Seminar Falak Nusantara

Solar Radio Burst: The Technique of Gain the Data

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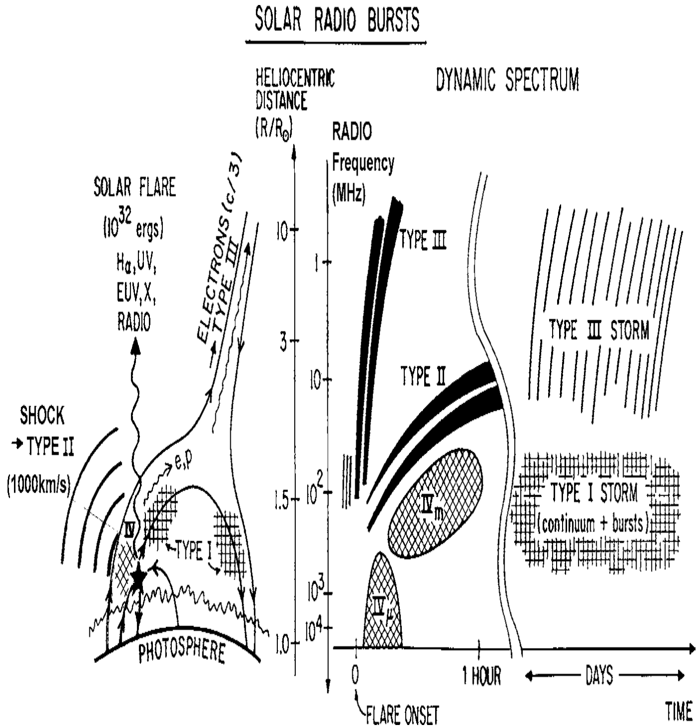
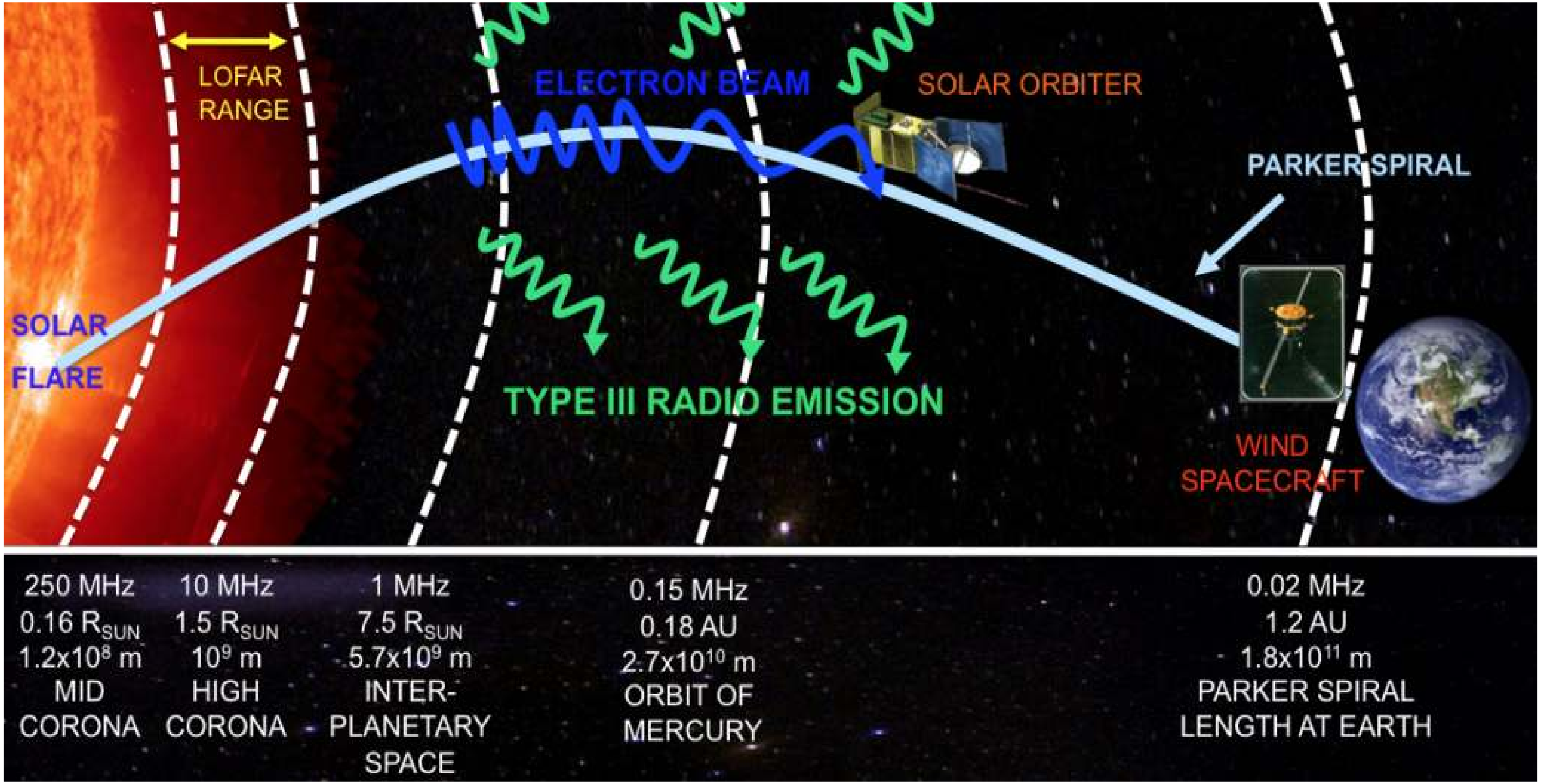
Introduction

- Solar radio observations have been carried out since 1944 when J.S Hey discovered that the Sun emits radio waves.
- This method reveals us to study energy release, plasma heating, particle acceleration and particle transport in solar magnetized plasma.
- The E-CALLISTO is an acronym stands for extended Compact Astronomical Low Cost Frequency Instrument for Spectroscopy and Transportable Observatory, is a worldwide network of frequency-agile solar spectrometer.

