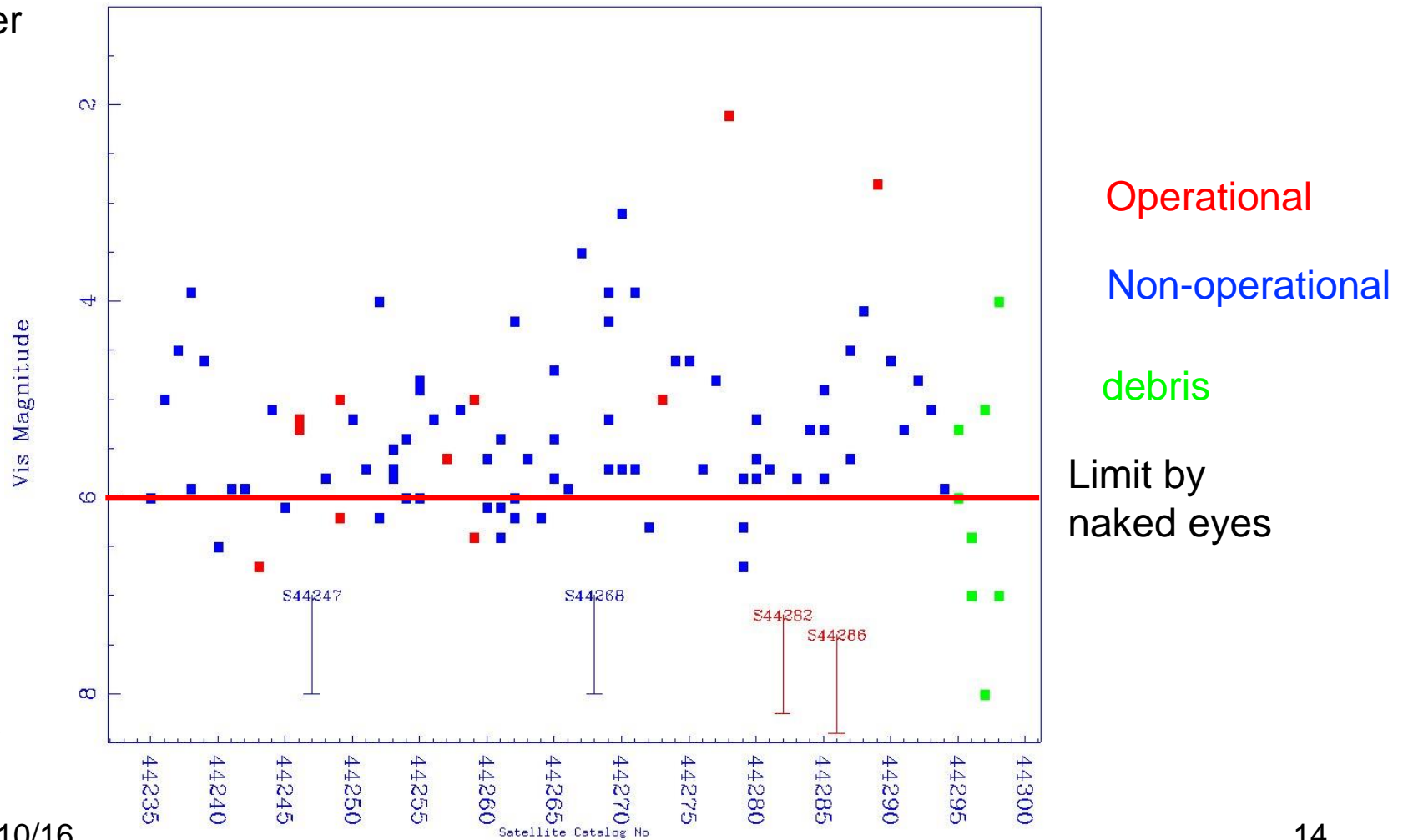
- Starlink: altitude ~ 550 km  
→ moves very fast ~ 2000 arcsec/sec
- Accurate position prediction at a given time  
→ point a telescope to this fixed position



