Radio Astronomy and Outreach activities at NASA's Deep Space Network

Cristina García Miró INTA/ISDEFE

13th Annual International Workshop on Environment and Alternative Energy

Nov. 11th, 2015

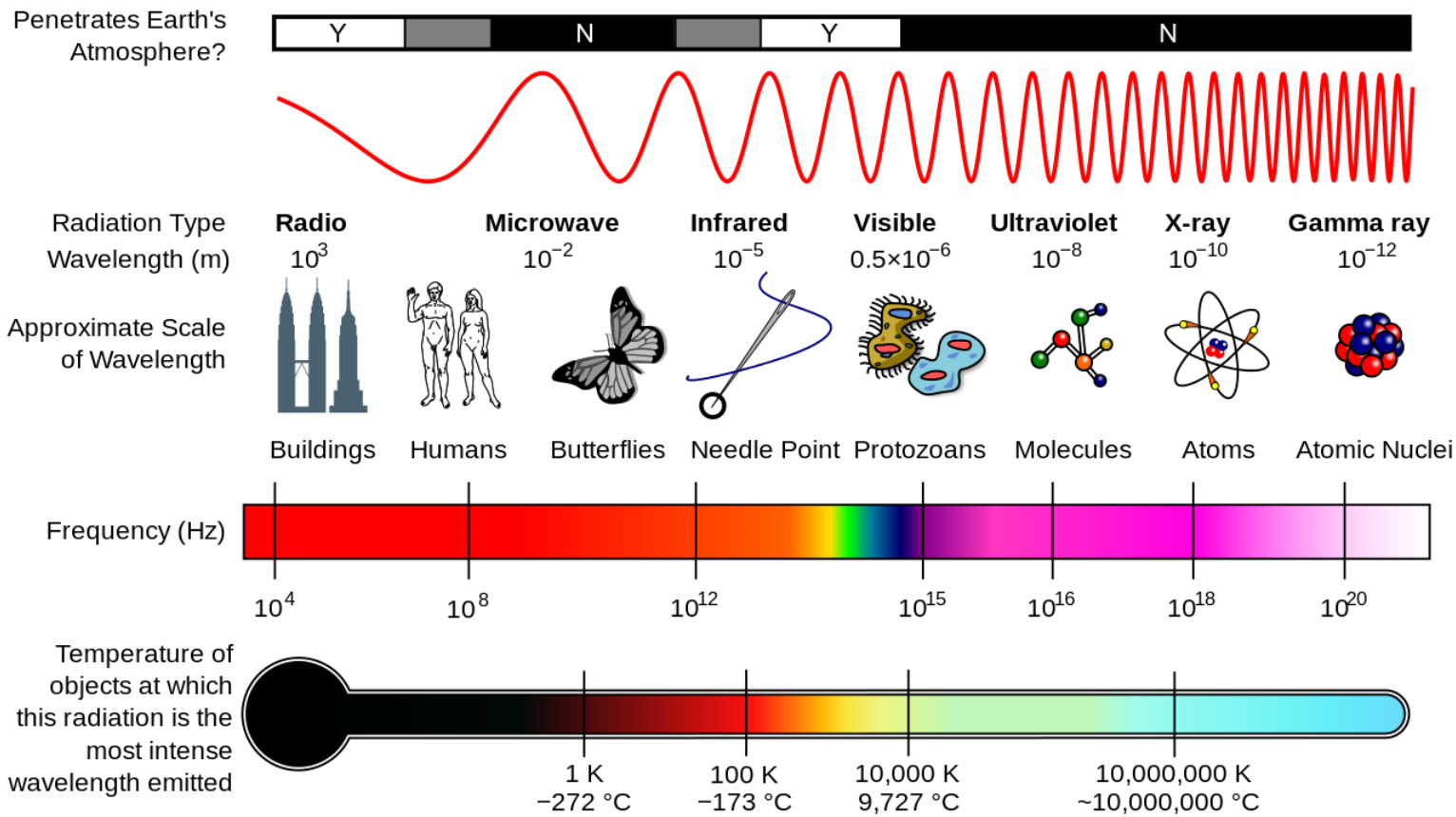
NASA's Deep Space Network

What is Radio Astronomy?
NASA´s DSN overview
Why RA with the DSN?
How do we observe with the antennas?
Some interesting experiences with students

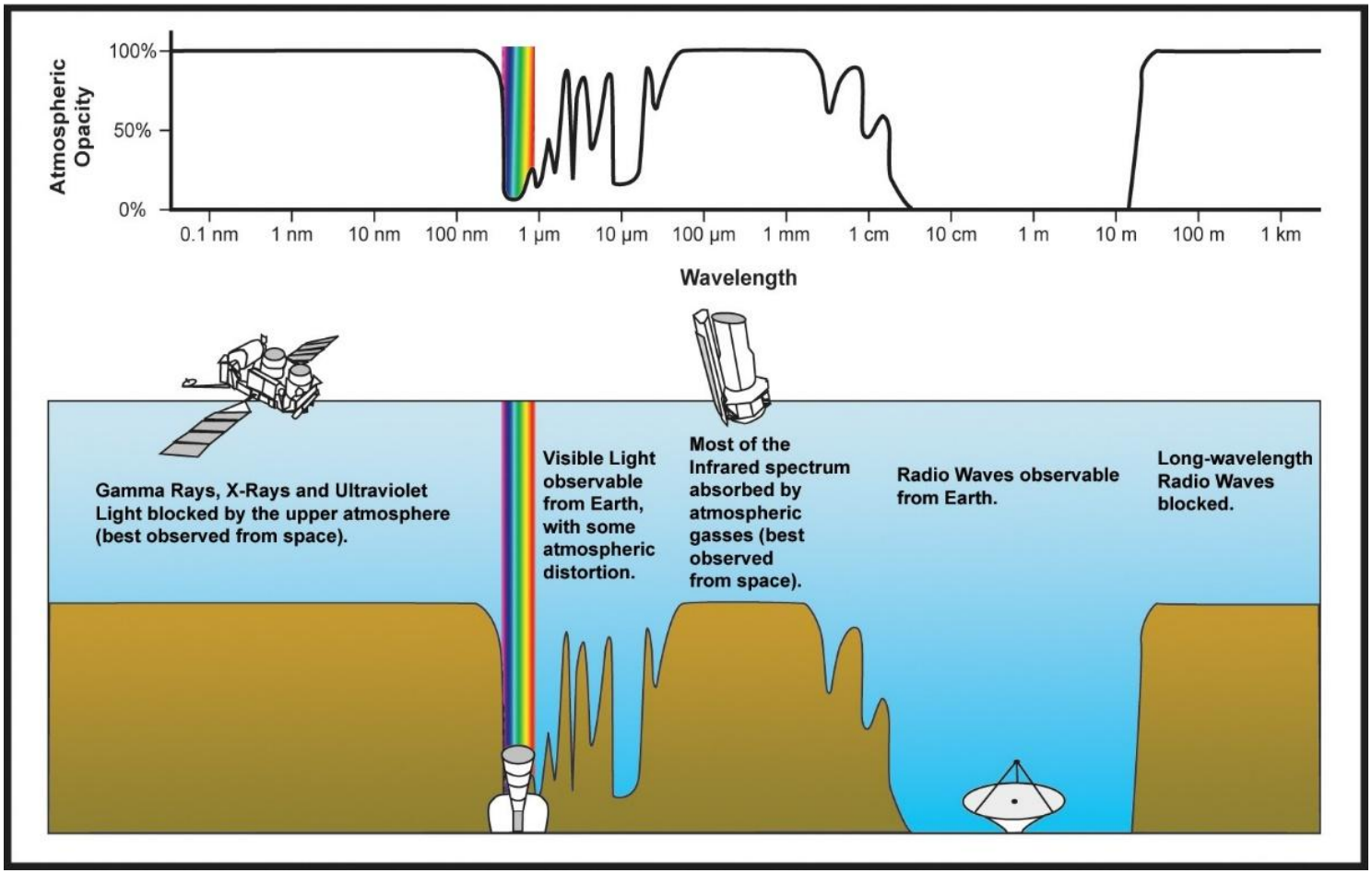
Radio Astronomy: a first “CONTACT”

Contact (1997): Jodie Foster at the Very Large Array (New Mexico, USA)

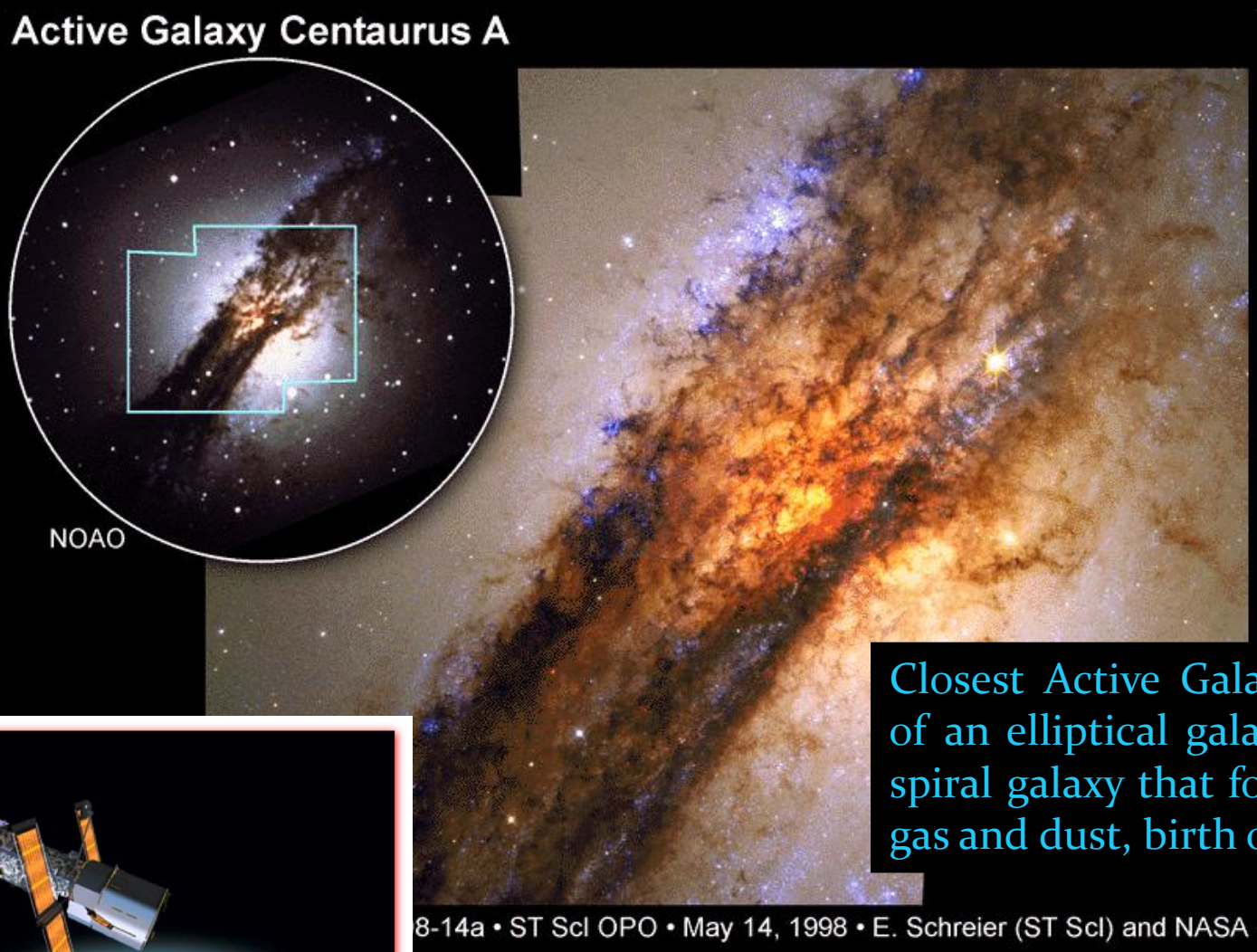
What is Radio Astronomy?



What is Radio Astronomy?



What is Radio Astronomy?



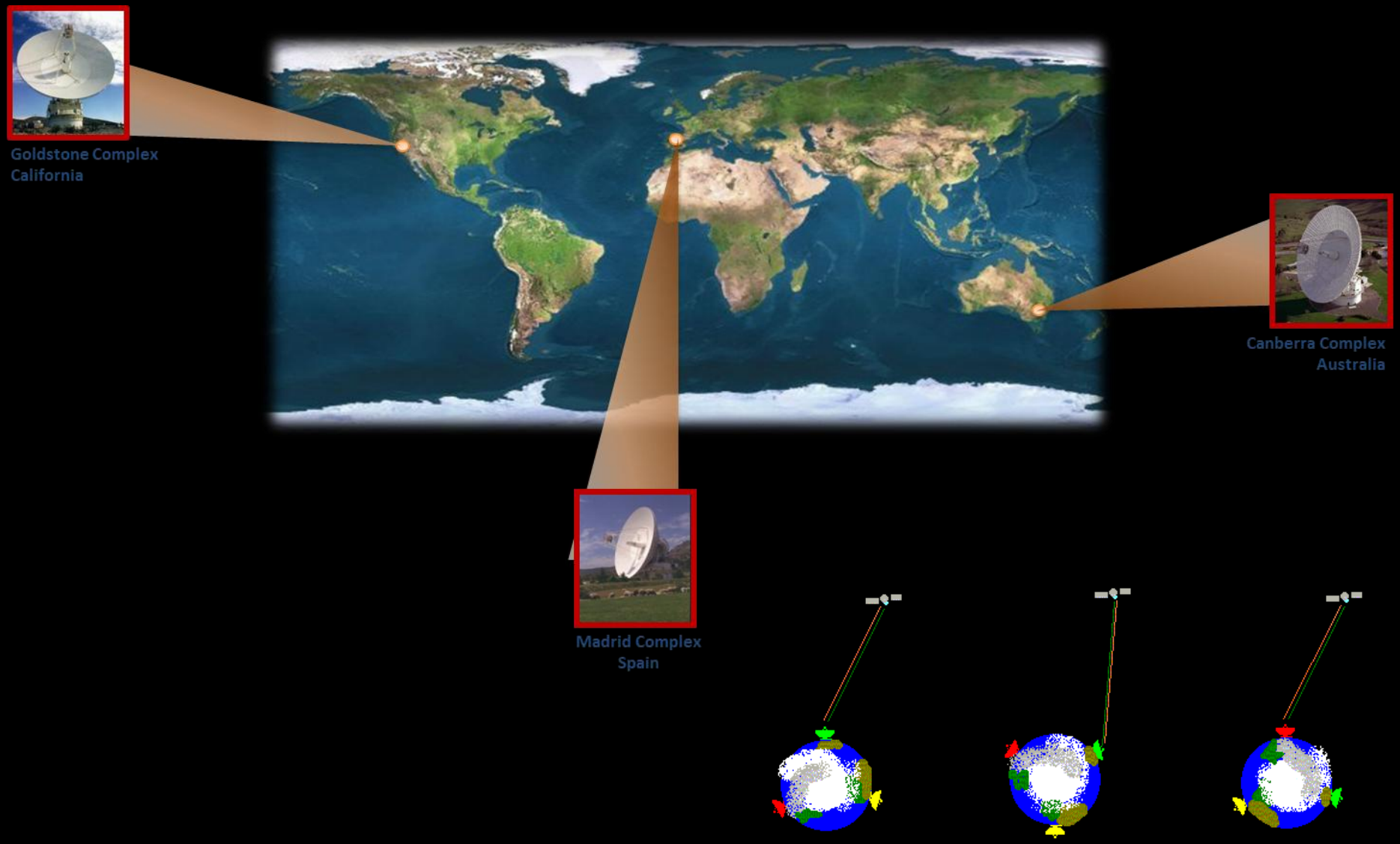
Closest Active Galaxy: interaction of an elliptical galaxy and a small spiral galaxy that formed a disk of gas and dust, birth of new stars.

What is Radio Astronomy?

RADIO SKY (night and day)

RADIO SKY (night and day)

NASA's Deep Space Network (DSN)



