FLARECAST: The automated solar flare forecasting system

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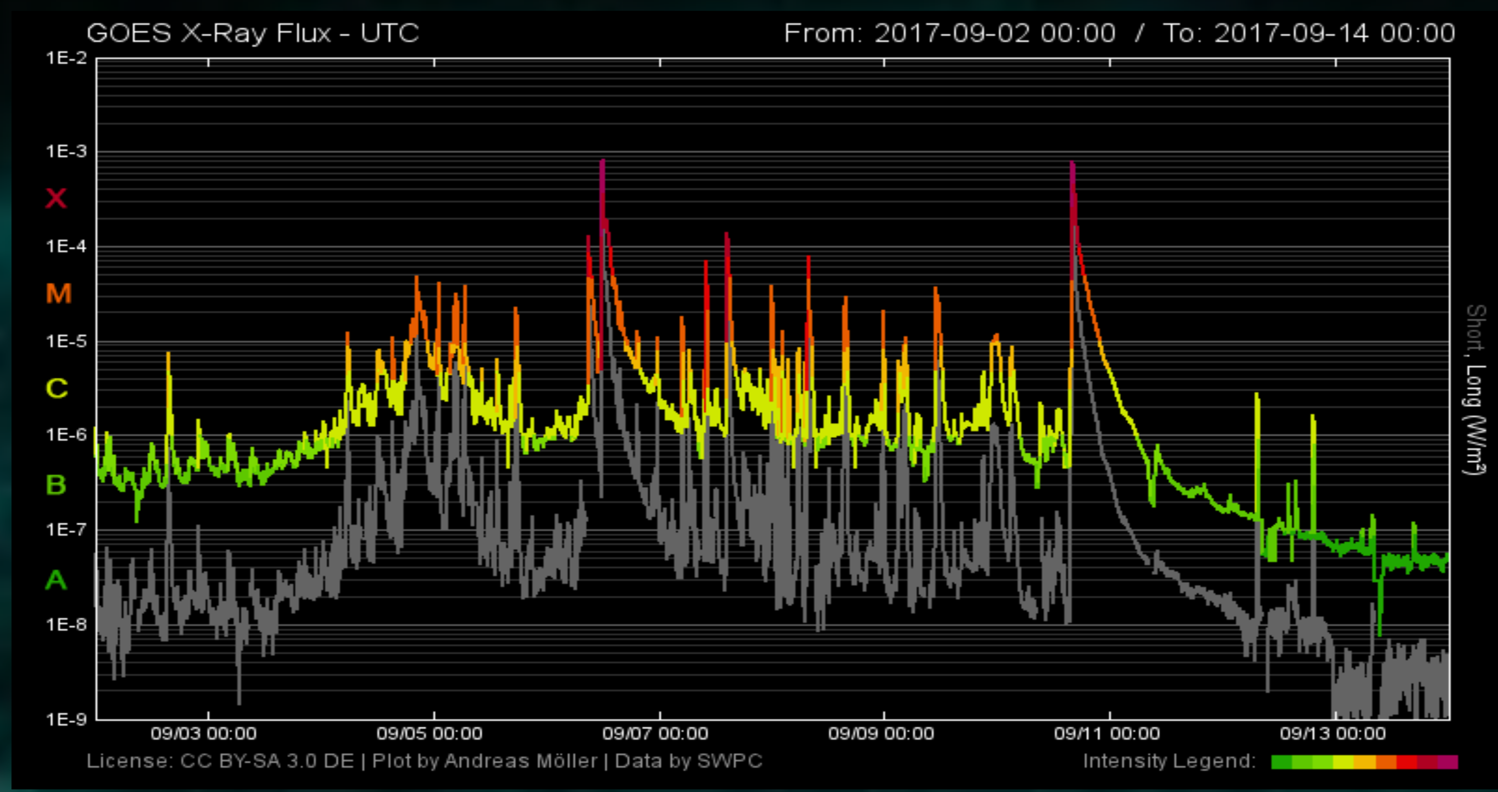
FLARECAST OBJECTIVES

Develop a solar flare prediction system based on automatically extracted physical properties of solar active regions, coupled with state-of-the-art solar flare prediction methods and validated using the most appropriate forecast verification measures.

