Diego Janches
GSFC/NASA

Characterizing the Near Earth Meteoroid Environment in Argentina

THE CATHOLIC UNIVERSITY OF AMERICA

UNIVERSIDAD NACIONAL DE LA PLATA

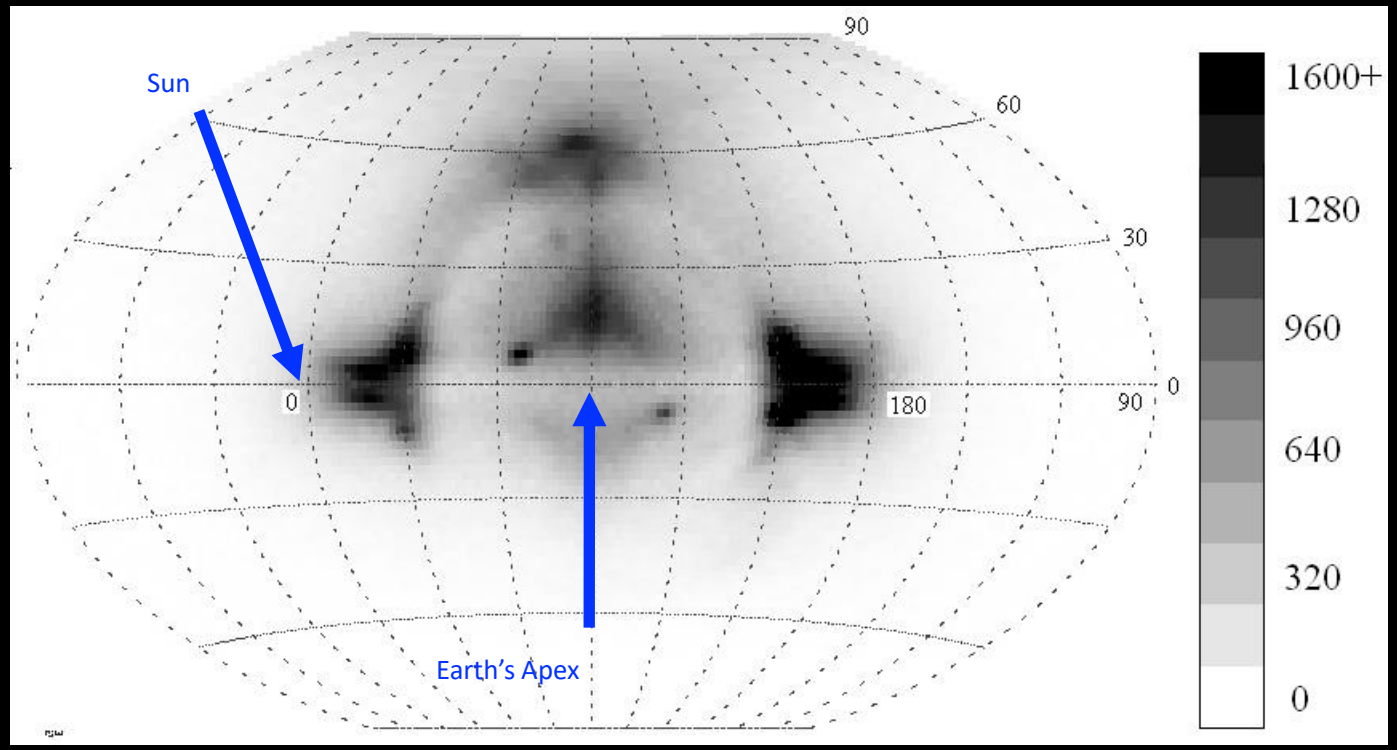
Meteoroid Environment

- Knowledge of the meteoroid environment for particles with masses in the 1 μg - 10 g range, from both the sporadic background and showers, is relevant to planetary science, upper atmospheric chemistry, space weathering of airless bodies and collisional risk assessment

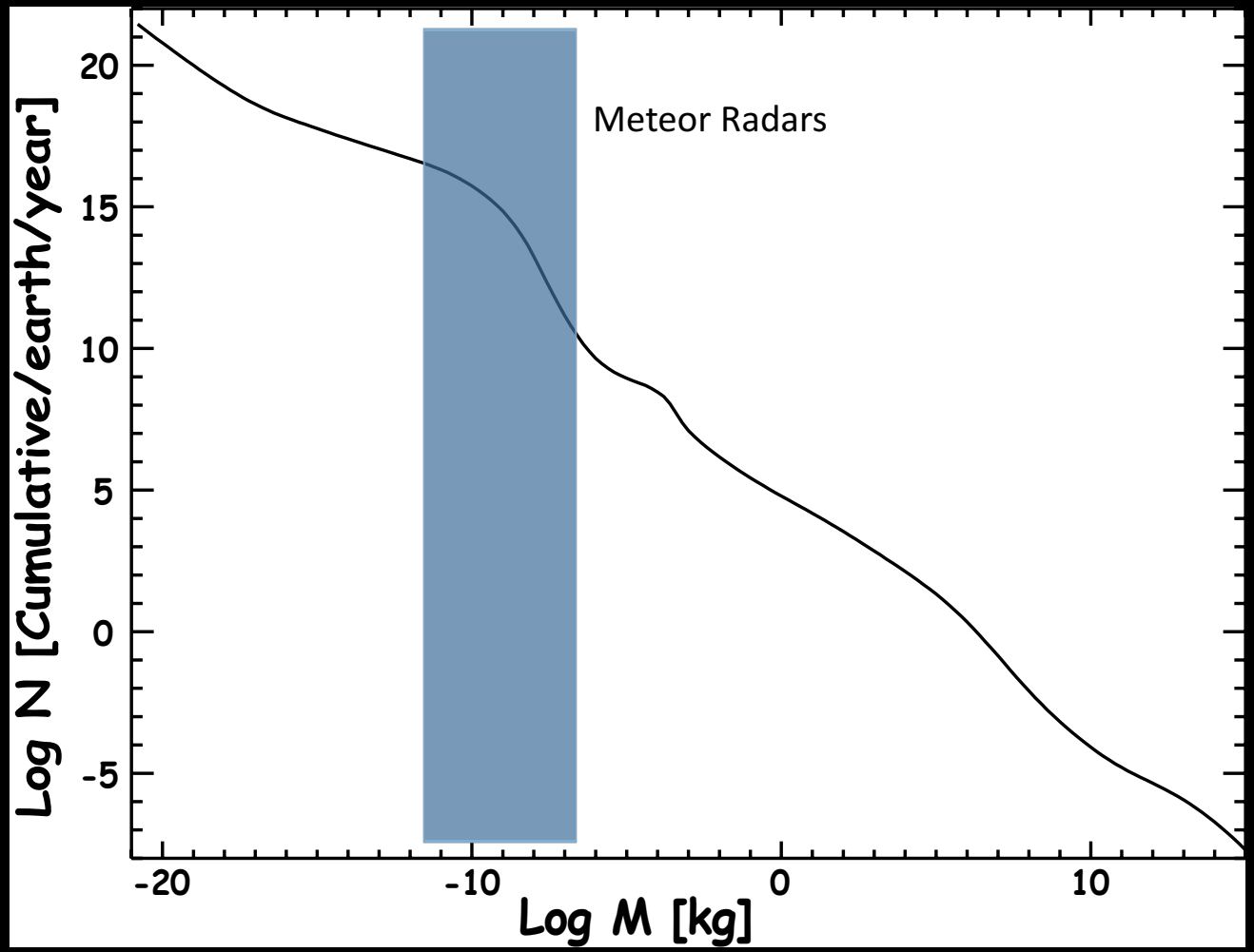
- Meteor radars provide continuous monitoring of most of this mass range

- Historically measurements have been heavily weighted in the northern hemisphere - specifically using the Canadian Meteor Orbit Radar (CMOR) - leaving us 'half blind' to the meteoroid environment

Meteoroid Environment



Meteoroid, Meteor and Meteorite

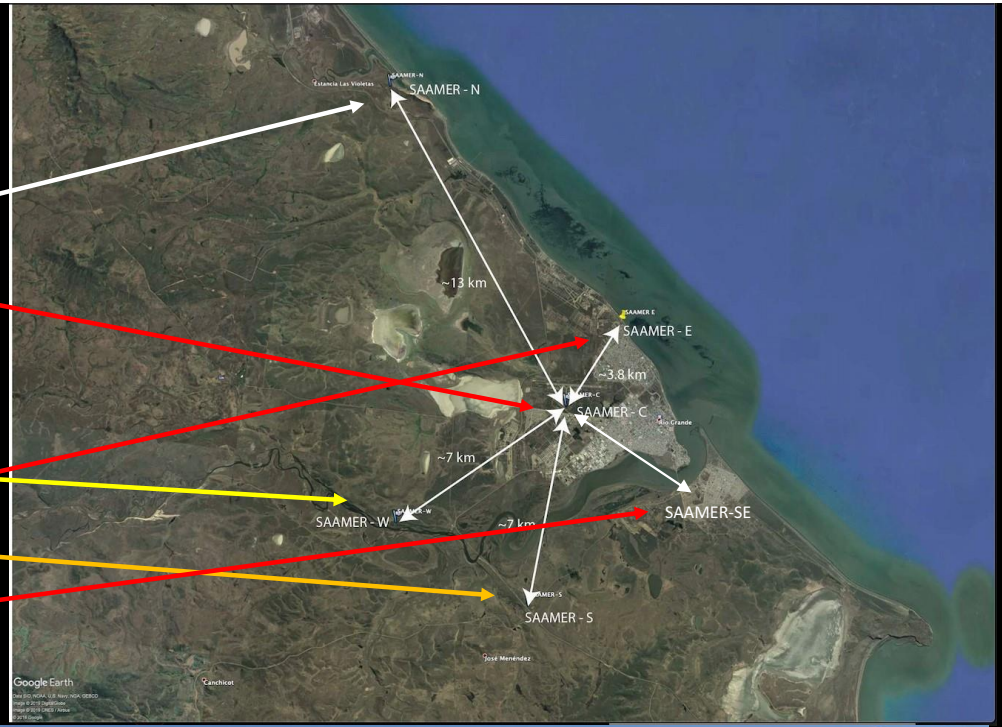


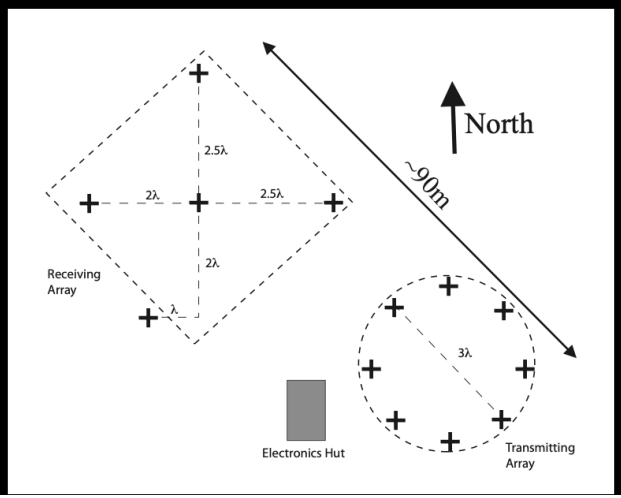
Observations at the most dynamic region on Earth