NASA's DSN: Goldstone

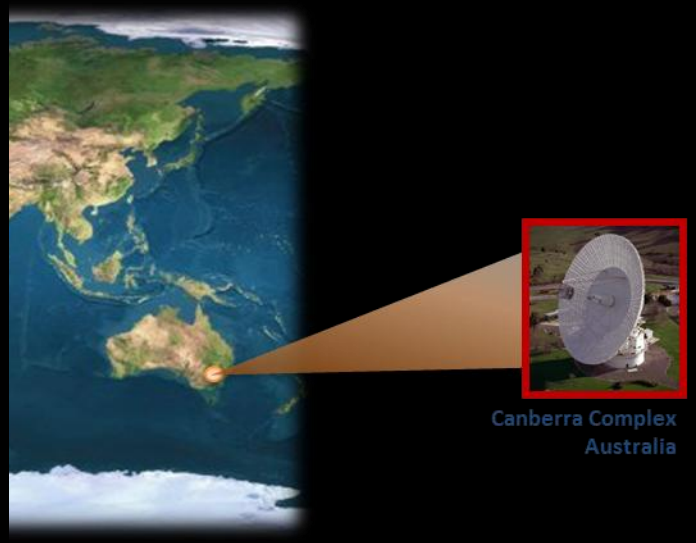
Goldstone Complex
California

NASA's DSN: Goldstone

Goldstone Complex
California

1963

NASA's DSN: Canberra

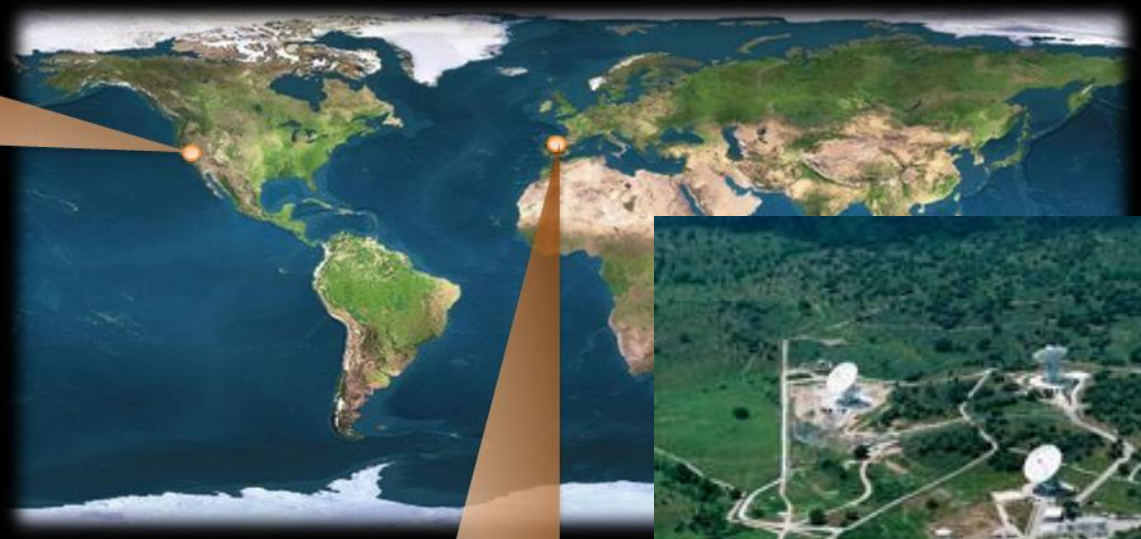


NASA's DSN: Canberra

NASA's DSN: Canberra

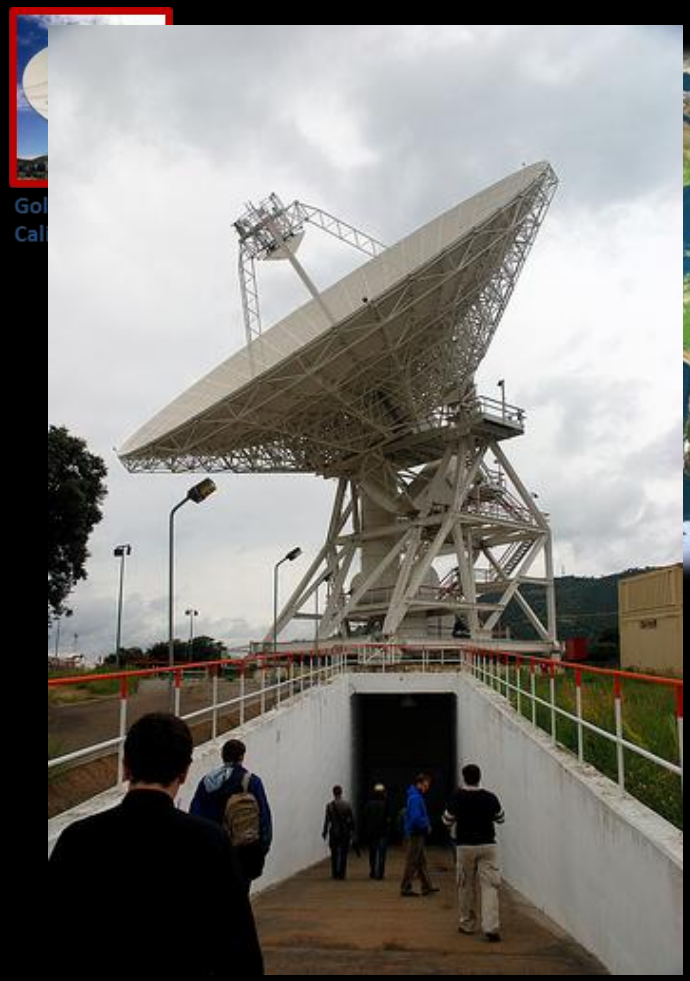
NASA's DSN: Madrid

Goldstone Complex
California

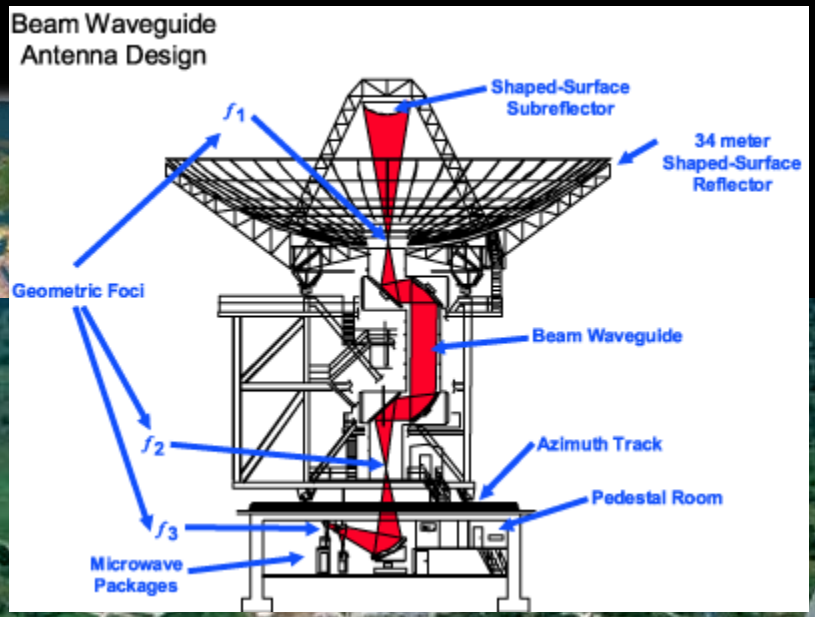


Madrid Complex
Spain

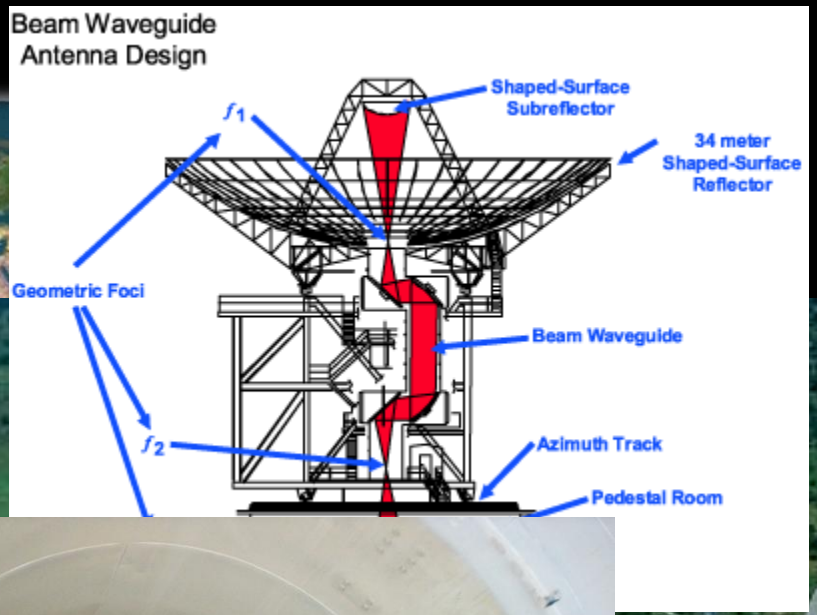
NASA's DSN: Madrid



Madrid Complex
Spain

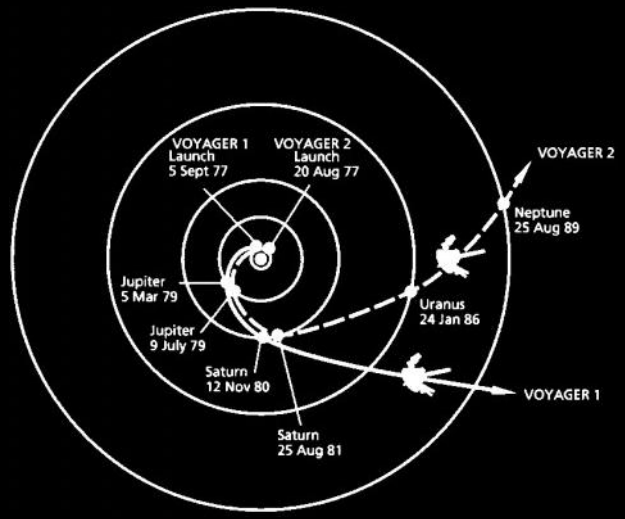


NASA's DSN: Madrid



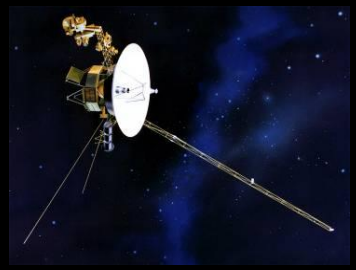
Interplanetary WIFI

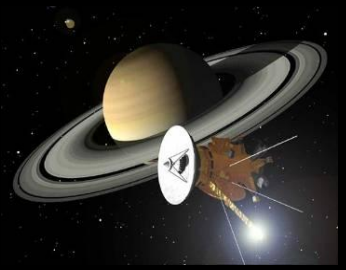
The power received by 70 m DSN antenna from Voyager is so small that if it were to be accumulated for 10 trillion years, it could power a refrigerator light bulb for ***one second!!!***

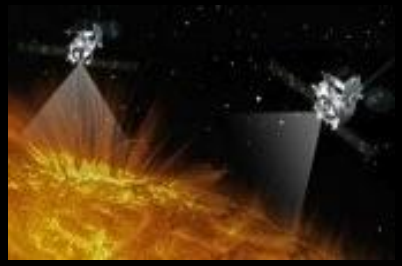


Can you hear me now?

Some projects supported by the DSN


Voyager 1


Cassini


Stereo A & B

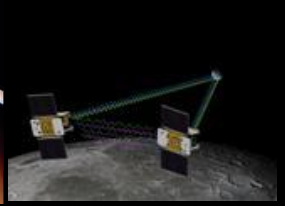
MRO

Mars Odyssey

Messenger

Cluster 1, 2, 3 & 4

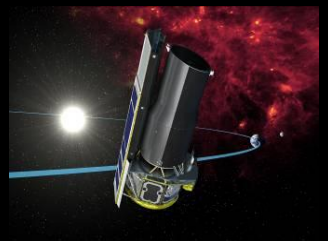
SOHO


GRAIL

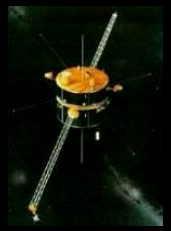
Dawn

New Horizons

Mars Exploration Rovers

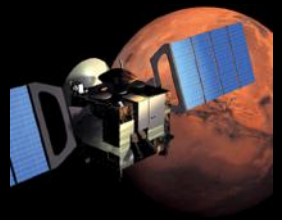

Spitzer

MSL

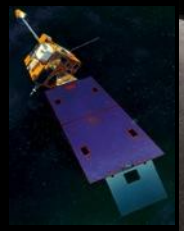

Wind

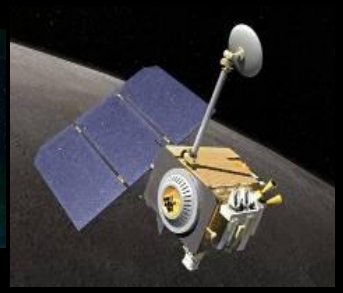
Rosetta

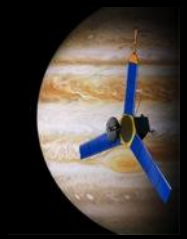
Kepler


Mars Express

Chandra

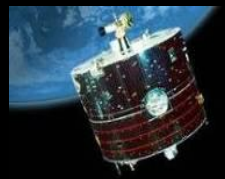

GOES


LRO

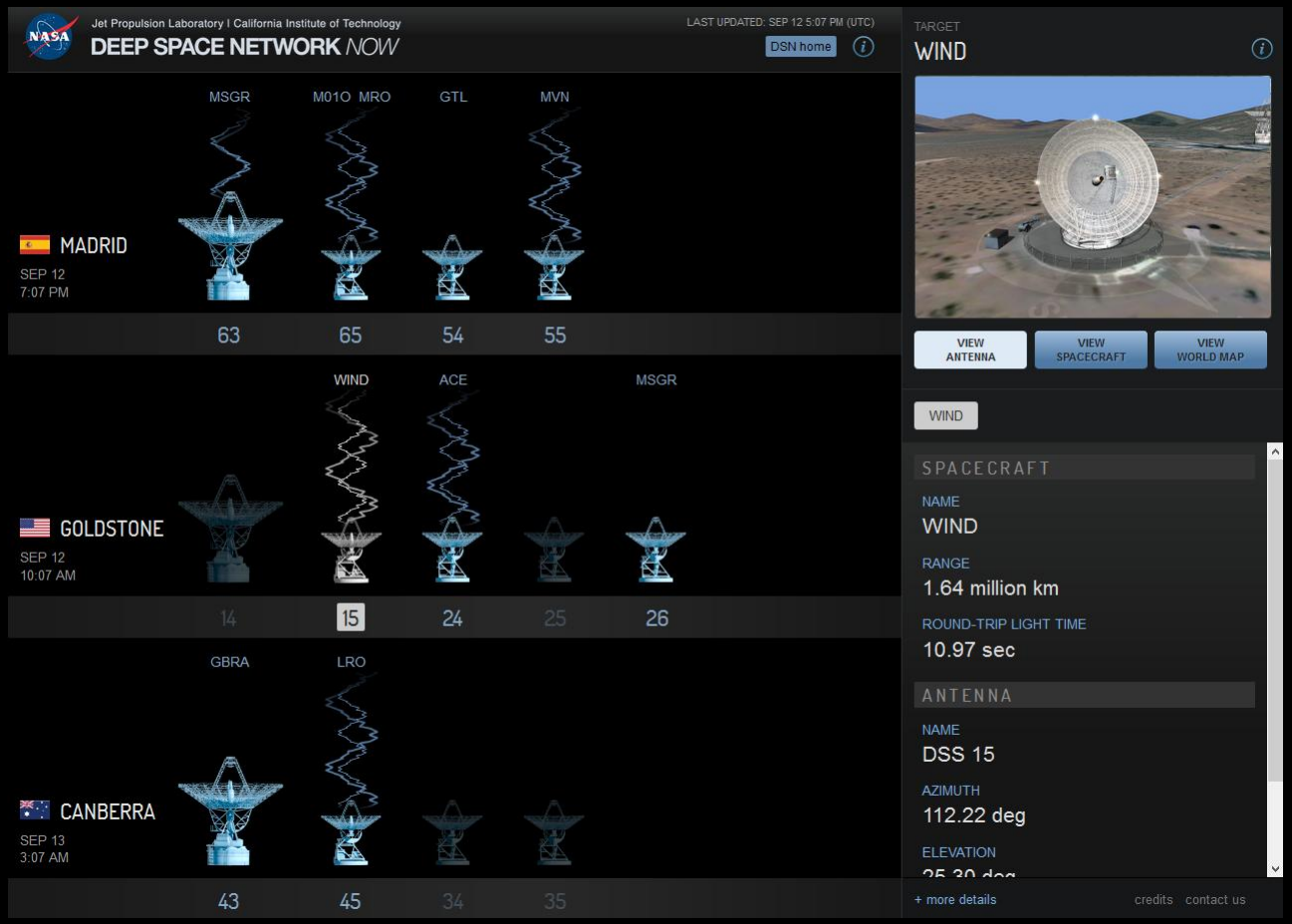

JUNO

ACE

Themis C


Geotail

DSN on-line

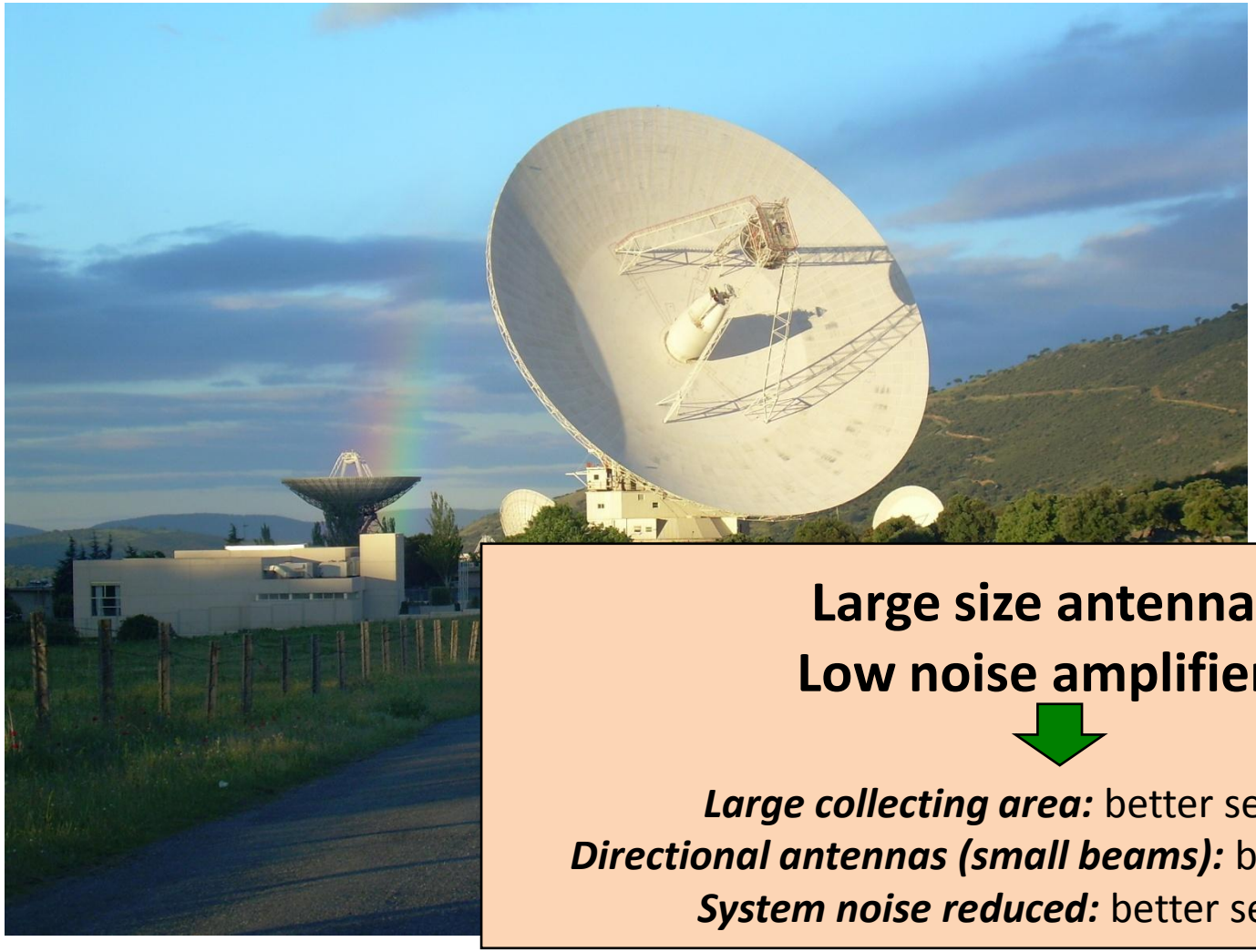


DSN now: http://eyes.nasa.gov/dsn/dsn.html

50th Anniversary of the DSN

50th Anniversary of MDSCC

Why RA at the DSNs?

