TOWARDS A NEXT-GENERATION *eCallisto* NETWORK

Javier Bussons (Universidad de Alcalá, UAH, Spain)

CELESTINA project: Castillian **E**-callisto **L**eading **E**xperimentation in **S**olar-**T**errestrial **I**nteraction with **N**ovel **A**ntennas

***SPARC project: SP**ace **A**wareness and **R**esearch **C**enter (Casa del Doncel, Sigüenza, Spain)

SBPLY/19/180501/000237

CESRA workshop, University of Hertfordshire, Hatfield, July 2023

“E-CALLISTO SPAIN” TEAM

Universidad de Alcalá:
Manuel Prieto, Javier Bussons (+Univ. Murcia),
Mario Fernández, Diego Abuelo

Universidad Politécnica de Cartagena:
José Luis G. Tornero, David Cañete

Universidad Complutense de Madrid:
José Ignacio Hidalgo, Jorge Alvarado

Universidad de Extremadura:
Francisco Chávez, Francisco Fdez de Vega

Physicists, engineers, mathematicians, computer scientists (bio-inspired algorithms)

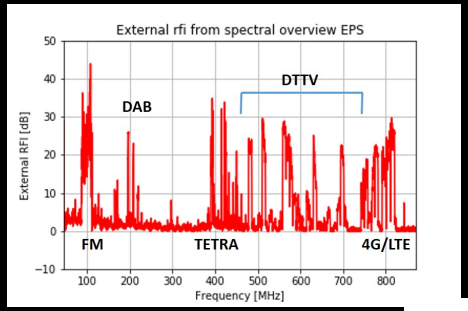
E-CALLISTO SPAIN

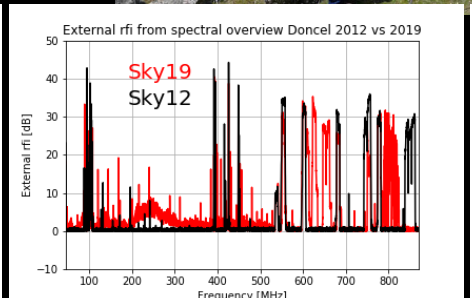
HISTORY:

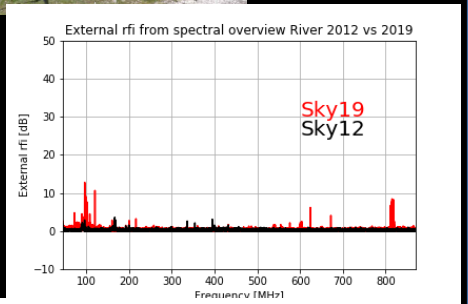
2012 Prof. Monstein's RFI measurement campaign

2013-14 Callistos installed: Alcalá, Peralejos, Sigüenza

2014-18 Run on spare-time basis, no funding







2019 Rolling grant: CELESTINA project

Castillian **E**-callisto **L**eading **E**xperimentation in **S**olar-**T**errestrial **I**nteraction with **N**ovel **A**ntennas https://celestina.web.uah.es

2023 New application: SPARC project

SPace **A**wareness and **R**esearch **C**enter

(Casa del Doncel, Sigüenza)

Solar Phys (2020) 295:11
https://doi.org/10.1007/s11207-019-1577-5

https://doi.org/10.1007/s11207-019-1577-5

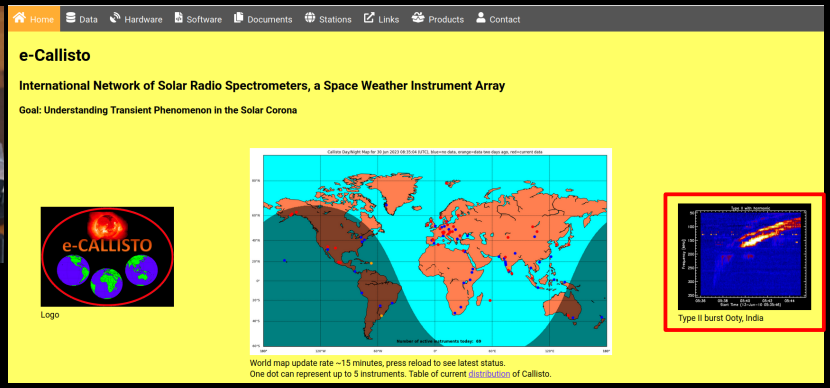
Increase in Interference Levels in the 45–870 MHz Band at the Spanish e-CALLISTO Sites over the Years 2012 and 2019

Manuel Prieto[1] · Javier Bussons Gordo[2] · Javier Rodríguez-Pacheco[1] · Agustín Martínez[1] · Sebastián Sánchez[1] · Andrés Russu[1] · Christian Monstein[3] · Rafael Fernández[1]