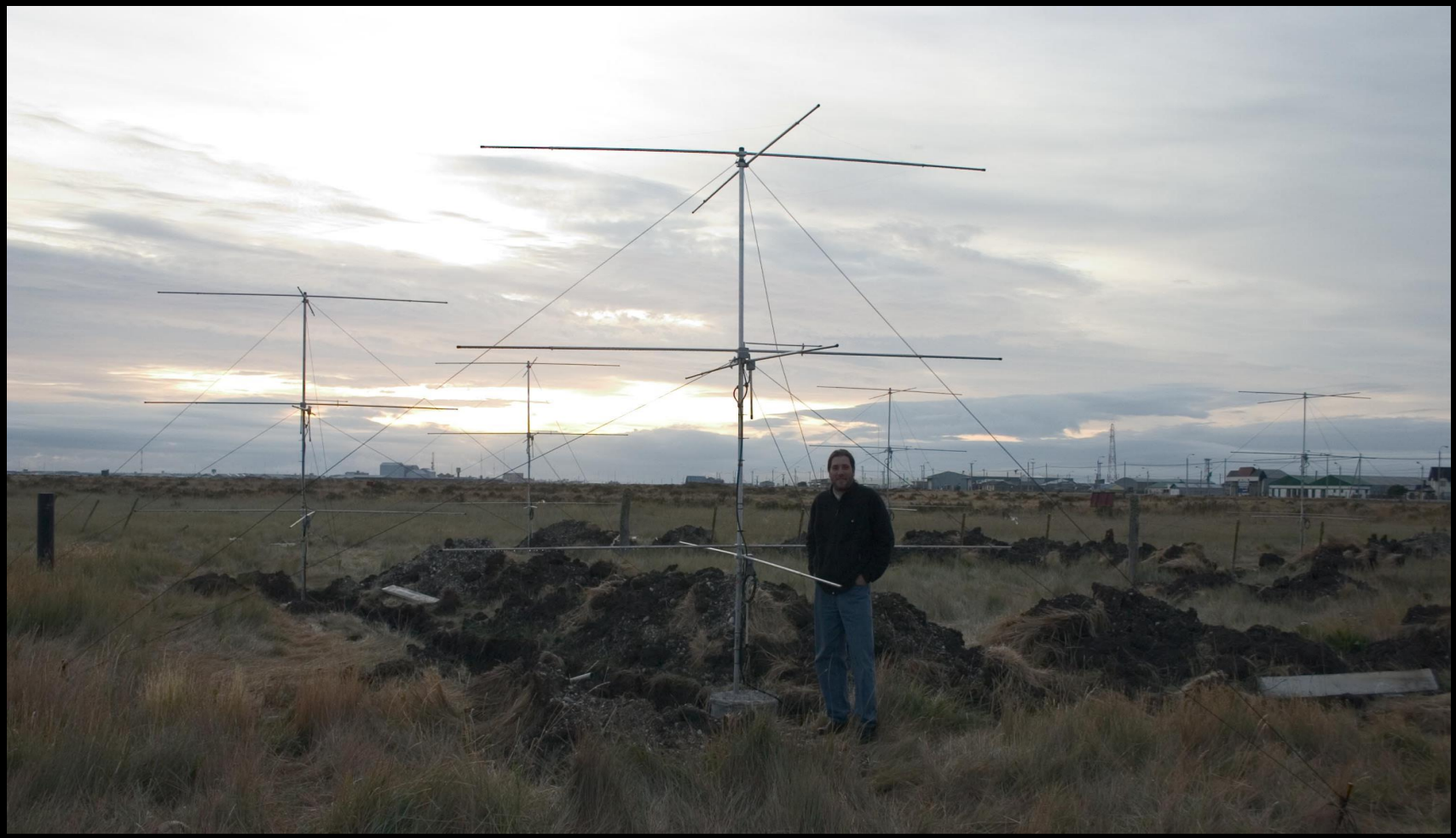
SAAMER
Southern Argentina Agile MEteor Radar

- Deployed in May 2008 for studies of gravity waves generated by winds over the Andes
- SAAMER is hosted by the Estacion Astronomica Rio Grande, located in Rio Grande, Argentina
- NASA and National University of La Plata collaboration
- 60 kW, 32.55 MHz transmitter (TX)

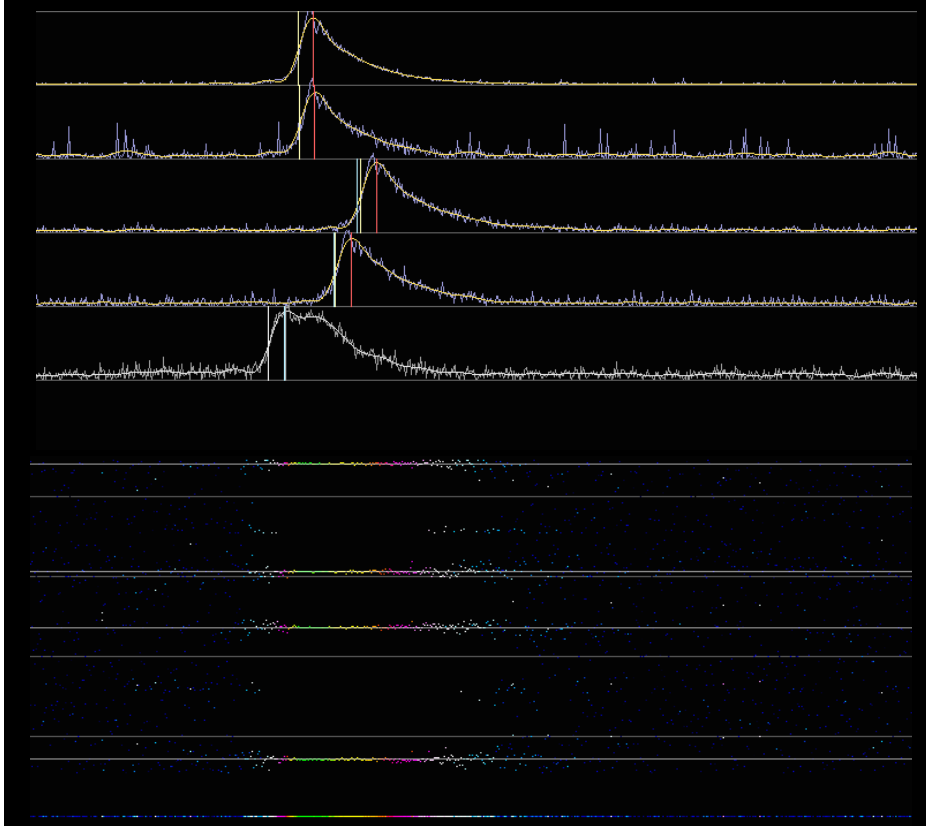
- **Central transmitting station (TX)**
  - SAAMER-C: May 2008, NSF Aeronomy
  - 60 kW, 32.55 MHz transmitter (TX)
- **Remote receiving stations (RX)**
  - SAAMER-N: August 2010, NSF Astronomy
  - SAAMER-W: August 2010, NSF Astronomy
  - SAAMER-S: January 2017, NASA Solar System Observations (SSO)
  - SAAMER-E: June 2019, SSO and NESC
  - SAAMER-SE: May 2022, NESC