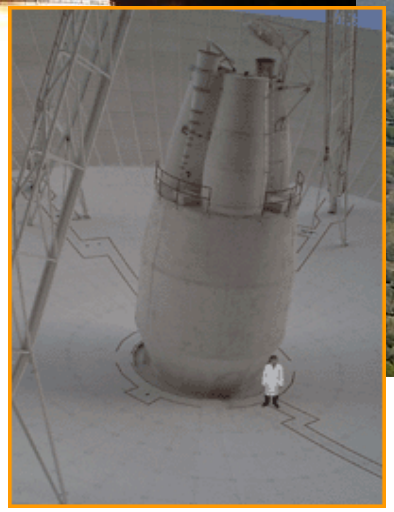


Large size antennas
Low noise amplifiers

Large collecting area: better sensitivity
Directional antennas (small beams): better resolution
System noise reduced: better sensitivity

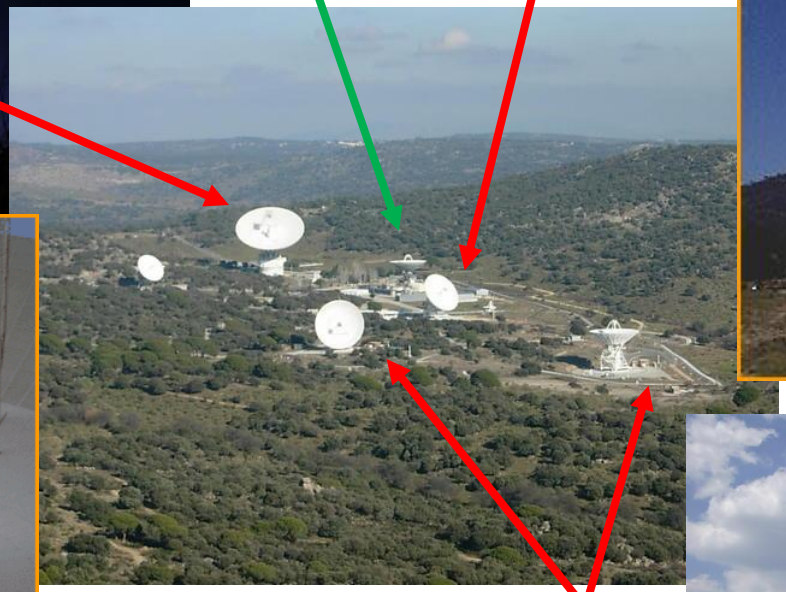
Radio Astronomy at the NASA's DSN

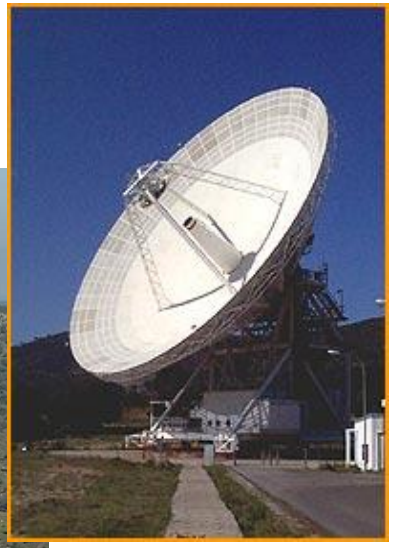
DSS-63 (70m)



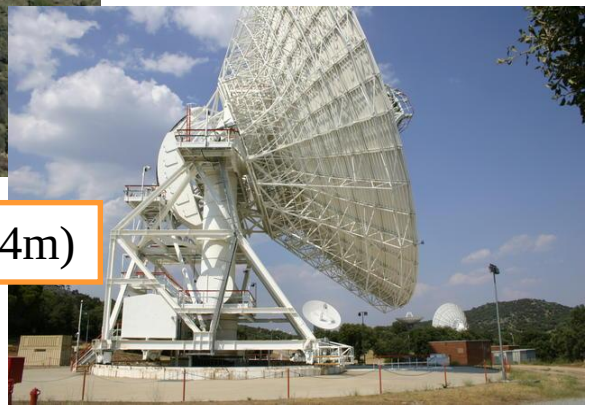
PARTNeR educational antenna (34m)

Geodesy (34m)





DSS-54/55 (34m)



How do we observe with the antennas?

SINGLE DISH

Continuum observations

Spectroscopy observations

INTERFEROMETRIC OBSERVATIONS

How do we observe with the antennas?

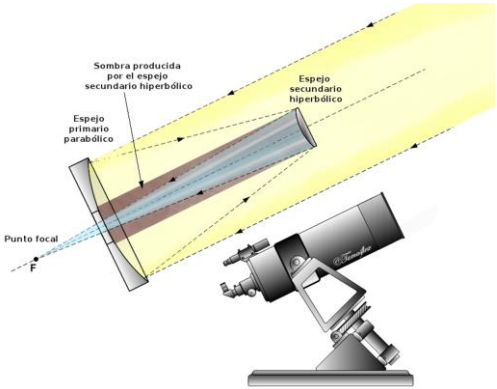
SINGLE DISH

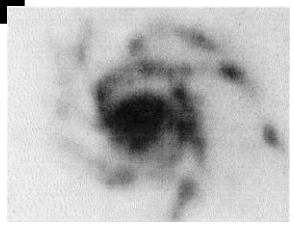
Continuum observations

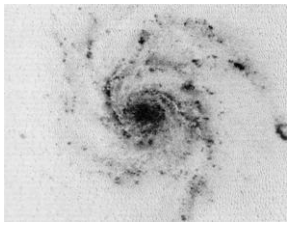
Spectroscopy observations

Radio waves 10^6x larger than optical waves: we need radio telescopes 10^6 larger to achieve same resolution.

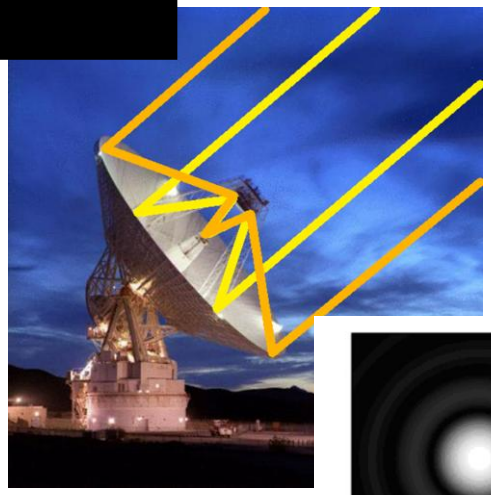
Several points from focal plane simultaneously:

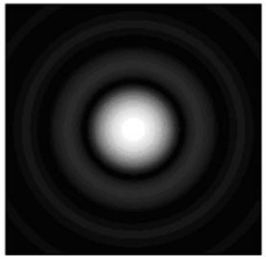






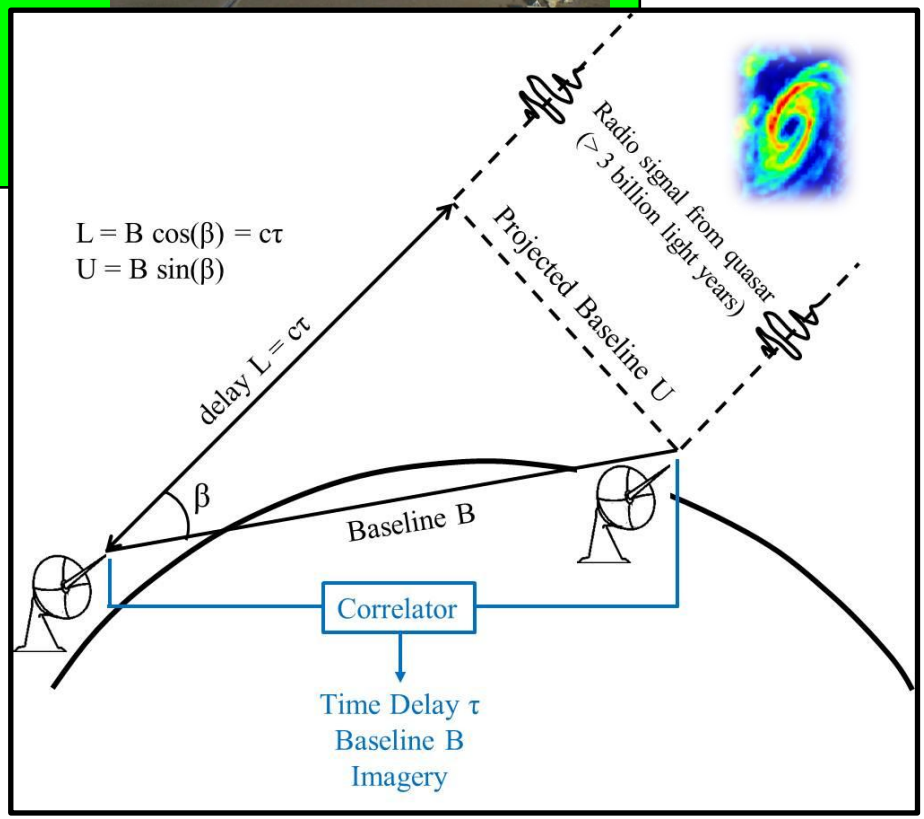
Just one point from focal plane: Airy disk





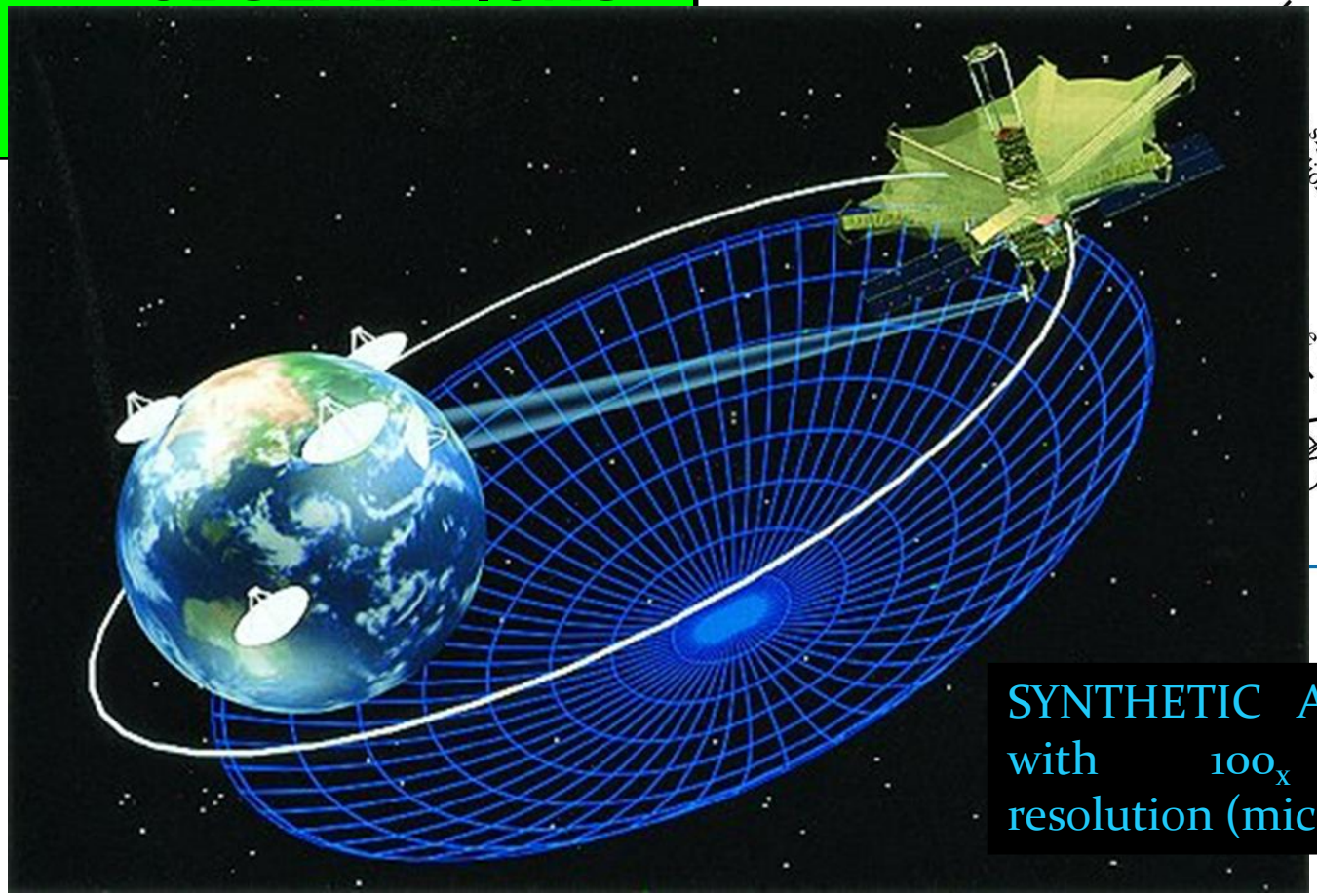
How do we observe with the antennas?

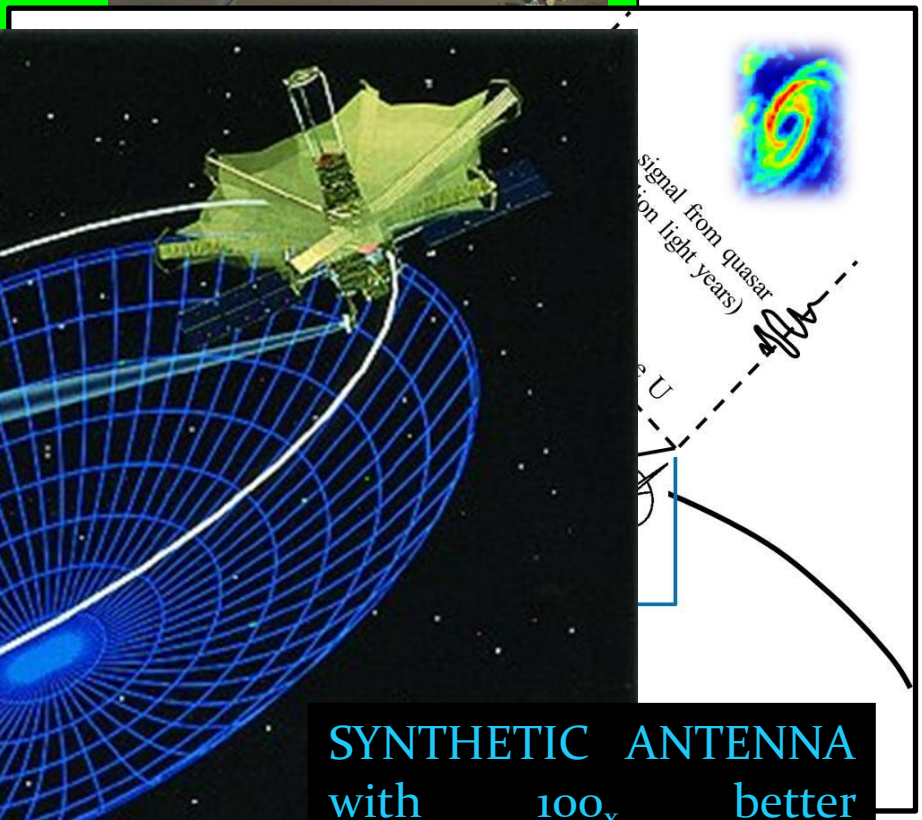
INTERFEROMETRIC OBSERVATIONS



How do we observe with the antennas?

INTERFEROMETRIC OBSERVATIONS



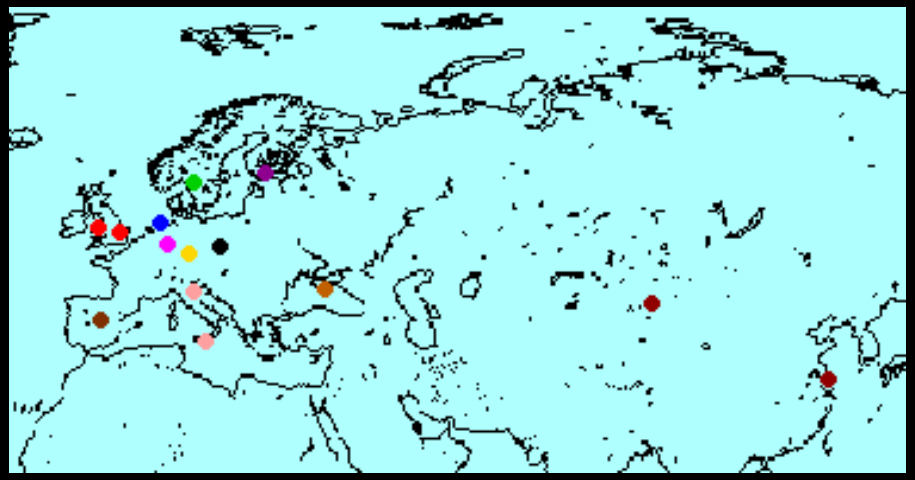


SYNTHETIC ANTENNA with 100_x better resolution (microarcsec)

How do we observe with the antennas?

European VLBI Network

Joint Institute for VLBI in Europe JIVE



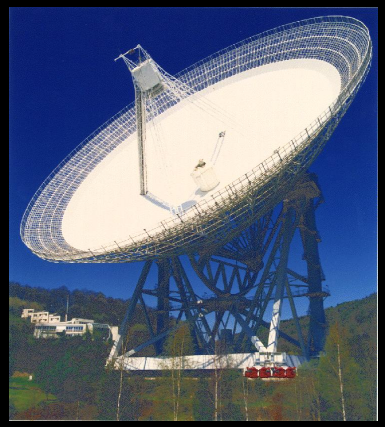
The EVN is the most sensitive interferometer thanks to the large collecting areas.

32m
Medicina

Arecibo

40m Yebes

70m MDSCC



100m Effelsberg

Sustainable Radio Astronomy?

Sustainable Radio Astronomy?

Photo credit: mShopper´s mind Propulsion Labs

Sustainable Radio Astronomy?