# Optical data on Starlink

Starlink Observed Magnitudes

brighter

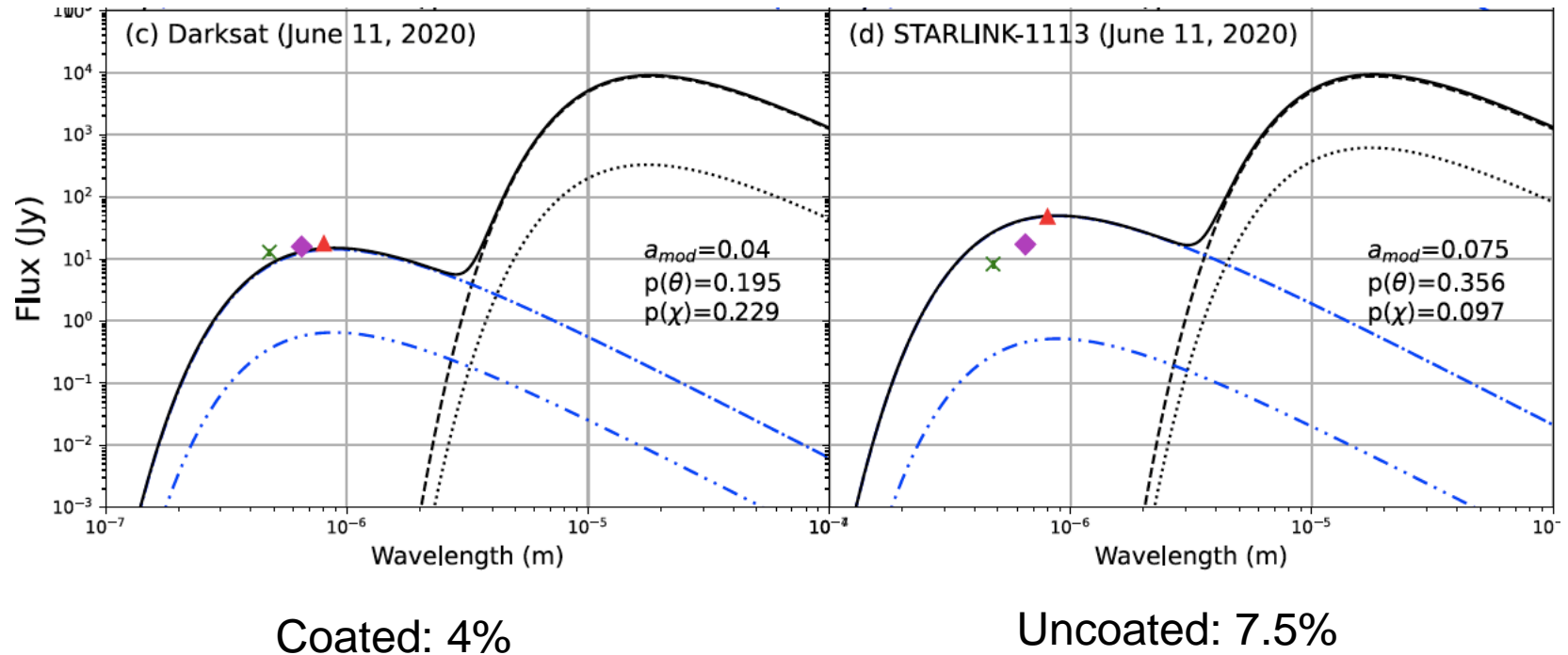


darker

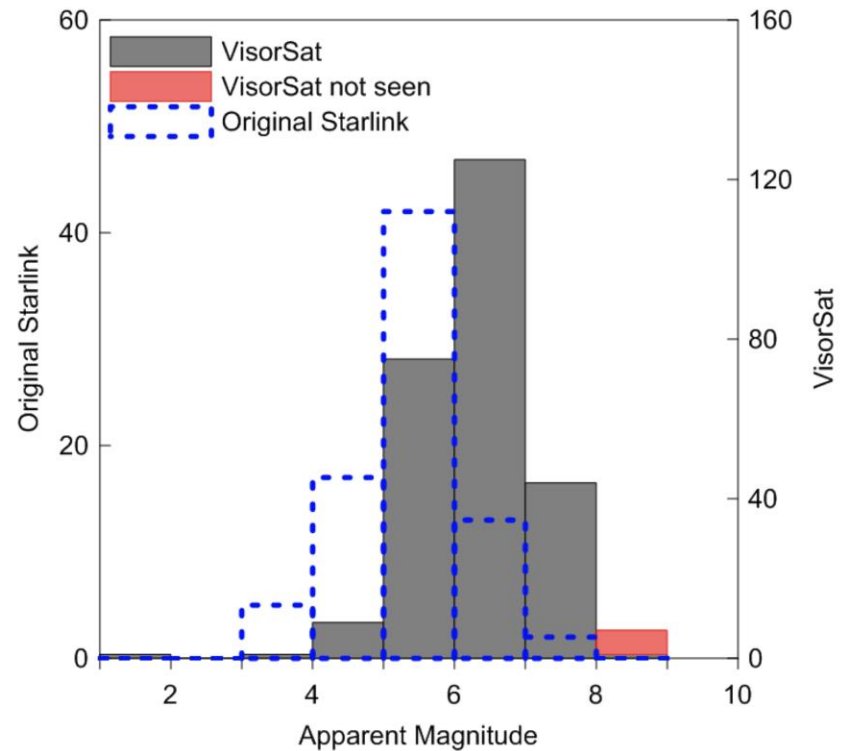
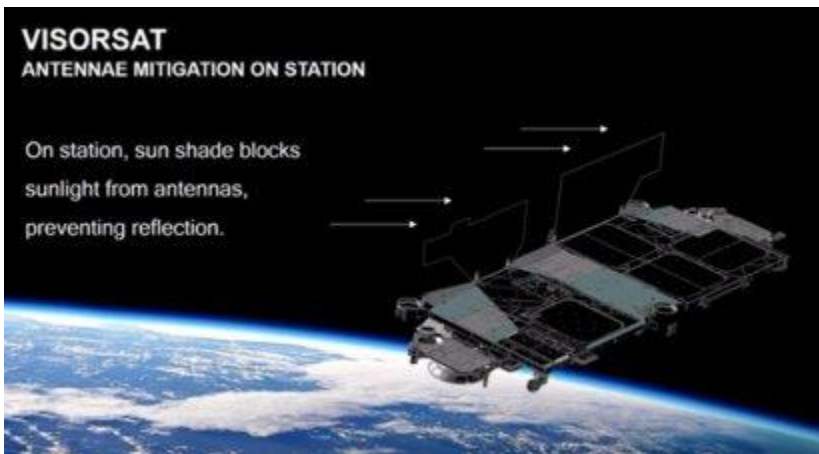
2021/10/16