Received: 24 July 2019 / Accepted: 23 December 2019 / Published online: 15 January 2020

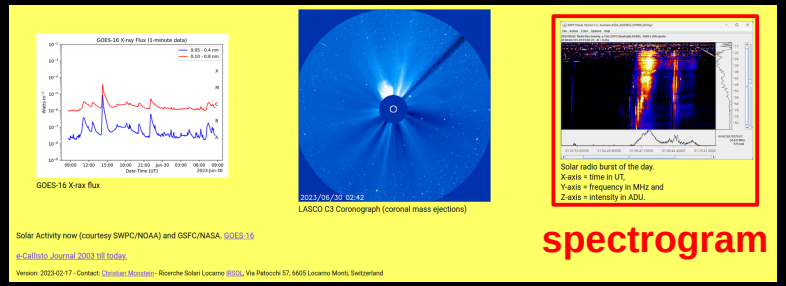
E-CALLISTO NETWORK

http://e-callisto.org ETH Zürich: Benz, Monstein,+



HISTORY – GOALS:

A worldwide network of low-cost solar spectrometers
An ISWI instrument, prompted by the IHY2007
Solar Radio Bursts (SRB) as key tool for Space Weather:
solar storm precursors
Science case: understanding transient phenomena in the solar corona



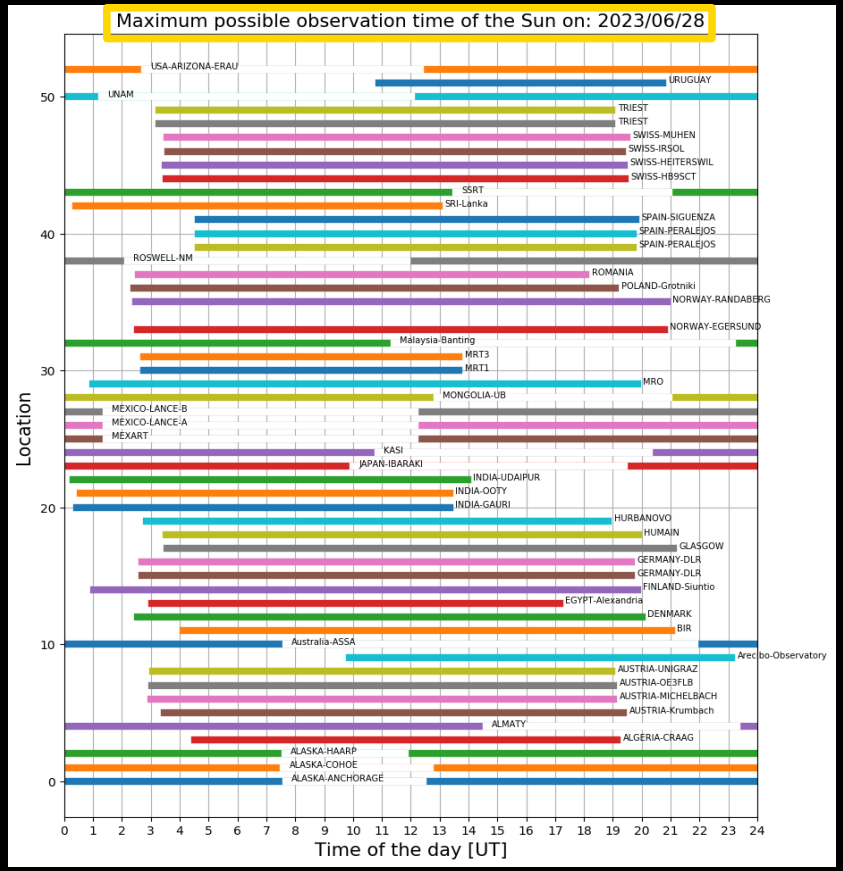
STRENGTHS:

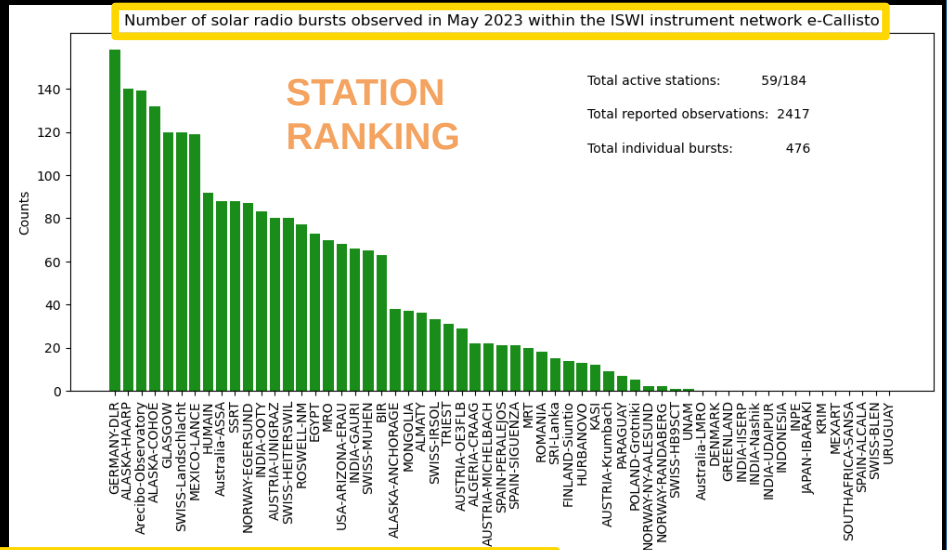
Low cost: easy installation/operation, educational/humanitarian side
Geographical coverage, geo redundancy
Broad frequency range: 45 – 870 MHz native, 20 – 80 MHz with LWA
Only global network monitoring 24/7 the solar corona at m/dam wlengths

UPDATE: 218 CALLISTO receivers

48 locations, 73 instruments (as of last week)
New/upgraded/first light after pandemic: `Spain (Peralejos+Sigüenza), ASSA, DLR Germany, Thailand, Arizona, Uruguay, Norway-Randaberg+Aalesund+Egersund, IRSOL, Alaska-HAARP, Egypt-Alexandria+Cairo, Malaysia-Banting, Arecibo, Mexico-LANCE, Romania, Paraguay, Finland-Siuntio, Siberia-SSRT, Rwanda-Kigali,...`

E-CALLISTO NETWORK





SRB EVENT REPORT

```
Product: e-CALLISTO_2023_05.txt
Prepared by PI e-Callisto
Please send comments and suggestions to christian.monstein(at)irsol.usi.ch
#
# Missing data: ##:##-##:##
#
#Date          Time            Type    Stations
#-------------------------------------------------------------------------------
20230501        07:01-07:04     III     AUSTRIA-UNIGRAZ, Australia-ASSA, EGYPT-Alexandria, GERMANY-DLR, (GLASGOW), HUMAIN, IND
20230501        07:42-07:44     III     AUSTRIA-UNIGRAZ, Australia-ASSA, EGYPT-Alexandria, GERMANY-DLR, (GLASGOW), HUMAIN, IND
20230501        09:35-09:43     III     AUSTRIA-OE3FLB, AUSTRIA-UNIGRAZ, EGYPT-Alexandria, GERMANY-DLR, GLASGOW, HUMAIN, INDIA
20230501        10:54-10:55     III     ALGERIA-CRAAG, AUSTRIA-OE3FLB, AUSTRIA-UNIGRAZ, Arecibo-Observatory, BIR, EGYPT-Alexan
SIGUENZA, SWISS-HEITERSWIL, SWISS-IRSOL, SWISS-Landschlacht, SWISS-MUHEN, TRIEST
20230501        11:53-12:14     VI      Arecibo-Observatory, (EGYPT-Alexandria), GERMANY-DLR, GLASGOW, (HUMAIN), SWISS-HEITERS
20230501        12:54-12:55     III     AUSTRIA-UNIGRAZ, Arecibo-Observatory, (EGYPT-Alexandria), GERMANY-DLR, GLASGOW, SWISS-
20230501        13:08-13:09     RBR     ALGERIA-CRAAG, AUSTRIA-Krumbach, AUSTRIA-MICHELBACH, AUSTRIA-OE3FLB, AUSTRIA-UNIGRAZ,
SWISS-Landschlacht, SWISS-MUHEN, TRIEST
20230501        13:41-13:56     III     ALGERIA-CRAAG, AUSTRIA-OE3FLB, AUSTRIA-UNIGRAZ, Arecibo-Observatory, (EGYPT-Alexandria
ARIZONA-ERAU
20230501        14:28-14:29     III     ALGERIA-CRAAG, AUSTRIA-OE3FLB, AUSTRIA-UNIGRAZ, Arecibo-Observatory, BIR, EGYPT-Alexan
SWISS-Landschlacht, SWISS-MUHEN, TRIEST, USA-ARIZONA-ERAU
20230501        14:46-14:46     III     Arecibo-Observatory, GERMANY-DLR, (GLASGOW), (SWISS-Landschlacht)
20230501        15:38-15:39     III     Arecibo-Observatory, GERMANY-DLR, GLASGOW, MEXICO-LANCE, NORWAY-EGERSUND, SWISS-HEITER
20230501        16:40-16:41     III     Arecibo-Observatory, (GERMANY-DLR), (GLASGOW), MEXICO-LANCE, USA-ARIZONA-ERAU
20230501        21:22-21:22     III     ALASKA-ANCHORAGE, ALASKA-COHOE, ALASKA-HAARP, MEXICO-LANCE, ROSWELL-NM, USA-ARIZONA-ER
20230501        22:18-22:23     III     ALASKA-ANCHORAGE, ALASKA-COHOE, ALASKA-HAARP, Australia-ASSA, MEXICO-LANCE, ROSWELL-NM
20230501        22:35-22:36     III     (ALASKA-COHOE), ALASKA-HAARP
20230501        23:08-23:08     III     ALASKA-COHOE, ALASKA-HAARP, Australia-ASSA, USA-ARIZONA-ERAU
20230502        00:59-00:59     III     ALASKA-COHOE, ALASKA-HAARP, Australia-ASSA
20230502        02:32-03:21     III     ALASKA-COHOE, Australia-ASSA, INDIA-GAURI, INDIA-OOTY, SSRT
20230502        04:00-04:01     III     Australia-ASSA, INDIA-GAURI, INDIA-OOTY, SSRTFIN
20230502        05:18-05:24     III     Australia-ASSA, EGYPT-Alexandria, GERMANY-DLR, INDIA-GAURI, INDIA-OOTY, NORWAY-EGERSUN
20230502        11:28-11:29     III     AUSTRIA-UNIGRAZ, Arecibo-Observatory, EGYPT-Alexandria, GERMANY-DLR, GLASGOW, HUMAIN,
20230502        14:04-14:04     III     Arecibo-Observatory, GERMANY-DLR, GLASGOW, SWISS-Landschlacht
20230502        16:30-16:32     III     Arecibo-Observatory, (GERMANY-DLR), (GLASGOW), MEXICO-LANCE
20230503        03:39-03:40     III/J   ALASKA-COHOE, ALASKA-HAARP, ALMATY, Australia-ASSA, INDIA-GAURI, INDIA-OOTY, MONGOLIA-
20230503        04:33-05:12     VI      ALASKA-COHOE, Australia-ASSA, GERMANY-DLR, HUMAIN, INDIA-GAURI, INDIA-OOTY, (MONGOLIA-
20230503        07:26-07:31     III     AUSTRIA-OE3FLB, AUSTRIA-UNIGRAZ, Australia-ASSA, EGYPT-Alexandria, GERMANY-DLR, GLASGO
```