Research with Robledo

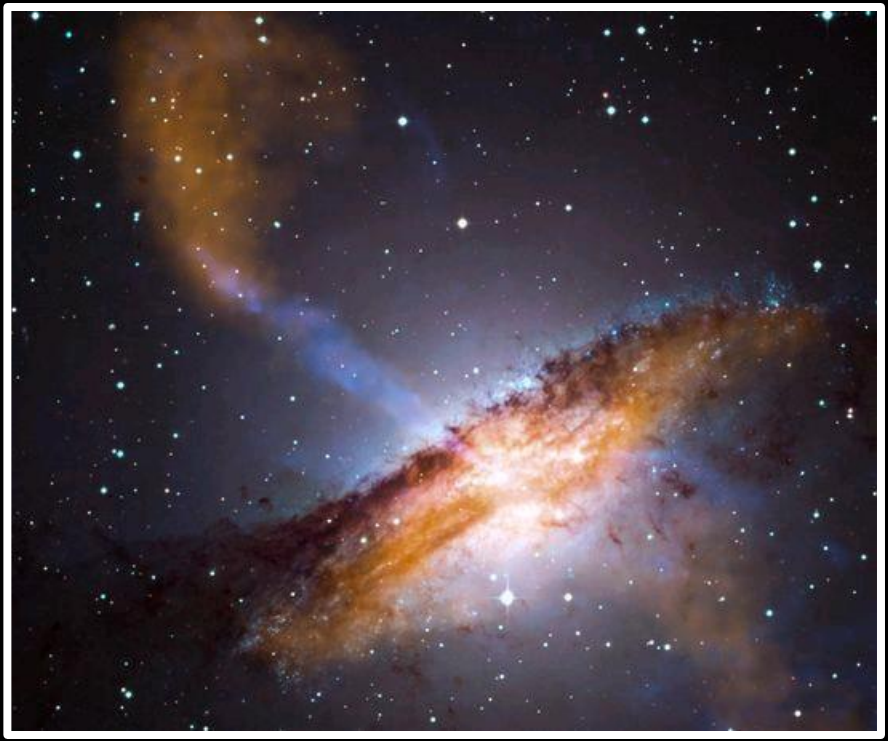
Beyond our Galaxy

Within the Milky Way

The Solar System

Outreach and educational activities with students

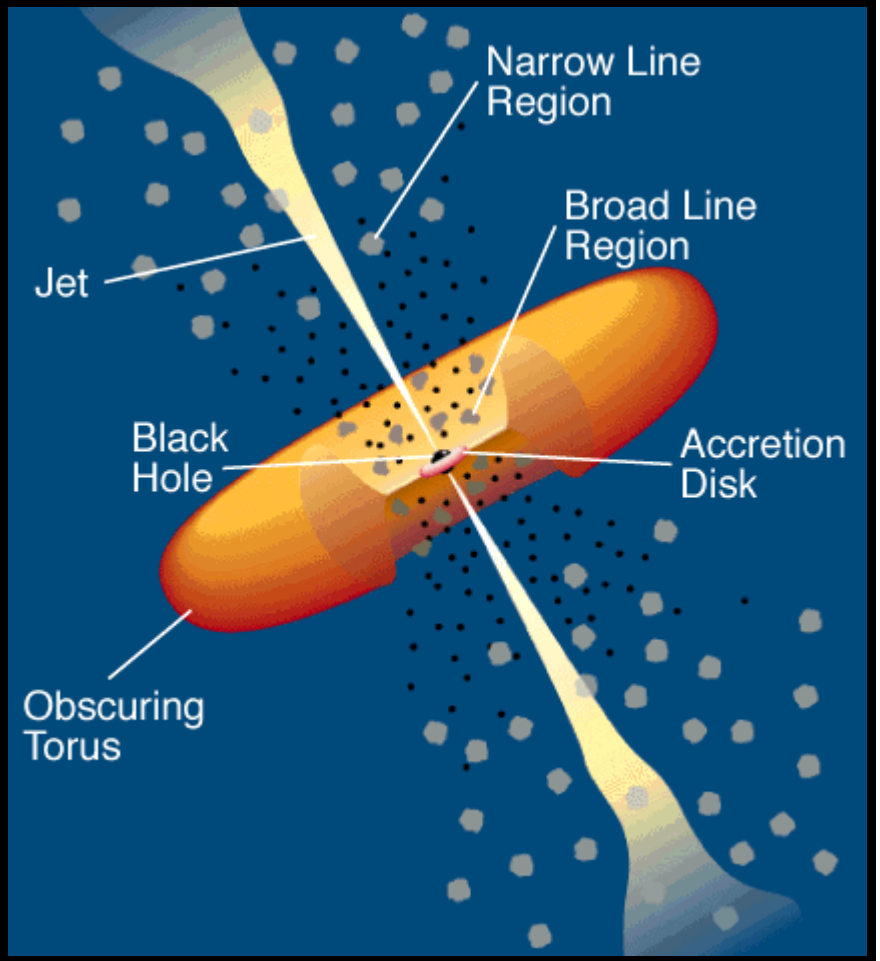
Beyond our Galaxy

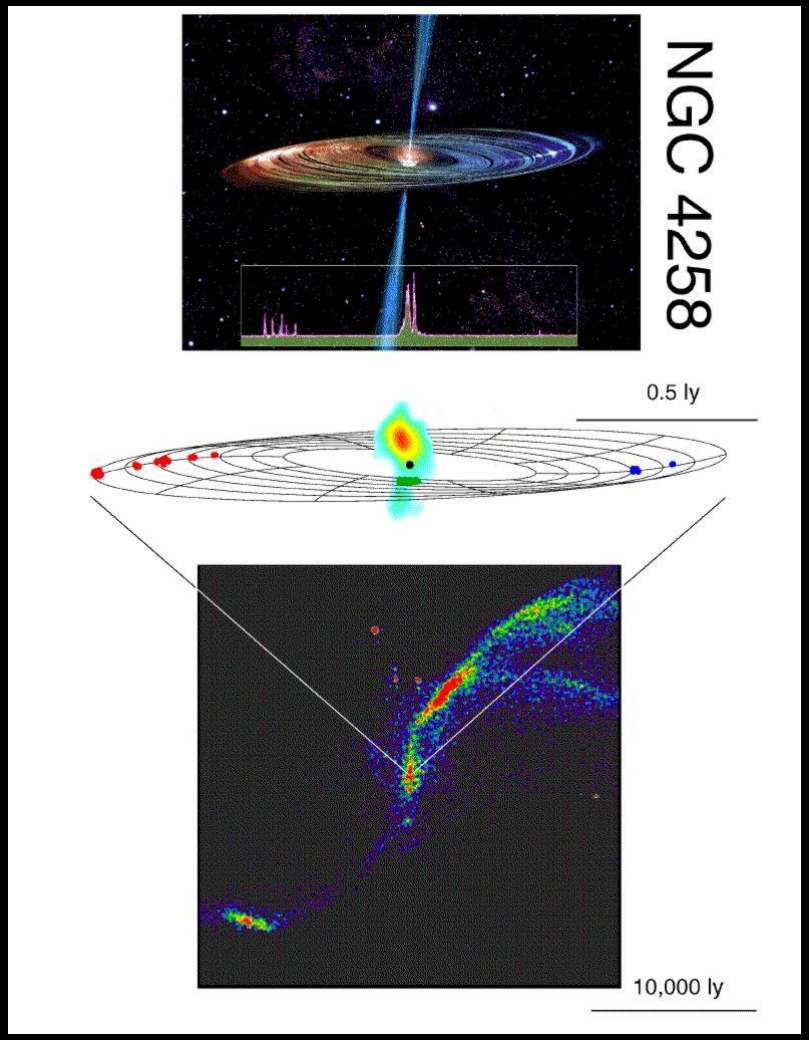


Water in supermassive black holes

The death of a star: SN1993J

Water in supermassive black holes





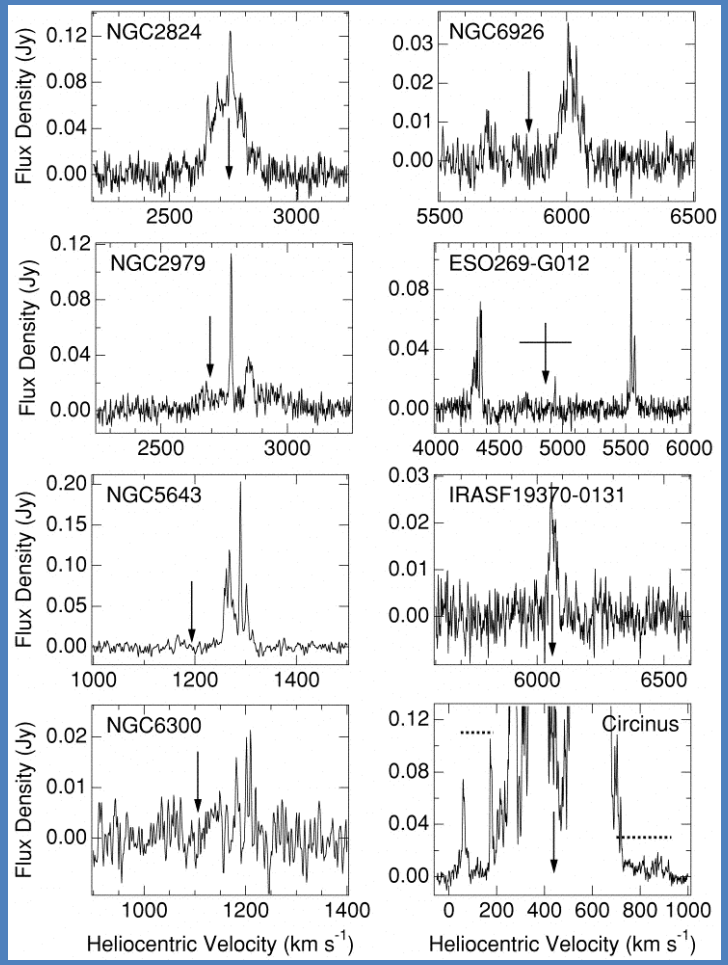
Water in supermassive black holes

SAMBA Survey Project

Harvard Smithsonian Center for Astrophysics

Water maser emission from Active Galactic Nuclei

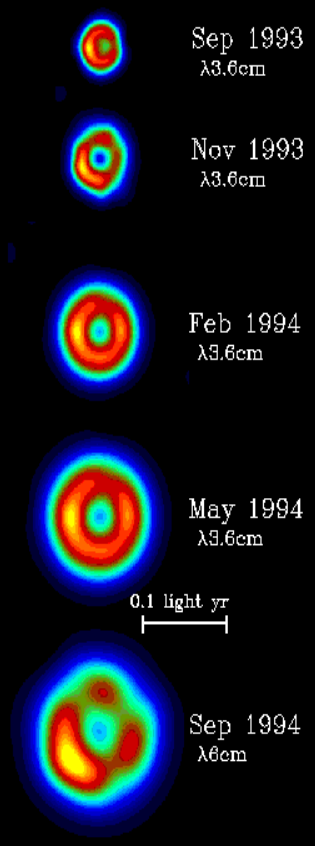
(Kondratko et al., 2006)



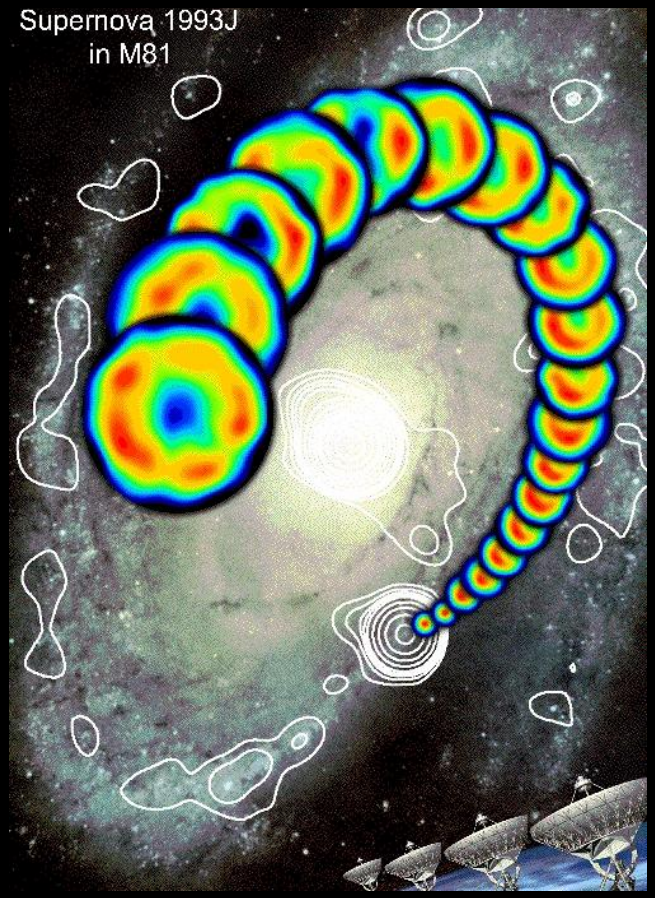
The death of a star: SN1993J

- Supernova type II in M81
- Constant symmetric expansion, with recent deceleration

Supernova remnant follow up: SN1993J



(Marcaide et al., 95)

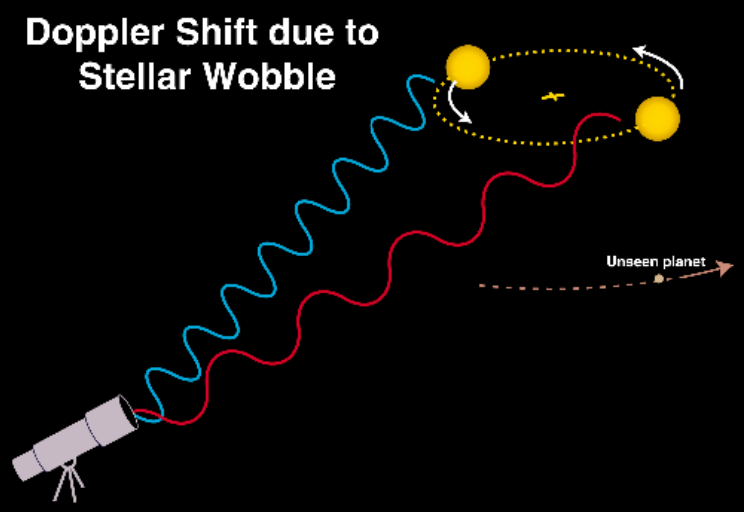


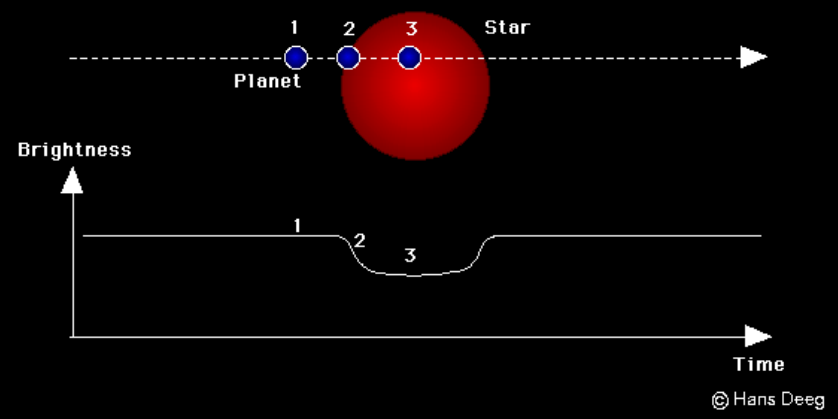
(Bartel et al., 2000)

The Milky Way, our Galaxy

Search for extrasolar planets
Pulsars

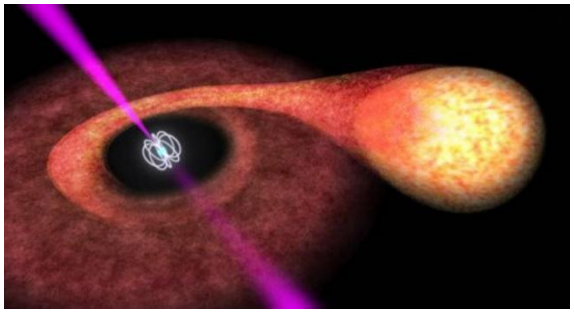
Extrasolar planets search

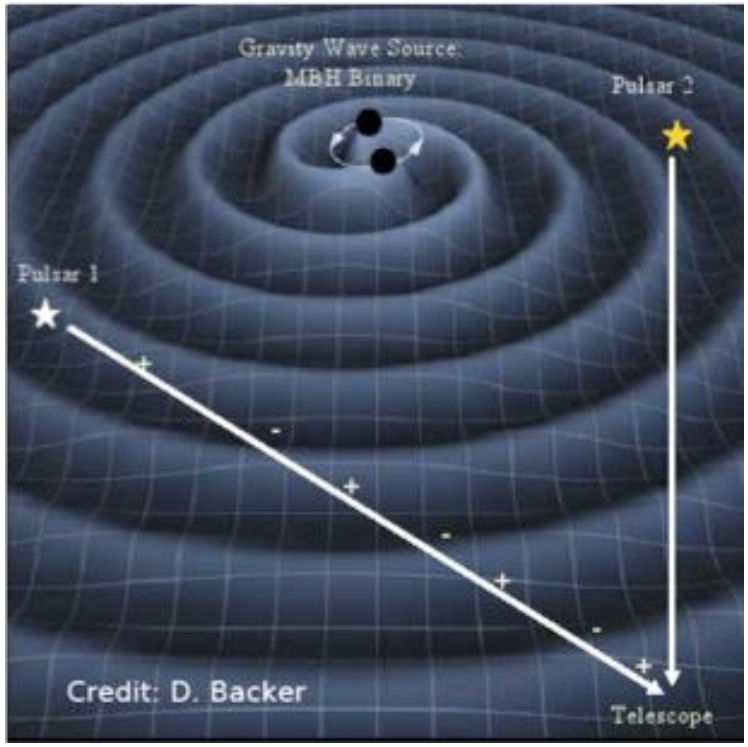




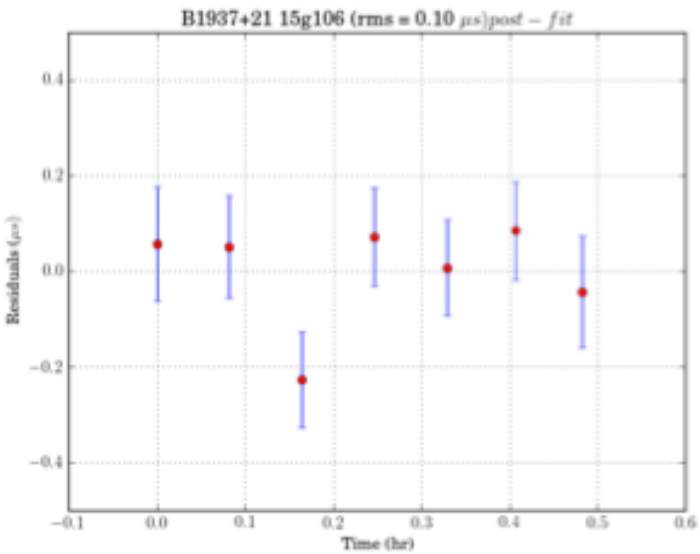
Search of extrasolar planets in red dwarfs *(Guirado et al., 2006)*

Pulsars



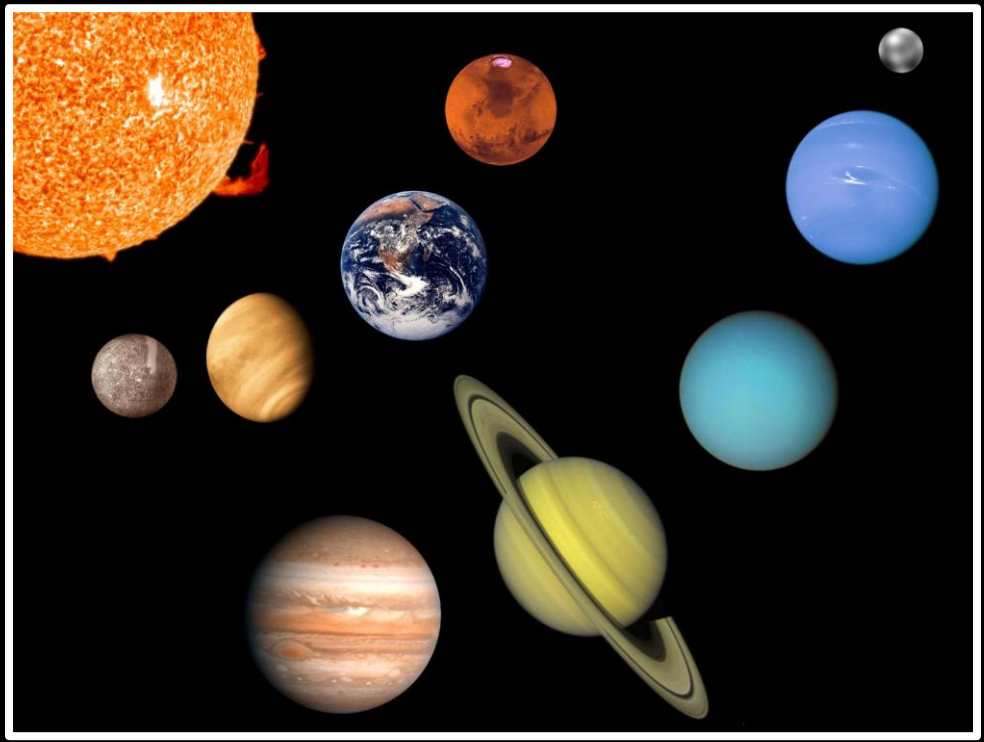


Detection of gravitational waves using msec pulsars



Reach noise level ~10-50ns: after 1 year of observations already achieved 100ns noise level.