# Multi-band measurements

Fitting the blackbody radiation curve → derivation of reflectivity



# Need much darker satellites



Mallama (2020)



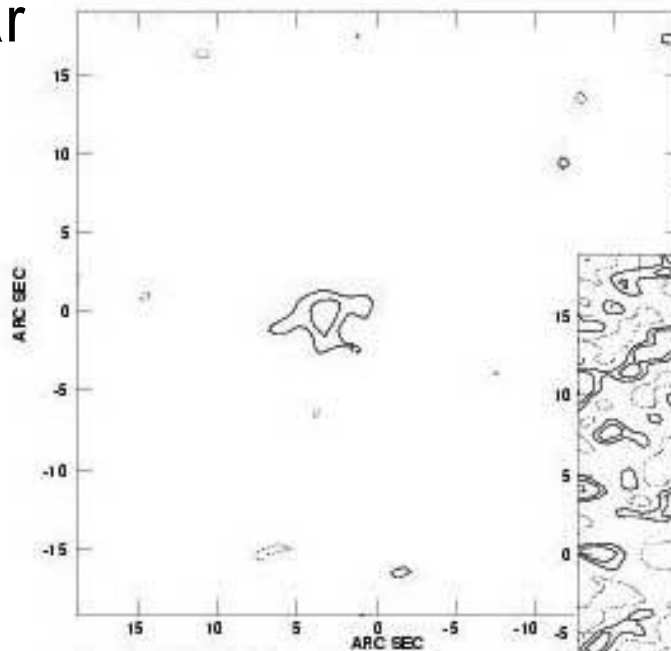
# Issues to be resolved

- Satellites are still TOO bright ( $> 7$  mag)  
→ need new technologies to further reduce brightness
- There is no international organization for regulating satellite brightness, total number of satellites (collision avoidance), and others.

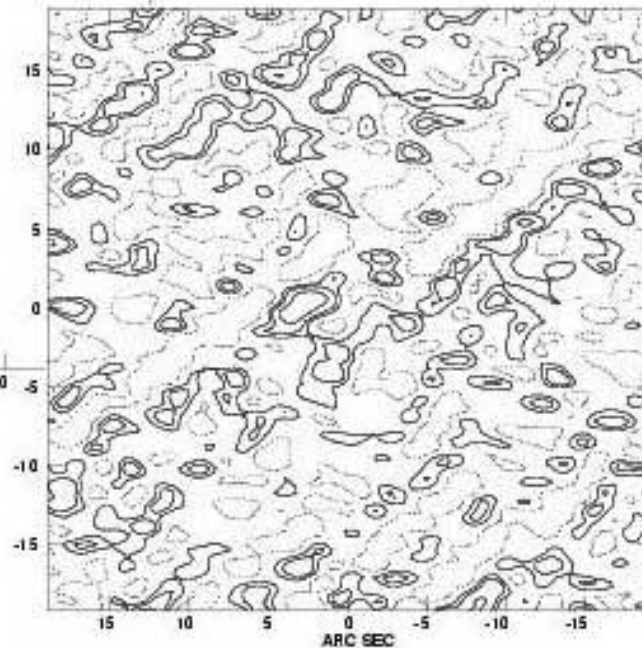
# Interfered image at VLA

Credit: G.B. Taylor, NRAO/AUI/NSF.