Javier Bussons (UAH) – CESRA workshop, July 2023

E-CALLISTO NETWORK

LEGACY:
- Worldwide instrument deployment + training + tech assistance, supplies
- Centralized data storage: fits + png quicklook
  Archive: 2012 – now (just a few stations before 2012)
- Daily reports since 2020 by human **visual inspection**
- Practical web site: data, s/w and h/w documentation, coverage maps, papers, tools, newsletter, … + Facebook and other comm channels

TOWARDS A NEXT-GENERATION INSTRUMENT:
Gradual takeover of responsibilities, shared by many institutions

- **Automated SRB identification** +classification [urgent need]
- **Data calibration** in Solar Flux Units (SFU)
- **Open-access services:** elaborated products, alerts, pipeline
- **Instrument improvement** and standardization
- **Network expansion**, site testing (RFI)

→ Make the network more USEFUL + VISIBLE to the community

SRB IDENTIFICATION + CLASSIFICATION (Spanish contribution)

Solar Physics (2023) 298:82
https://doi.org/10.1007/s11207-023-02171-0

RESEARCH

Automatic Burst Detection in Solar Radio Spectrograms Using Deep Learning: deARCE Method

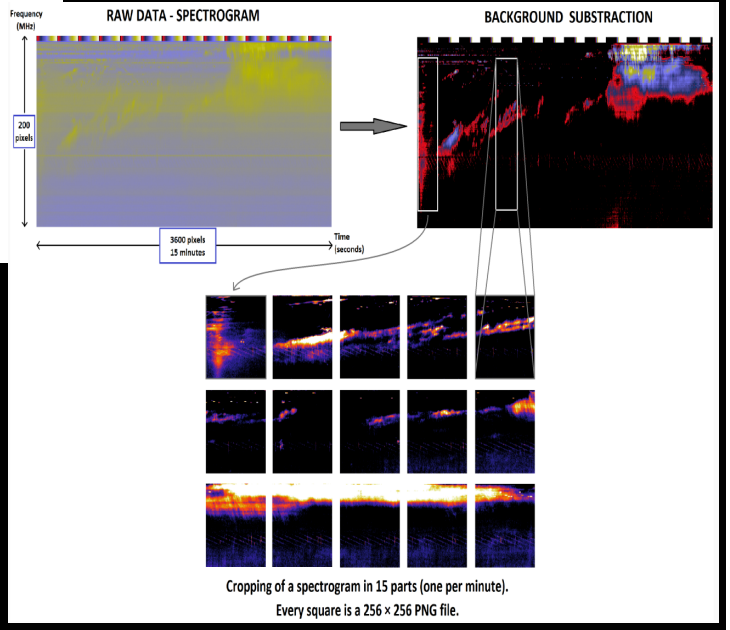
deep Automatic Radioburst Compilation Engine