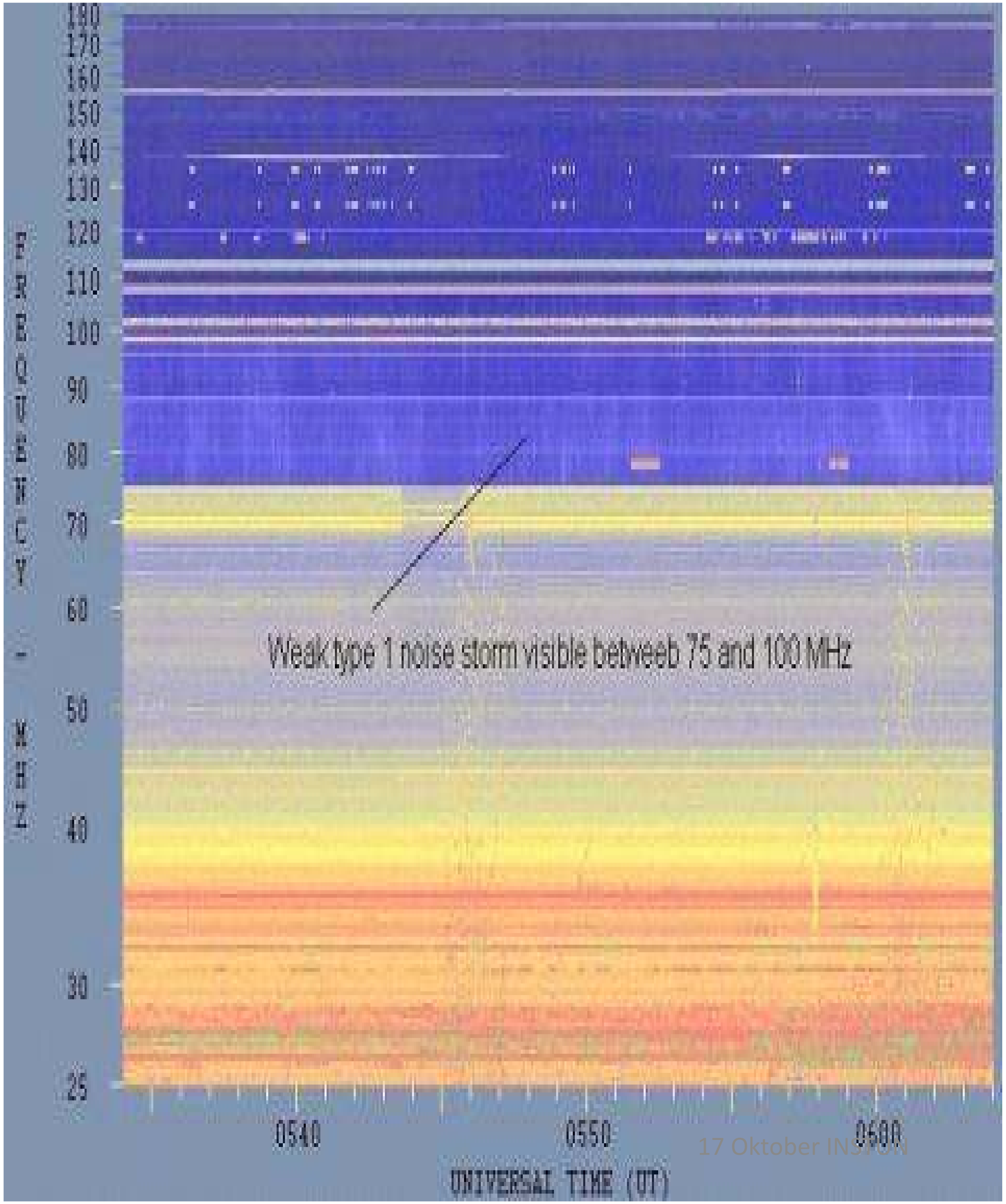


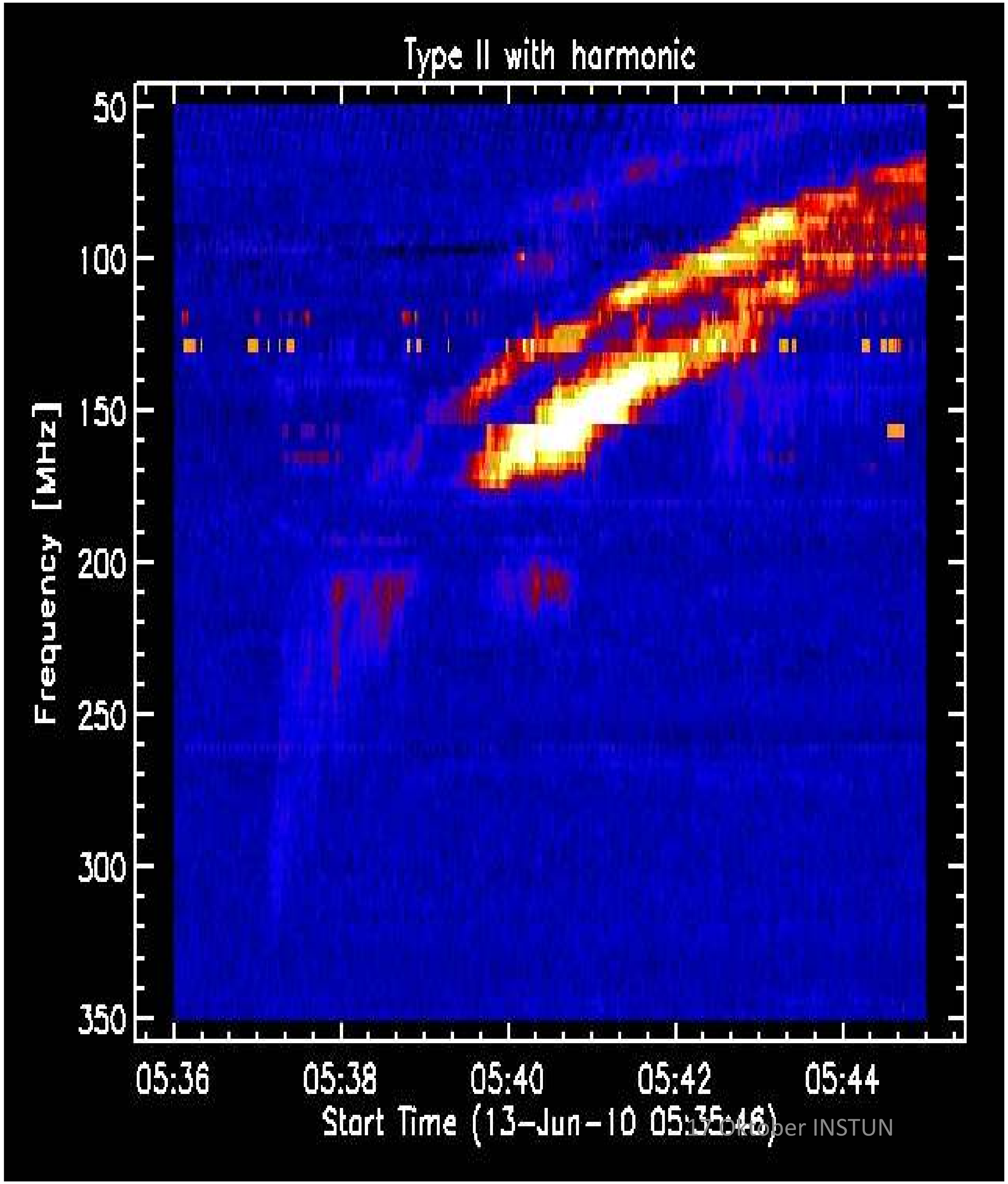
- The Coronal Mass Ejections(CMEs) & Solar Flare

Phenomenon	Time scale	Place of origin	Wavelength range	Associated optical feature
Quite Sun	Steady	Whole Sun	Whole Spectrum	Solar disk
Basic component	~11 years	Whole Sun	$S_{v, max}$ at dm waves	Solar disk
(S- component)	Months-days			
Noise storms	Days-hours	Restricted areas inside active region	Dm-m-Dm waves	Large spot groups
Various types of bursts	Minutes-seconds	Restricted areas inside active region	Whole radio range	Flares (often)

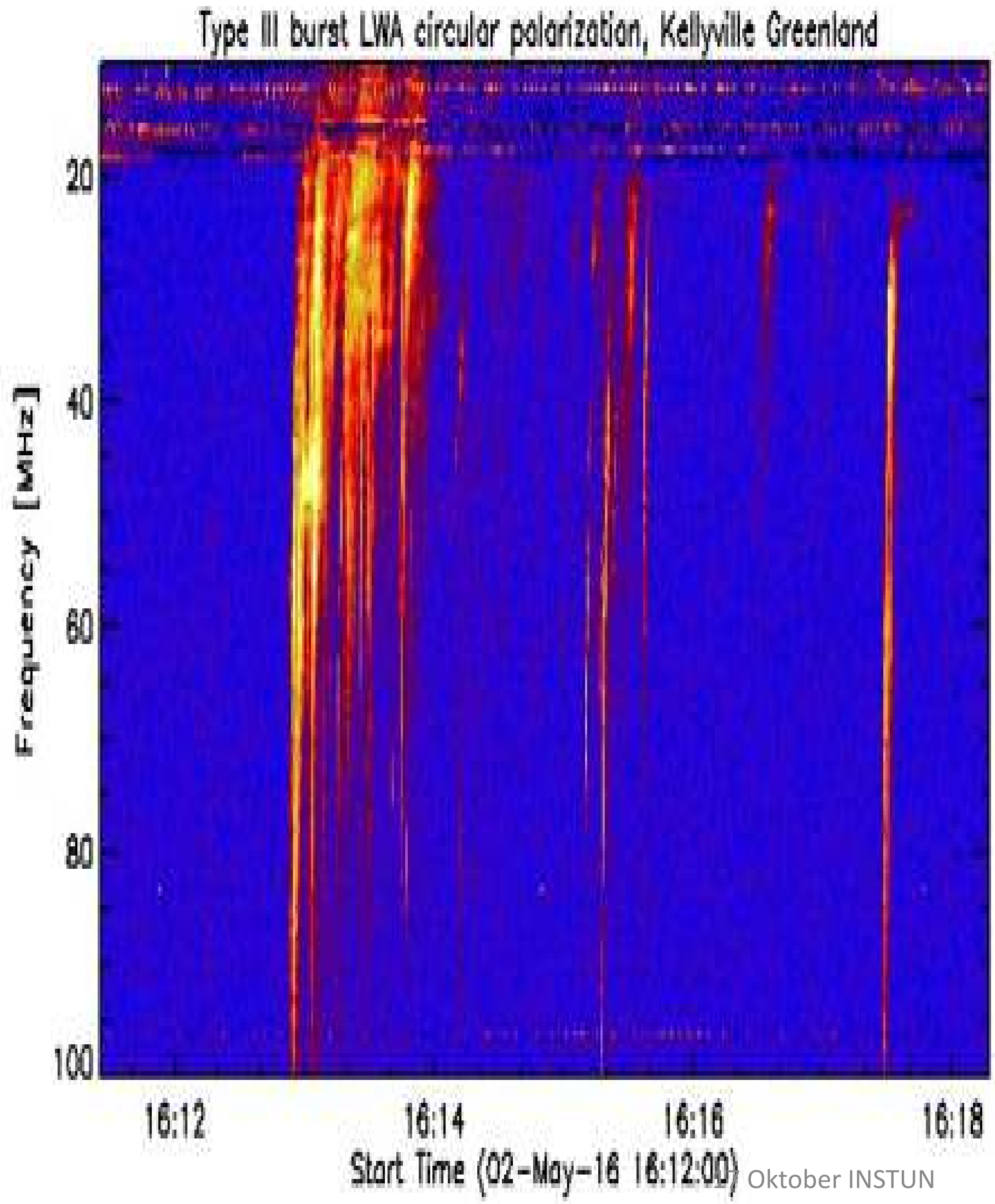

LOFAR
RANGE
ELECTRON BEAM
SOLAR ORBITER
PARKER SPIRAL
SOLAR
FLARE
TYPE III RADIO EMISSION
WIND
SPACECRAFT
250 MHz
0.16 R_{SUN}
$1.2x10^8$ m
MID
CORONA
10 MHz
1.5 R_{SUN}
10^9 m
HIGH
CORONA
1 MHz
7.5 R_{SUN}
$5.7x10^9$ m
INTER-
PLANETARY
SPACE
0.15 MHz
0.18 AU
$2.7x10^{10}$ m
ORBIT OF
MERCURY
0.02 MHz
1.2 AU
$1.8x10^{11}$ m
PARKER SPIRAL
LENGTH AT EARTH

Type I

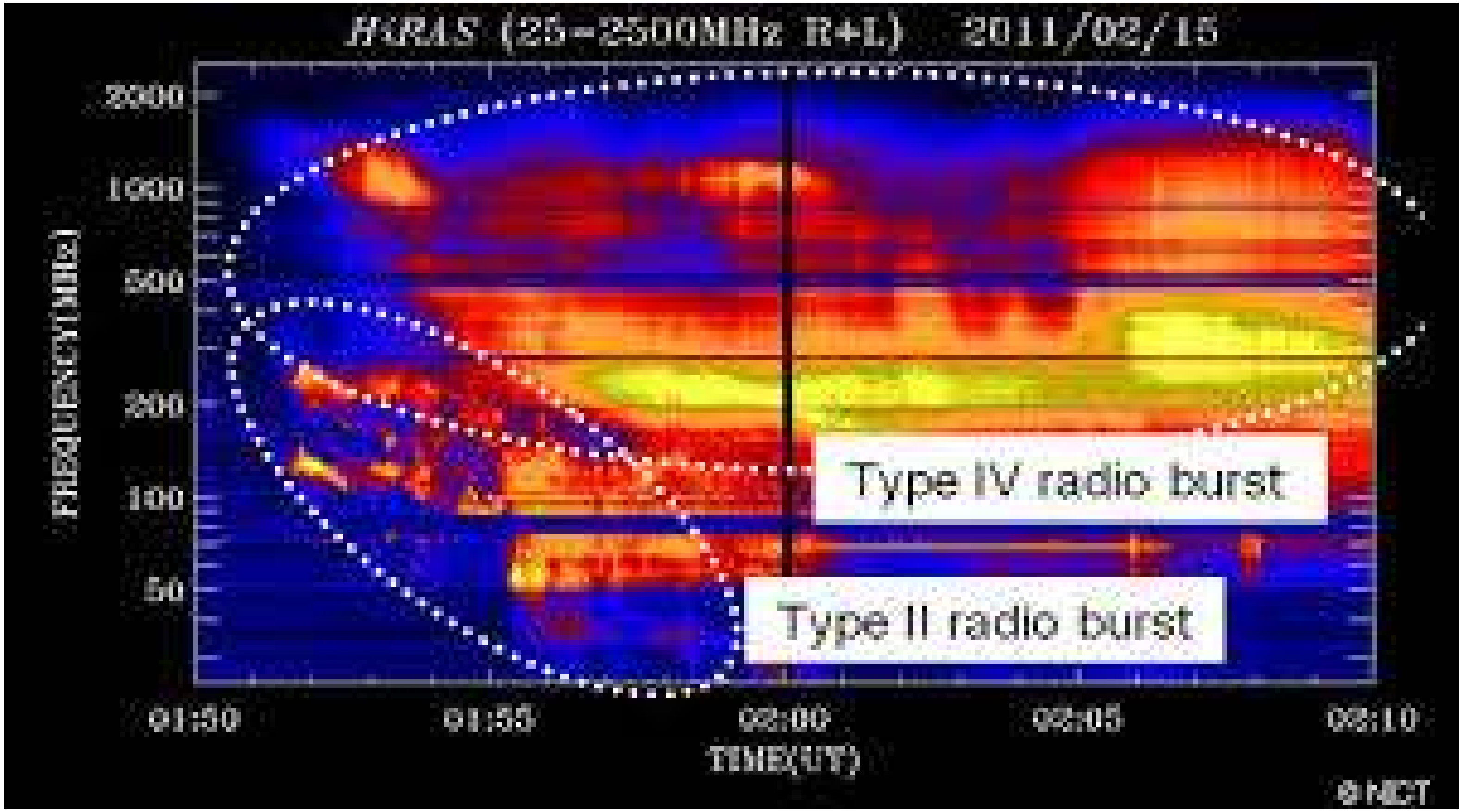

FREQUENCY - MHZ
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
25
Weak type 1 noise storm visible betweeb 75 and 100 MHz
0540
0550
0600
UNIVERSAL TIME (UT)


Type II with harmonic
Frequency [MHz]
50
100
150
200
250
300
350
05:36
05:38
05:40
05:42
05:44
Start Time (13-Jun-10 05:35:46)