FLARECAST MAKES POSSIBLE:

- To understand the drivers of solar flare activity and improve flare prediction
- To provide a globally accessible flare prediction service that facilitates expansion
- To engage with space weather end users and inform policy makers and the public



The Solar X-ray flux for the week of September 3, 2017

FLARECAST AT A GLANCE: What does the data tell us about flare prediction?

Input: SDO HMI images

Output: a flare prediction of the kind:

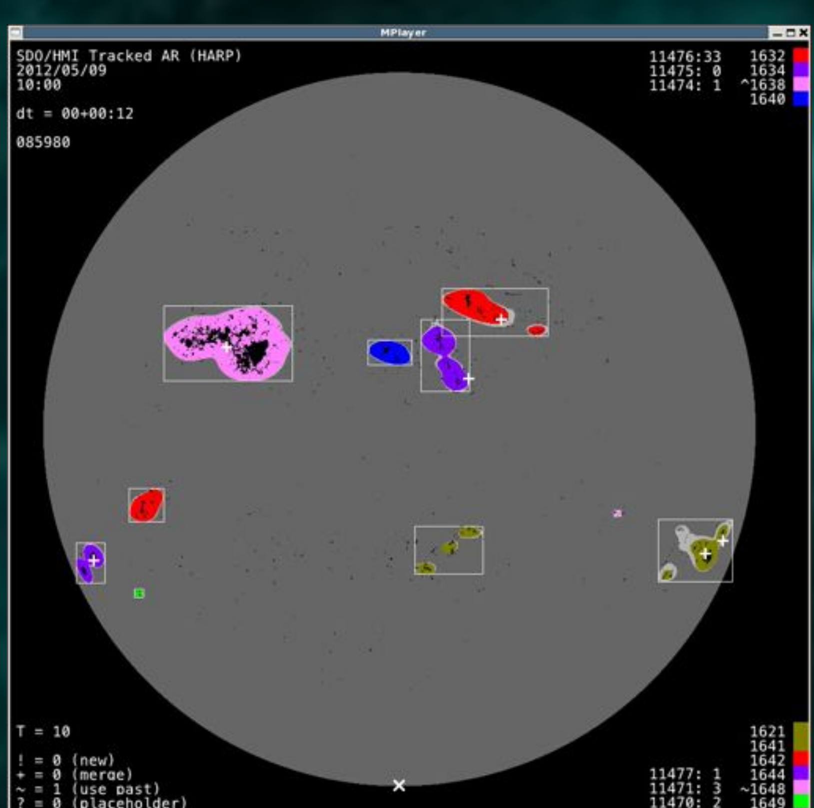
- Binary forecasting:
  - Flare or No Flare
  - Probabilistic: 0 <p< 1
- For the following characteristics
  - Within a flare class (e.g. M1 – M9.9)
  - Within a forecast time window (e.g. 24 hours) & above a threshold

Steps: Data loading —> Feature property extraction —> prediction learning —> forecast verification