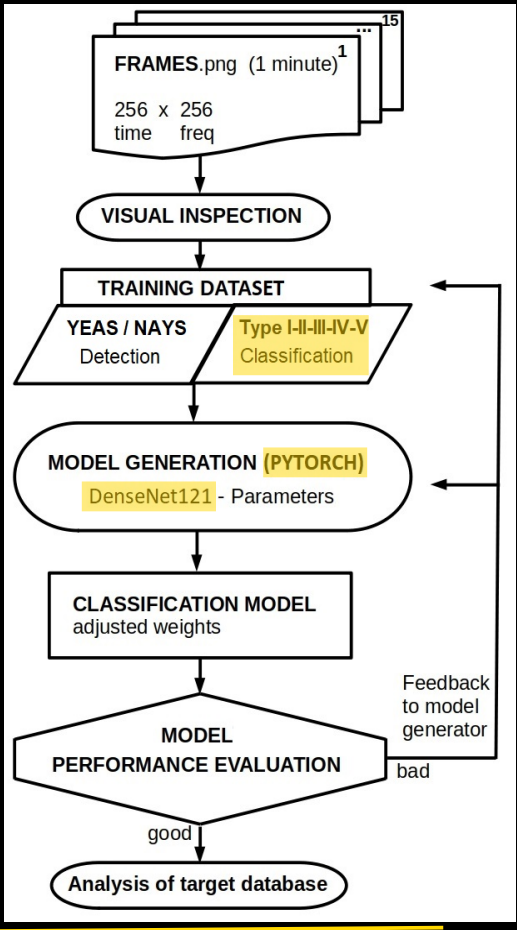
Javier Bussons Gordo[1,2] · Mario Fernández Ruiz[3] · Manuel Prieto Mateo[3] · Jorge Alvarado Díaz[4] · Francisco Chávez de la O[5] · J. Ignacio Hidalgo[4] · Christian Monstein[6]

Received: 22 December 2022 / Accepted: 19 May 2023

https://doi.org/10.1007/s11207-023-02171-0

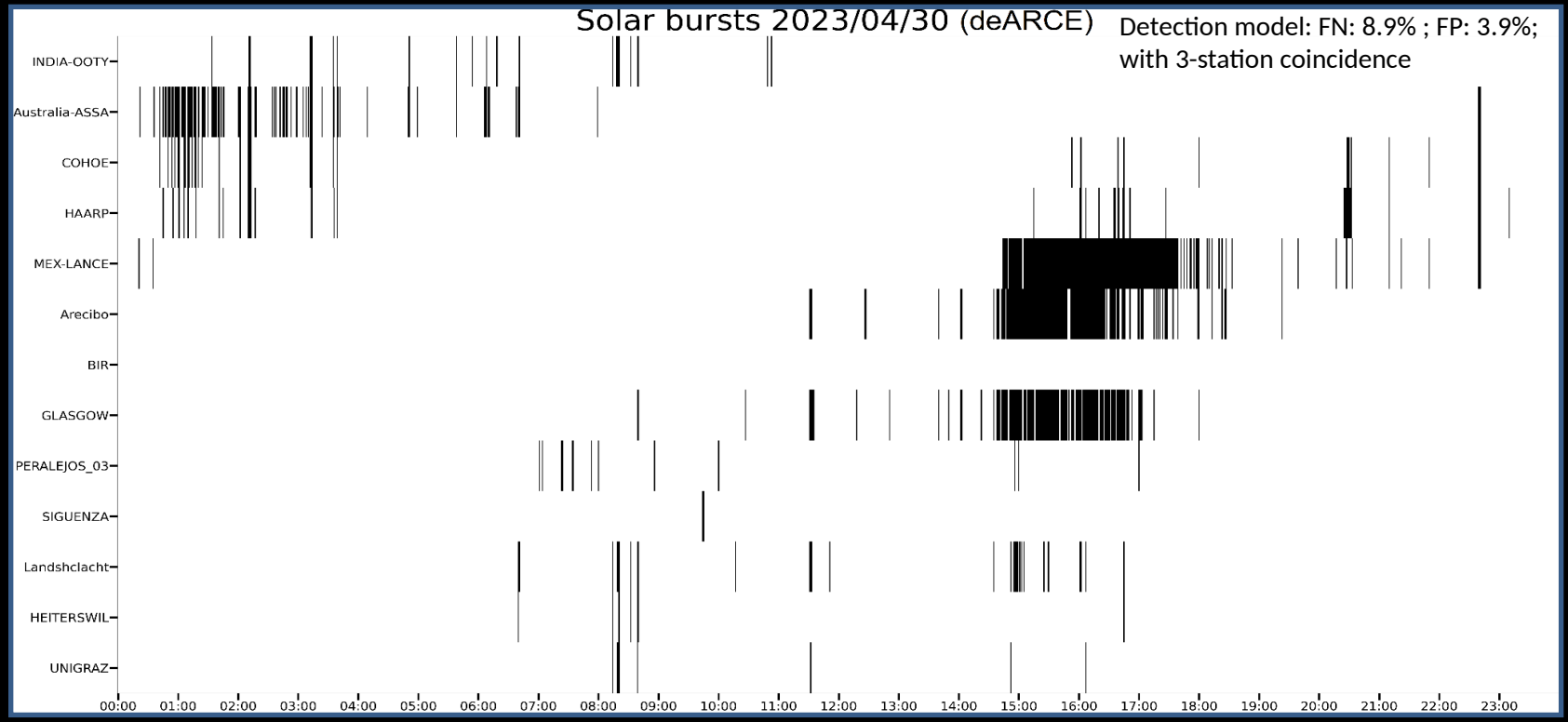
RESULTS (for models currently in use):
Detection model: FN: 14.71% ; FP: 4.36%.
Classification model: Type I: 88.9%; Type II: 95.1%;
Type III: 92.3%; Type IV: 97.19%; Type V: 81.3%.