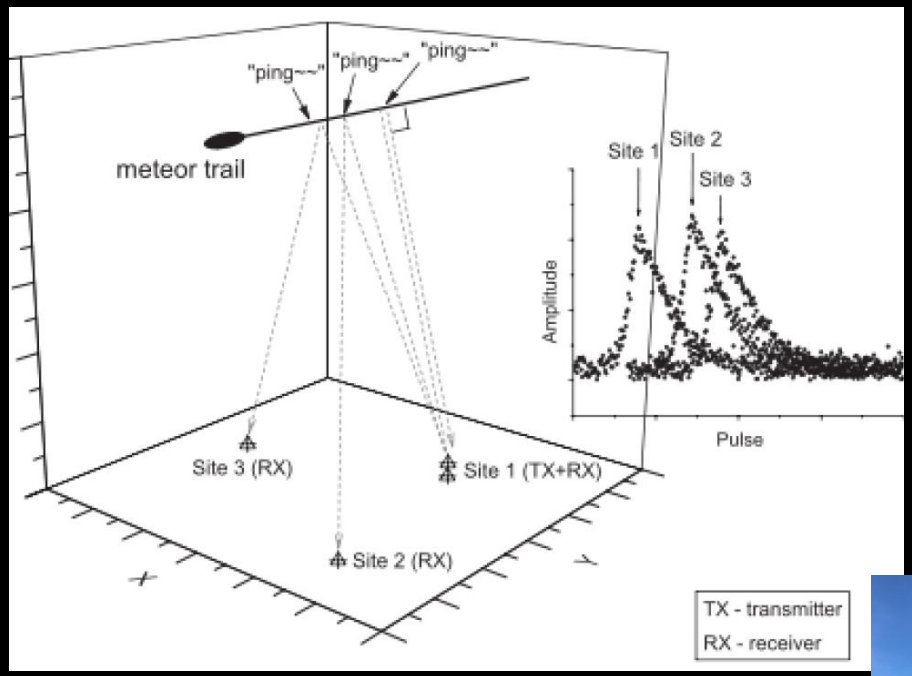




METEOR ECHO DETECTION: AMPLITUDE AND PHASE VALUES

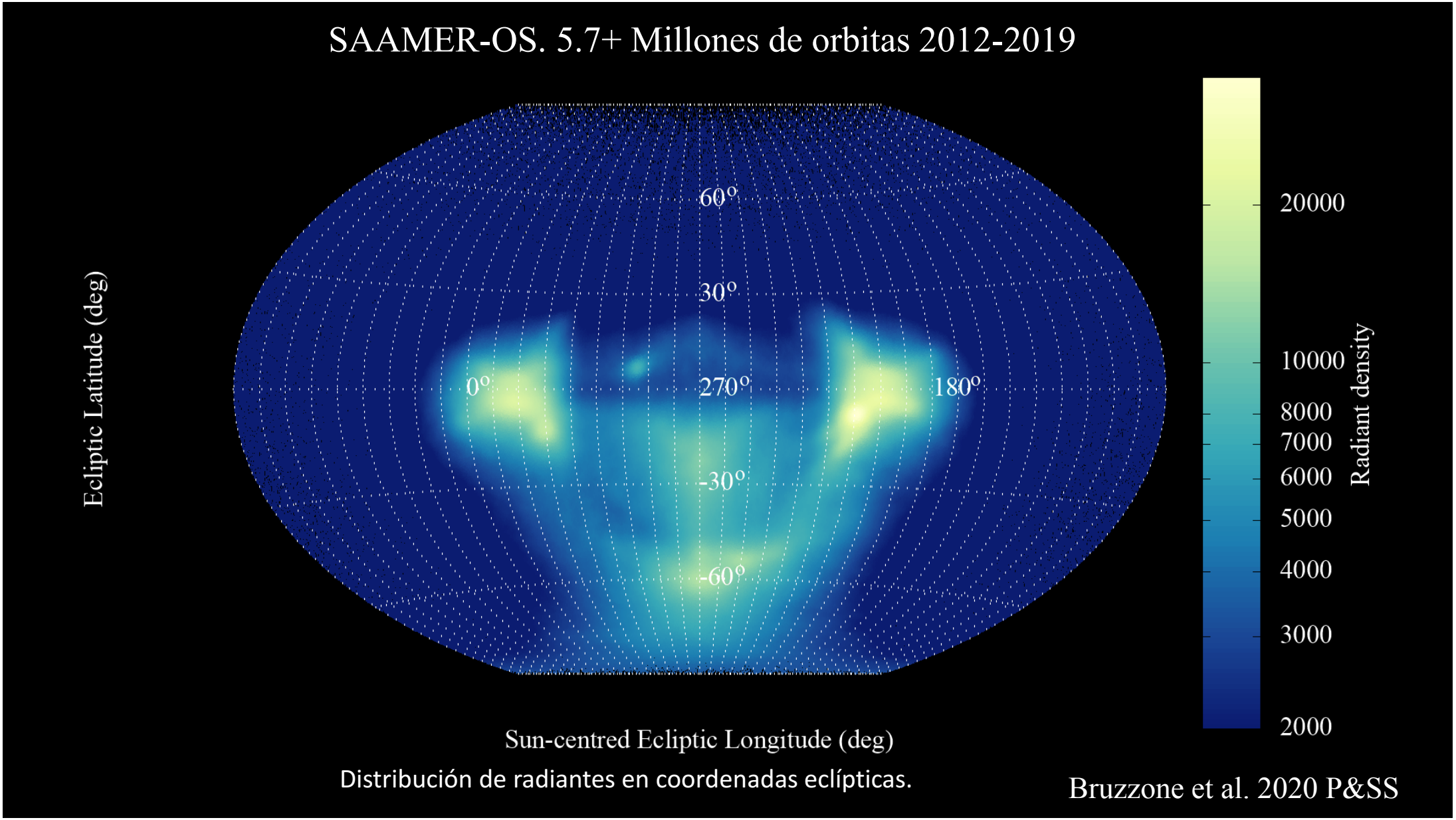


Multistation amplitudes and phases with SAAMER



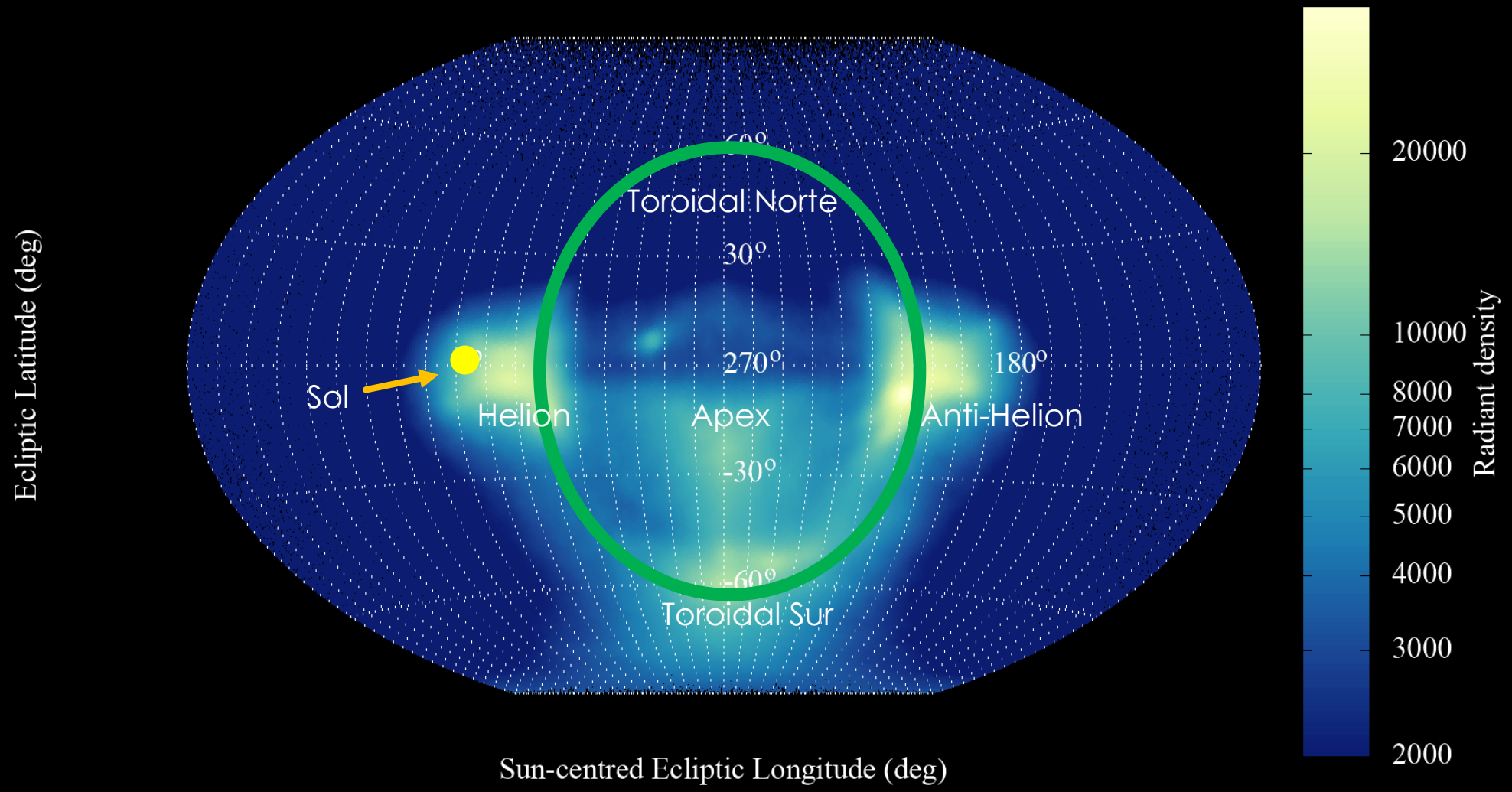
Ye at al. 2015 MNRAS

SAAMER-W remote station shelter



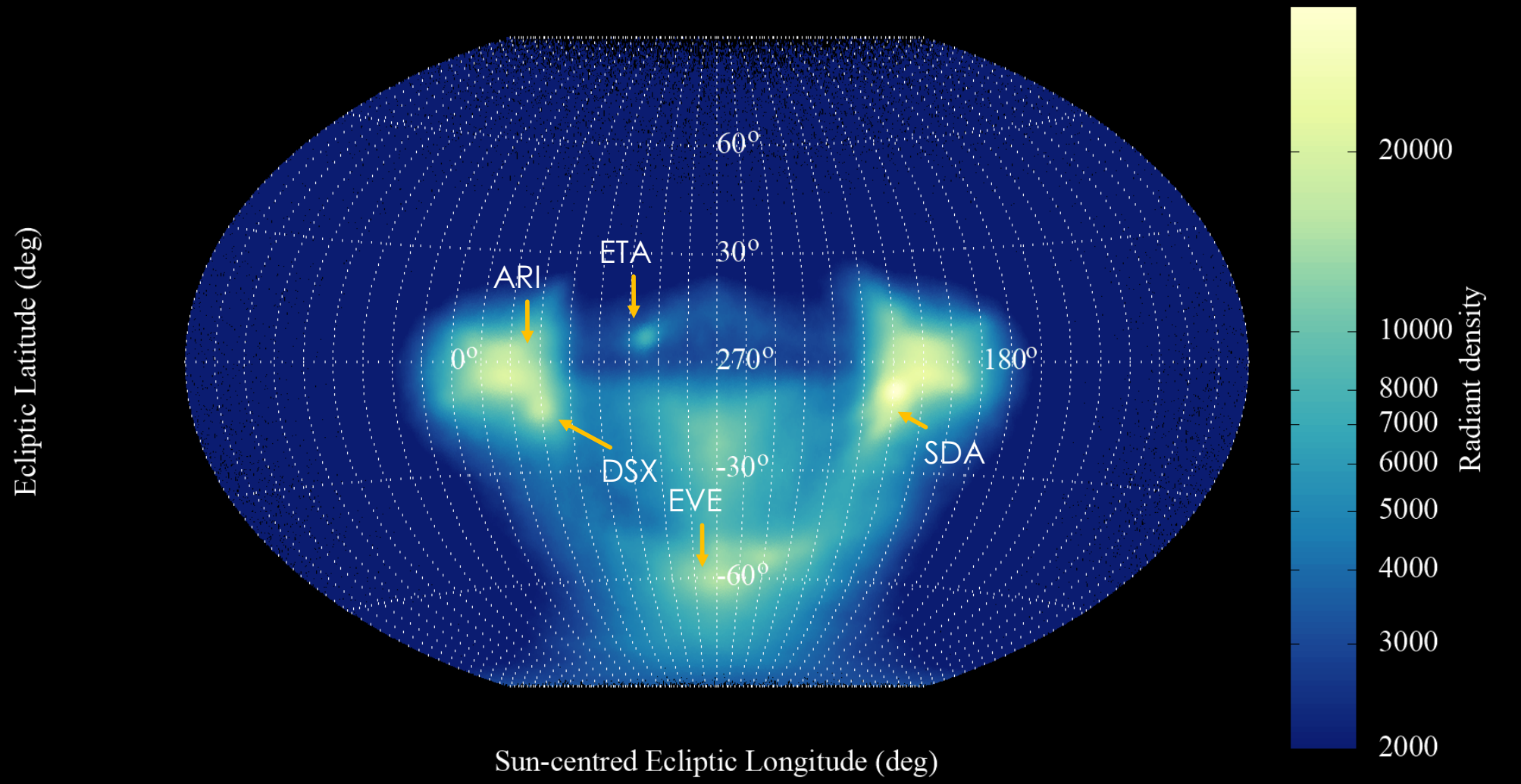
Distribución de radiantes en coordenadas eclípticas.