The Solar System

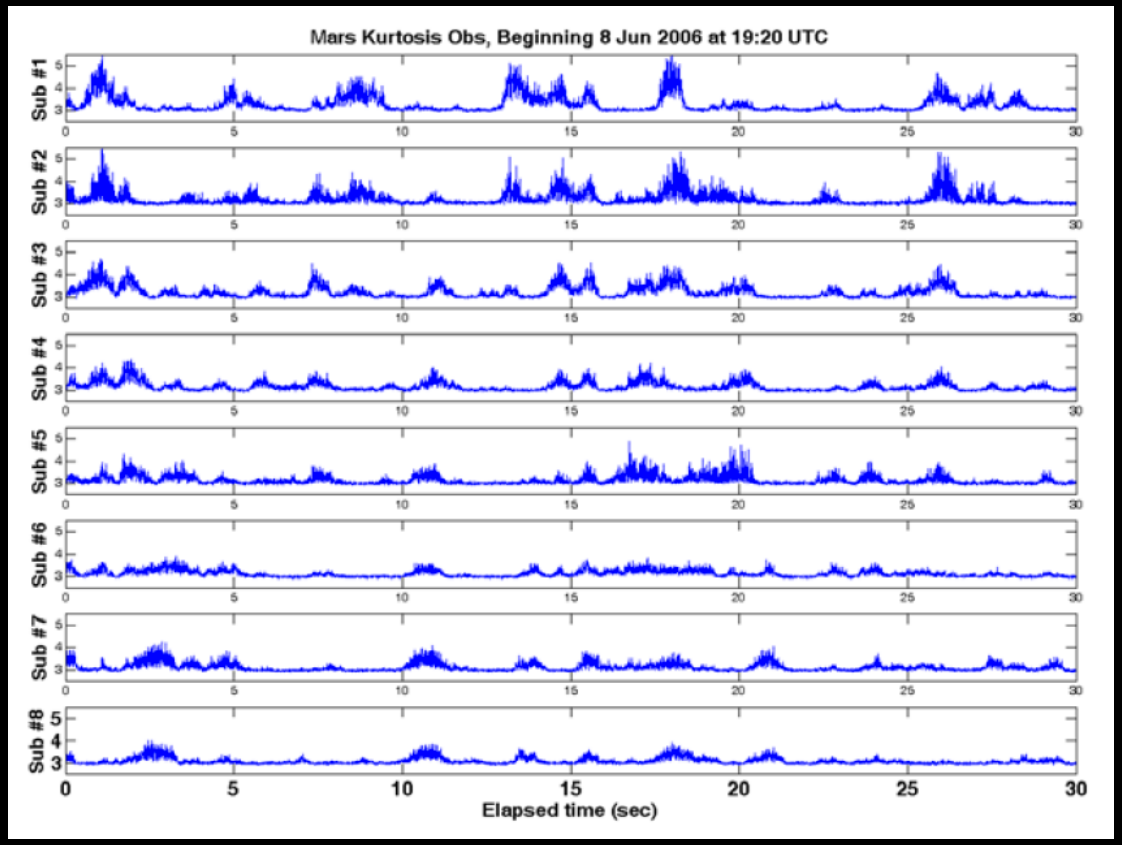


Mars dust storms

Storms in Mars

Detection of non-thermal radiation emitted by electrical discharges in dust storms *(Ruf et al., 2009).*

Storms in Mars

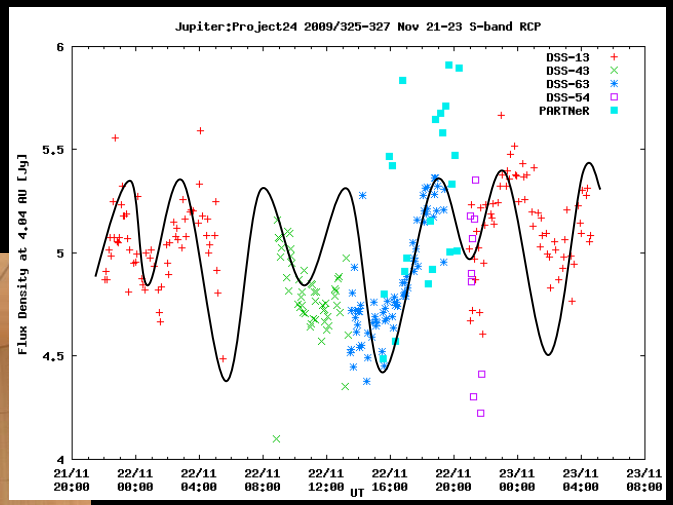


Detection June 2006,
19:14 . 22:40 UTC

Measure of the Kurtosis:
non-thermal radiation
(Ruf et al., 2009)

Outreach and educational activities with students

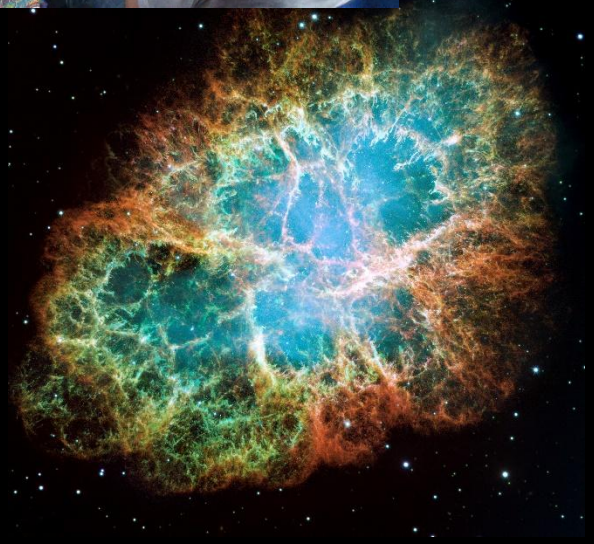
Jupiter Project 24, IYA 2009
in collaboration with PARTNeR and GAVRT



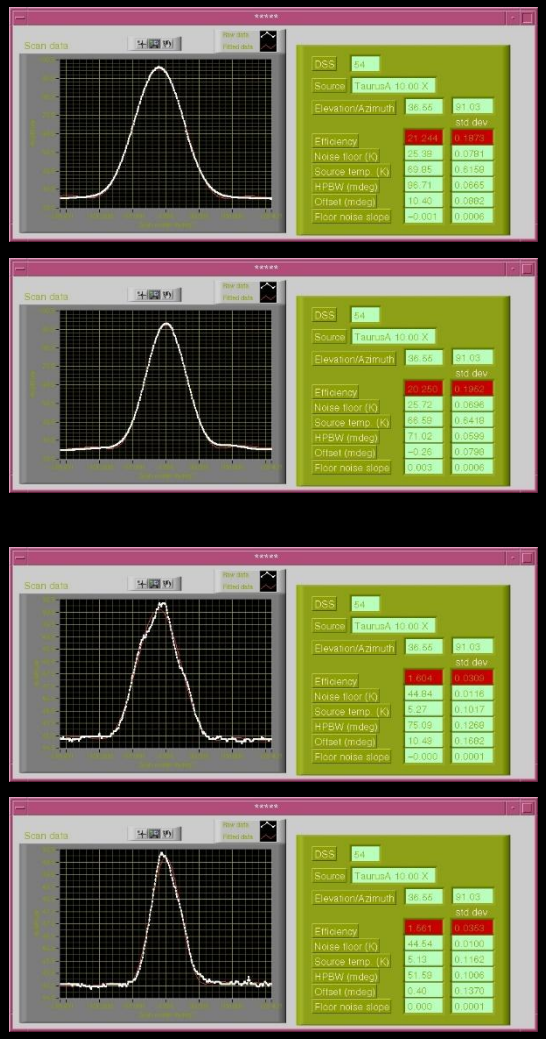
Star party
Robledo primary school, 2009

Outreach: “Stellar GPS”
Jacobs & Garcia-Miro, 2012

Secondary school students
RA workshops, 2013 & 2015



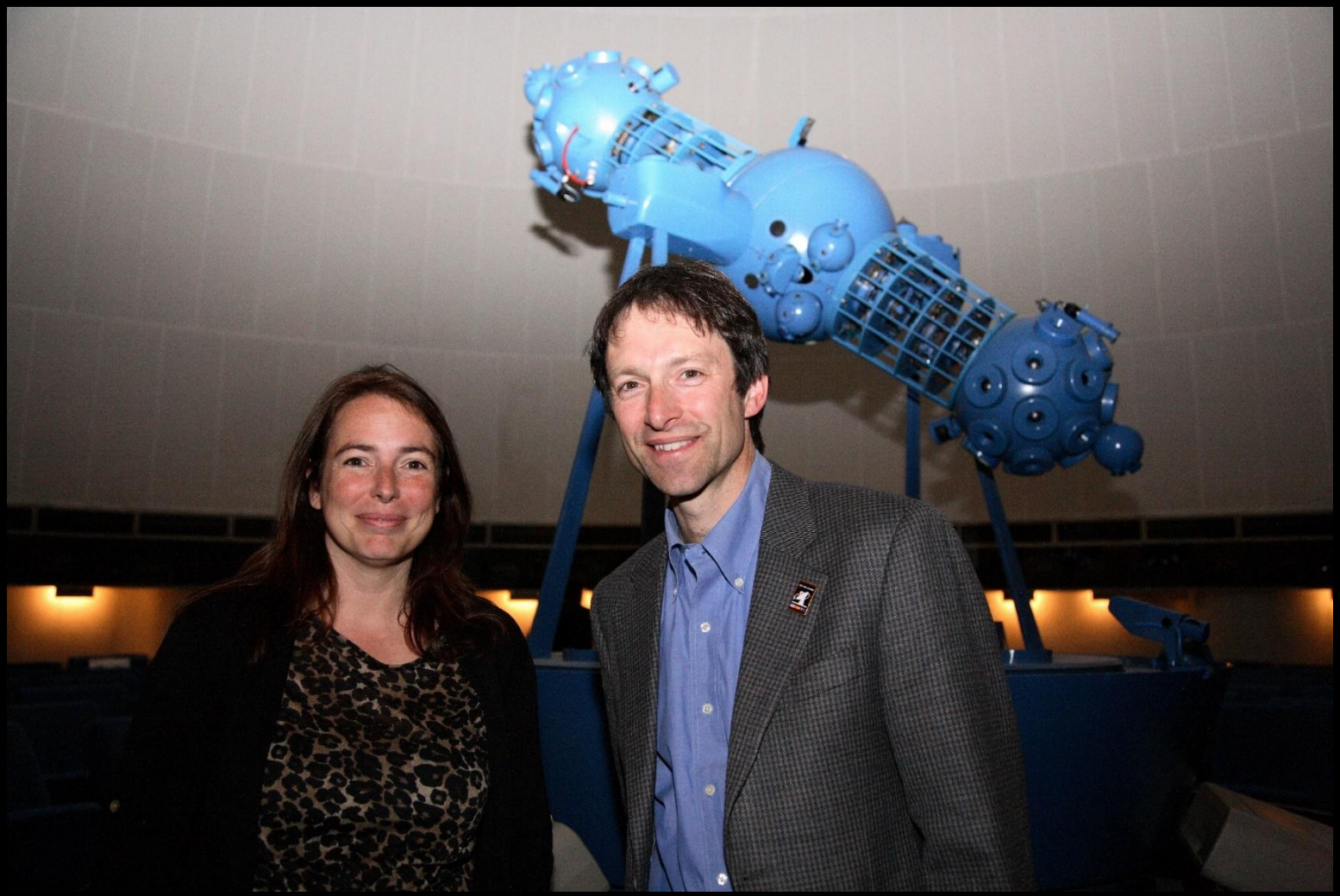
Crab Nebula continuum observations



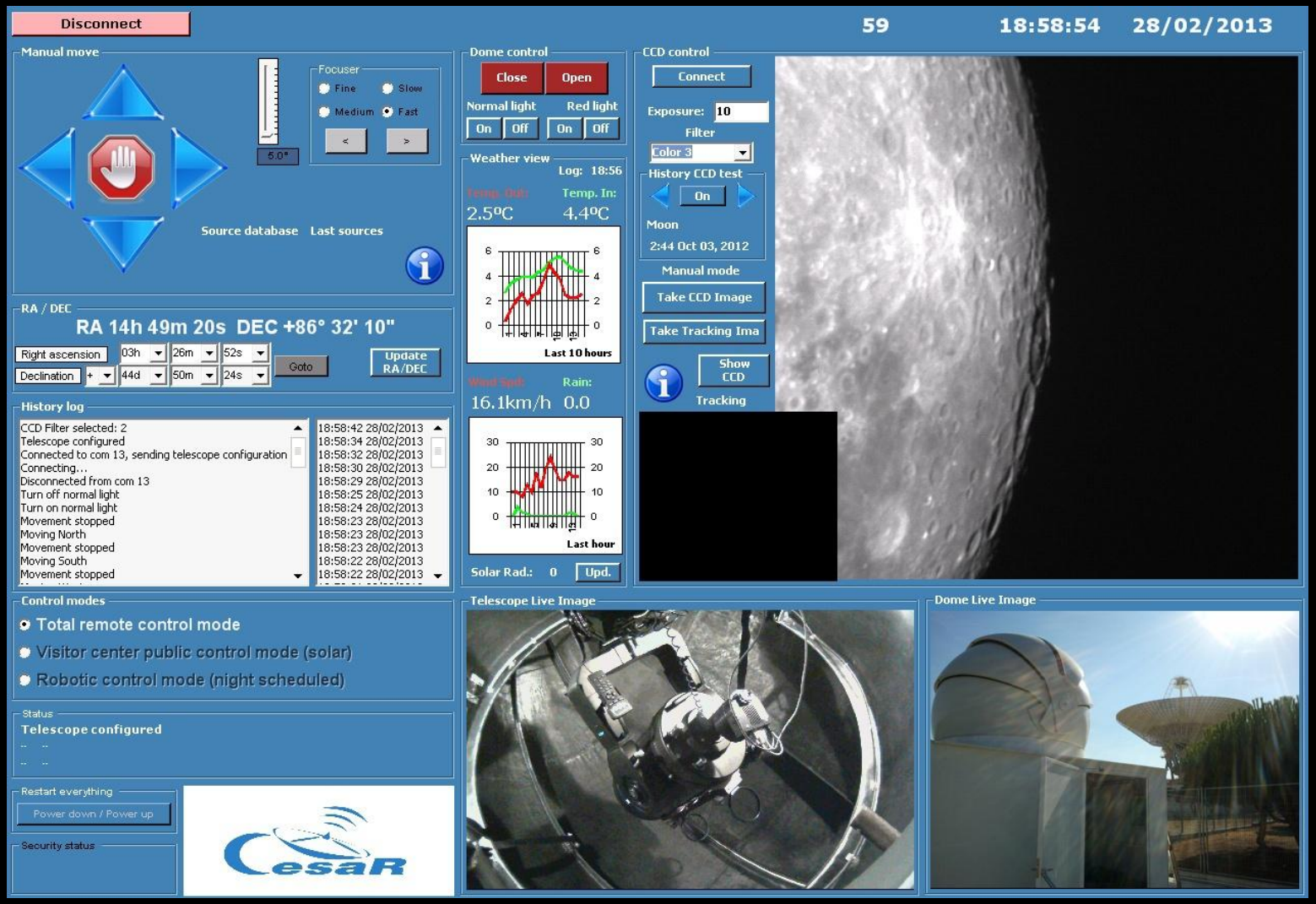
X-band
8.4 GHz

Ka-band
32 GHz

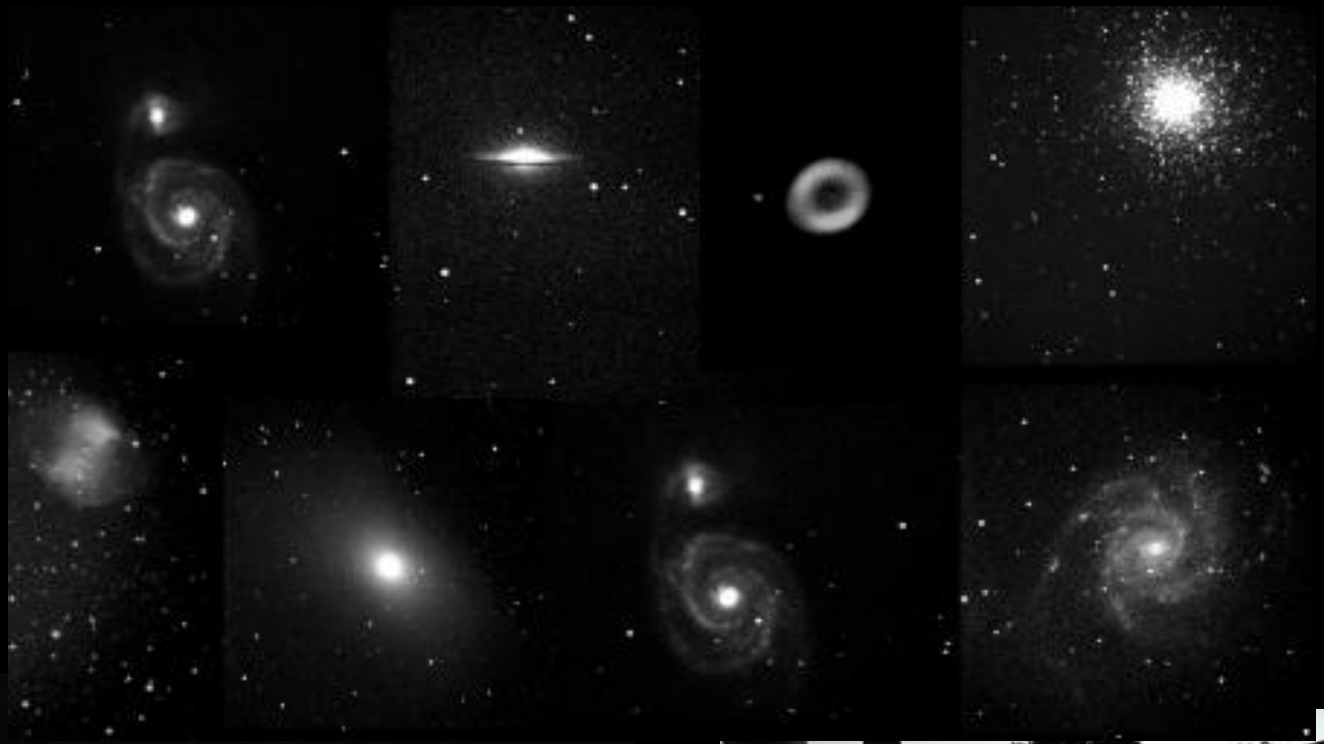
Outreach: “The DSN: the most important science tool of the last 50 years” Lazio & Garcia-Miro, 2014