* In preparation: paper on eCallisto SRB's during the **2012-2019 reportless period**

CROSS-MATCH FUNCTIONALITY



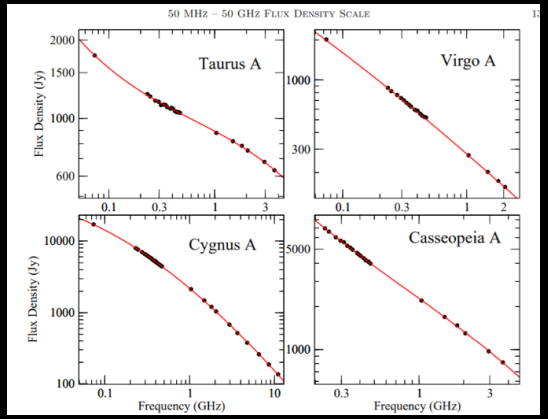
OTHER APPROACHES: ROBUST two-station correlation + freq. masking (UniGraz), thresholding + multi-station majority classif. (Trieste), Humain, Birr, Glasgow, DLR Germany … → WG

CALIBRATION

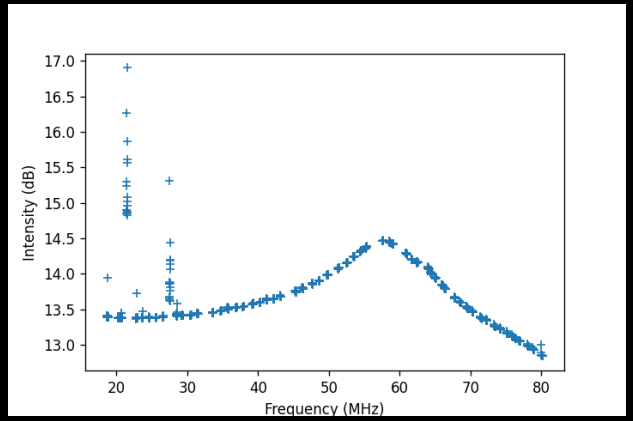
LOFAR / eCallisto inter-calibration (Zucca+)

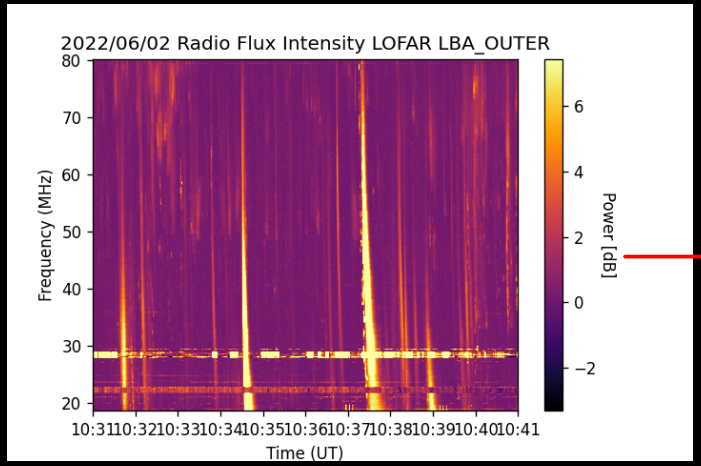
- Use calibrated LOFAR flux to adjust eCallisto instruments
- Bandpasses for various sites to be issued and updated every season
- Pass-on option: proceed by geo-zone in 4-5 steps