star

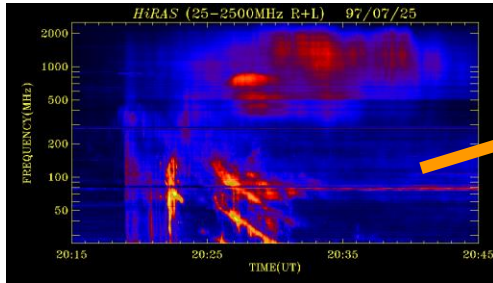


Satellite interference  
25 deg away from the star



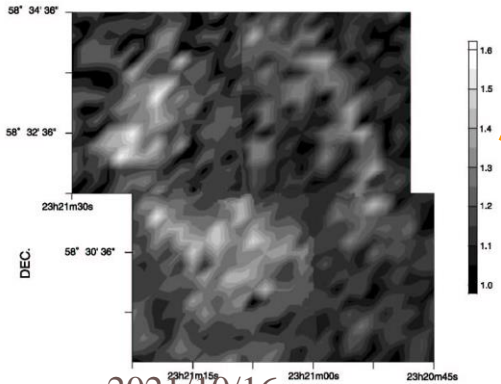
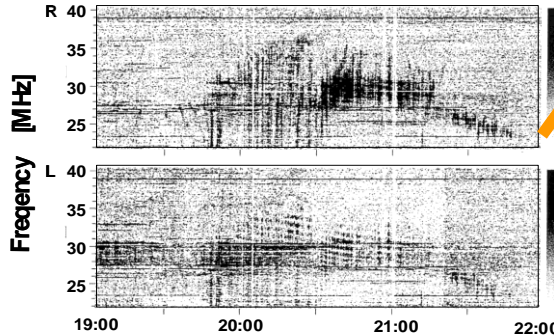
No interference

# Targets and Intensities

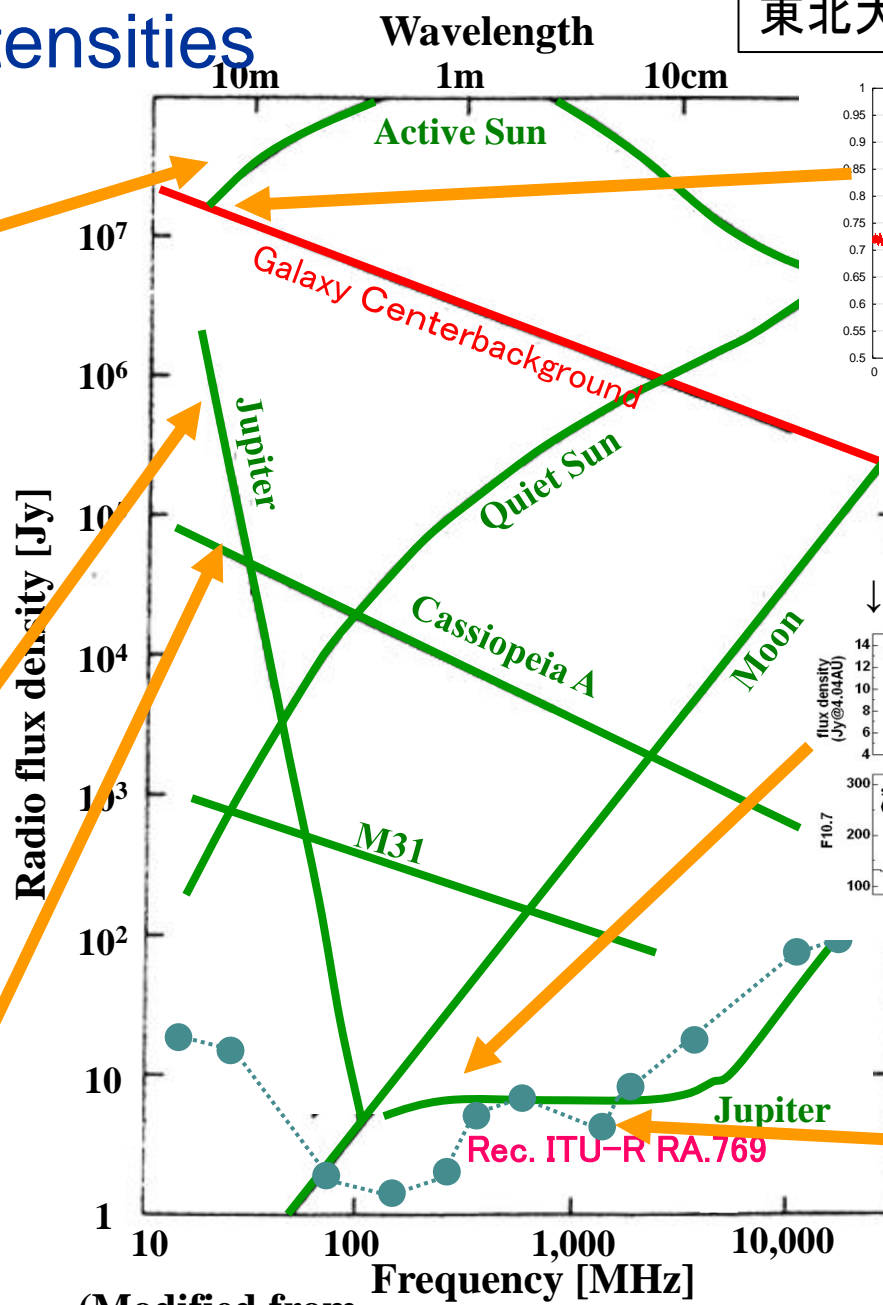


↑太陽電波バーストスペクトル  
(<http://sunbase.nict.go.jp>)