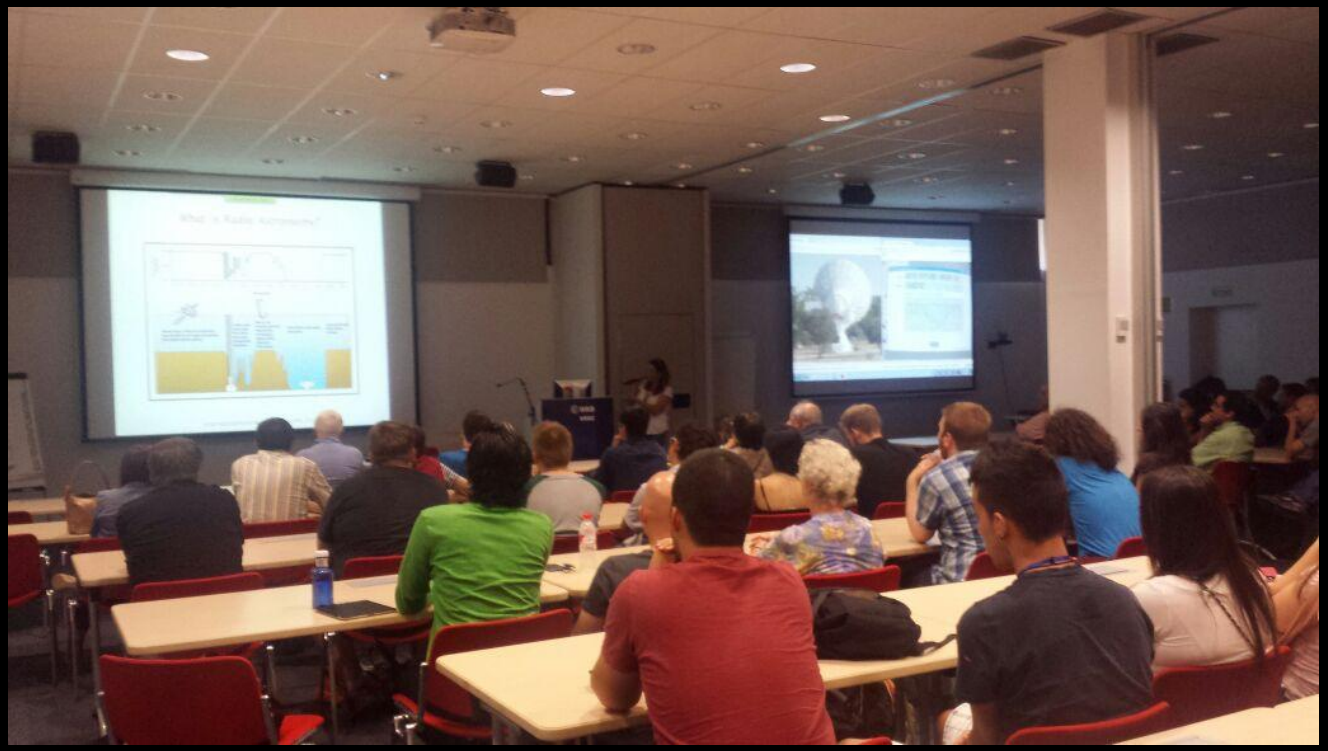
CESAR 12” optical telescope



ESAC star party, 2015



15m CESAR RT demonstration
UC3M summer school, 2015



“Searching for light” MDSCC Family day & Robledo Primary school, 2015

“Introduction to Radio Astronomy”
Navarra Public University summer school,
Sep. 22-25, 2015

Radio Astronomy and Outreach activities at NASA's Deep Space Network

Cristina García Miró INTA/ISDEFE

13th Annual International Workshop on Environment and Alternative Energy

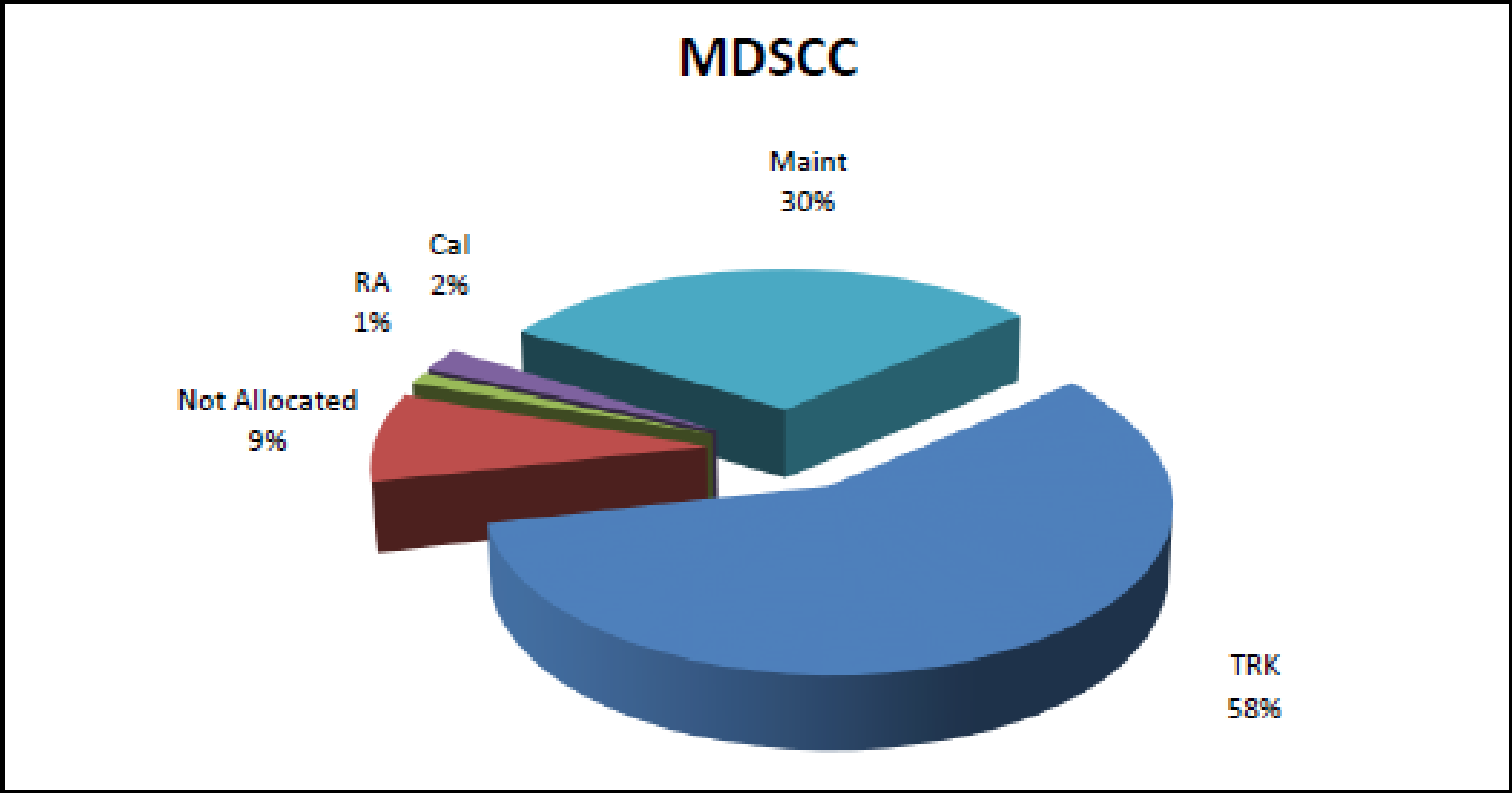
Nov. 11th, 2015

NASA's Deep Space Network

(vídeo http://mdscc.org/index.php?Section=Videos&Id=4)