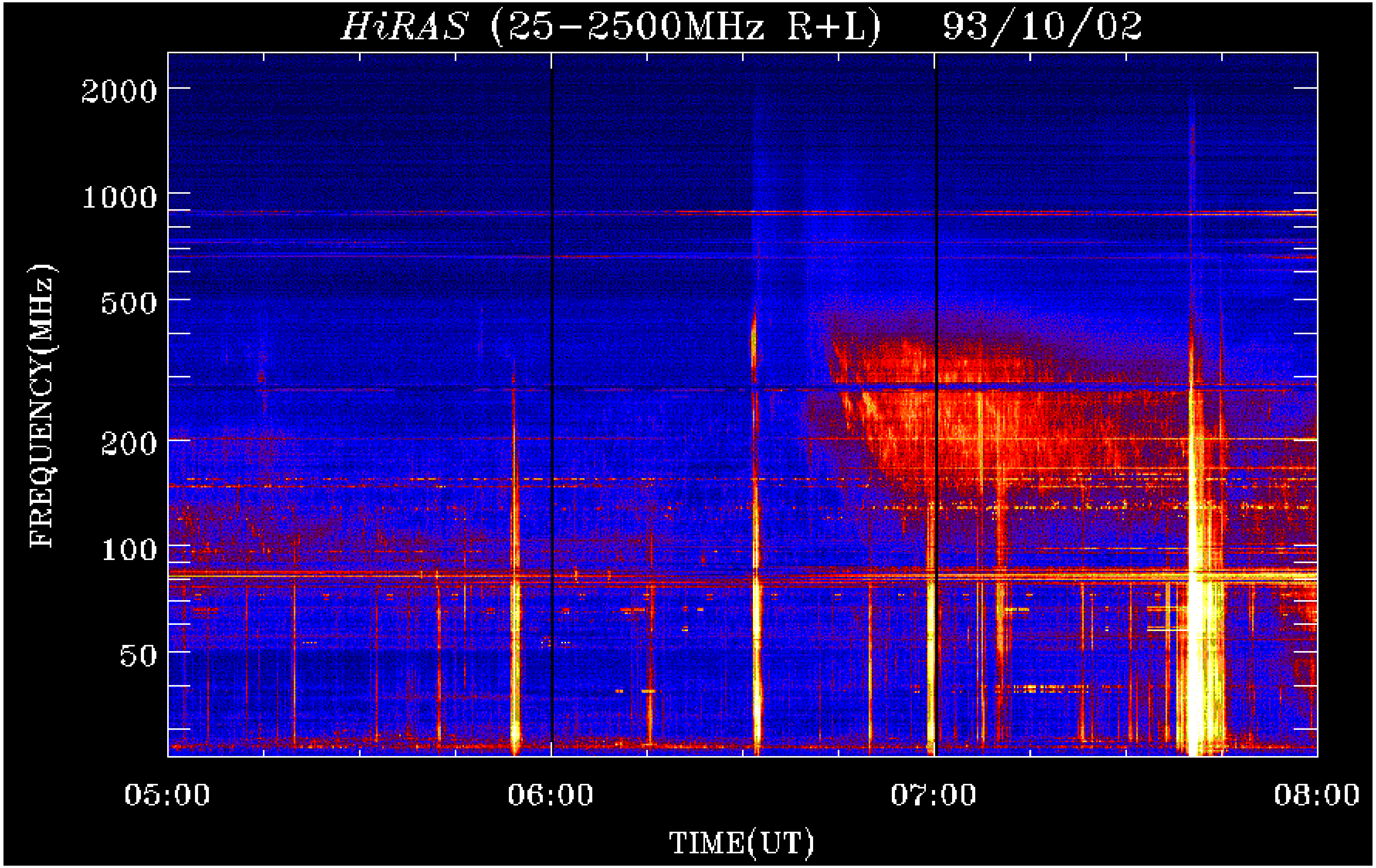
Type II


Type III burst LWA circular polarization, Kellyville Greenland
Frequency [MHz]
20
40
60
80
100
16:12
16:14
16:16
16:18
Start Time (02-May-16 16:12:00)

Type III


HiRAS (25-2500MHz R+L) 2011/02/15
FREQUENCY(MHz)
2000
1000
500
200
100
50
01:50
01:55
02:00
02:05
02:10
TIME(UT)
Type IV radio burst
Type II radio burst
© NICT

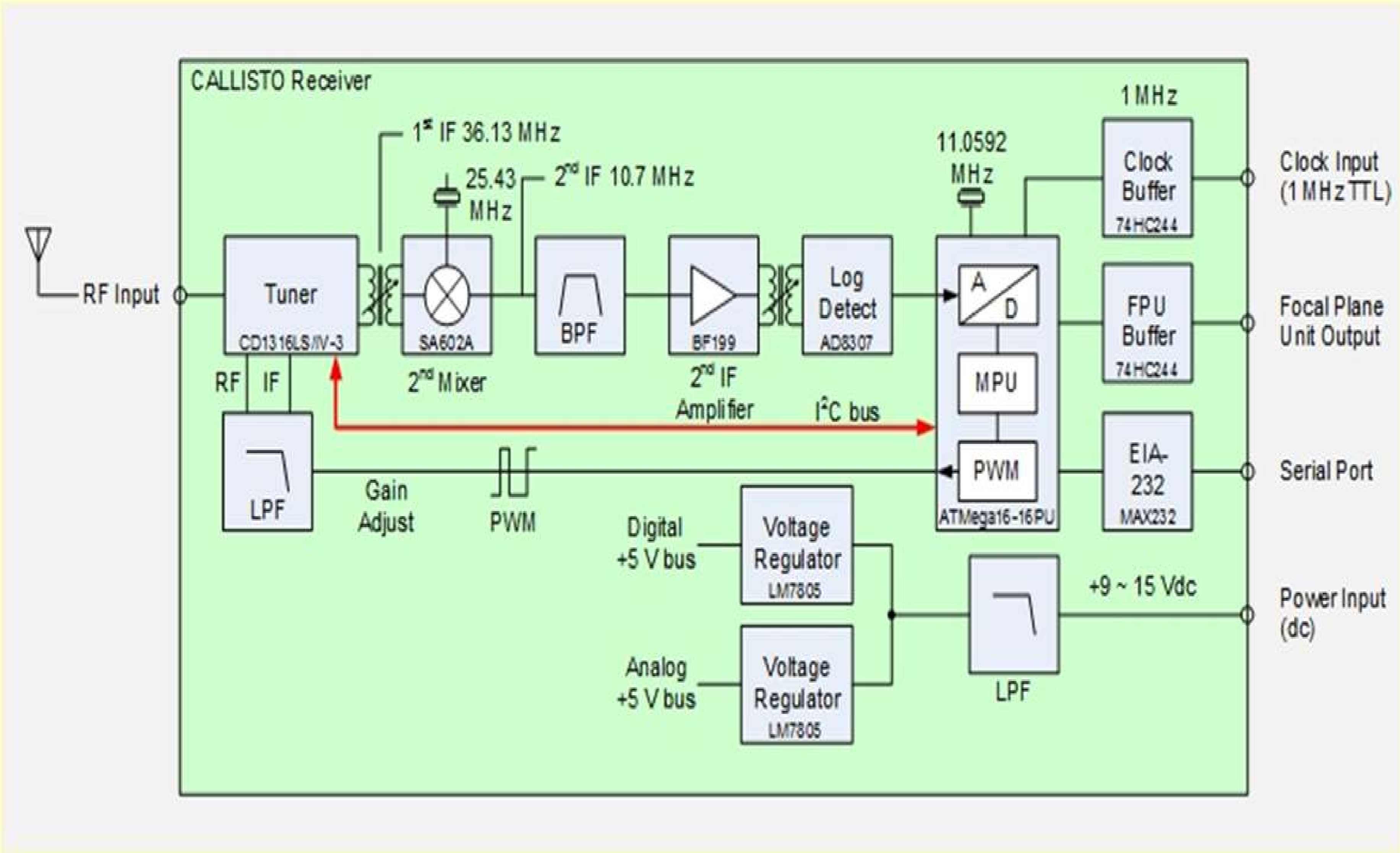
Type IV


HiRAS (25-2500MHz R+L) 93/10/02
FREQUENCY(MHz)
2000
1000
500
200
100
50
05:00
06:00
07:00
08:00
TIME(UT)

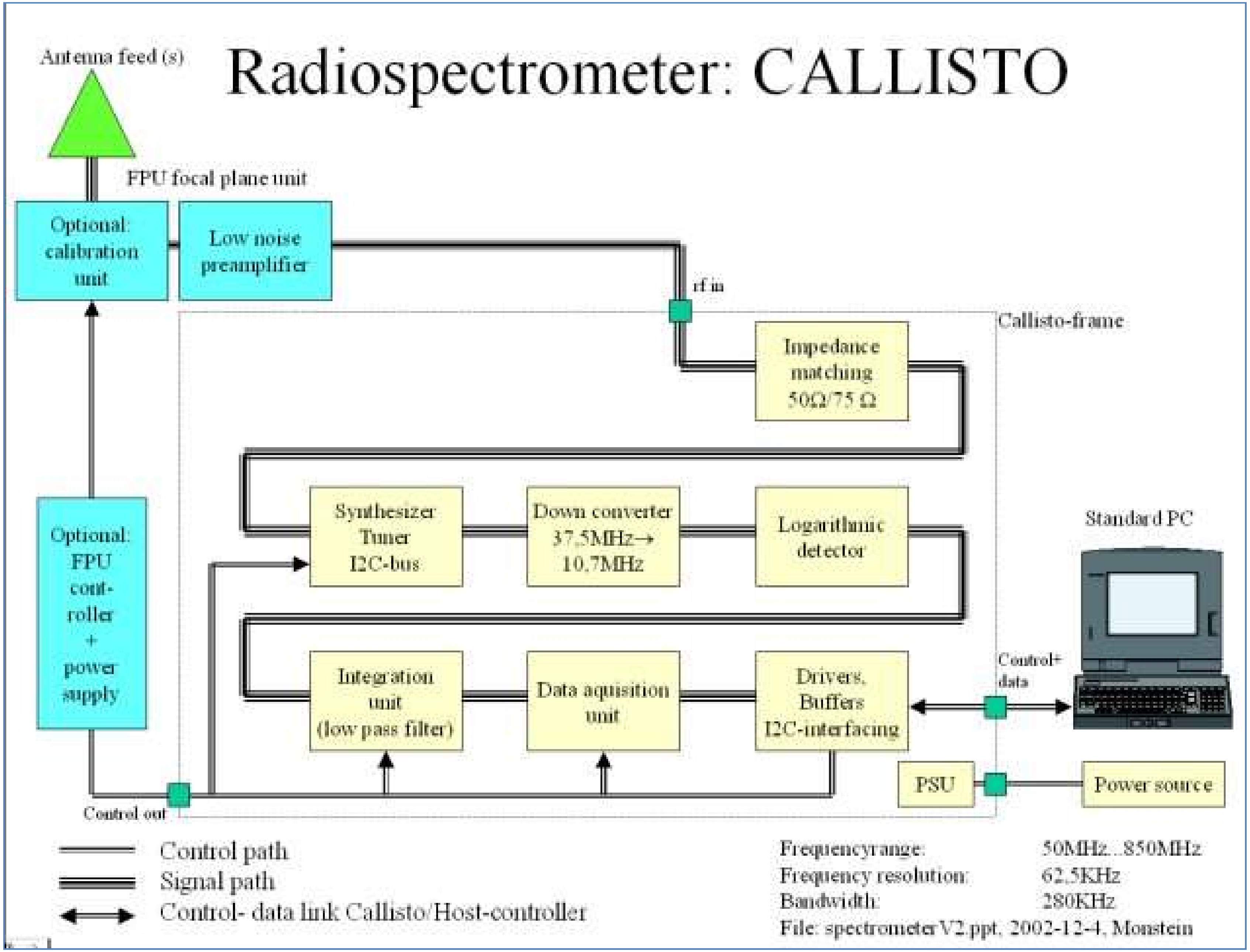
Type V

S. No.	Type of burst	Event characteristics	Associated phenomenon	EM	Frequency bandwidth	Duration	dcp (%)
1	Type I	Narrow band, short duration spikes superposed over a continuum emission	Active regions, flares, eruptive prominences	PE	50-500 MHz	Single burst$\approx$ 1s Noise storm: hours-days	$\approx 0.5 - 1$
2	Type II	Slow drifting $\approx$ 1 MHz s^{-1}; second harmonics occurs	Flares, MHD shocks, proton emissions	PE	20-150 MHz	3-30 mins	≈ 0.5
3	Type III	Fast drifting $\approx$ 100 MHz s^{-1}; occurs isolated, in groups or storms second harmonics are seen	Active regions, flares	PE	10 kHz-1 GHz	isolated$\approx 1-3$ s groups $\approx 1-10$ mins storms $\approx$ mins-hours	F$\approx$ 0.5 H$\lesssim$ 0.3
4	Type IVs	Smoothly varying broad band continuum	Flares, proton emissions	GS	20 MHz-2 GHz	Hours-days	≈ 0.5
5	Type IVm	Smoothly varying broad band continuum; slow drifting	Eruptive prominences, MHD shocks	GS	20-400 MHz	30-120 mins	Increases from low to ≈ 1
6	Type V	Smooth, short lived continuum emission; always follow by Type III groups/storms	Active regions, flares	PE	10-200 MHz	1-3 mins	very low (< 0.1)