↓木星電波バースト  
(Konno et al. 2002)

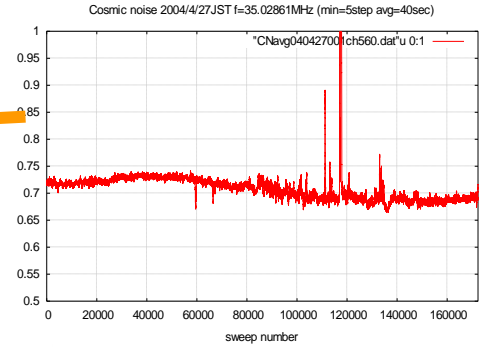


2021/10/16  
Cassiopeia-A 電波マップ  
(Oya & Iizama, 2003)



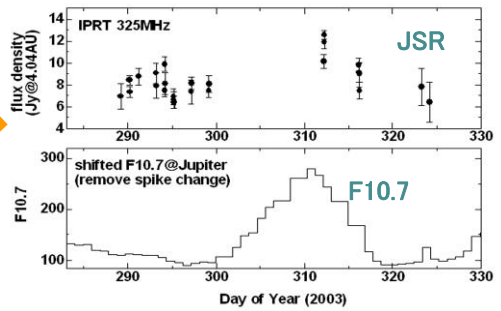
(Modified from Kraus, 1986)

$(1\text{Jy}=10^{-26}\text{W}/\text{m}^2/\text{Hz})$



↑銀河電波雑音レベル  
(Hiyama, 2004)

↓木星シンクロトロン放射



Jovian synchrotron radiation (top) and solar f10.7 (bottom)

Threshold for RAS obs.

Radio astronomers want to observe at all frequency range.

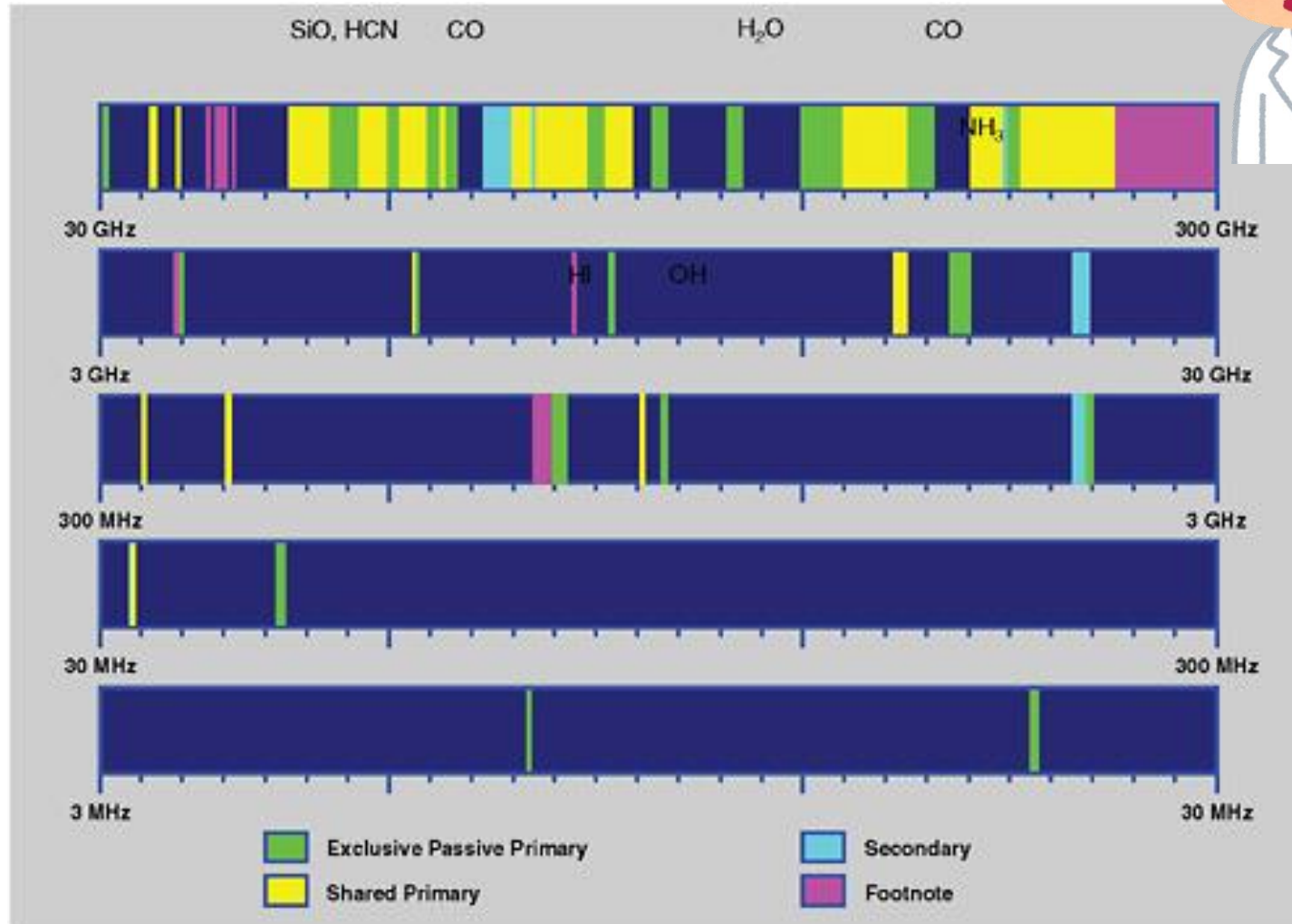
Other radio users may want to emit at all frequency range.