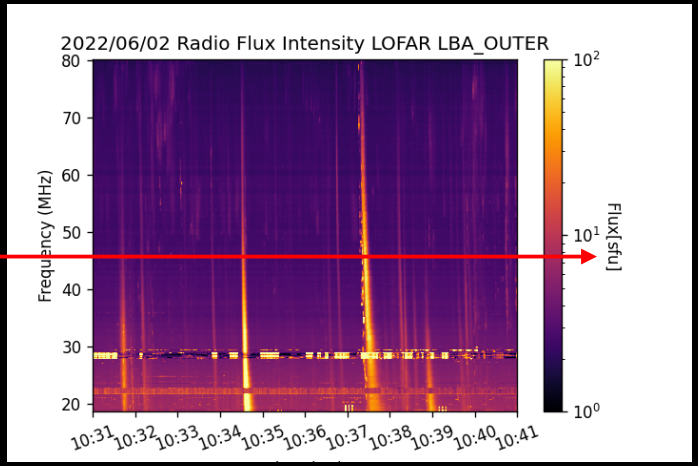
Spectral Model



Bandpass (quasi real time)







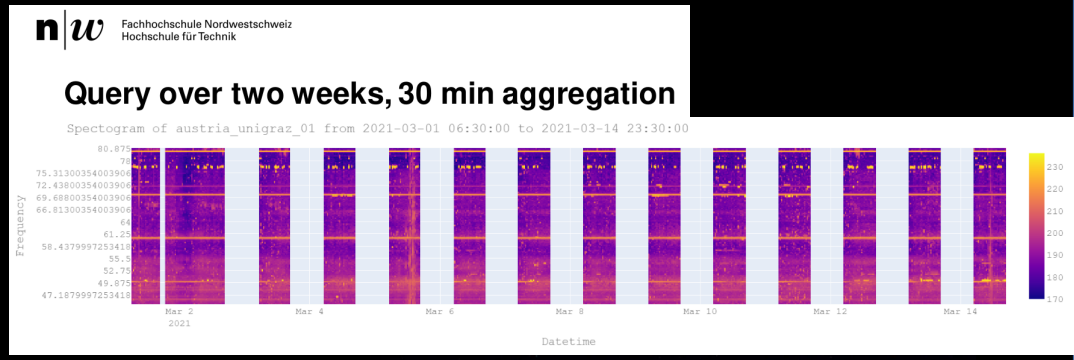
DATA COMPATIBILITY

- LOFAR and Learmonth data conversion to eCallisto format now available

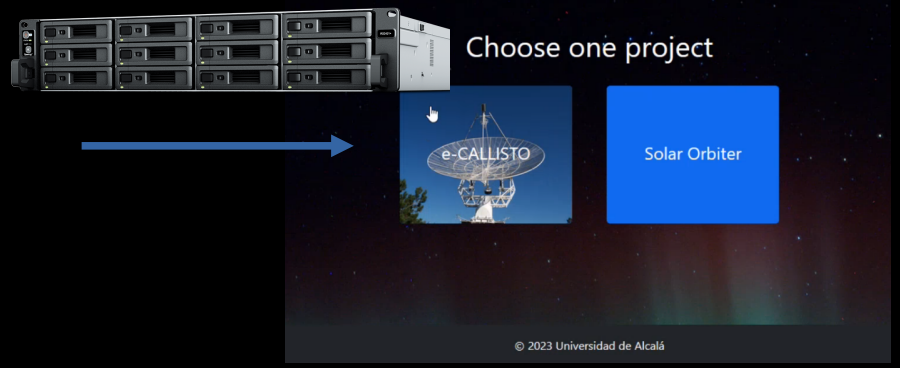
OPEN SERVICES / PRODUCTS (Data Center)

Fach Hoschschule Nord WestSchweiz
(FHNW, A. Csillaghy, V. Timmel)
- Centralized eCallisto Data Archive

Now also:
- Solutions for faster data queries + browsing
- RadioSpectra.py package, PANDAS, Rest-API on top
- eCallisto spectrograms treated as TimeScaleDB



SPARC project: SPace-weather Awareness + Research Center
Casa del Doncel, Sigüenza, Spain (in progress)
- NAS: Synology2421RP+, 12-24 bay storage server (144 TB)
- Data/Service Center for eCallisto and beyond (SWx): other ground-based data (Learmonth, NOAA), Solar Orbiter, ...