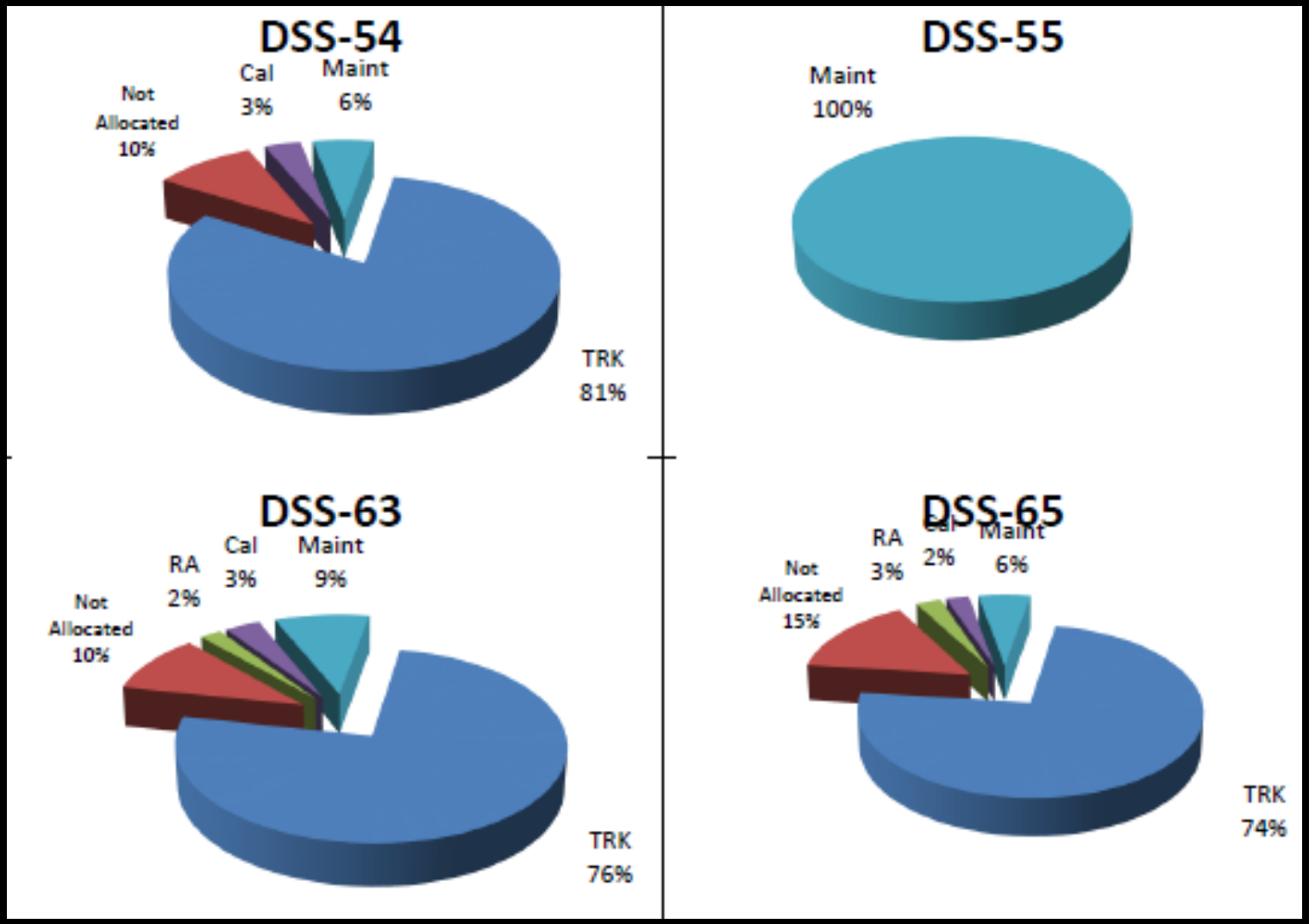
DSN usage

SEP 2015

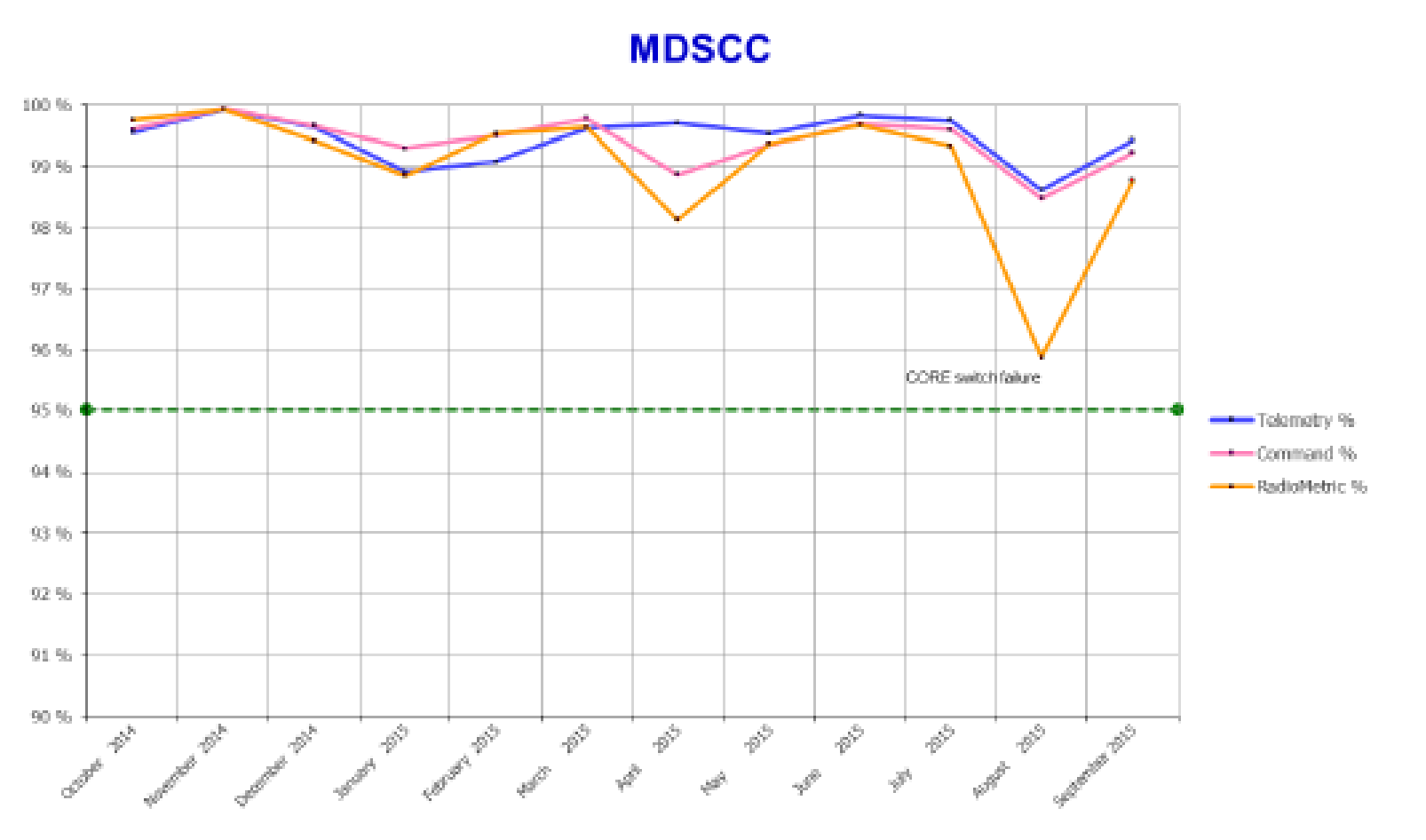


DSN usage

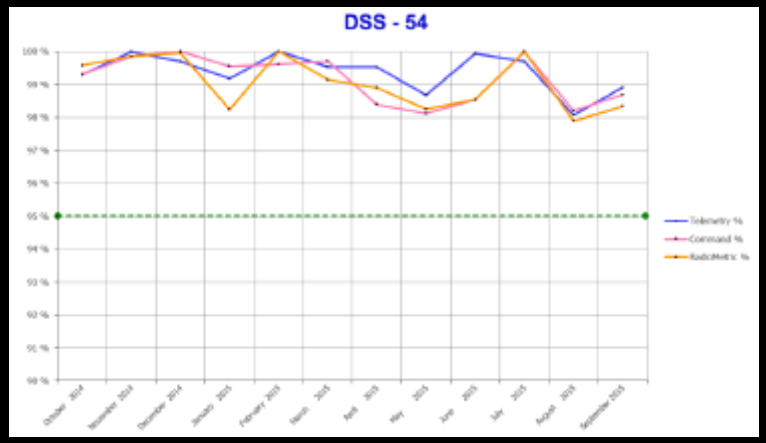
SEP 2015

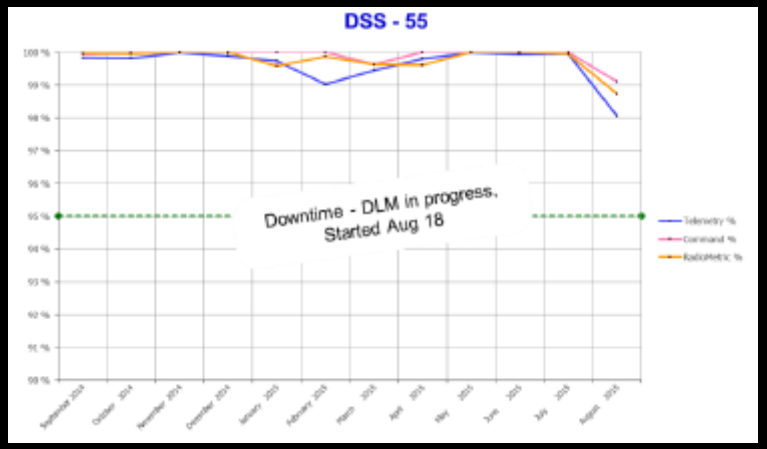


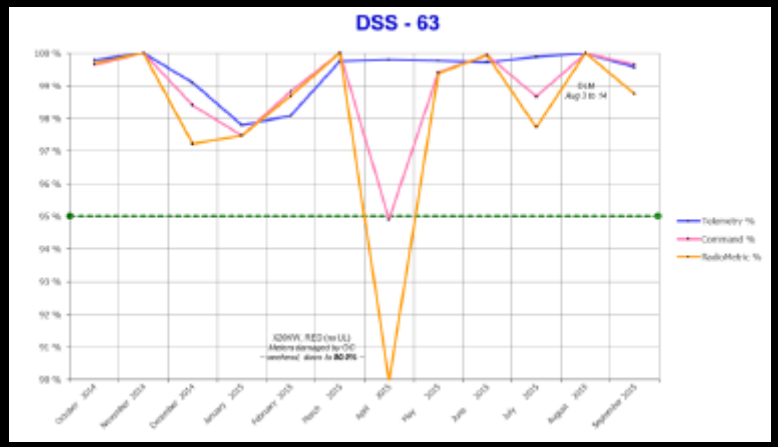
DSN performance: Madrid

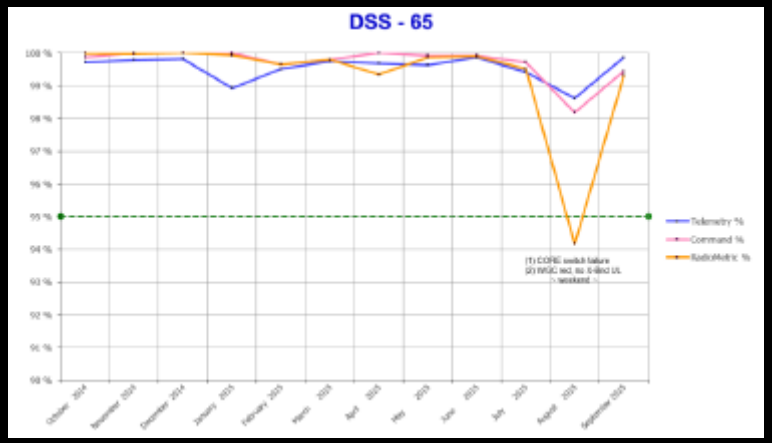


DSN performance

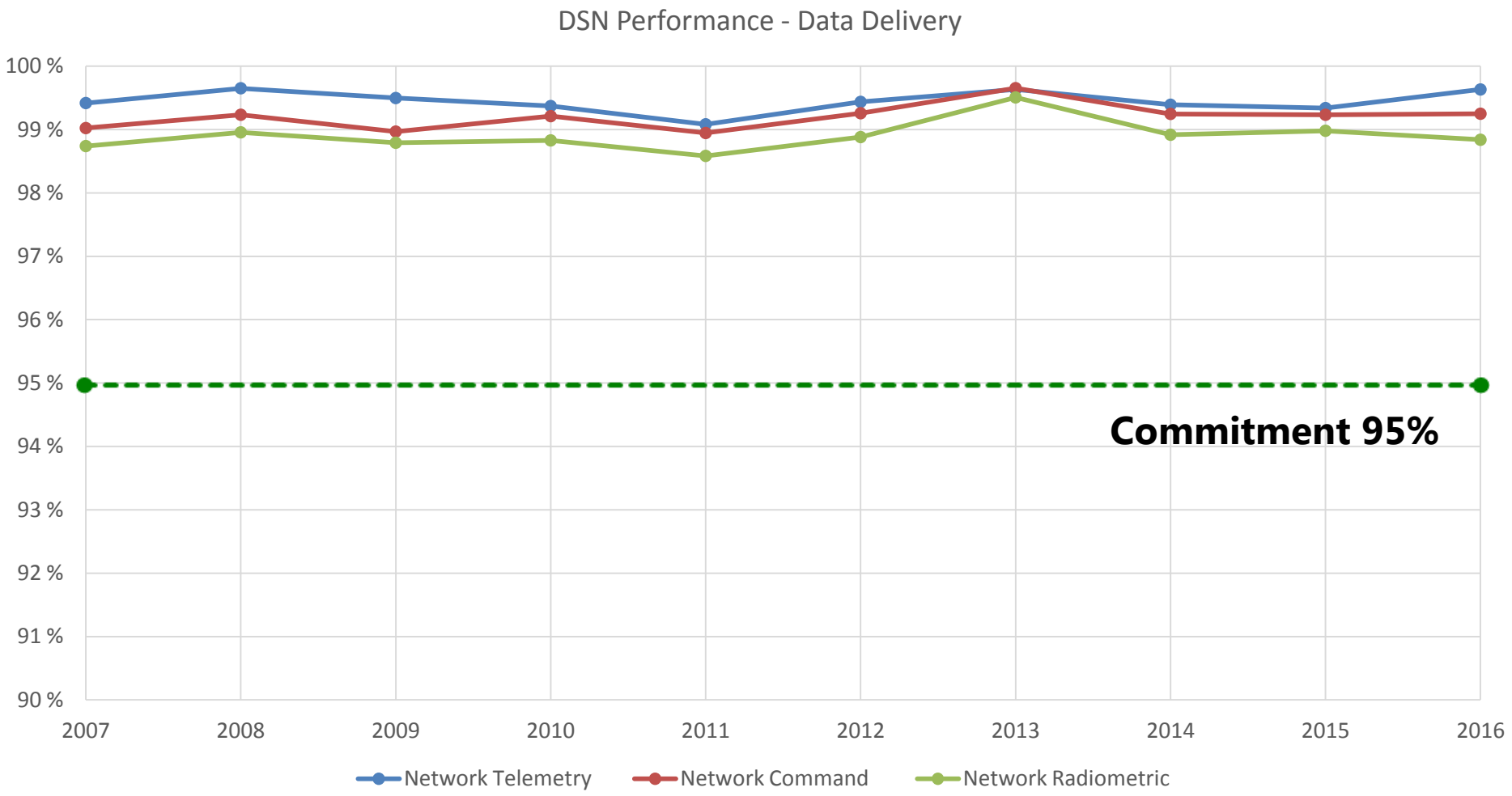






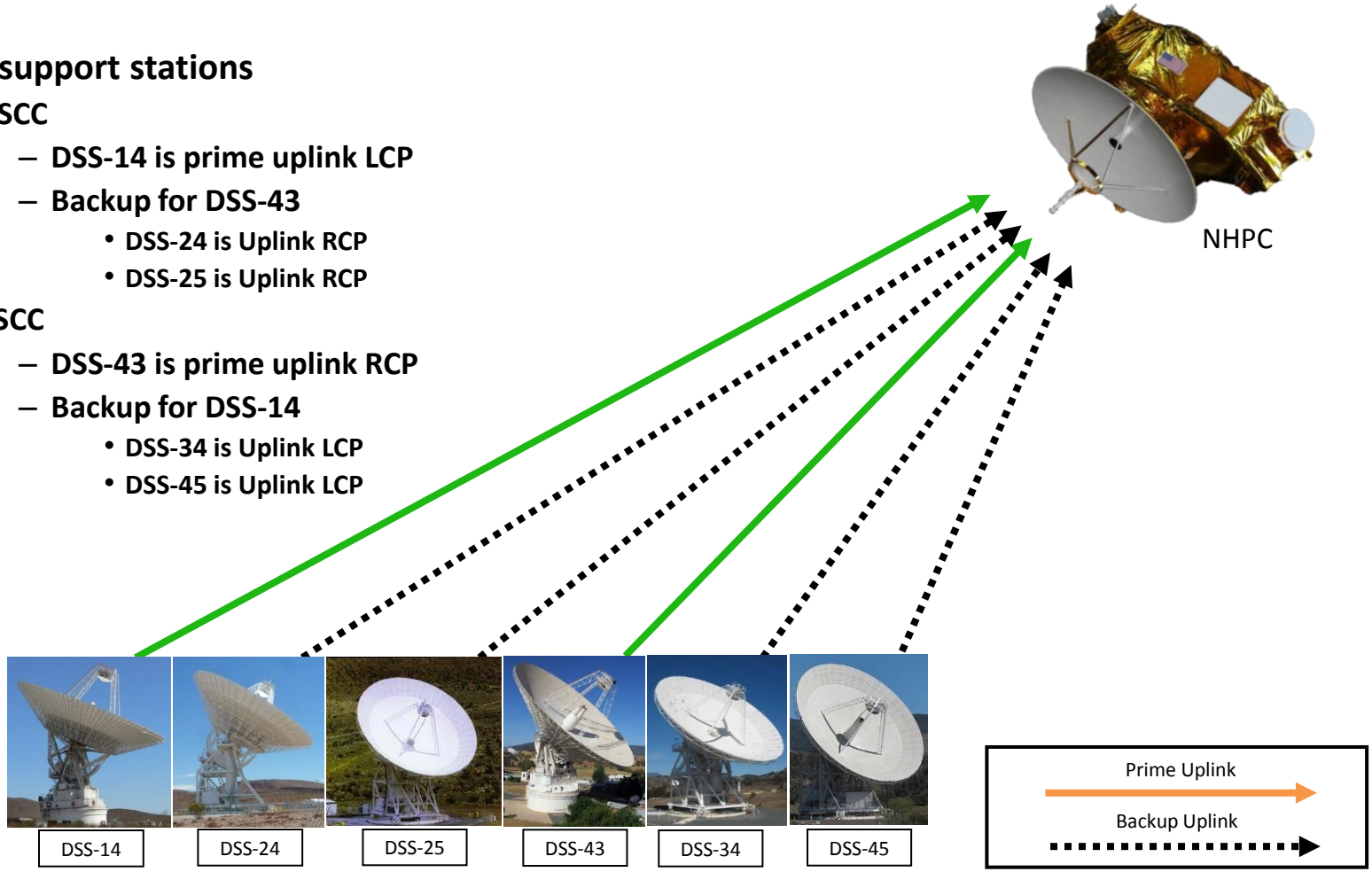


DSN performance

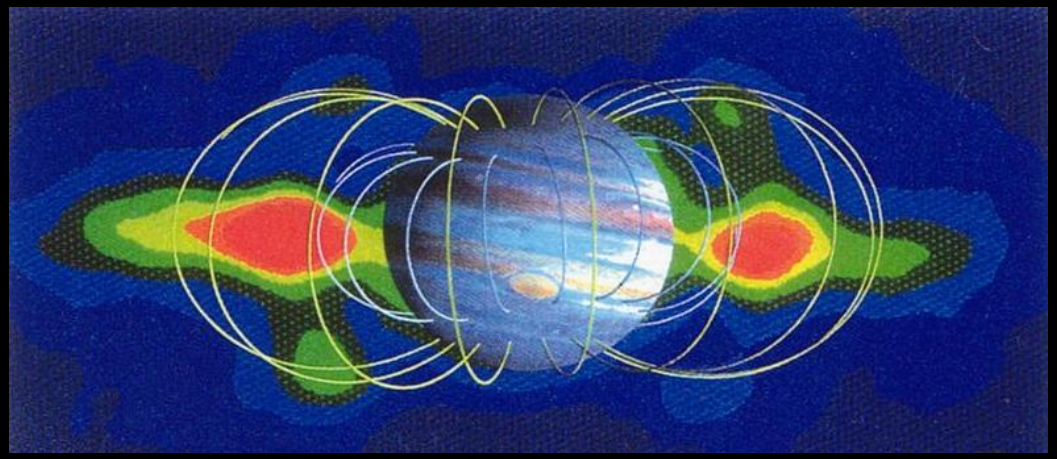


NH Pluto encounter: support Stations

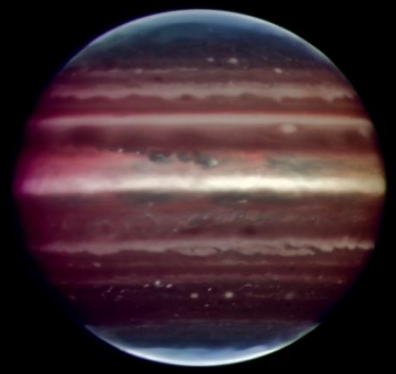
- **Level 1 support stations**
  - **GDSCC**
    - **DSS-14 is prime uplink LCP**
    - **Backup for DSS-43**
      - **DSS-24 is Uplink RCP**
      - **DSS-25 is Uplink RCP**
  - **CDSCC**
    - **DSS-43 is prime uplink RCP**
    - **Backup for DSS-14**
      - **DSS-34 is Uplink LCP**
      - **DSS-45 is Uplink LCP**



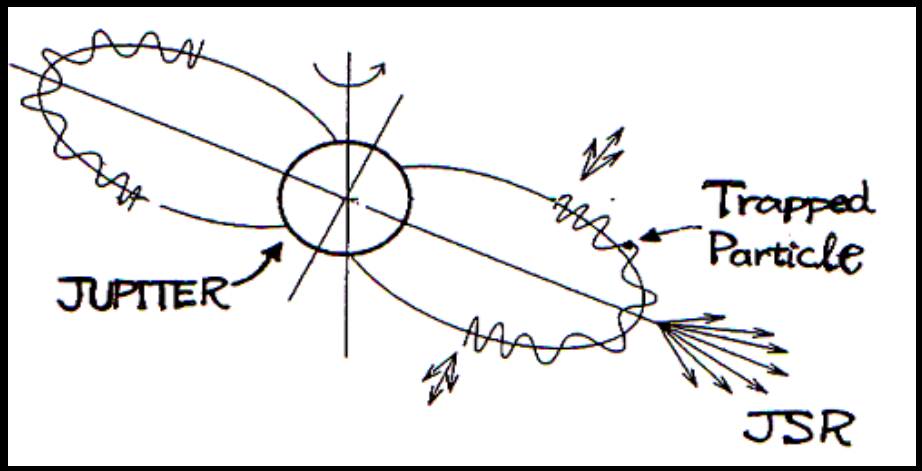
Continuum emission: Jupiter



Thermal emission: black body



Non-thermal emission: Synchrotron



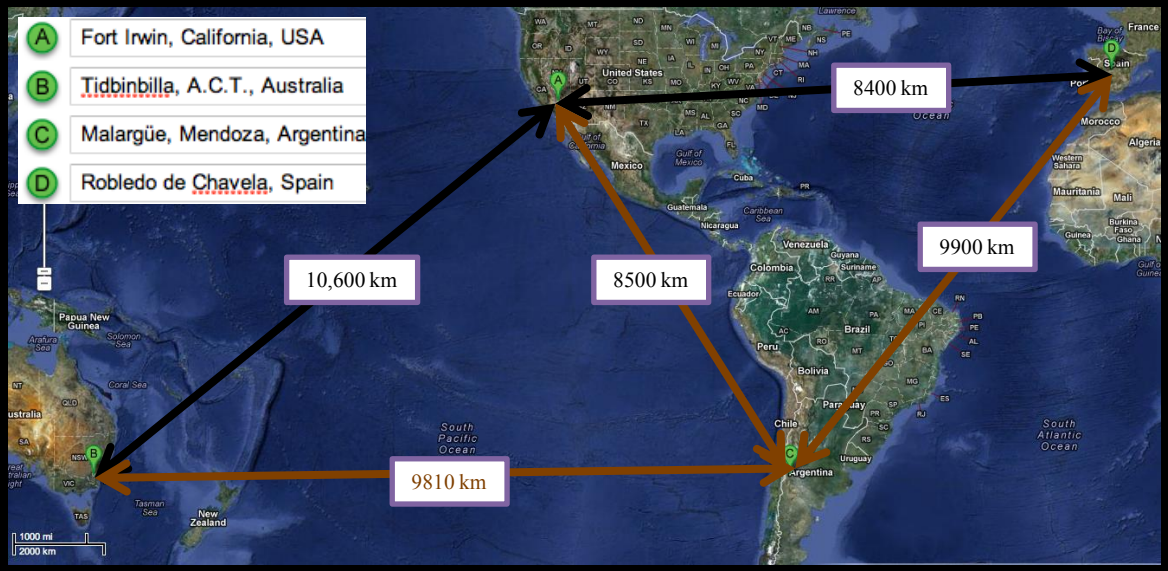
How do we observe with the antennas?

The VLBA interferometer made of 10 antennas (25m diameter) with same equipment.

Sustainable Radio Astronomy?

Photo credit: Fender blender pro

The stellar GPS: celestial reference frame

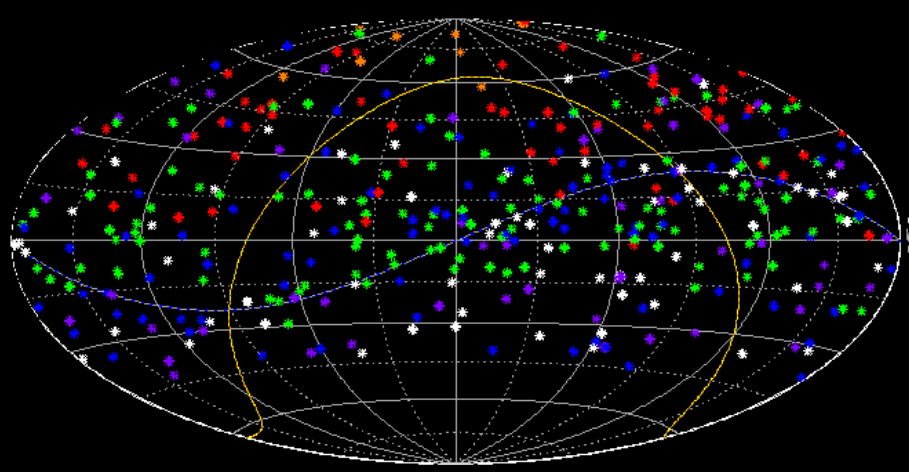


NASA DSN + ESA

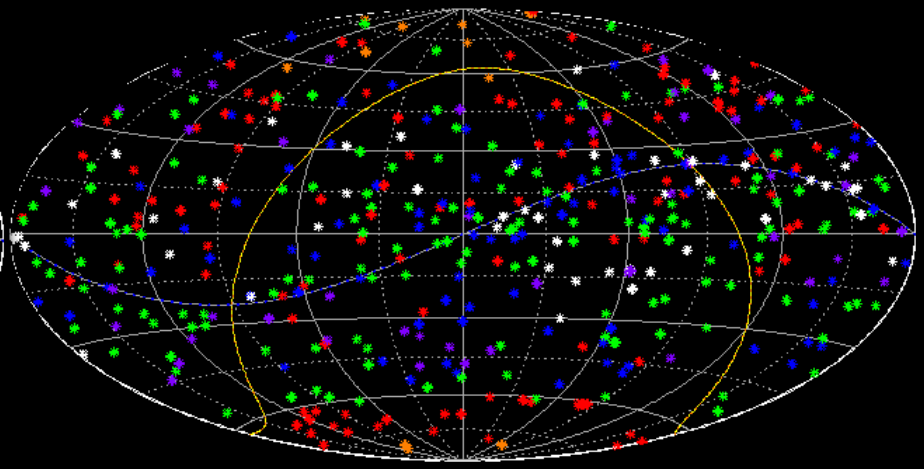
X/Ka star catalog

Declination Sigma

Orange: < 100 μas
Red: < 200
Green: < 300
Blue: < 500
Purple: < 1000
White: > 1000