SAAMER-OS. 5.7+ Millones de orbitas 2012-2019



Distribución de radiantes en coordenadas eclípticas.

Bruzzone et al. 2020 P&SS

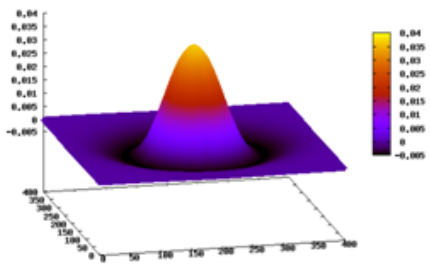


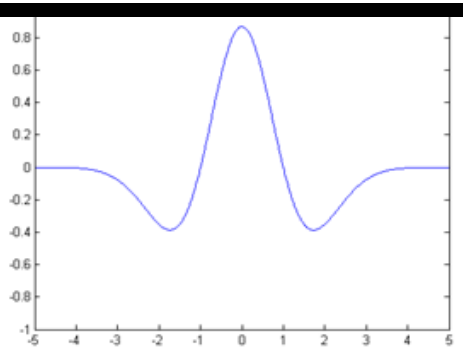
Distribucion de radiantes en coordenadas eclipticas.

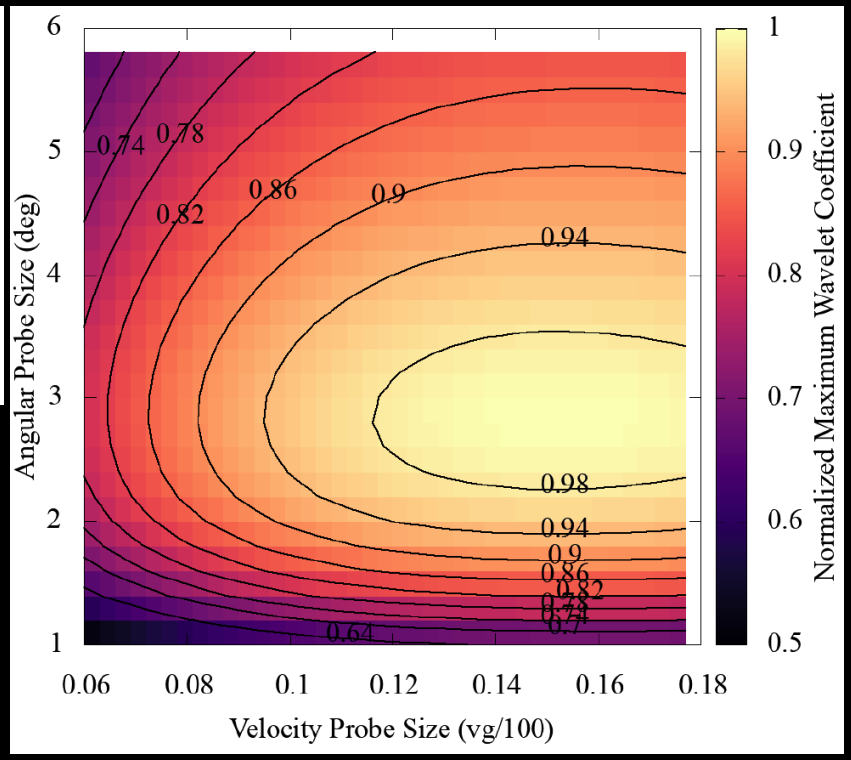
Bruzzone et al. 2020 P&SS

3D-WAVELET: REALCE DE AGRUPAMIENTO DE RADIANTES EN EL ESPACIO DE FASE

$$W(x_0, y_0, v_{g0}) = \frac{1}{(2\pi)^{3/2}\,\sigma_v^{1/2}\,\sigma_a} \int_{vg_{\min}}^{vg_{\max}} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} f(x, y, v_g)$$
$$\times \left(3 - \frac{(x-x_0)^2 + (y-y_0)^2}{\sigma_a^2} - \frac{(v_g - v_{g0})^2}{\sigma_v^2}\right)$$
$$\times \exp\left(-0.5\left[\frac{(x-x_0)^2 + (y-y_0)^2}{\sigma_a^2} - \frac{(v_g - v_{g0})^2}{\sigma_v^2}\right]\right)$$

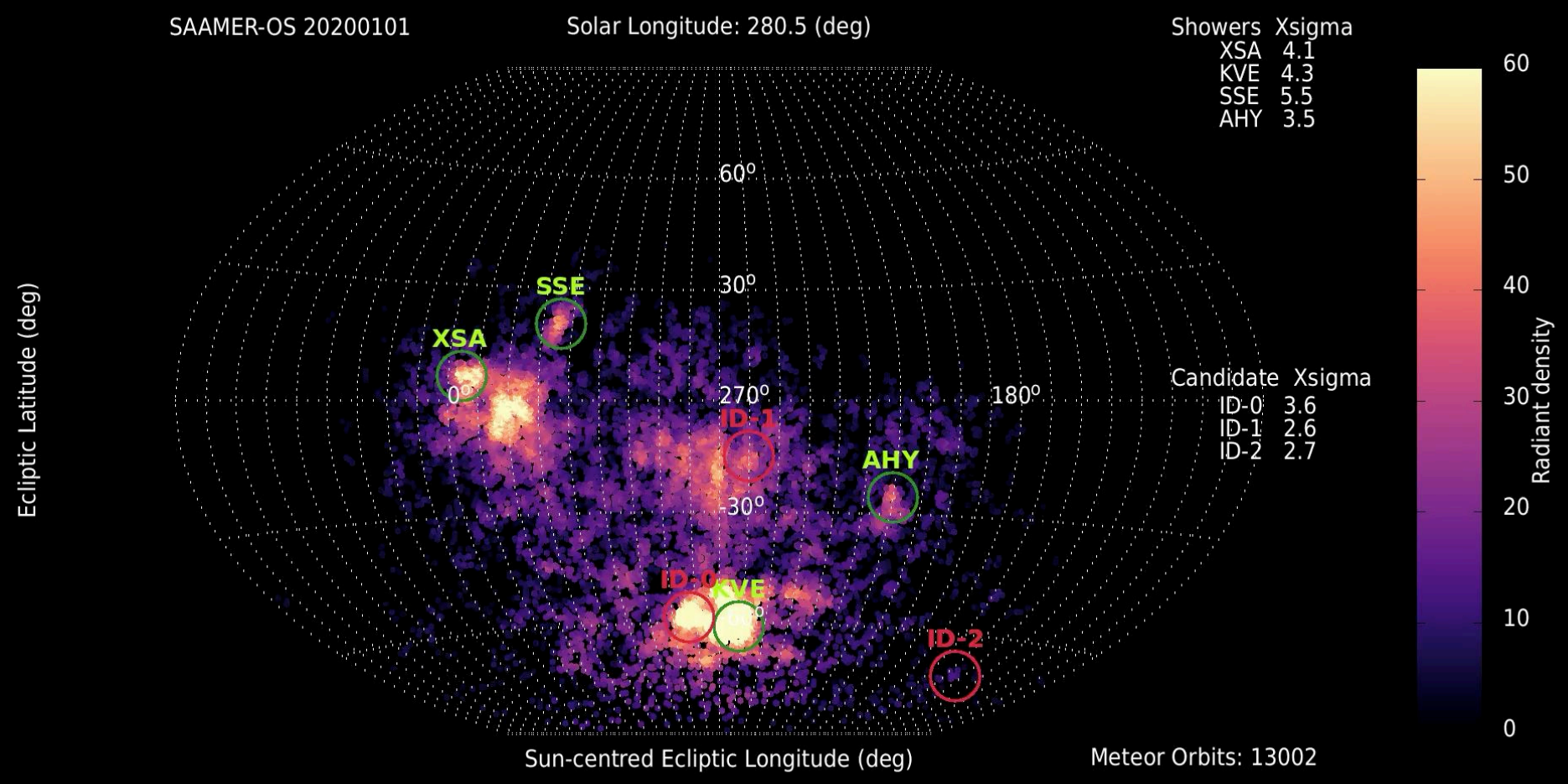






Brown et al., 2008, 2010, Icarus. Bruzzone et al., 2015 MNRAS. Bruzzone et al. 2020 P&SS

Monitoring the southern sky meteoroid environment



of 20201005 Solar longitude: 192.50 deg
#Interval of Julian Days: 2459127.499899 and 2459128.499901
#Station meteor counts: CNW__ 49 CN_S_ 52 C_WS_ 294 CNWS_ 133 CN__E 350 C_W_E 229 CNW_E 433 C__SE 610 CN_SE 566 C_WSE 1910 CNWSE 6375
#File: ROBORB_20201005.sl has 9839 meteor orbits
#Reference Database: METEORDB_2018_decelcorr.db
#Current Database: ROBORB_20201005.db
#Wavelet run parameters:
angular probe size: 2.5deg
velocity probe size: 15%
time-window: 1.0deg
0.5 deg angular resolution and 5% in vg
ll0_min: 0 ll0_max: 360 beta_min: -90 beta_max: 40
vg_min: 11 vg_max: 78 slon_min: 192.50 slon_max: 192.50
Meteor speeds corrected for deceleration (Bruzzone et al. 2020).
#
#
#Shower association: 4 deg and 15% in vg of known shower radiants.
#xsigma > 3.0 and rcnt > 30
#Shower candidates labeled as ID-number. We use the following criteria: xsig > 11.5, 6.0 deg, and 15% in geo speed
#away of known shower radiants.