5



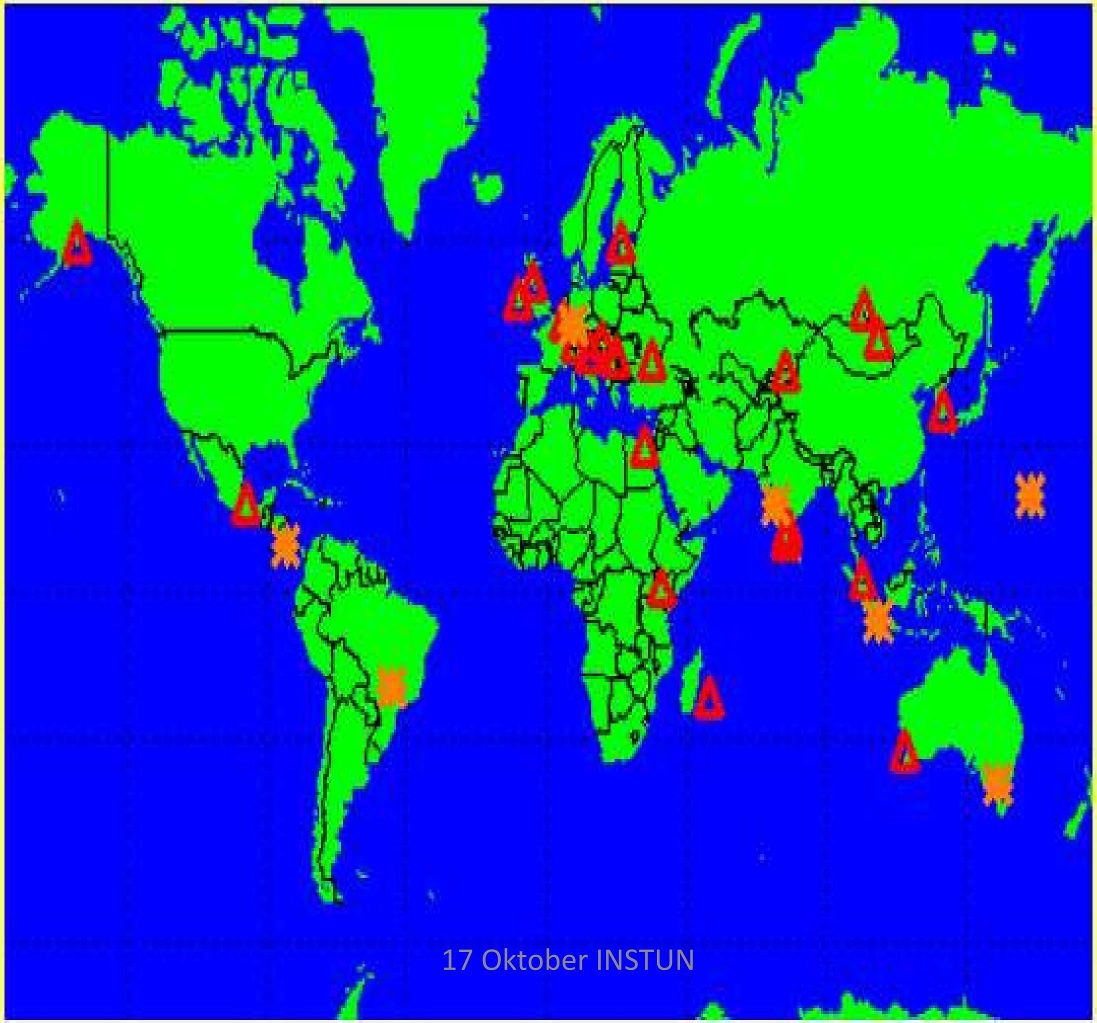
CALLISTO SCHEMATIC DIAGRAM

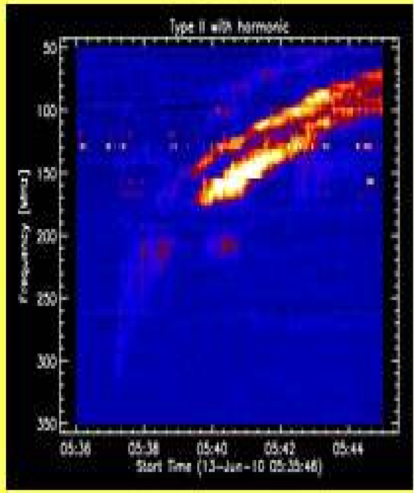

Radiospectrometer: CALLISTO
Antenna feed (s)
FPU focal plane unit
Optional: calibration unit
Low noise preamplifier
rf in
Callisto-frame
Impedance matching 50Ω/75 Ω
Synthesizer Tuner I2C-bus
Down converter 37,5MHz→ 10,7MHz
Logarithmic detector
Optional: FPU cont-roller + power supply
Integration unit (low pass filter)
Data aquisition unit
Drivers, Buffers I2C-interfacing
Standard PC
Control+ data
PSU
Power source
Control out
Control path
Signal path
Control- data link Callisto/Host-controller
Frequencyrange: 50MHz...850MHz
Frequency resolution: 62,5KHz
Bandwidth: 280KHz
File: spectrometerV2.ppt, 2002-12-4, Monstein