www.flarecast.eu

DATA LOADING

The Solar Dynamics Observatory (SDO) Spacecraft



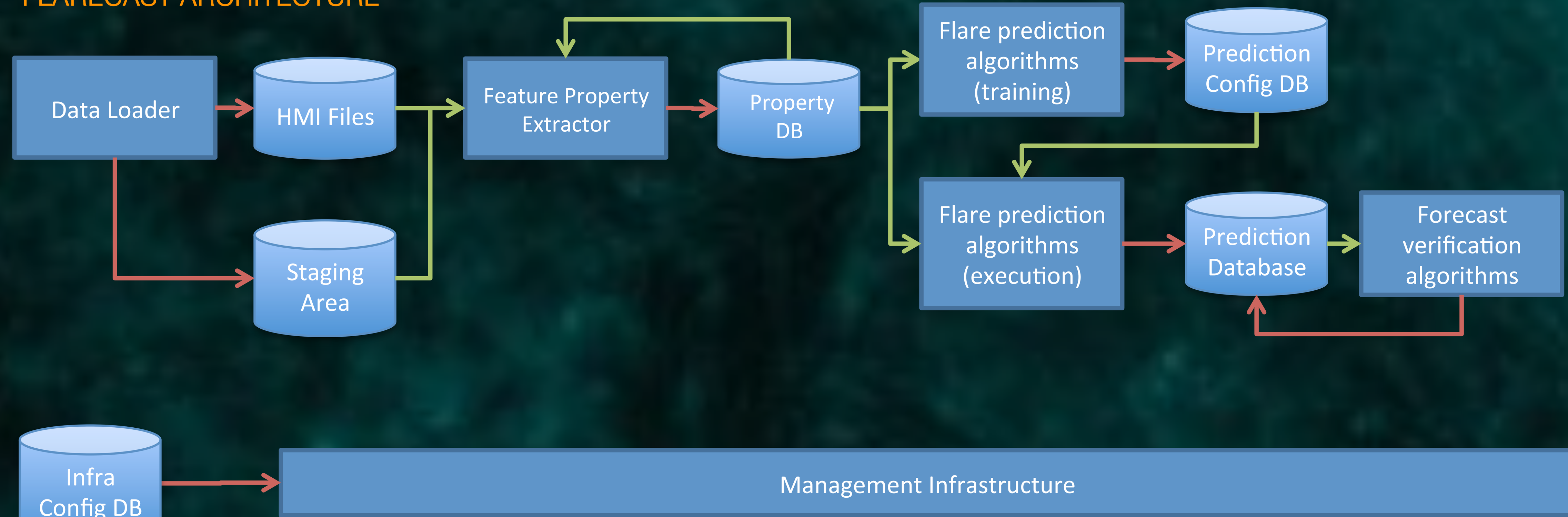
LOADER INPUT DATA:

SDO / HMI data

- LOS magnetograms (hmi.M_720s)
- SHARP vector magnetograms – definitive (hmi.sharp_720s)
- SHARP vector magnetograms – NRT (hmi.sharp_720s_nrt)

Solar Region Summary (SRS) active region & flare data (YYYY_events.tar.gz)