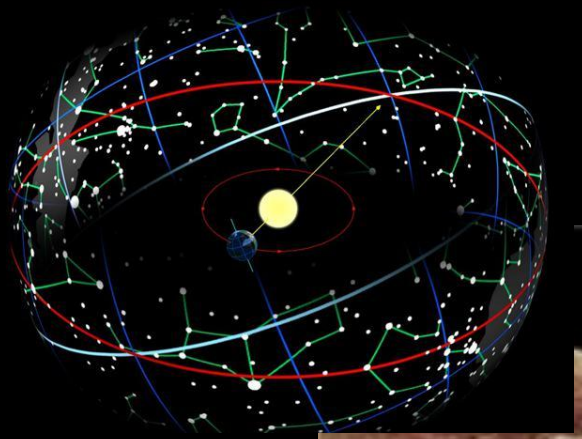


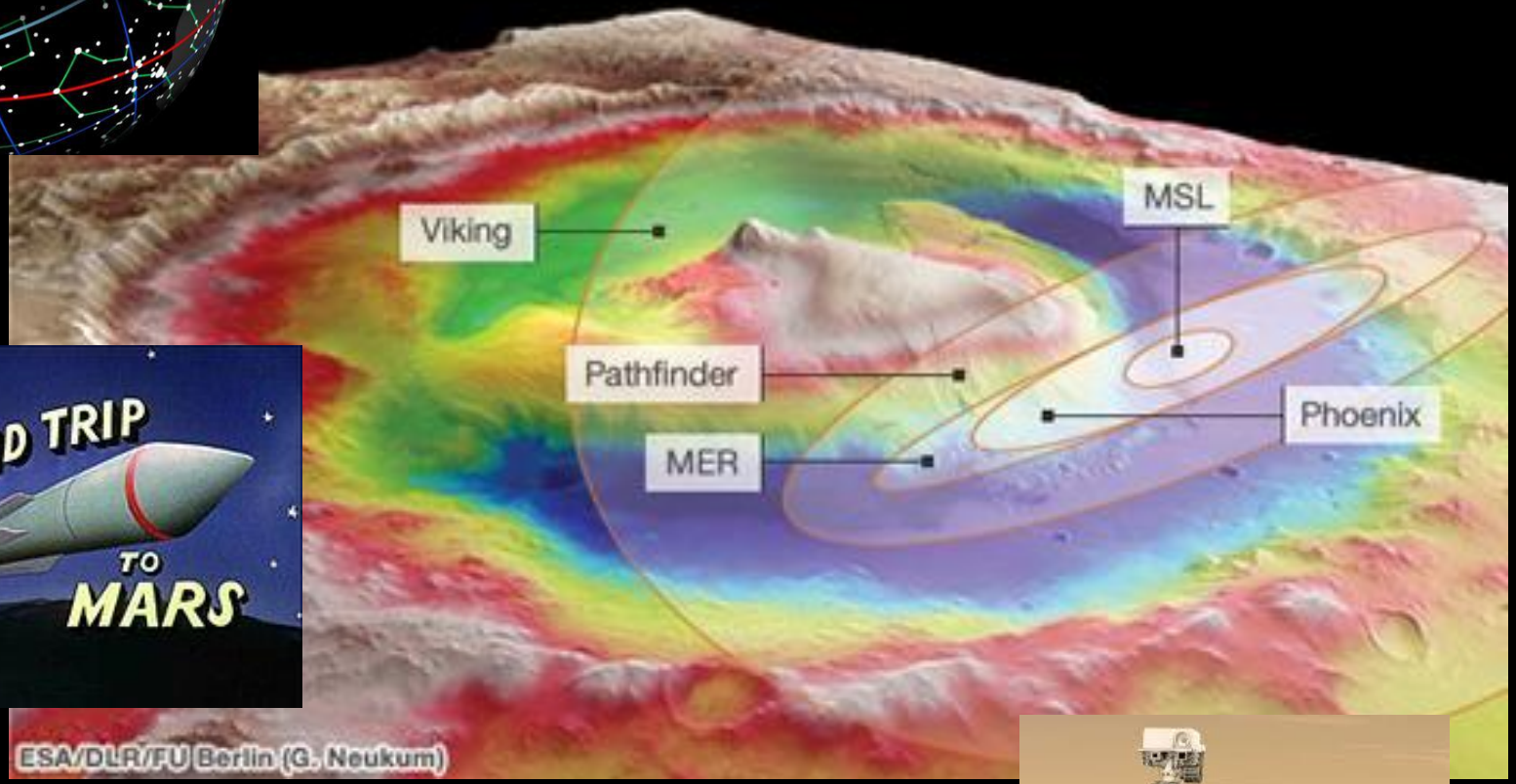
Before

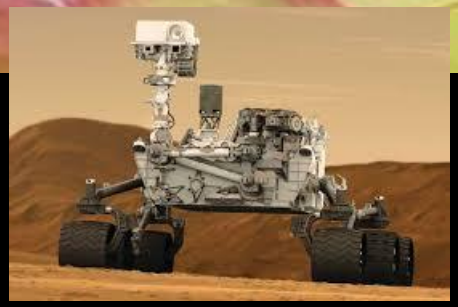


Now

The stellar GPS

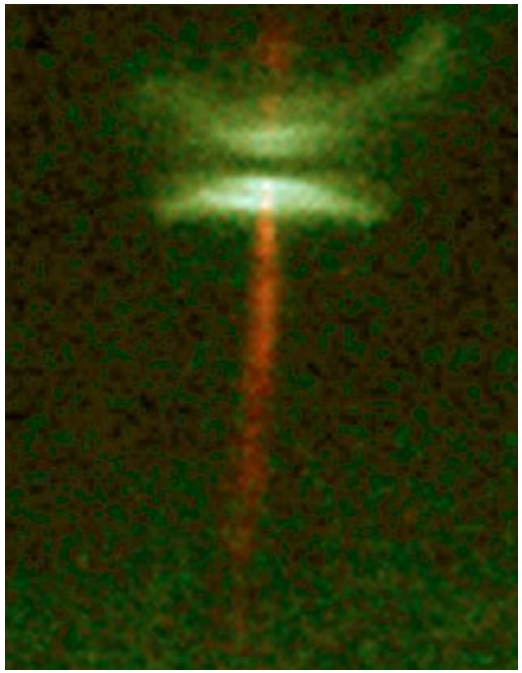






The error ellipse for Curiosity landing was about 6x19Km while it was 300Km for Viking in1976.

Just born stars chemistry

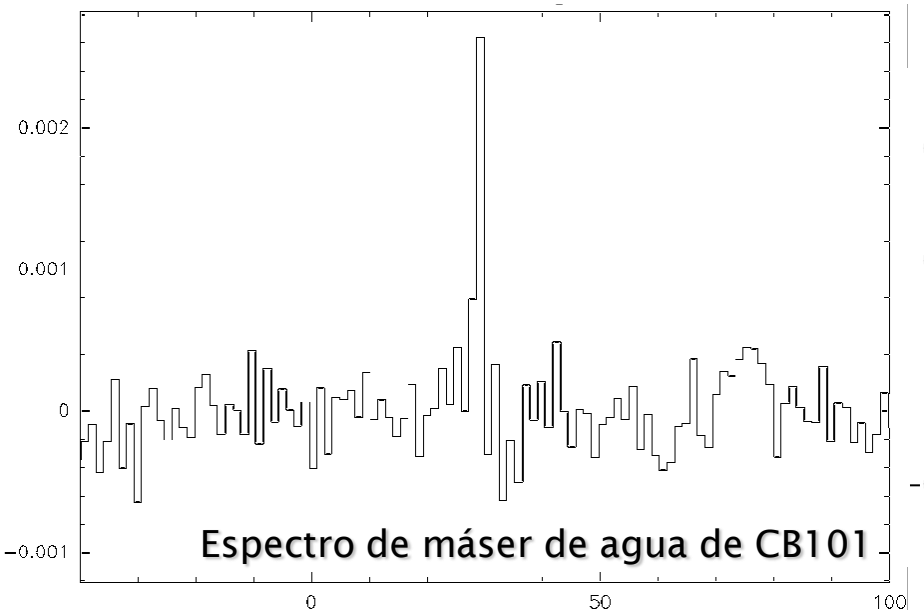


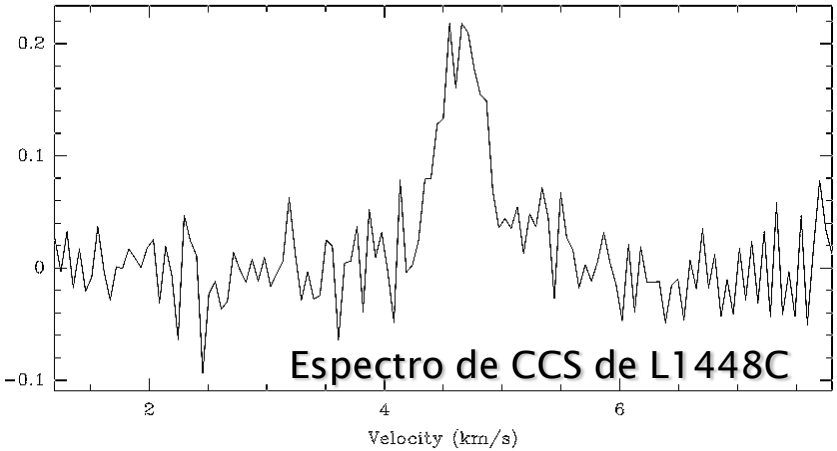
Protoplanetary disk and collimated jet in HH-30, Taurus *(Hubble Space Telescope, 2000)*

- Very energetic mass loss processes in form of jets or winds:
  - **Water maser emission** (high density and temperature): traces collimated jets and protoplanetary disks.
  - **Ammonia emission**: traces dense gas.
  - **CCS emission** (Carbon-Carbon-Sulfur): traces youth, it is destroyed during stellar formation.

Just born stars chemistry

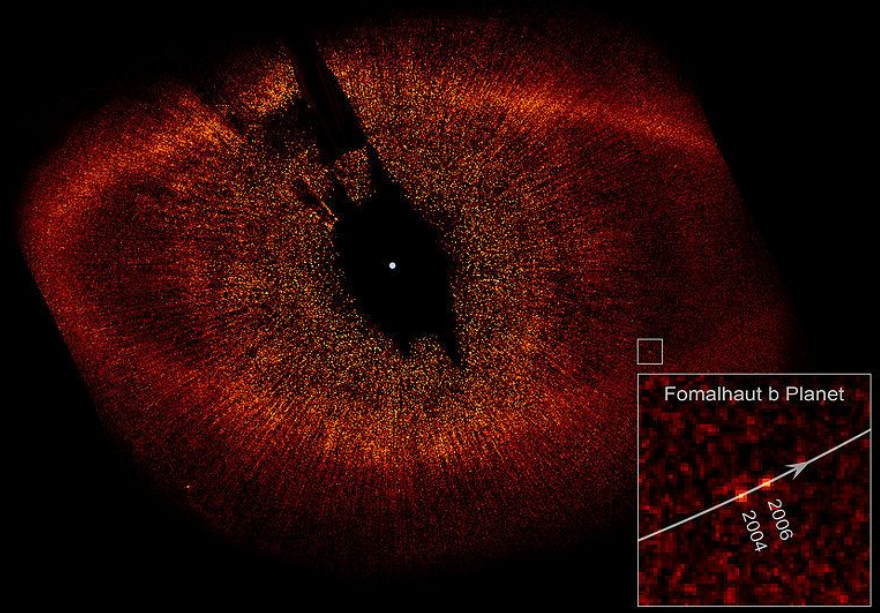
- Bok globules: cold molecular clouds and isolated where low mas star formation occurs.





(Gregorio-Monsalvo et al., 2006)

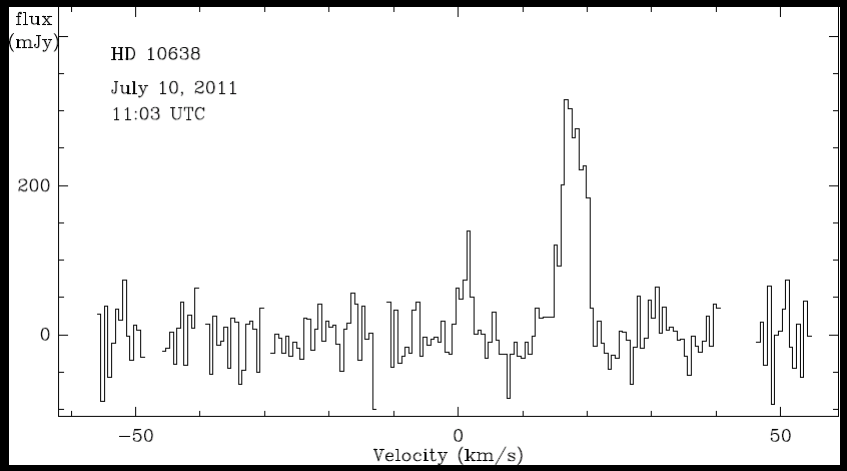
Extrasolar planets search



Search for extra solar planets in young debris planetary disks

Water maser spectrum in HD 10638

(Bendjoya et al., in preparation)

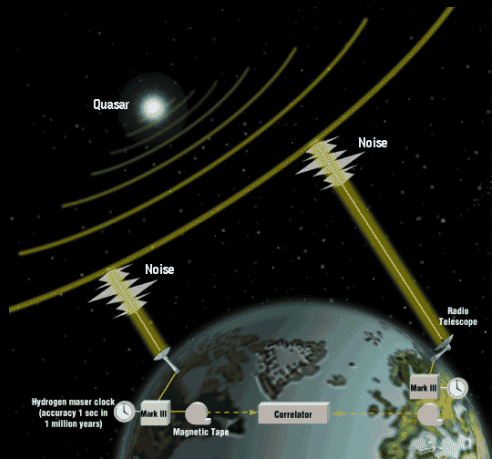


Geodesy studies: plate tectonics

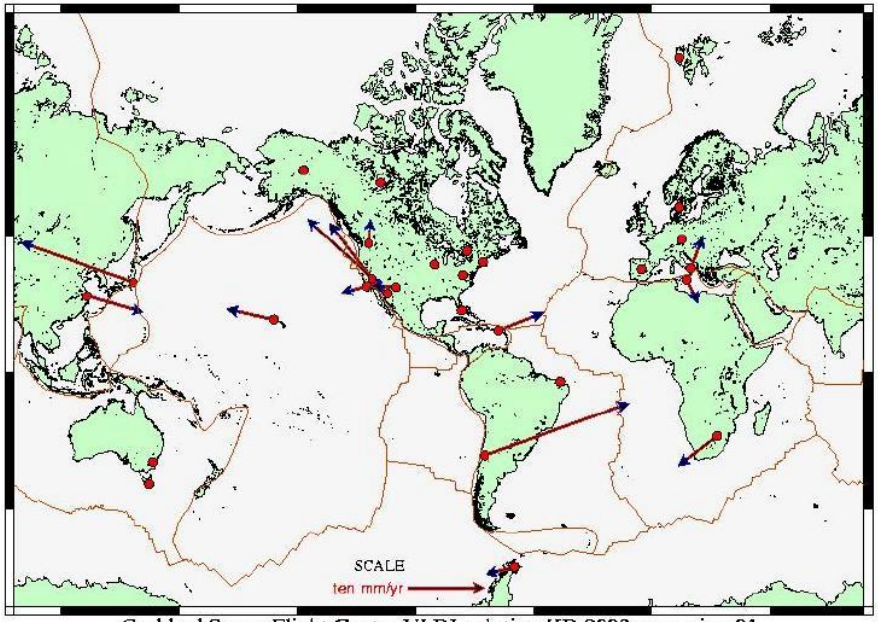
In 1961, model of plate tectonics came into prominence, explaining the observed spreading of the sea floor and uplifting of mountain ranges

Precise measurement was critical to providing the evidence --- accomplished by observing space radio sources with pairs of antennas on different plates.

The DSN was ideally suited to this task and provided much of the data required to hone this new model

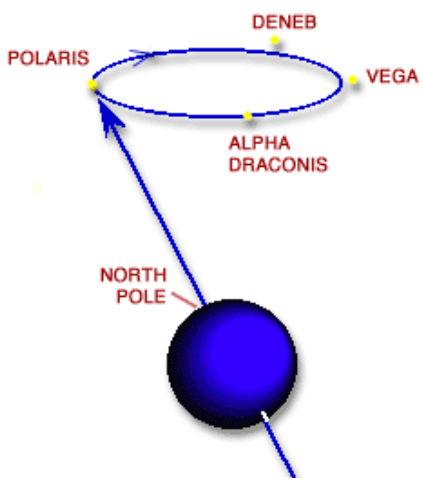


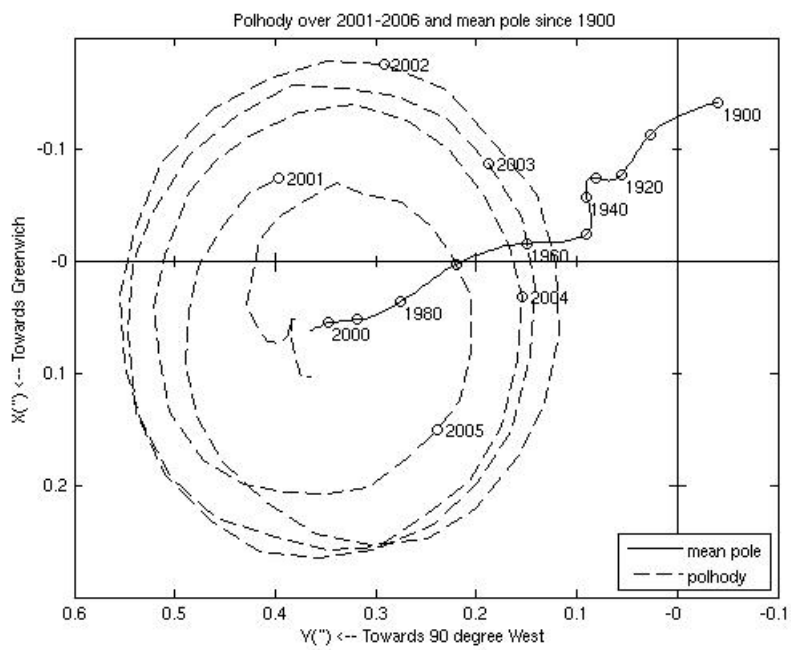
Geodesy studies: plate tectonics



Earth pole rotation

- **Precession:** circle of 23.4° every 26000 years. Due to Sun and Moon gravity.
- **Nutation**: 9.2 arcsec every 18.6 years. Due to 5° difference between lunar and earth orbits.
- Other movements with shorter period: Earth is not spherical.
- Maintained by International Earth Rotation and Reference Systems Service (IERS).





Outreach activities

- **IYA09 celebration:** Jupiter Project 24, talk at Sydney Cervantes institute, star party at Robledo primary school with 500 people, “She is an astronomer” outreach talk, 2009.
- **Year of Solar System celebration:** *La Aventura del Saber, 2011*
- Madrid planetarium talk about ***“Stellar GPS: Navigating in the Solar System”,*** *C.* Jacobs & Garcia-Miro, 2012.
- Bolden visit support, 2012.
- Madrid planetarium talk about **“The DSN: The most important Science tool of the last 50 years”**, J. Lazio & Garcia-Miro, 2014
- **CESAR collaboration** (TVC 12” optical telescope and ESAC Radio Telescope): ESAC star party, UC3M summer course, hands-on remote session from Argentina, 2015.
- MDSCC **“Family day”** organization, **“Searching for light”** outreach talk at MDSCC and Robledo Primary school, *C.* Jacobs & Garcia-Miro, 2015.
- **“Introduction to Radio Astronomy”** UPNA and Pamplona Planetarium summer course, Sep. 22-25, 2015.

Outreach: Sydney outreach talk, 2009

Outreach: “She is an astronomer” outreach talk, IYA 2009

Outreach: Year of Solar System, 2011

Outreach: Bolden visit, 2012