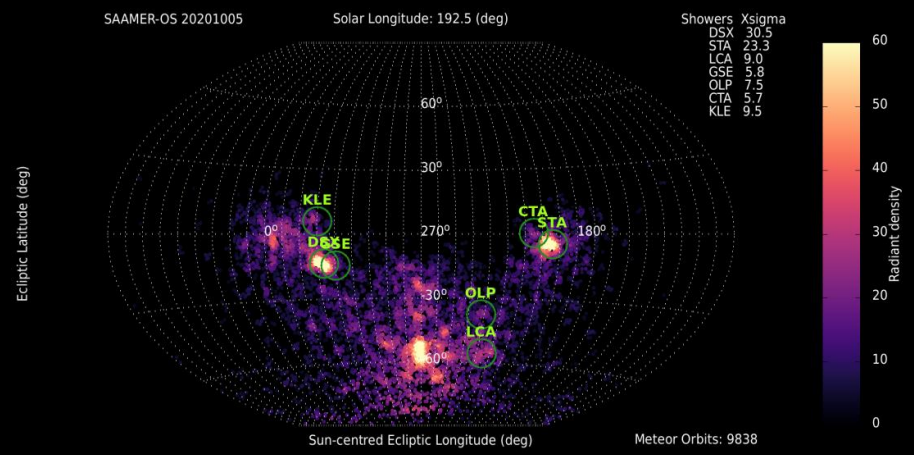
ll_0	beta	vg(km/s)	wc	wcerr	radcount	xsigma	med	sigma	std	Shower
326.522	-13.500	30.644	358.382	52.247	460.000	30.549	1.355	11.687	11.064	DSX
194.098	-4.500	27.795	327.355	53.897	444.000	23.315	24.407	12.993	24.911	STA
225.986	-55.500	39.110	78.349	36.973	294.000	8.992	3.640	8.308	8.619	LCA
319.683	-14.500	26.472	58.306	46.444	314.000	5.810	-1.235	10.248	6.008	GSE
231.927	-37.500	29.185	52.825	31.177	156.000	7.508	0.697	6.943	5.886	OLP
205.008	0.500	39.110	59.793	37.535	303.000	5.705	7.909	9.095	17.844	CTA
329.807	6.000	45.275	57.285	26.436	174.000	9.452	-0.099	6.071	8.408	KLE
270.847	-53.000	35.474	176.464	51.729	522.000	14.079	11.494	11.717	13.818	ID-0
333.036	-13.000	32.176	152.048	51.264	465.000	12.970	3.592	11.446	10.370	ID-1
152.872	-4.000	16.252	54.882	19.505	34.000	12.859	-0.817	4.332	3.371	ID-2
158.692	-42.500	17.917	47.503	17.738	31.000	12.186	-0.522	3.941	3.113	ID-3

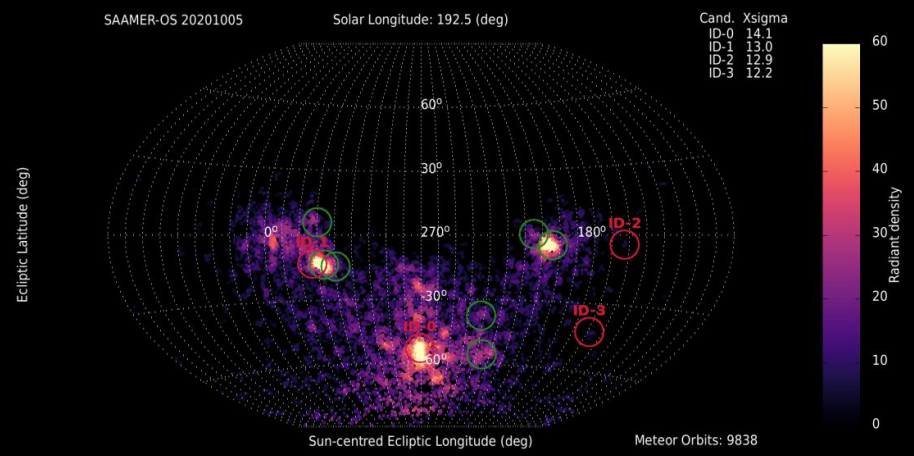
Preliminary orbital elements.
Orbital elements for each shower computed with radcount meteors.

a(AU)	ecc	inc(deg)	omega(deg)	Omega(deg)	q(AU)	M(deg)	Shower
0.912	0.851	28.630	208.434	12.429	0.136	48.052	DSX
1.872	0.823	5.681	118.683	12.453	0.332	343.341	STA
3.180	0.750	66.874	58.495	12.425	0.795	353.505	LCA
0.733	0.820	27.081	202.083	12.429	0.132	74.263	GSE
0.809	0.610	57.193	143.736	12.425	0.316	279.471	OLP
3.138	0.968	0.934	325.981	192.245	0.101	354.127	CTA
3.465	0.989	34.751	21.221	192.419	0.039	4.645	KLE
0.986	0.021	73.672	131.925	12.424	0.966	229.880	ID-0
1.183	0.852	25.290	217.489	12.430	0.175	31.521	ID-1
5.373	0.843	1.894	48.652	12.511	0.844	357.487	ID-2
3.352	0.741	19.451	46.375	12.432	0.868	354.894	ID-3

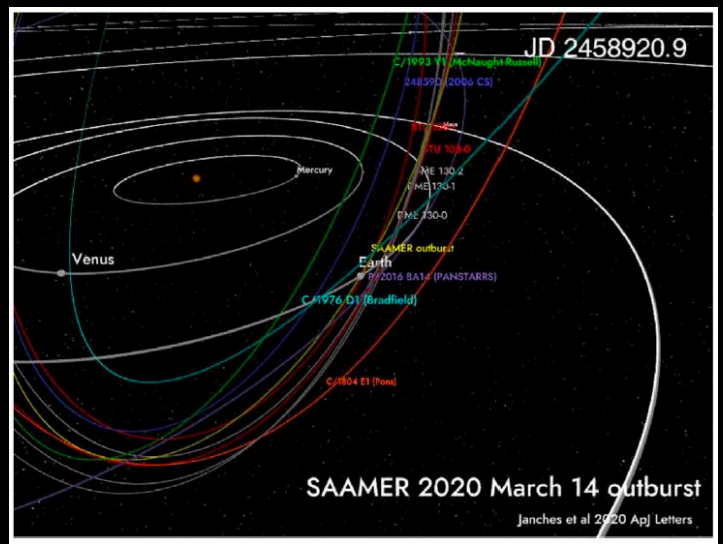
SAAMER-OS Shower fluxes down to radar magnitude +9
32.55 MHz
All fluxes within 3deg of shower radiant and in met. km-2 hr-1.
RFF: Radar response function (RRF)-corrected fluxes.
LimMass: Limiting mass in kg (Verniani 1973, Schult et al., 2020).
s: mass index.
ZHR: Zenithal hourly rate from scaled RRF to 6.5 mag.
* *
* DISCLAIMER *
* Fluxes are preliminary and should not be used for planning purposes.*
* *

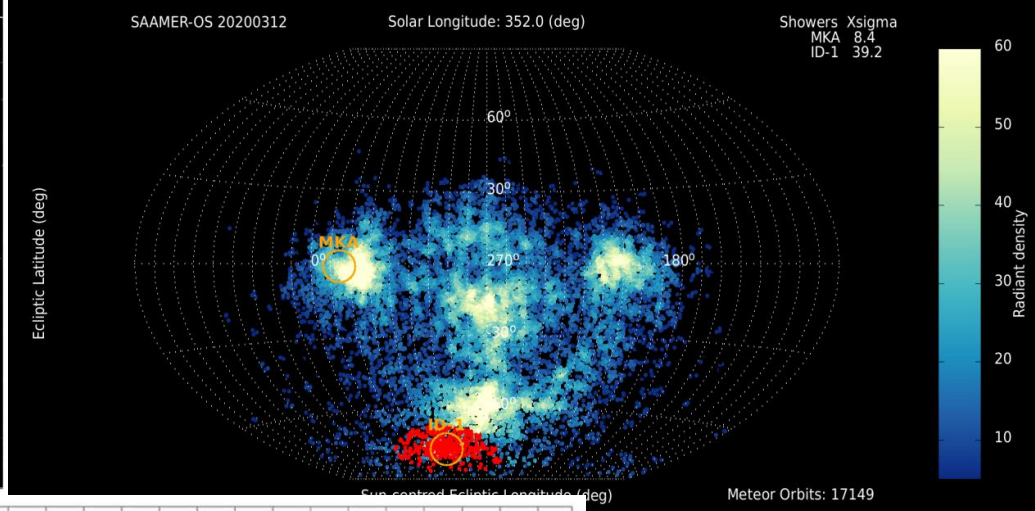
Name	RFF	LimMass	s	ZHR
CTA	2.176e-02	3.0e-08	2.00	4.26
DSX	6.996e-02	4.2e-08	2.00	13.70
GSE	1.355e-02	7.5e-08	2.00	2.65
KLE	2.247e-02	1.6e-08	2.00	4.40
LCA	6.521e-03	1.1e-08	2.00	1.28
OLP	5.729e-03	4.1e-08	2.00	1.12
STA	6.422e-02	8.0e-08	2.00	12.5