FLARECAST ARCHITECTURE



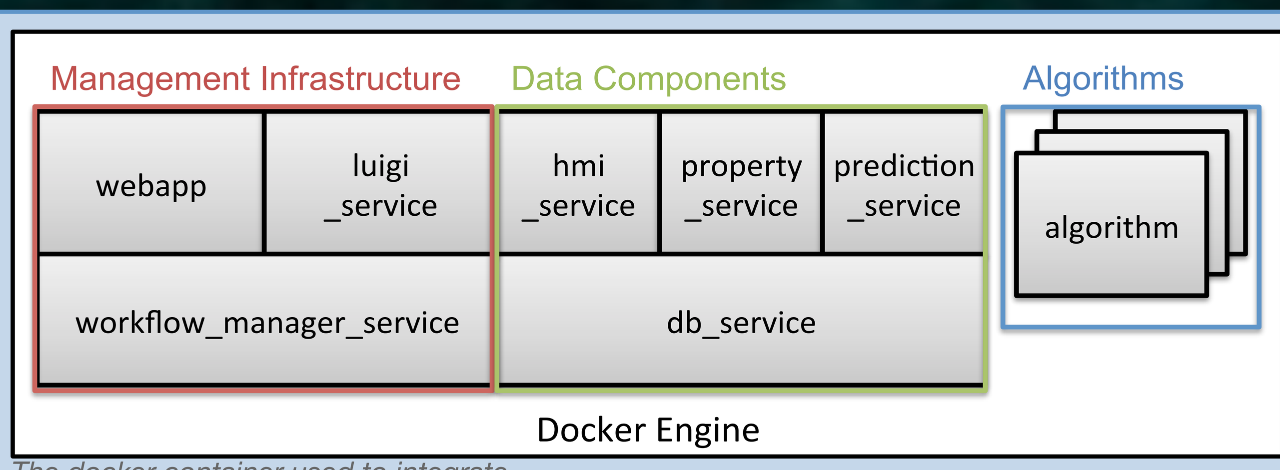
PREDICTION LEARNING

Non ML
Linear Discriminant Analysis
Bayesian Quantile Regression

Standard ML
Clustering and Regression Analysis
Simple Recurrent Neural Networks

Innovative ML
Multi-Task Lasso
Poisson Re-Weighted Multi Task Lasso
Hybrid Method
Simulated Annealing
Reccurent Neural Network trained with an evolutionary algorithm
Random Forest

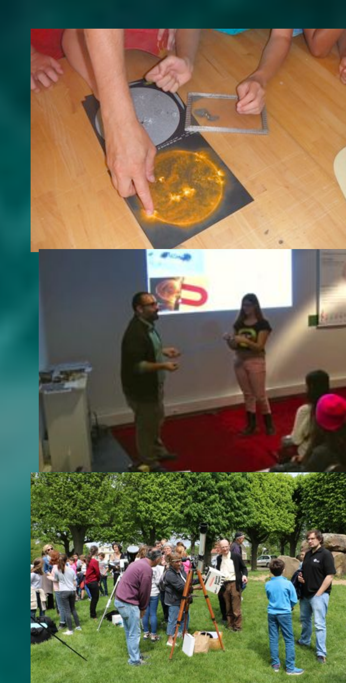
Advanced ML
Multi-Layer Perceptron
Possibilistic C-Means



The docker container used to integrate program modules into the infrastructure

PUBLIC ENGAGEMENT

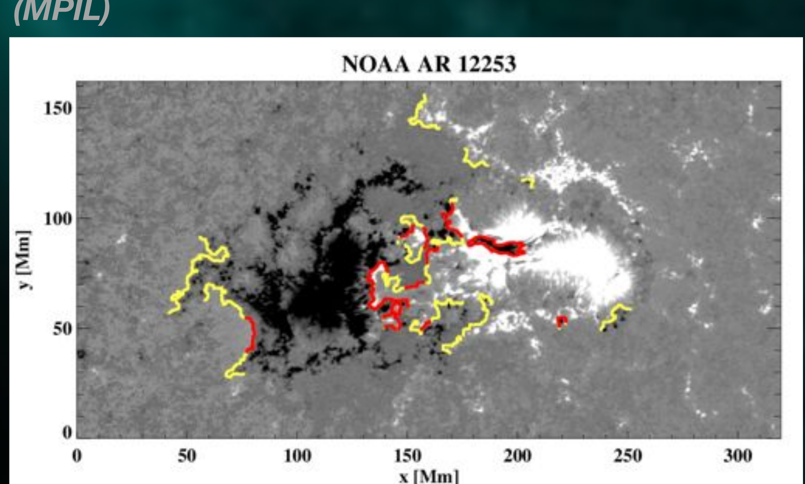
Following the evolution of science communication from Public understanding of science —> Dialog with the Public —> Public engagement in science —> Public participation in science —> Responsible Research and Innovation (RRI)



See also poster 'Spaceship - the Maker Space for Astronomy' by Hanna Sathiapal

FEATURE PROPERTY EXTRACTION

Example of a Property Extraction Algorithm: Extraction of Magnetic Polarity Inversion Lines (MPIL)



SHARP NRT B_r magnetogram of NOAA Active Region 12253 at 20:00 UT on 2 Jan 2015, superimposed with MPIL detections (yellow and red contours).