e-Callisto

International Network of Solar Radio Spectrometers

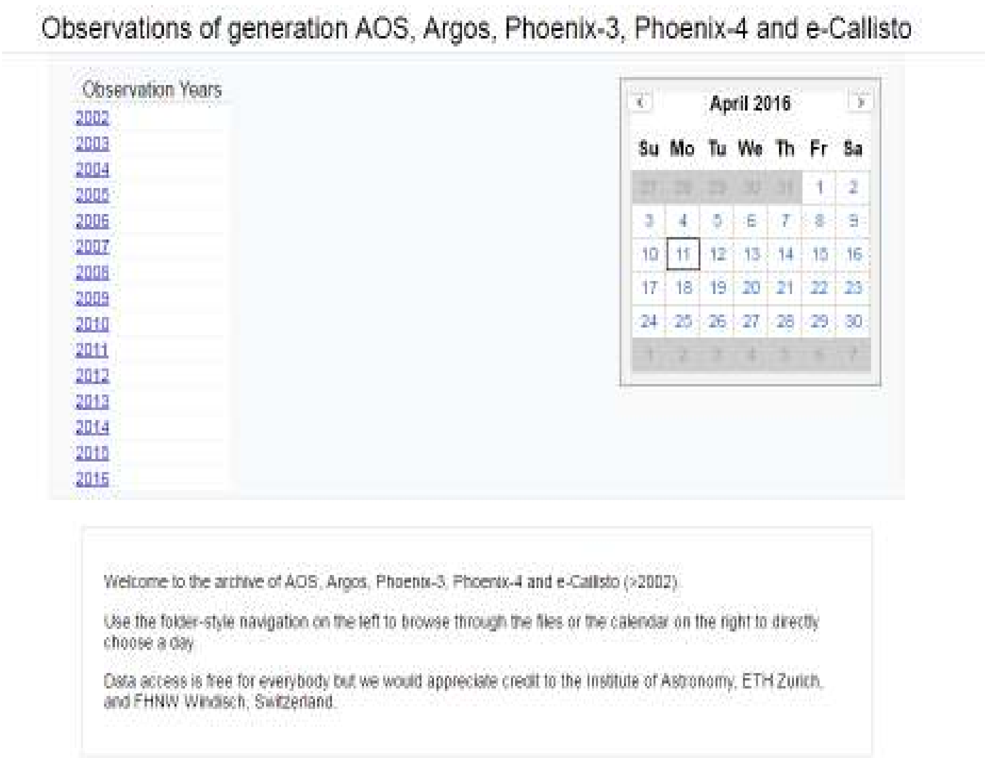
e-Callisto logo



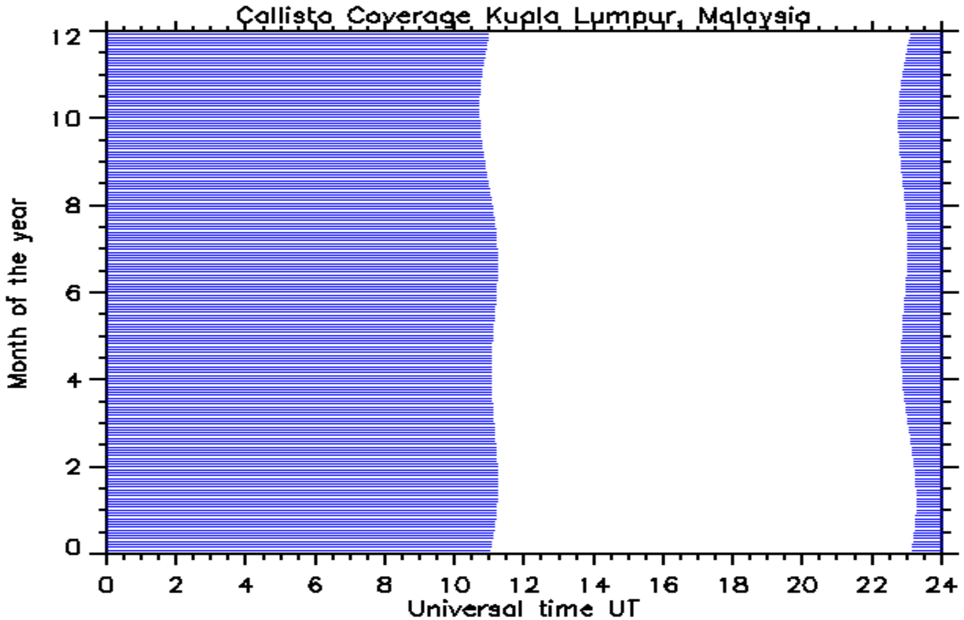


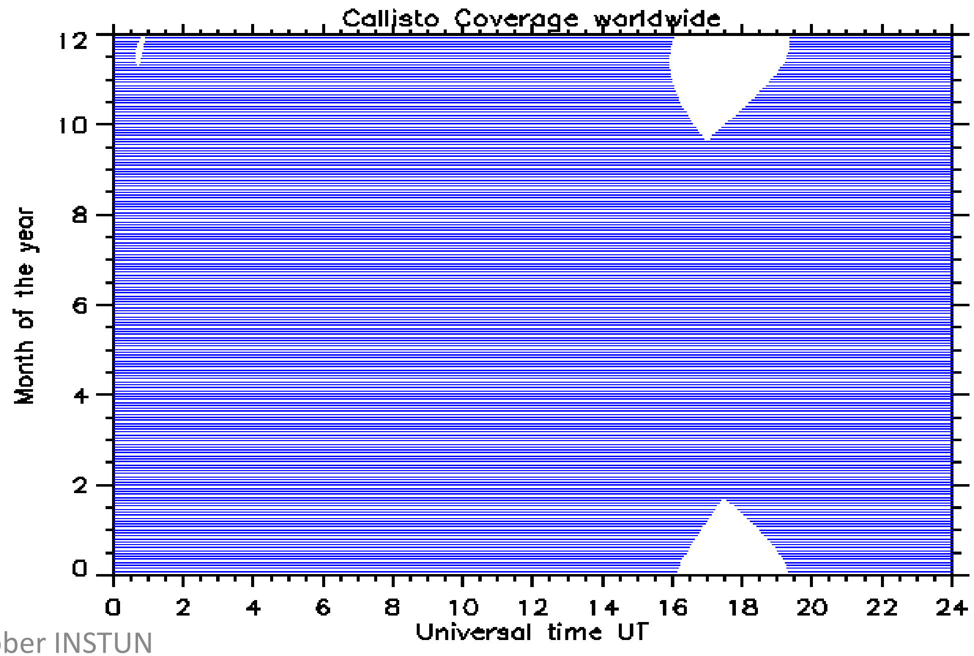
Type II burst (Ooty)

- The CALLISTO (Compound Low Cost-Low Frequency for Transportable Observatories) system is one of the most outstanding international project under the International Space Weather Initiatives (ISWI) since 2002



Simulation of solar burst data from different sites in CALLISTO network (Credicted to: http://www.e-callisto.org/)

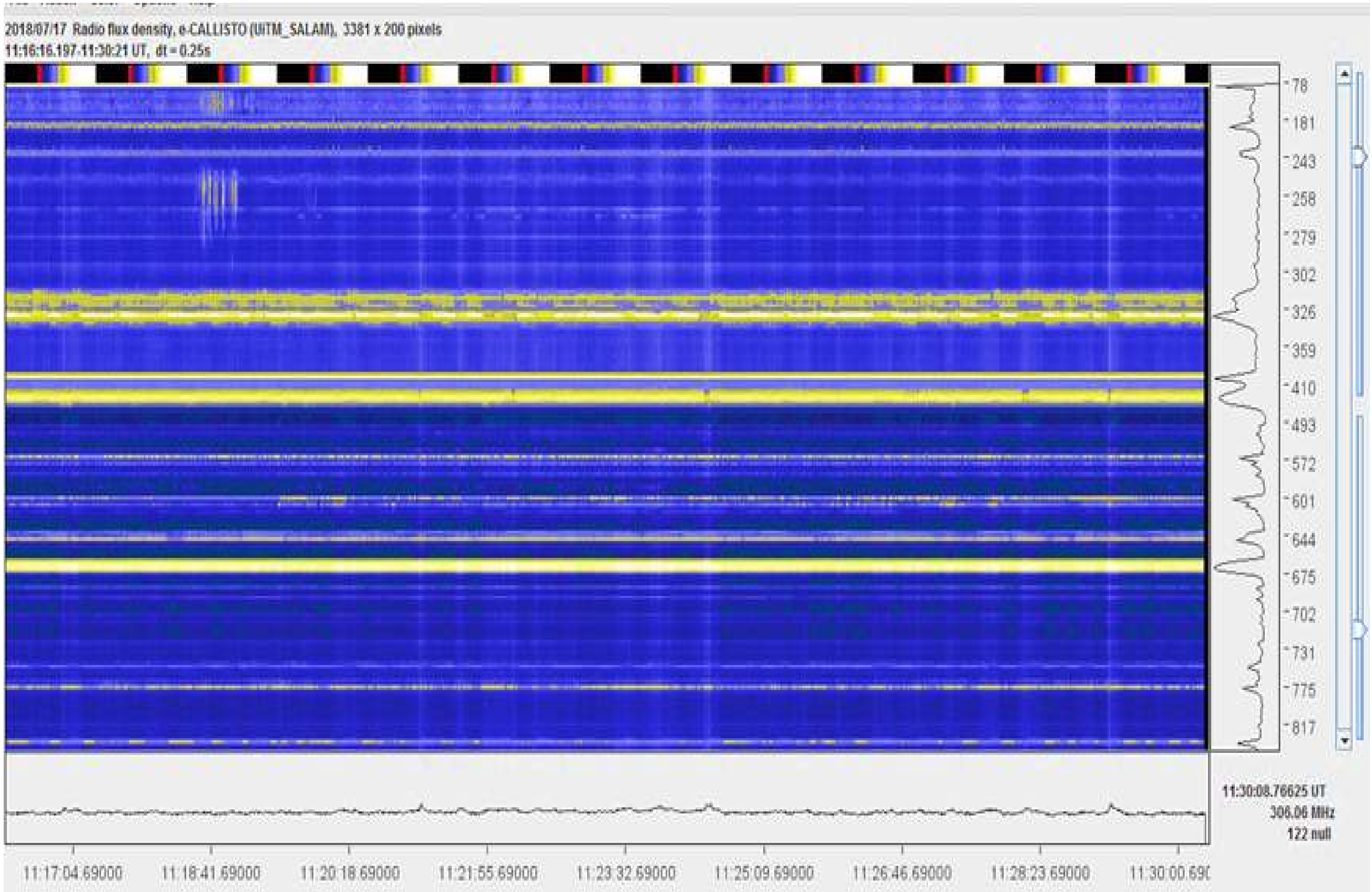

Callisto Coverage Kuala Lumpur, Malaysia
Month of the year
Universal time UT


Callisto Coverage worldwide
Month of the year
Universal time UT

17 Oktober INSTUN

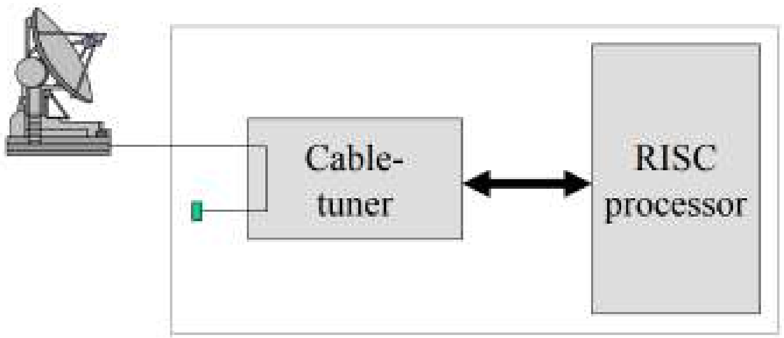
LOG PERIODIC DIPOLE ANTENNA (LPDA)

SPECIFICATION OF THE ANTENNA	PREVIOUS ANTENNA	NEW ANTENNA
Frequency range (MHz)	45-870	80 - 800
Number of element	18	23
Antenna length (m)	7.25	8.4
Boom length (m)	5.75	6.4
Material of the element	Aluminium	Aluminium
Gain (dB)	6.80	7.28
Directivity, t	0.8	0.8


2018/07/17 Radio flux density, e-CALLISTO (UITM_SALAM), 3381 x 200 pixels
11:16:16.197-11:30:21 UT, dt = 0.25s
78
181
243
258
279
302
326
359
410
493
572
601
644
675
702
731
775
817
11:30:08.76625 UT
306.06 MHz
122 null
11:17:04.69000
11:18:41.69000
11:20:18.69000
11:21:55.69000
11:23:32.69000
11:25:09.69000
11:26:46.69000
11:28:23.69000

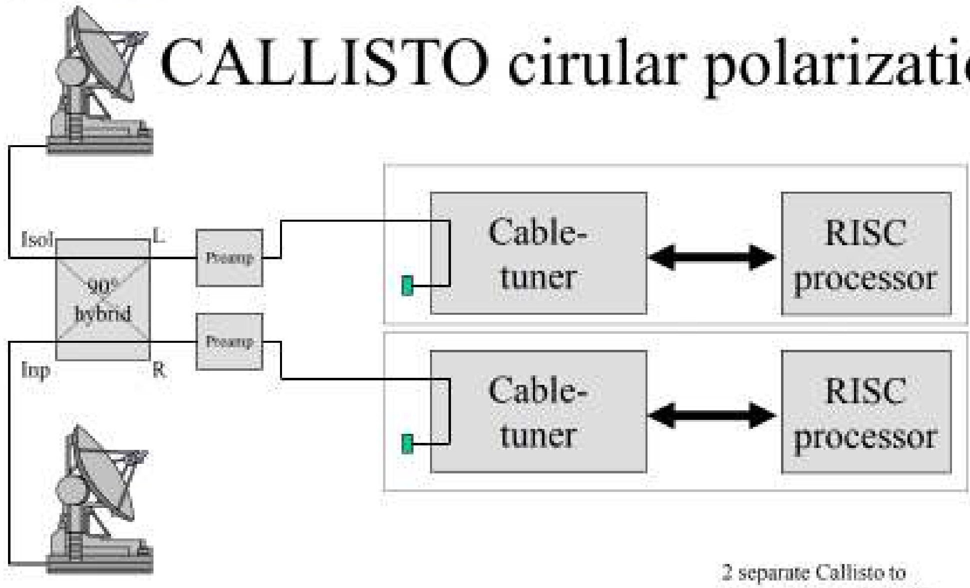
CALLISTO System : http://www.e-callisto.org/