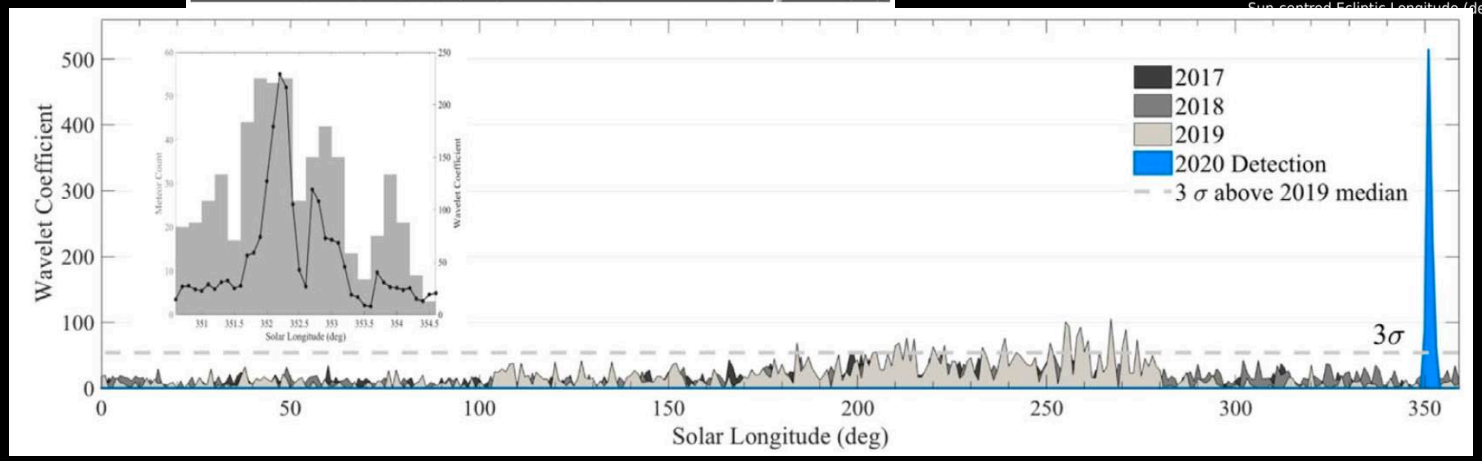




Outburst inesperado 14 de Marzo de 2020 β-Tucanid / δ-Mensid



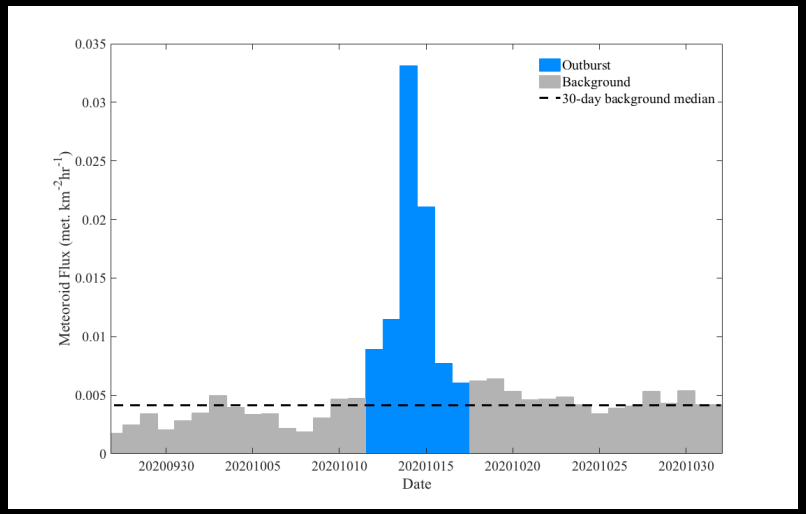


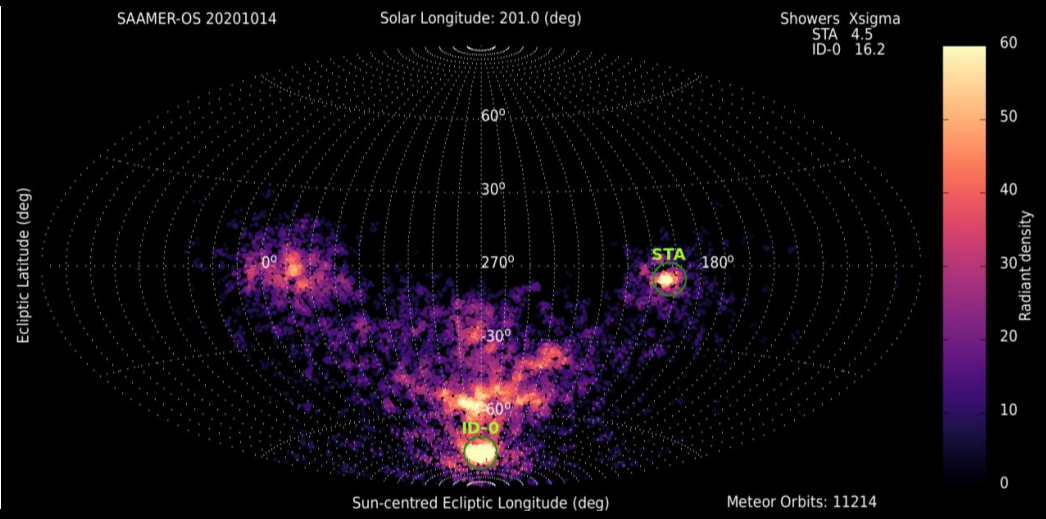


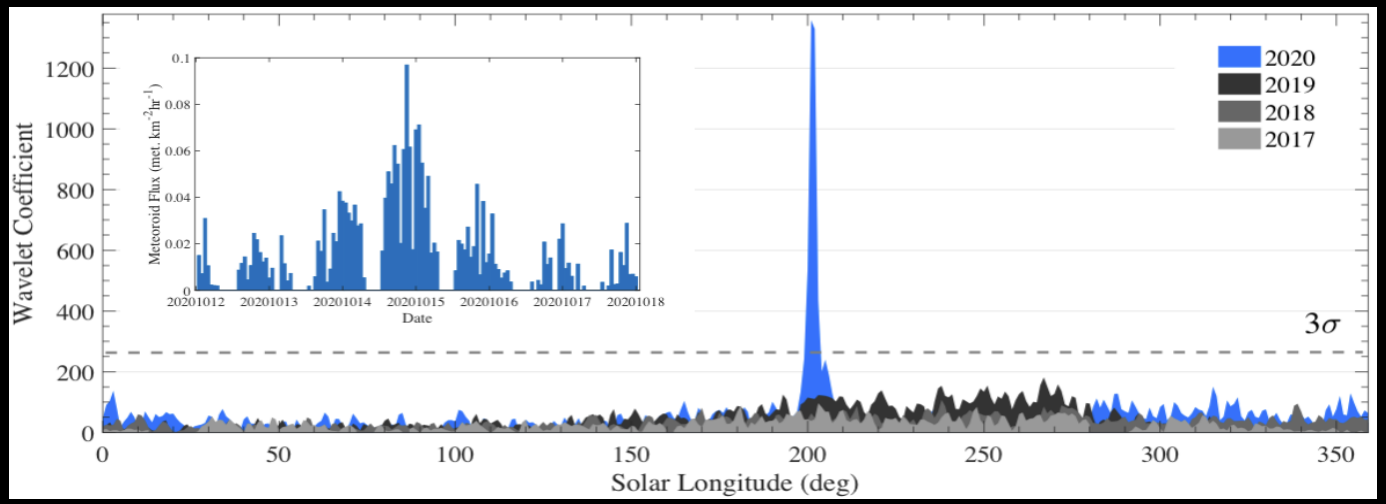
(248590) 2006 CS un NEA de D-2km como mejor candidato creador de la lluvia. (D'=0.05)

Janches, Bruzzone, Weryk, Weigert, Brunini 2020, ApJL

THE A-CARINID SHOWER OUTBURST OCTOBER12-18, 2020

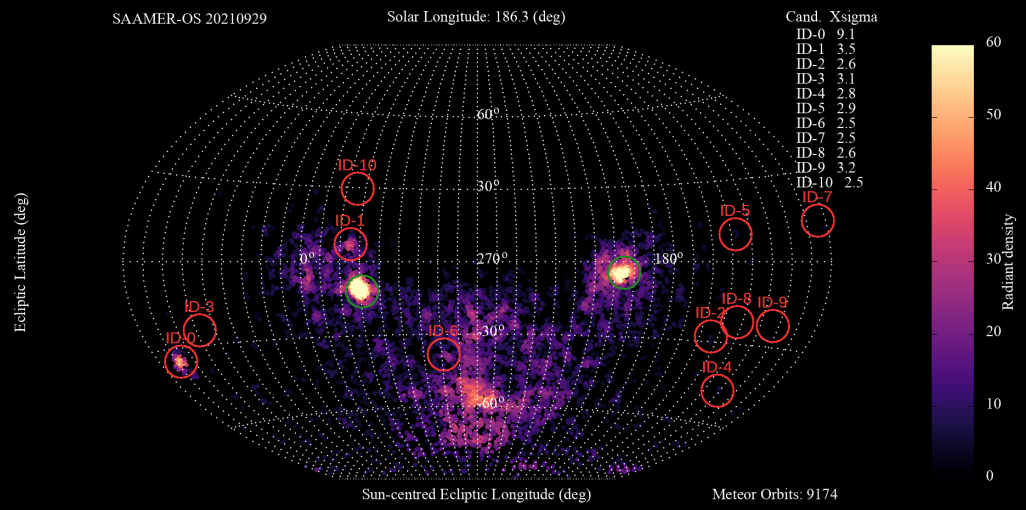


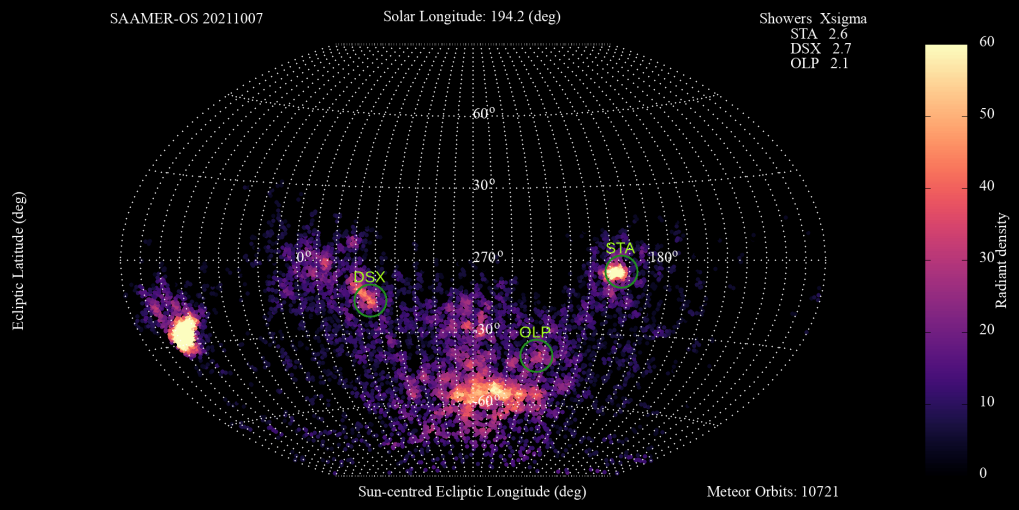




Bruzzone et al. 2021 PSJ.