All radio users, including astronomers, have to **SHARE** the frequency resource.

# Coordination

- International
  - Global: **International Telecommunication Union** @ Geneva → protection criteria for radio astronomical observations (60+ years!)
  - Regional: Asia-Pacific region, Europe, Americas, Arab league, African union
- National (Japan)
  - Ministry of Internal affairs and Communication (総務省) → Radio law (電波法)

# Small portions only



# High-Frequency Use by Radio Services

- ~2010  
radio services (transmit radio waves) use primarily in lower frequencies, e.g., < 10 GHz
- Recent advancement of technologies have allowed radio users to use higher frequency regions; e.g., 3mm band, and up to 450 GHz for a short range use

# Car radar experiment @ Nobeyama

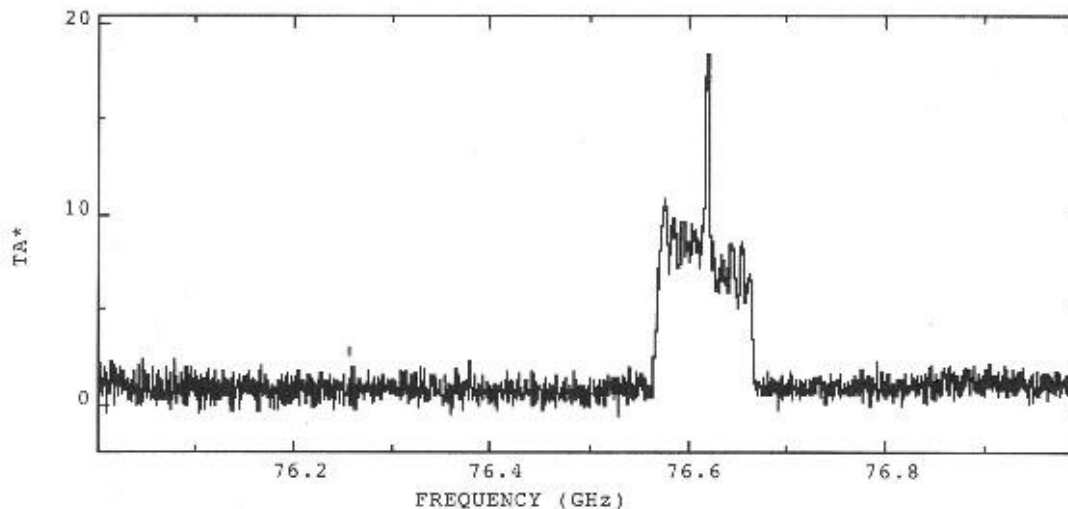
```
F76hv-n    F7679
Comments
Spectrum-id = 00011 (
Ref. coordinate = RA,DEC
RA offset +00d00'00.0"
DEC offset +00d00'00.0"
Center freq. = 76.500000(GHz)
r.m.s. = 0.4151(K)
Baseline order = *
```

```
F76hv-n .INTEG
) : DATE(M D Y) = 05 19 15
  : P.A. = 0.000d
  : RA (2000) = +00h00m00.0s : l = 0.000D
  : DEC(2000) = +00d00'00.0" : b = 0.000D
  : ARY-All : v = 100000'00.0"
  : Integ time(O
  : Scaling fact
```

15. 5. 19 13:26 A11  
477m

**~76 GHz !!**

477m from 45m tel. → must be separated beyond 135 km





# Spectrum Management for Radio Astronomy Service (RAS)

- In April, 2019, NAOJ has established a new division, **Spectrum Management Office (周波数資源保護室)**.
  - A unified gateway to the international/national coordination
  - More radio use in higher frequency ranges
- Before April, 2019, the frequency sub-committee took the role on a voluntary basis.