CALLISTO Standard mode for one linear polarization



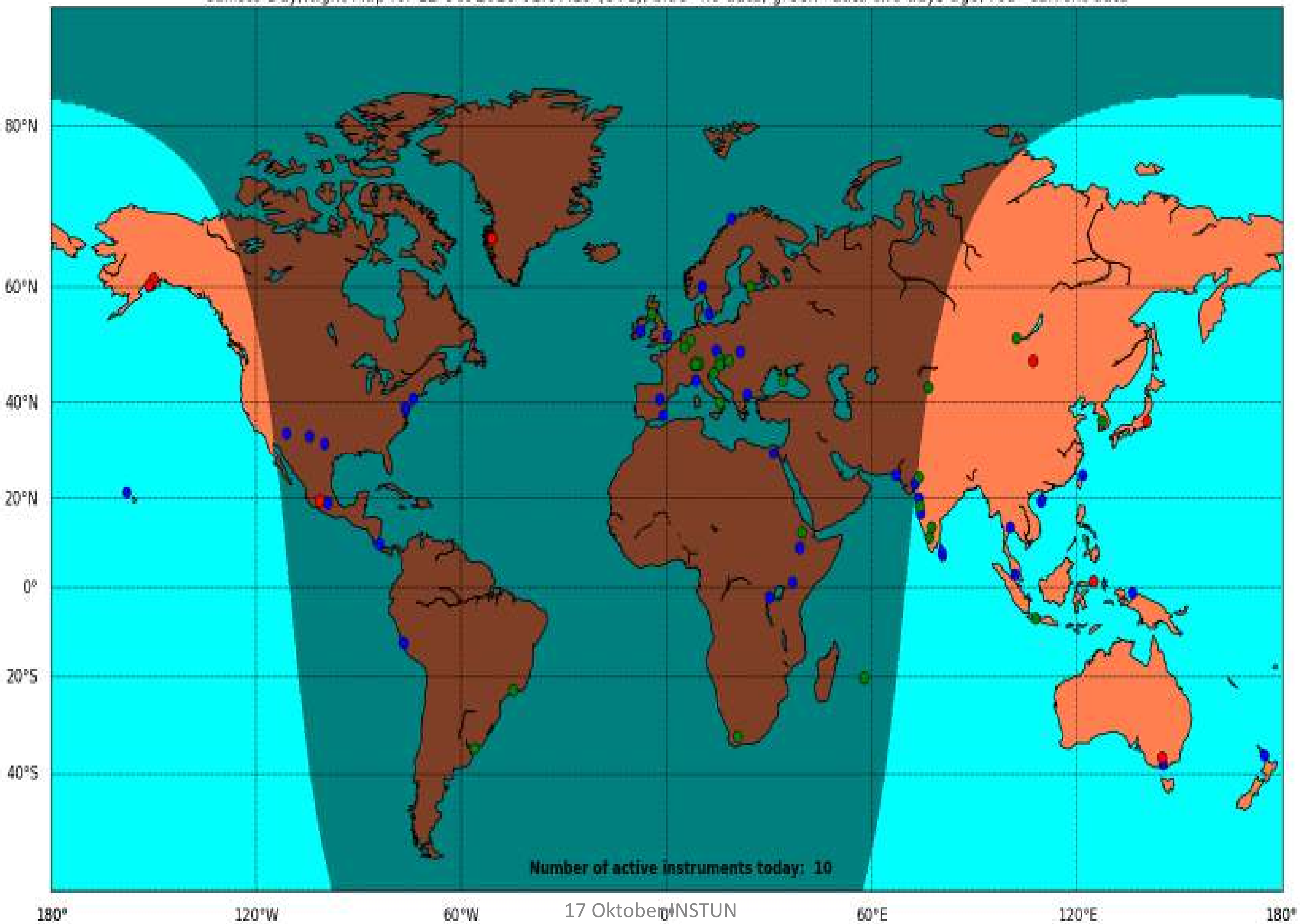
- low cost version
- single antenna, one polarization

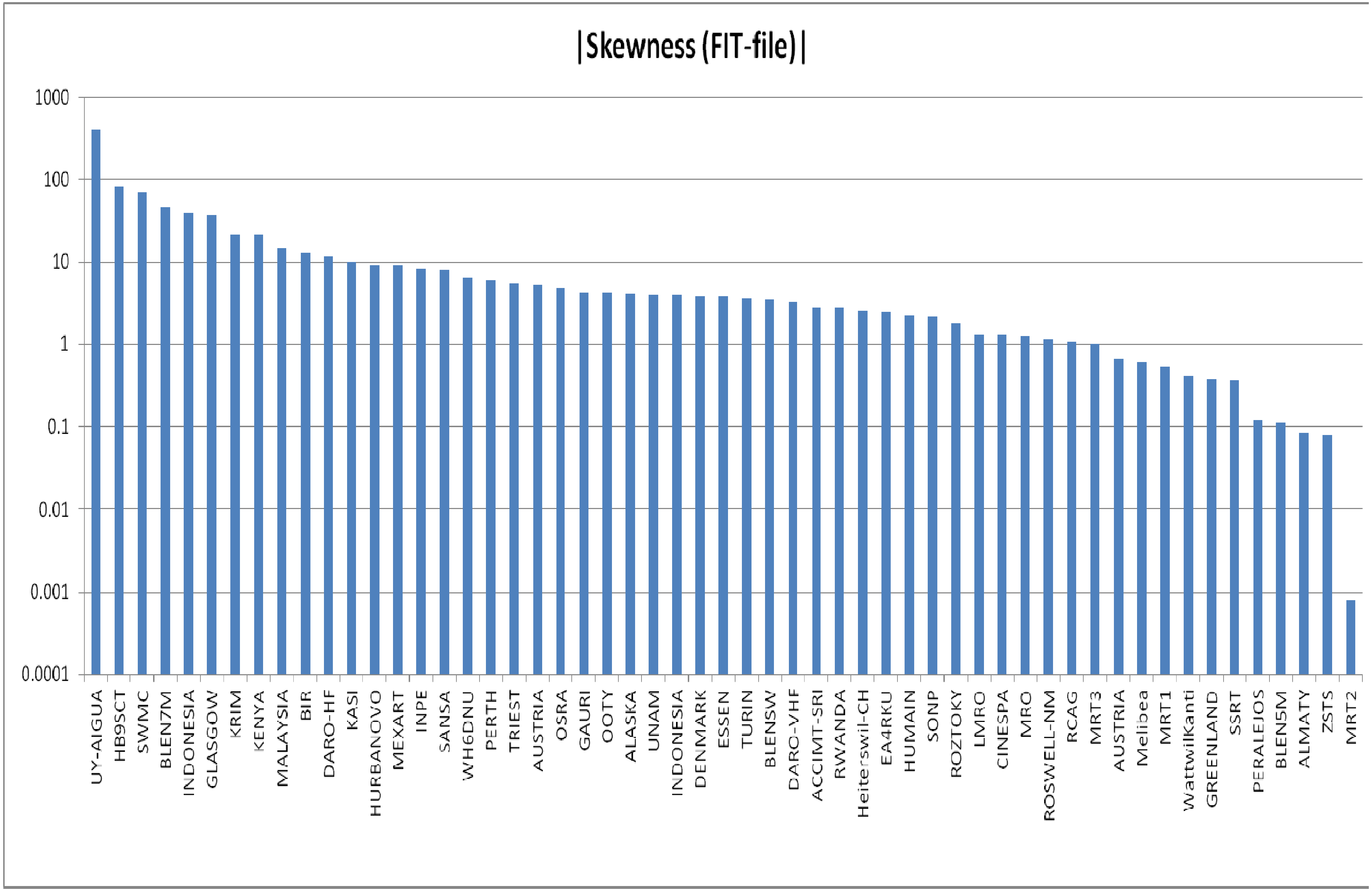
CALLISTO cirular polarization



2 separate Callisto to
measure 2 polarizations
at the same time

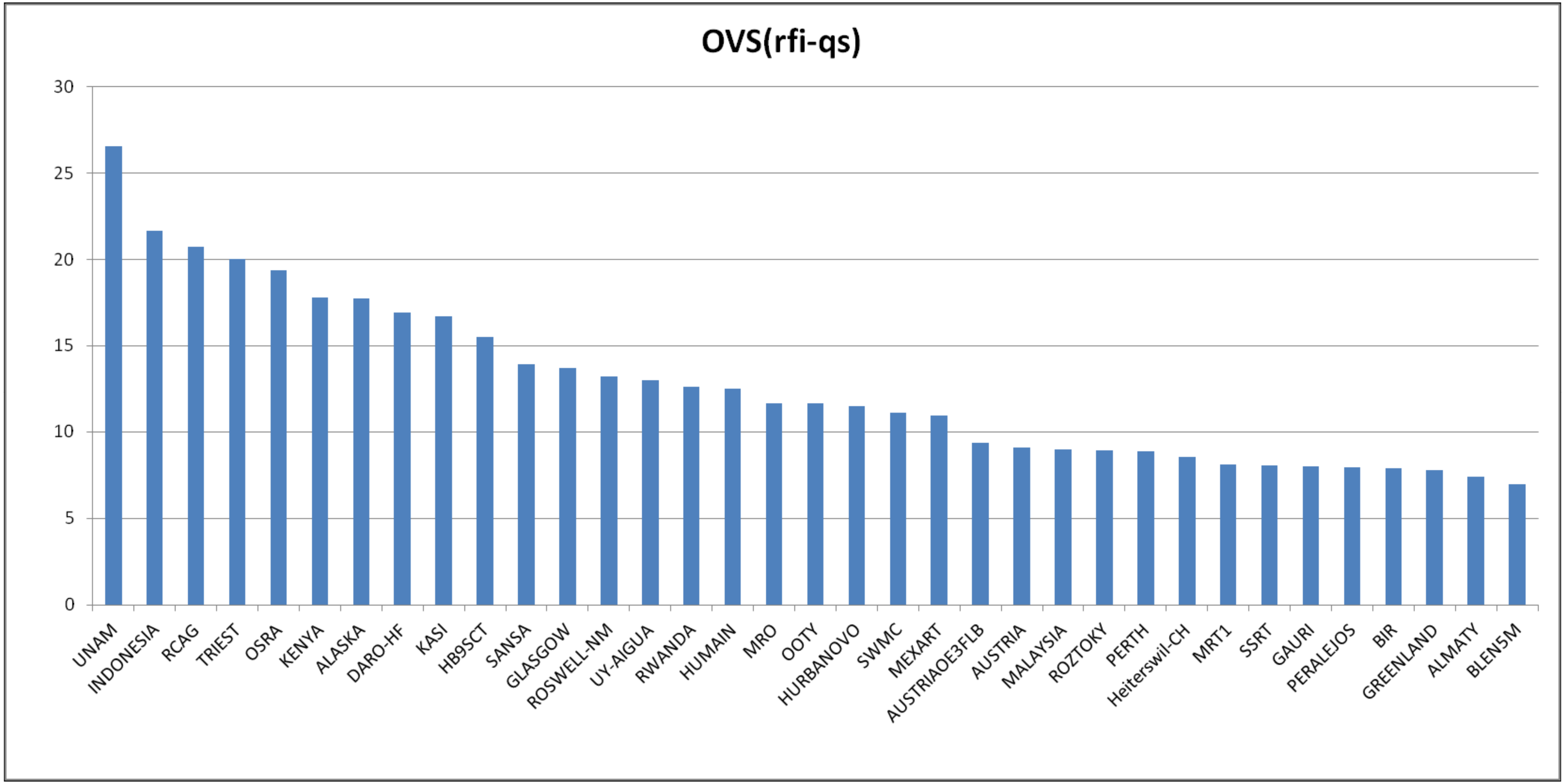
Callisto Day/Night Map for 12 Oct 2018 01:07:19 (UTC), blue=no data, green=data two days ago, red=current data