PRIMEROS METEOROIDES DEL COMETA 15P/FINLAY: LAS ARIDAS. SETIEMBRE 29 Y OCTUBRE 7 2021 (~700-1000+ ORBITAS)






```
Preliminary Orbital elements:
a = 3.8757 ± 0.13419
e = 0.74506 ± 0.0087518
inc = 6.7752 ± 0.14077
omega = 346.6047 ± 0.33142
Omega = 13.7109 ± 0.00042713
q = 0.988 ± 0.00055952
M= 1.3123 ± 0.084403
```

Osculating Orbital Elements

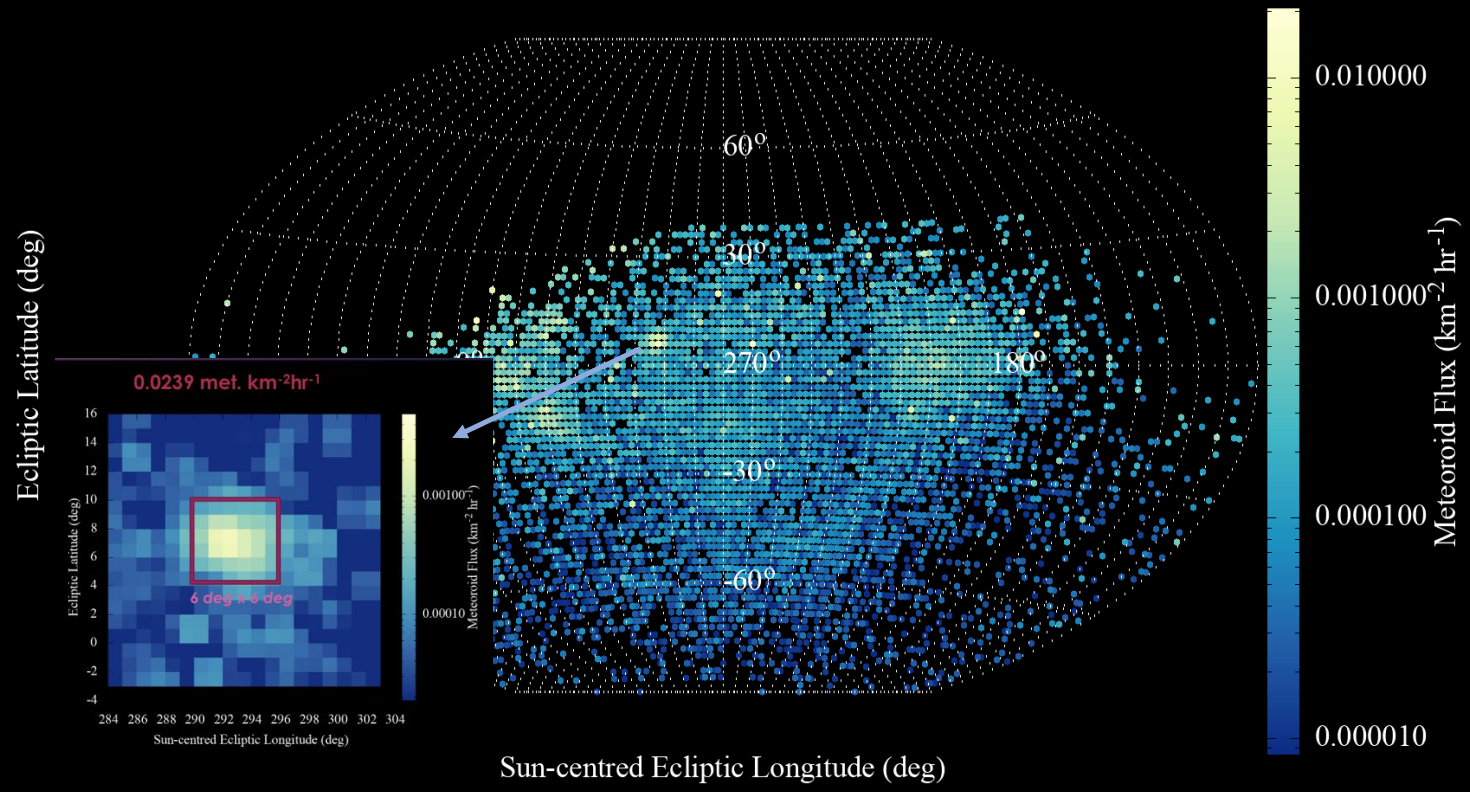
Epoch 2457116.5 (2015-Apr-04.0) TDB
Reference: JPL K213/10 (heliocentric **IAU76/J2000** ecliptic)

Element	Value	Uncertainty (1-sigma)	Units
e	0.7201558034847423	8.0167E-8	
a	3.487328744456628	4.2016E-7	au
q	0.9759087104770275	3.2618E-7	au
i	6.799403418548348	1.2185E-5	deg
node	13.77910019239303	.00014142	deg
peri	347.5530676979072	.00014505	deg
M	14.82336876725389	6.2051E-6	deg
tp	2457018.555021955709 2014-Dec-27.05502196	2.8817E-5	TDB
period	2378.689530671165 6.512497003890937	.00042989 1.1770e-6	d y
n	0.1513438367462875	2.7352E-8	deg/d
Q	5.998748778436229	7.2275E-7	au

Janches, Bruzzone, Weryk et al. 2022 en preparación

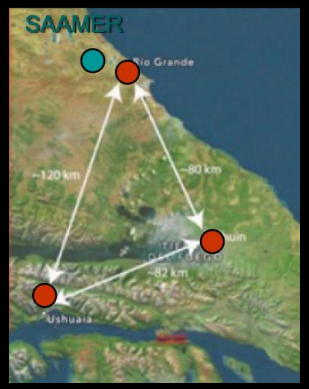
FLUJO DE LLUVIAS (ETA): 0.024 met. km^{-2} hr^{-1}

CMOR 13yr-average within 3 deg of ~0.028 met. km^{-2} hr^{-1}



*Total meteoroid flux within a 3deg (half width) window, s=1.9, no sporadic subtraction.

All-Sky Network and Detection Software for Fireballs (ANDES-Fire)



Simultaneous EO/Radar

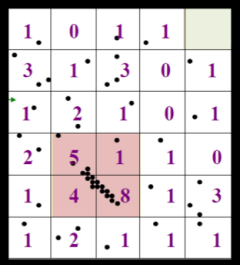
Use existing SAAMER
Deploy 4 Fripon Cameras

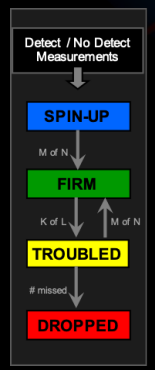
Rio Grande, Ushuaia & Despedida in Ops, Tolhuin in work

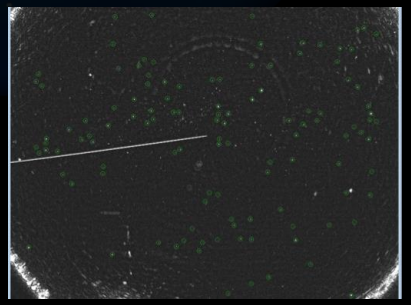
Initial software completed with continuous day/night collection

Software Development
Camera interface,Detection module, Astrometry app, Real-time w/i3 CPU, CAMS compatible for trajectory/orbits

Cluster / Tracker Meteor Detector







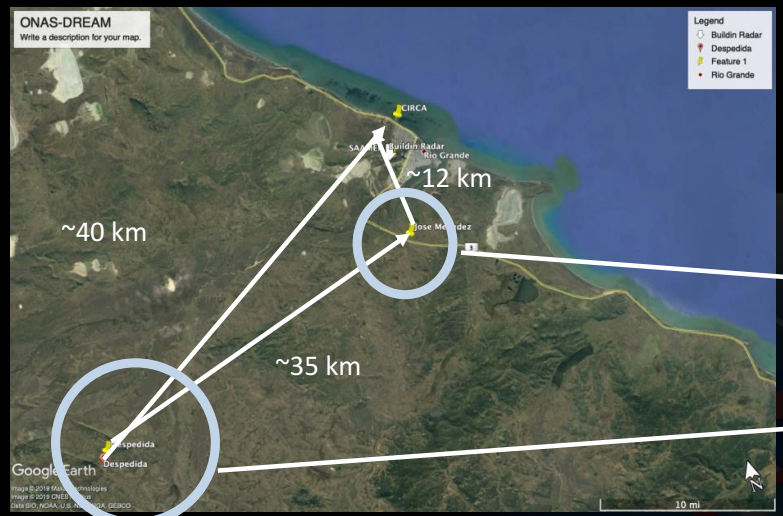
All-sky Astrometry

Based on 12 parameter fit – Borovicka 1995

M= +1 or brighter

Funded by NASA-SSO

Optical Cameras



- Optical Network At SAAMER for Detection of Radar Echoes Arising from Meteors (ONAS-DREAM)
- Three MEO-provided Watec WAT-902H2 Ultimate with a 17mm lens cameras were deployed (2 cameras in Rio Grande and 1 in Despedida) to measure simultaneously meteors via optical and radar techniques