Property Extraction Algorithms

Data Source	Property Group	Developer	Status
SWPC catalogues			**(To do / In progress / Under testing / Delivered)**
	Solar Region Summary properties	TCD	Delivered
Details	GOES X-ray events	TCD	Delivered
LOS magnetograms			
	SMART-derived properties (Ahmed et al., 2013)	TCD	In progress
	SMART delta finder (Padinhatteeri et al., 2015)	TCD	To do
Details	Effective connected magnetic field strength (B_{eff}) (Georgoulis & Rust, 2007)	AA	Delivered
Details	Fractal dimension (Georgoulis, 2012)	AA	Delivered
Details	Multi-fractal structure function s(q) inertial range index k (Georgoulis, 2012)	AA	Delivered
Details	Fourier power spectral index (Guerra et. al., 2015)	TCD	Delivered
Details	CWT power spectral index (Hewett et. al., 2008)	TCD	Delivered
Details	Generalised correlation dimension (Georgoulis, 2012)	AA	Delivered
Details	Holder exponent h (Conlon et al., 2010)	AA	In progress
Details	Hausdorff dimension D(h) (Conlon et al., 2010)	AA	In progress
	WTMM (Conlon et al., 2010)	TCD	Under testing (further investigated in WP6)
Details	Decay index (Zuccarello et al. 2014)	TCD	Delivered
Details	Magnetic polarity inversion line characteristics (Mason & Hoeksema 2010)	TCD	Delivered
Details	3D magnetic null point (Greene 1992)	TCD	Delivered
Details	R (Schrijver 2007)	TCD	Delivered
Details	$^{L}WL_{SG}$ (Falconer et al. 2008) *	TCD	Delivered
Details	Ising energy (Ahmed et al. 2010)	AA	Delivered
Details	WG_M and S_{l-f} (Korsos et al. 2015)	AA	Delivered
Details	Magnetic helicity injection rate proxy (Park et al. 2013)	TCD	Delivered
Vector magnetograms			
Details	SHARP properties (Bobra et al. 2014)	TCD	Delivered
Details	Magnetic helicity injection rate (Berger & Field 1984)	TCD	Delivered
Details	Magnetic energy injection rate (Kusano et al. 2002)	TCD	Delivered
Details	Non-neutralized currents (Georgoulis et al., 2012)	AA	Delivered
Details	Flow field characteristics (Deng et al. 2006; Wang et al. 2014)	TCD	Delivered
	Magnetic bipolar feature characteristics	TCD	Under testing (further investigated in WP6)
Intensity images			
	Flow field characteristics	TCD	Under testing (further investigated in WP6)

FORECAST VERIFICATION

	Forecasted Flare	Forecasted No-Flare
Observed Flare	True Positive	False Negative
Observed No-Flare	False Positive	True Negative

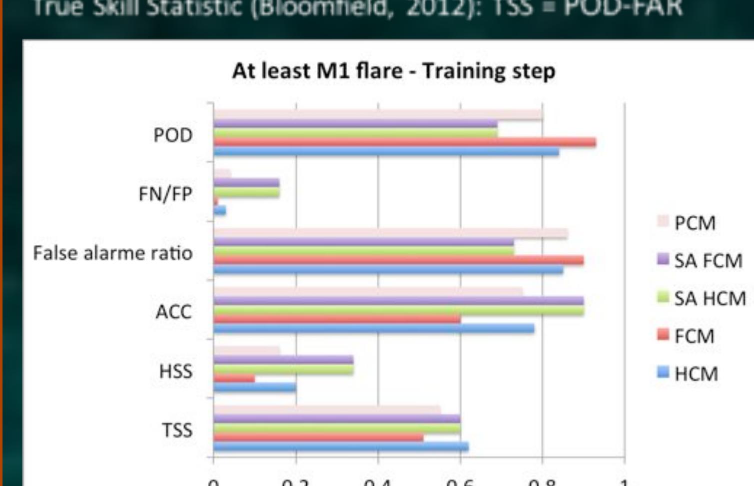
Probability of detection: $POD = \frac{TP}{TP+FN}$