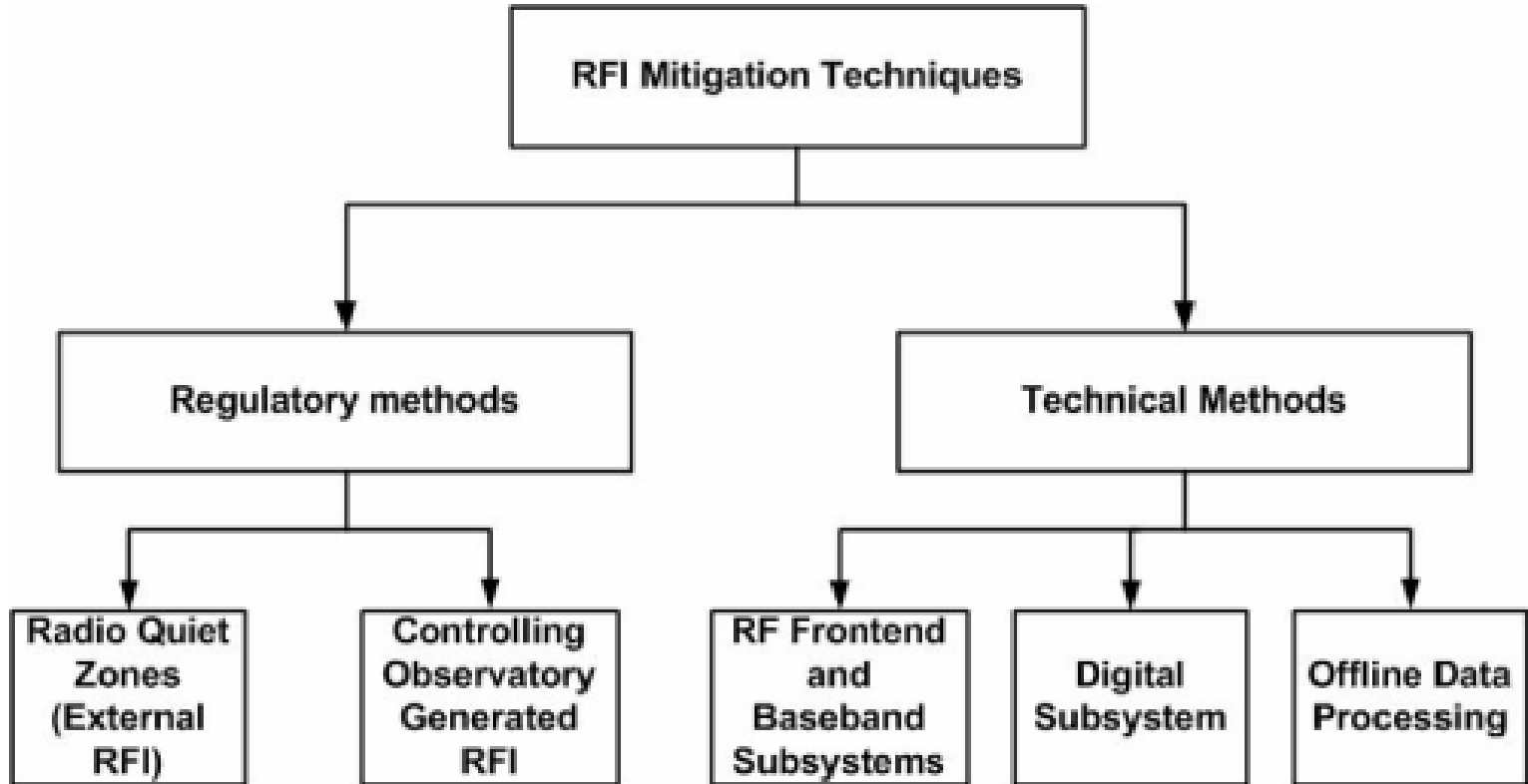
If you are interested in our activity, please visit at

- Spectrum Management Office, NAOJ:  
<https://prc.nao.ac.jp/freqras/index.html>
- English page is under construction  
(^\_^)!