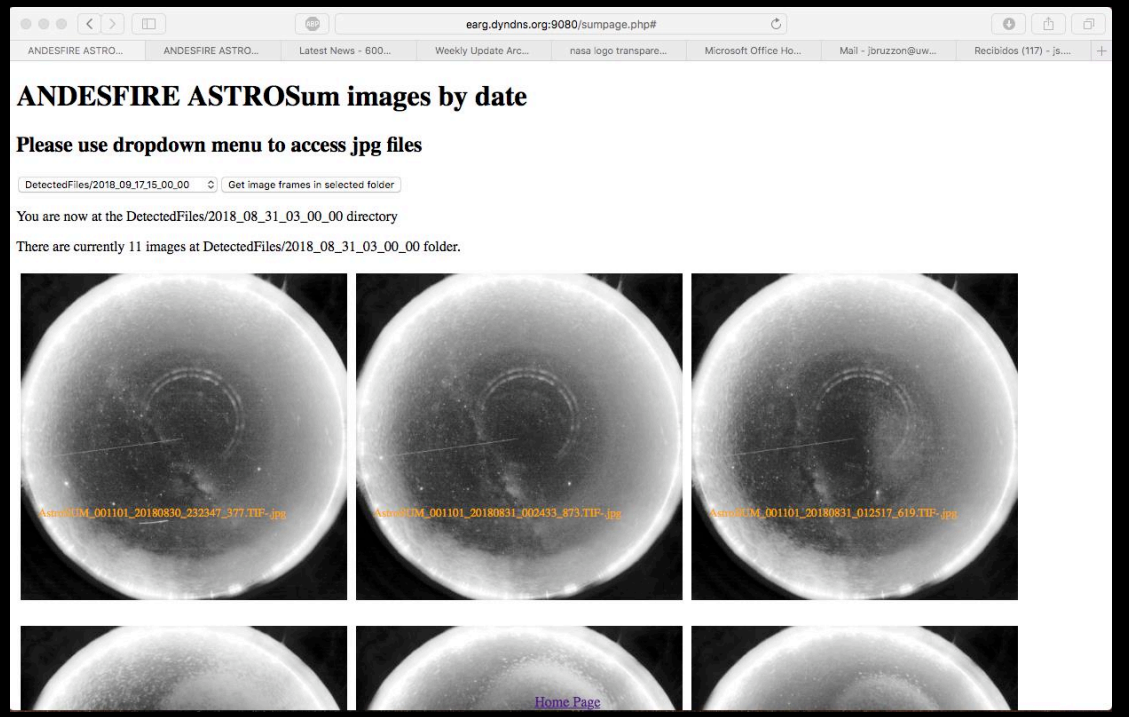
- 12 parameter fit all sky astrometric resolution

- Sensitive to faint (> 7 mag) meteors

- ~10 orbits/day

ONAS-DREAM

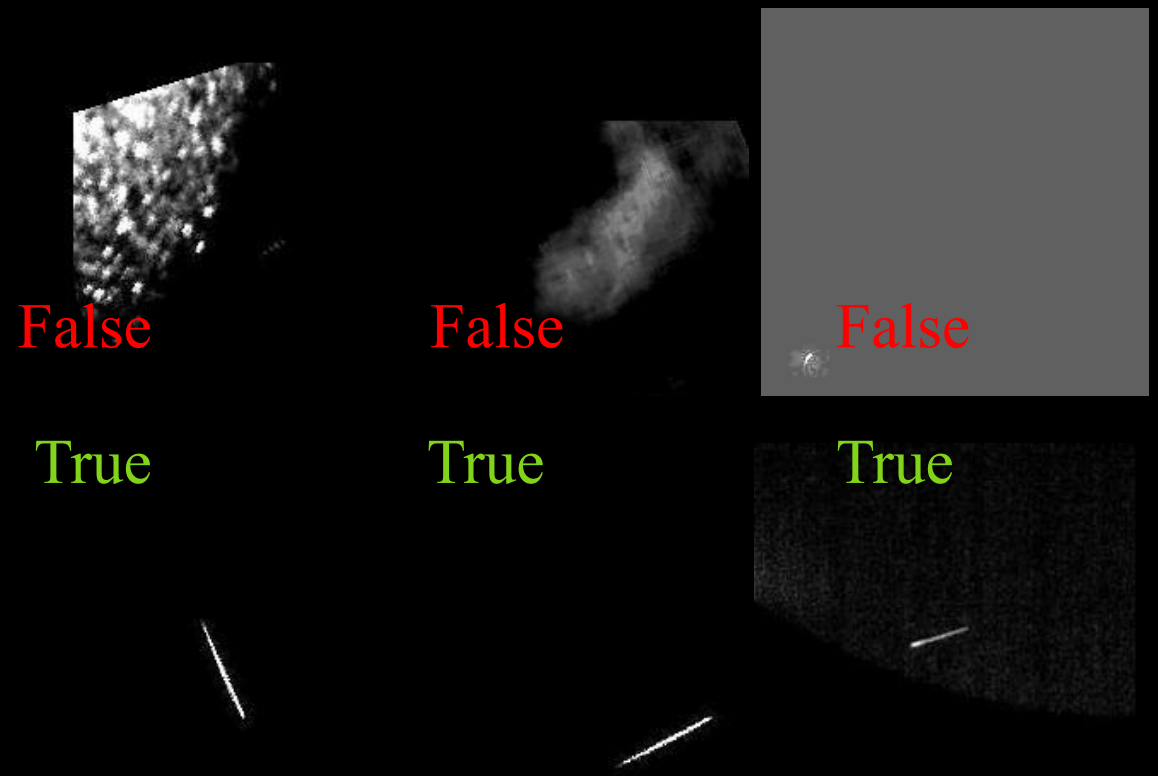
- Continuous 10-second 30fps video feeds for input in automatic fireball detection routines. All exposures are analyzed and archived.
- All-sky astrometric calibration using 60 second exposures @ 10-13 arcmin/pixel.
- Orbit determination for simultaneous
- detections with other stations in
- Tierra del Fuego.
- Dedicated website featuring current
- detections and system status.



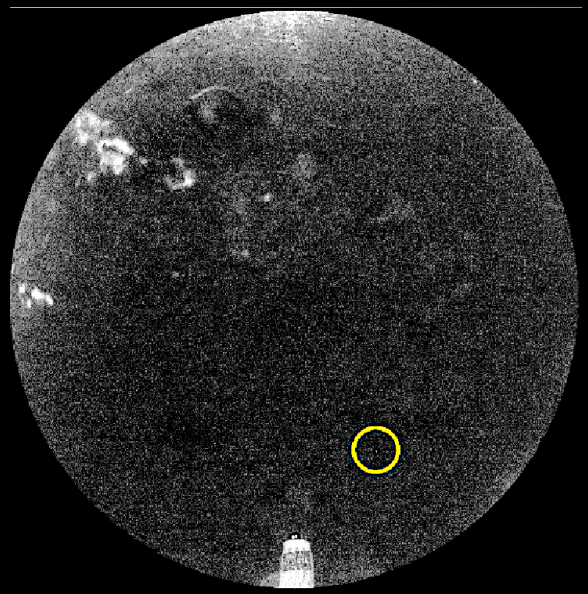
- Deployed since mid 2018 with
- 18 fireballs detected.

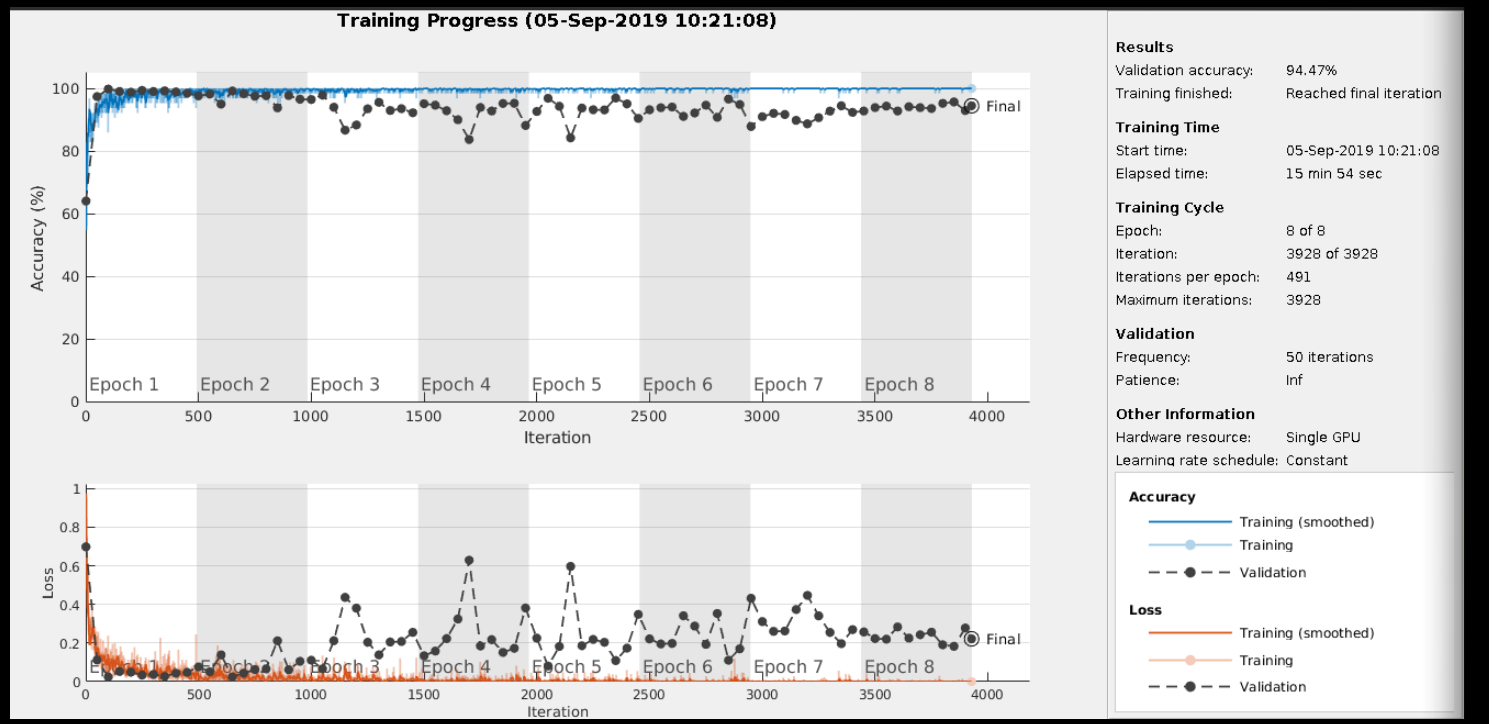
- Recently, we employed Deep Learning to train a Convolutional
- Neural Network (CNN) to classify meteor imagery improving our detection yields. A simple binary classification is performed on a synthetic dataset built from past detections.
- The synthetic dataset includes 20,000 synthetic true and false detections.

Binary classification:
Meteor (TRUE) not meteor (FLASE).



- The classification through our trained CNN returns up to 95% validation accuracy.
- Several CNN were tested with similar results: Alexnet, GoogleNet.
- The trained CNN network will be used to look for missed detections in our archive.





Conclusions

-Meteoroid and Space Debris environments are an important component of Space Weather

-Argentina plays a major role on characterizing the meteoroid environment with collaboration with NASA and Space Debris is of high interest too.

-Strengthening the collaborations NASA-CONAE/Universities on this area

-Opportunities foe ML techniques for data processing.