OTHER CONTRIBUTIONS:
eCallisto Website Mirror (UNAM, E. Aguilar), ...→ WG

e-callisto data

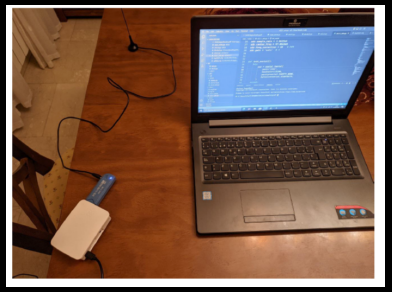
172.29.21.84/dashboard/stations.php

e-callisto data Home Data Burst Reports Statistics Stations Help

Stations Map

INSTRUMENT IMPROVEMENT – RECEIVERS, ANTENNAS

REQUIREMENTS DEFINITION (WG):
- Time resolution
- Frequency resolution
- Frequency range(s)
- Sensitivity



RaspberryPi4 + hackRFOne
1 MHz to 6 GHz operating frequency
Sampling rate: 20 Msps
Compatible with GNU Radio
TX/RX

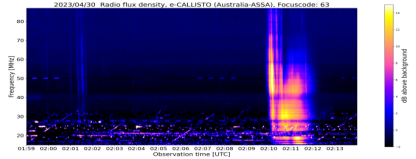
Yes, but … RETHINKING OUR INSTRUMENTATION

Portable, autonomous equipment:
- could eCallisto2.0 be powered by solar panels/batteries?
- make use of 4G/5G, Starlink?
- reduce uploaded (raw) data volume via front-end IA?
- lighter rotors? → handier antennas
- single-board computers (RaspberryPi, BeagleBone, Arduino)?

New operating systems, platforms, tools, languages (bye MSoft

Digital vs Analog Receiver → Software Digital Radio

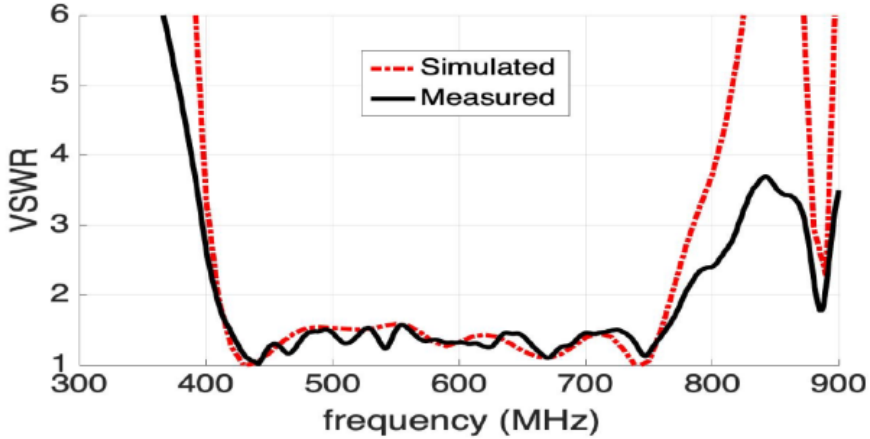
- Receiver development. SDRs and “In-place” calibration
  - SDR device with transmission features
  - Calibration file with reference solar radio burst as input



INSTRUMENT IMPROVEMENT – RECEIVERS, ANTENNAS

Signal processing and electronics for future spectrometers:
Wideband FFT, PCB, … (Finland, Norway, Malaysia, Paraguay,...)
LWA Front-End Electronics revision (ASSA+)

ANTENNA DEVELOPMENTS (UAH+UPCT, Spain):
Wide band vs “sweet band” antennas (ASSA)
Geometry modification of standard CLP-5130 (UAH)
Propose new antennas: lighter, easy to deploy/relocate (UAH, MWA)
New antenna concepts: leaky-wave (UPCT) for rough imaging



THANK YOU VERY MUCH, MUCHAS GRACIAS

Any questions?

REFERENCES

http://e-callisto.org

https://celestina.web.uah.es JCCM PROJECT Reference Number: SBPLY/19/180501/000237

Prieto et al. Increase in Interference Levels in the 45 - 870 MHz Band at the Spanish e-CALLISTO Sites over the Years 2012 and 2019. Solar Physics (2020) 295:11. https://doi.org/10.1007/s11207-019-1577-5

Bussons et al. Automatic Burst Detection in Solar Radio Spectrograms Using Deep Learning: deARCE Method. Solar Physics (2023) 298:82. https://doi.org/10.1007/s11207-023-02171-0