# Coordination with Starlink

- **Satellite → Earth**  
10.7-12.7 GHz  
(service link)  
17.8-18.6 / 18.8-19.3  
GHz (feeder link)
- **Earth → Satellite**  
14.0-14.5 GHz  
(service link)  
27.5-29.1 / 29.5-30.0  
GHz (feeder link)
- Serious RFI to a RAS  
band, 10.6-10.7 GHz  
  
→ suspend the  
channel, 10.7-10.95  
GHz, when a satellite  
is seen from a radio  
observatory

# Radio Frequency Interference Mitigation



J. M. Ford and K. D. Buch, "RFI mitigation techniques in radio astronomy," 2014 IEEE Geoscience and Remote Sensing Symposium, 2014, pp. 231-234

# RFI Mitigation by Astronomers

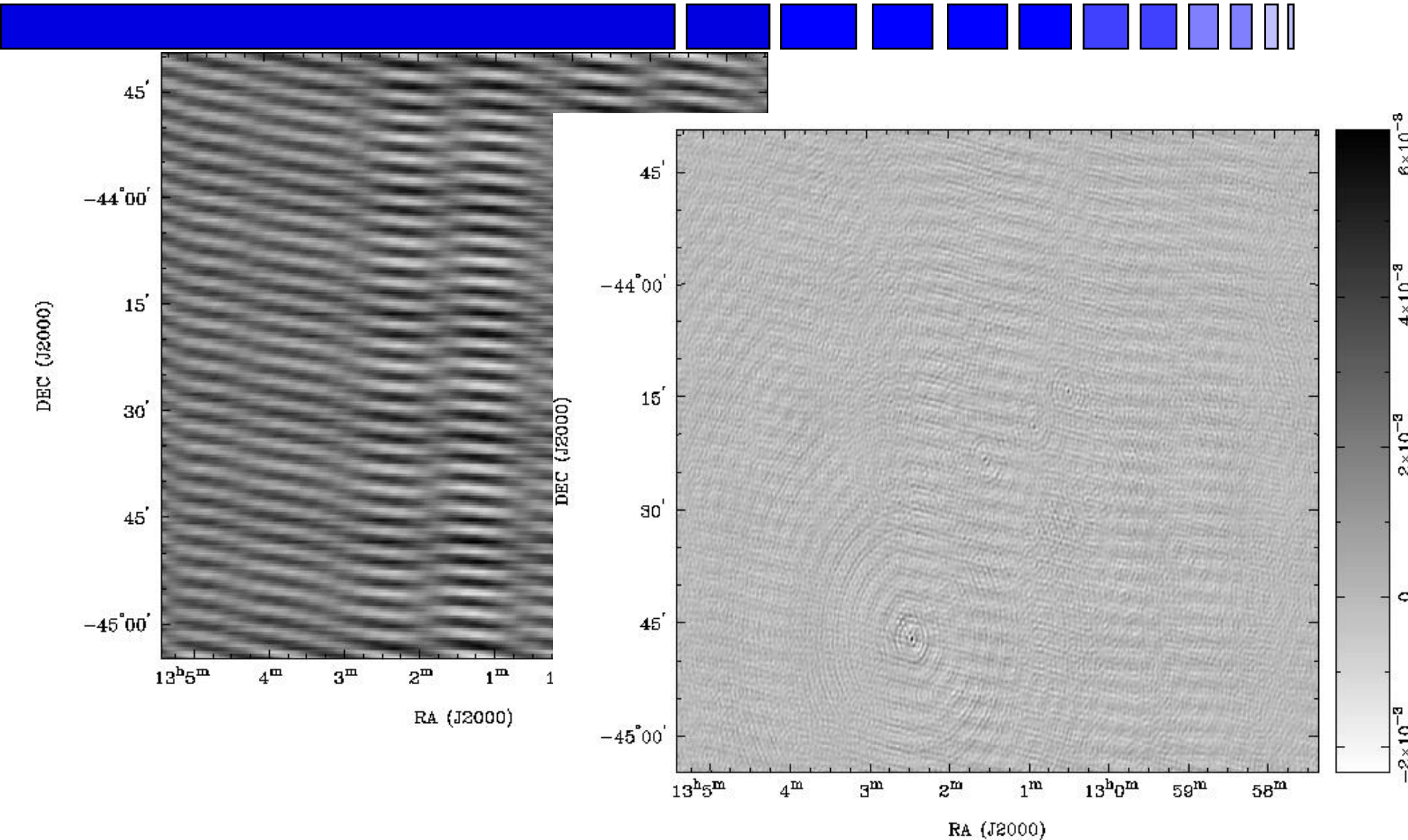
- To select a site as radio-quiet as possible
- To establish Radio Quiet Zones

These would work for ground-based RFI sources, but would not for RFIs from airplanes, satellites, balloons and High Altitude Platform Stations

# Mitigation Techniques

- RFI excision -- “cutting out” RFIs
  - blanking data
  - array beam-forming to null the direction of RFI sources
- RFI cancellation – “subtracting” RFIs
  - Use of a reference antenna together with post-processing
- Anti-coincidence – RFIs are not coherent in widely-spaced arrays; good for VLBI

# Before and after images



# Our sky is a shared natural resource

ITU Constitution and Convention, article 196

In using frequency bands for radio services, Member States shall bear in mind that **radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources** and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, ...



Respect to each other

New ideas for solving the problems  
through technological advancements

Dialogues and discussion

Patience for our better common future