False Alarm Rate $FAR = \frac{FP}{FP+TN}$

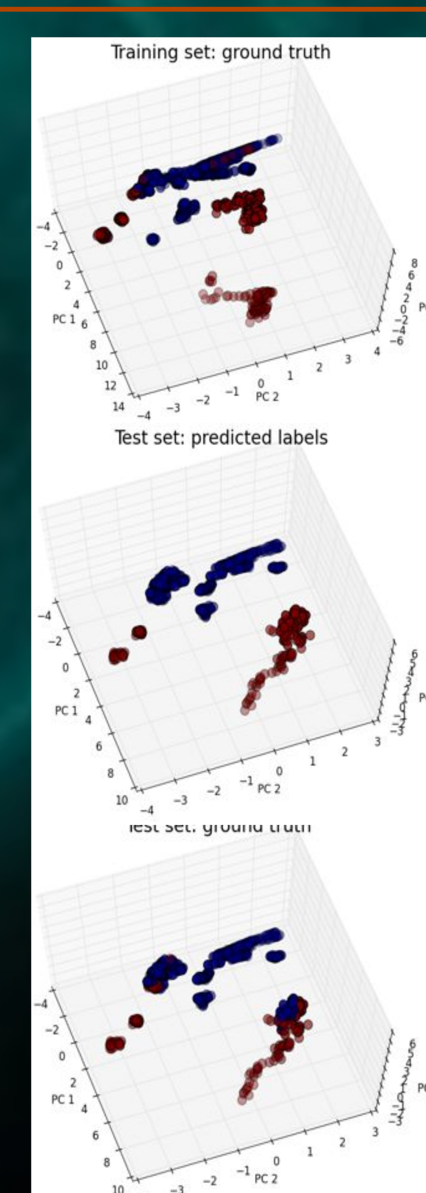
Accuracy $ACC = \frac{TP+TN}{TP+TN+FP+FN}$

Heidke Skill Score: $HSS = \frac{2(TP+TN)-N}{N}$

True Skill Statistic (Bloomfield, 2012): TSS = POD-FAR



Courtesy of C.Campi (CNR) and F.Benvenuto (U. Genova)



THE FLARECAST SCENE:

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Partners: Academy of Athens (Georgoulis, PI) , Northumbria U. (Bloomfield, Project Scientist), U. Genova (Piana), CNR (Massone), CNRS (Vilmer), U. Paris Sud (Buchlin), FHNW (Csillaghy), Met Office (Jackson)

A diverse group of ~50 scientists and engineers working together

Mix of expertise in flare prediction (AA, TCD, UN), mathematics (UGE, CNR), Computer Science (UPS, FHNW), user perspective (Met Office), and public engagement (FHNW)

The FLARECAST Team is: Aleksandar Torbica, Andre Csillaghy, Anna Maria Massone, Annalisa Perasso, Chloé Guennou, Colin Klauser, Costis Gontikakis, Cristina Campi, D. Shaun Bloomfield, Dario Vischi, David Jackson, Douglas Biesecker, Eric Buchlin, Etienne Pariat, Federica Sciacchitano, Federico Benvenuto, Flavio Müller, Fraser Lott, Frederic Baudin, Graham Barnes, Hanna Sathiapal, Ioannis Kontogiannis, Jonas Lüthi, Jordan Guerra, Kostas Florios, Manolis Georgoulis, Manuel Ramirez Lopez, Marco Soldati, Mark Worsfold, Michele Piana, Neal Hurlburt, Nicole Vilmer, Pablo Alingeri, Pascal Demoulin, Pedro Russo, Peter Gallagher, Roman Bolzern, Sabrina Guastavino, Samuel von Stachelski, Silvia Villa, Sophie masson, Sophie Murray, Stefan Müller, Sung-Hong Park, Vangelis Argoudelis, Vittorio Latorre, Véronique Bommier