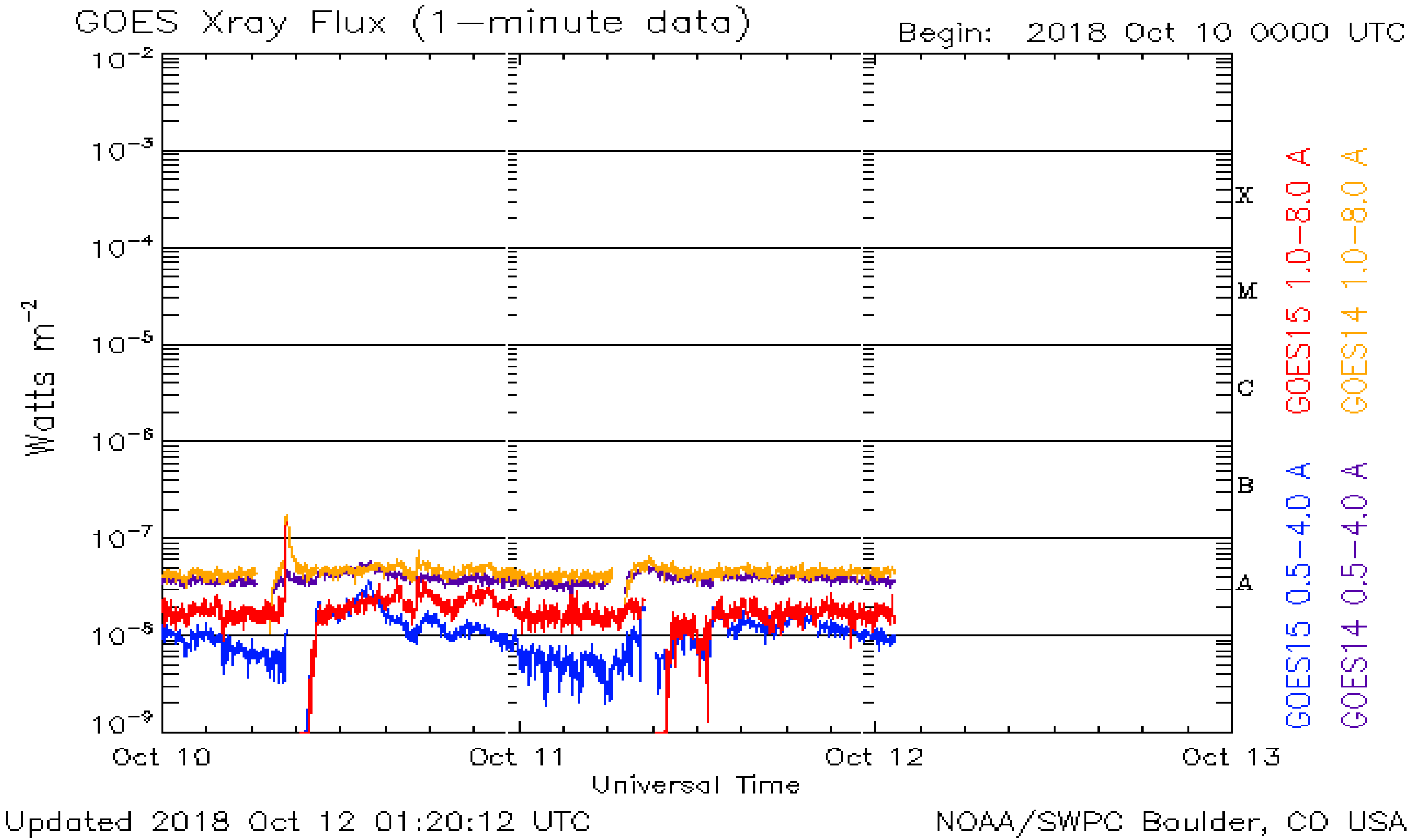




Skewness, derived from FIT-files which is a selection of the best 200 channels out of 13'200 possible channels.

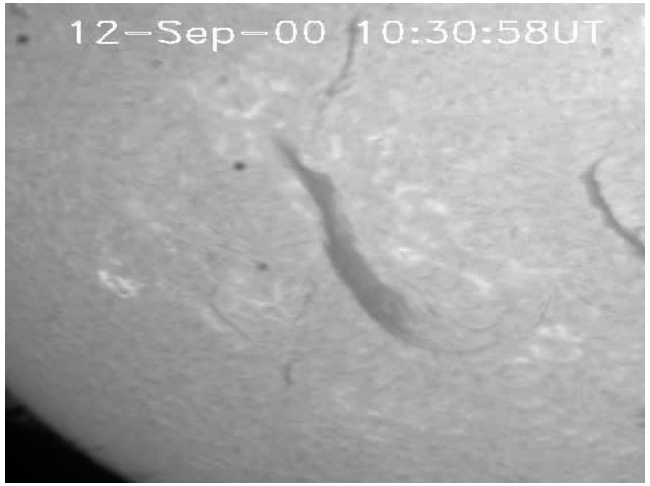
Y-axis shows the average minimum antenna gain which is required to observe the quiet Sun at local mean level of rfi.

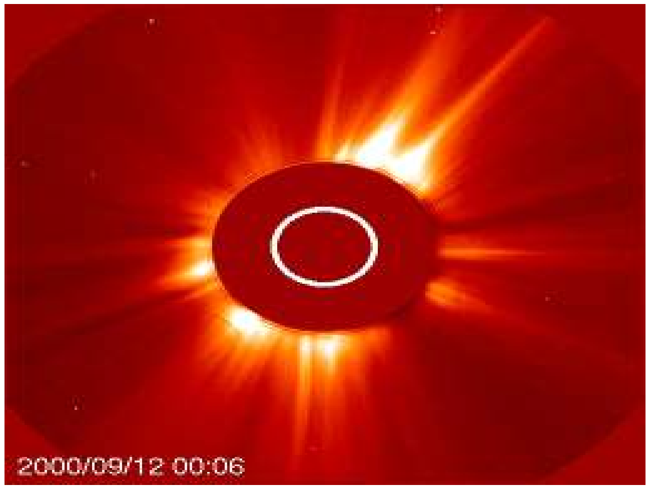


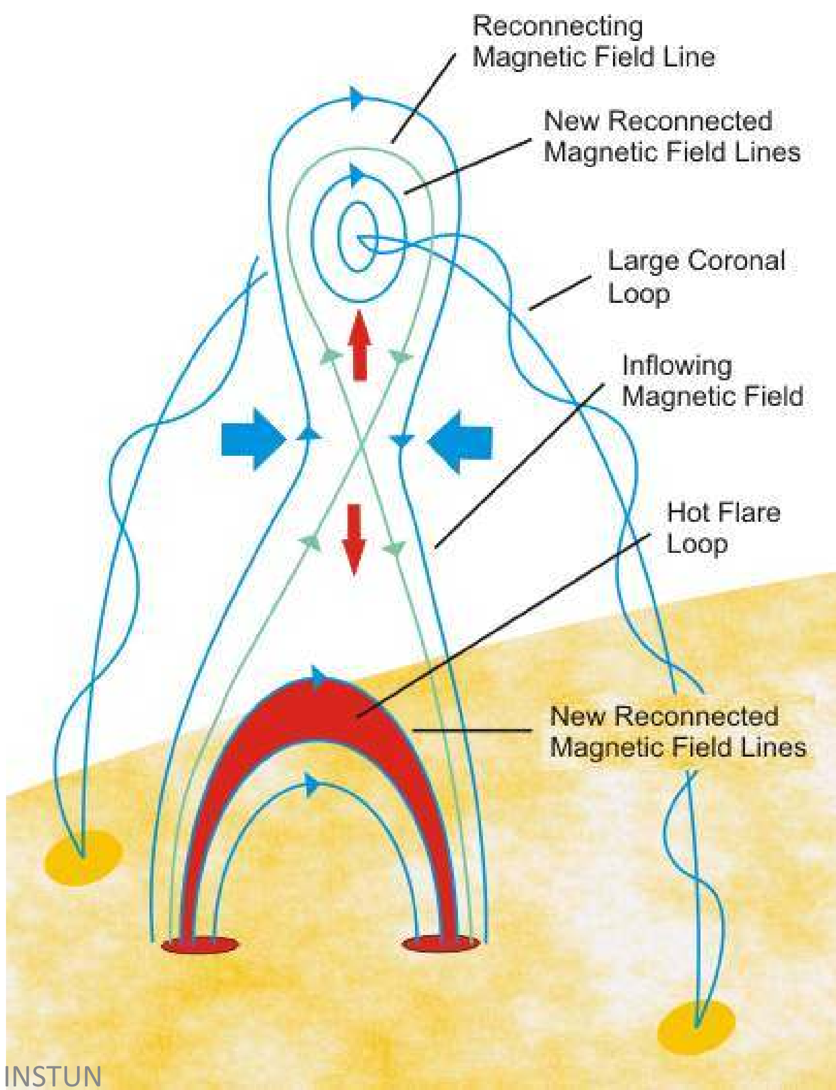


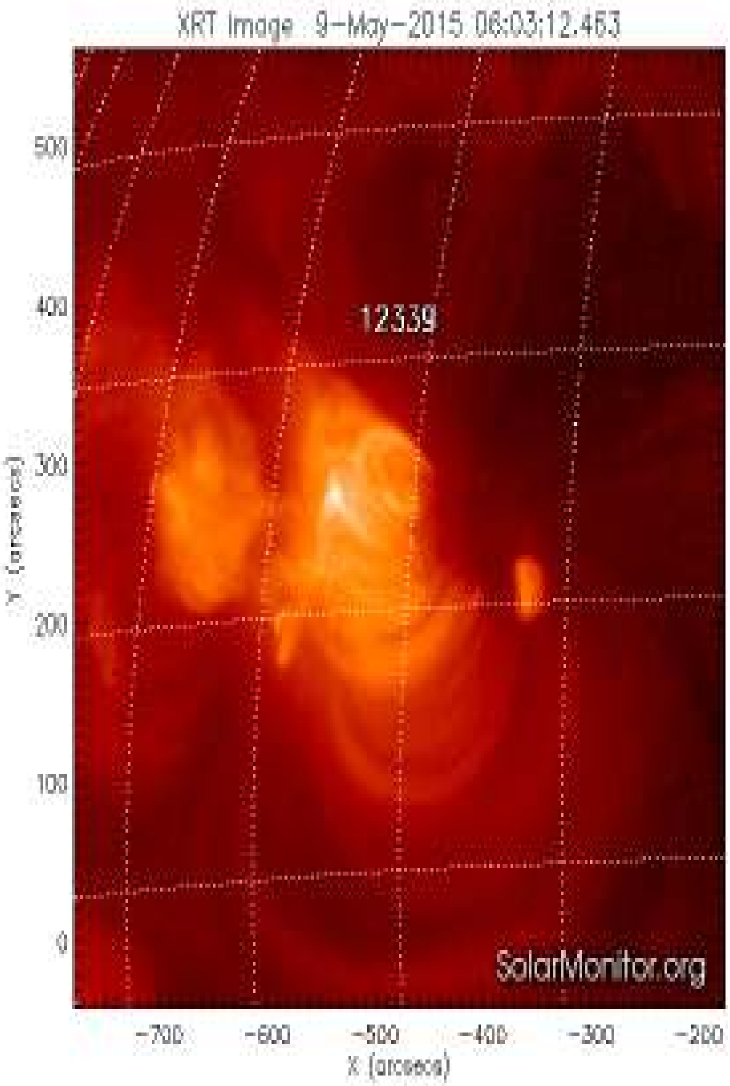
Solar Activity now (courtesy SWPC/NOAA) and GSFC/NASA.

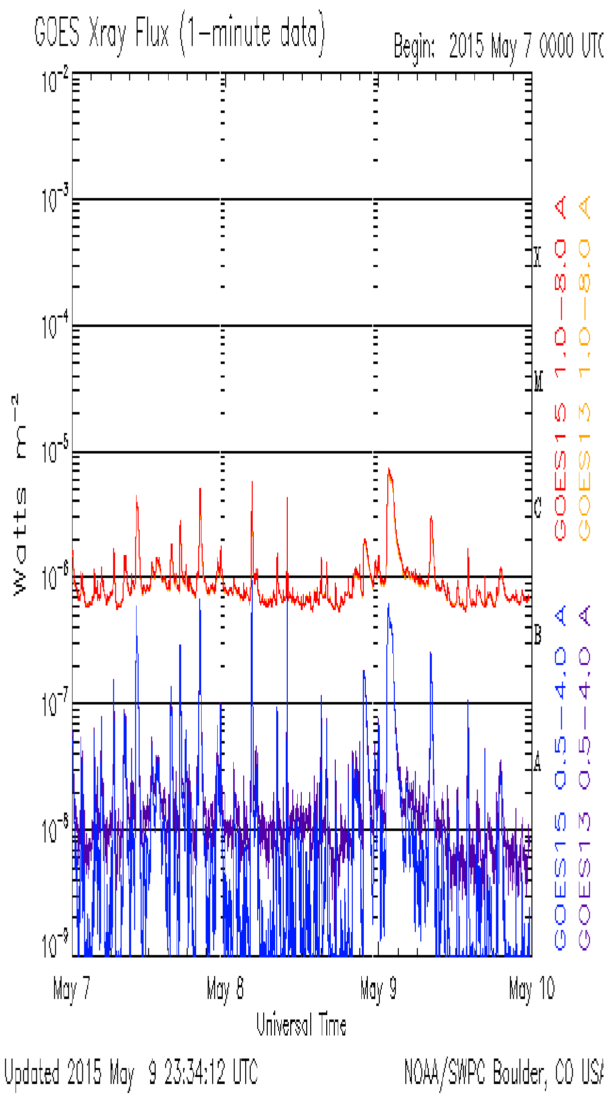
The "Standard" Model for Eruptive Flares

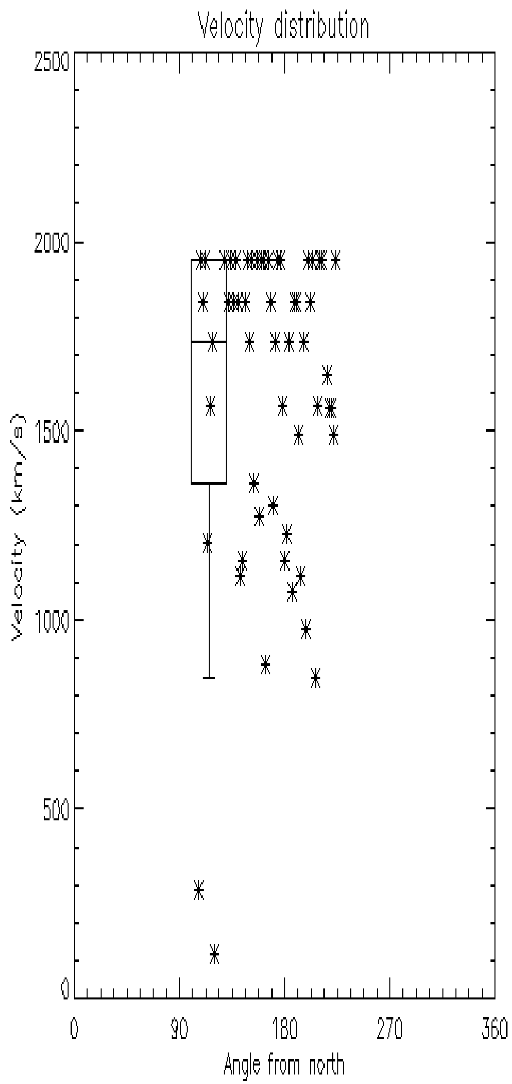


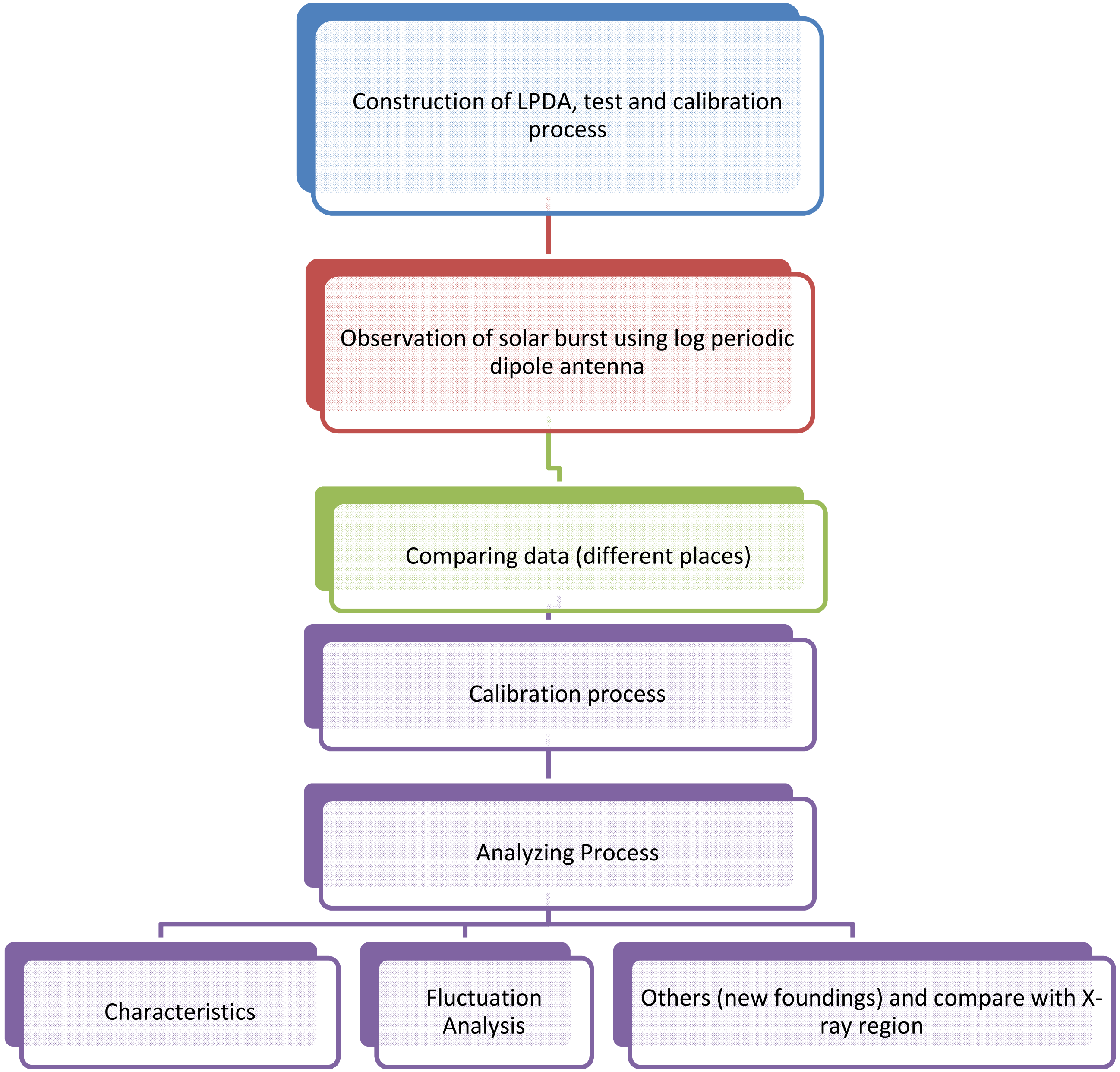





XRT Image 9-May-2015 08:03:12.463
12339
SolarMonitor.org
Y (arcsecs)
X (arcsecs)


GOES Xray Flux (1-minute data)
Begin: 2015 May 7 0000 UTC
Watts m^-2
GOES15 1.0—8.0 A
GOES13 1.0—8.0 A
GOES15 0.5—4.0 A
GOES13 0.5—4.0 A
X
M
C
B
A
May 7
May 8
May 9
May 10
Universal Time
Updated 2015 May 9 23:34:12 UTC
NOAA/SWPC Boulder, CO USA


Velocity distribution
Velocity (km/s)
Angle from north



17 Oktober INSTUN

What can I do with CALLISTO data?

- Connect a 50 Ω resistor to the input of the preamplifier and measure spectra for at least 12 hours. Extract one or more light curves out the FIT-files and process them with ALAVAR, a tool to derive the Allan-time out of a time series. Result -> instrument Allan-time (stability). Do the same with the antenna connected to the preamplifier and pointing to the sky. Compare the results.
- Determine shock wave speed of type II bursts for data stored in the archive and compare with other instruments. Produce a list containing date, time, CME-velocity and Newkirk model selected.
- Identify solar bursts and produce a list about date, time and burst type (I, II, III, IV, V, U, DCIM etc.) like this one: http://soleil.i4ds.ch/solarradio/data/BurstLists/2010-yyyy_Monstein/SGD_BLEN_2011_08.txt

- Make statistics about local radio interference as function of time & date, identify strong transmitters and produce optimized frequency programs (Occupancy plots). If you find out that those frequencies which are reserved for radio astronomy are interfered, according to the list of reserved frequencies, get into contact with OFCOM (office of communication).
- Correlate burst-time with x-ray data from GOES
- Correlate burst-time and structure with data from WIND- WAVE and STEREOs atellites.
- Make statistics about geostationary military down-links signals in the VHF-range (240 MHz – 300 MHz) to find out if they can be used as a check for stability of the receiving system. As an option one may find a way to use these transponders for calibration. By analyzing standard deviation divided by mean you might find out the coherence bandwidth in VHF. Compare the results with and without solar radio bursts.
- Find out if rfi at different stations are correlated or not. In case they are correlated what might be the origin of the rfi?
- Invent a statistical process to qualify different radio spectrometers with respect to local interference.
- Invent a statistical process to qualify different radio spectrometers with respect to sensitivity to solar burst in mV/SFU or dB/SFU or digit/SFU or any other measure.
- Do a measurement campaign with Callisto and an omni-directional antenna and measure rfi as function of geography (longitude, latitude) to generate an rfi map of your town or country. This can be used to identify radio-quiet areas.

References

Tousey, R. *The solar corona*. in *Space Research XIII, Proceedings*. 10 – 24 May, 1972. Madrid, Spain: Akademie-Verlag, Berlin.

Baker, D.N., et al., *Severe Space Weather Events – Understanding Societal and Economic Impacts*. 2008: The National Academies Press, Washington DC.

Pulkkinen, T., *Space Weather: Terrestrial Perspective.* Living Rev. Solar Phys., 2007. **4**.

Schwenn, R., *Space Weather: The Solar Perspective.* Living Rev. Solar Phys., 2006. **3**.

Gopalswamy, N., *Coronal mass ejections of solar cycle 23.* Journal of Astrophysics and Astronomy, 2006. **27**(2-3): p. 243-254.

Rust, D.M. and D.F. and Webb, *Soft X-ray observations of large-scale coronal active region brightenings.* Solar Phys., 1977. **54**: p. 403–417.

Chen, P.F., *Coronal Mass Ejections: Models and Their Observational Basis.* Living Rev. Solar, 2011. **8**.

Dere, K.P., et al., *EIT and LASCO Observations of the Initiation of a Coronal Mass Ejection.* Sol. Phys., 1997. **175**: p. 601–612.

Gopalswamy, N., *Radio-rich Solar Eruptive Events.* Geophys. Res. Lett, 2000. **27**(1427).

Hudson, H.S. and E.W. Cliver, *Observing coronal mass ejections without coronagraphs.* J. Geophys. Res., 2001. **106**(25): p. 199-213.

Joel C. Allred, et al., *Radiative Hydrodynamic Models of the Optical and Ultraviolet Emission from Solar Flares.* ApJ, 2005. **630**(1).

Benz, A.O., *Plasma Astrophysics*. 2002, Dordrecht: Springer.

Aschwanden, M.J., & Güdel, M. , *The coevolution of decimetric millisecond spikes and hard X-ray emission during solar flares.* ApJ, 1992. **401**(2): p. 736-753.

Fleishman, G.D., Gary, D. E., & Nita, G. M. , ApJ, 2003. **593**.

T.B. Veronese, et al., *Fluctuation analysis of solar radio bursts associated with geoeffective X-class flares.* Journal of Atmospheric and Solar-Terrestrial Physics, 2010.

Nindos, A., et al., *Observations and Models of a Flaring Loop.* Astrophys. J., 2008. **533**: p. 1053-1062.


THANK YOU