Solar Orbiter

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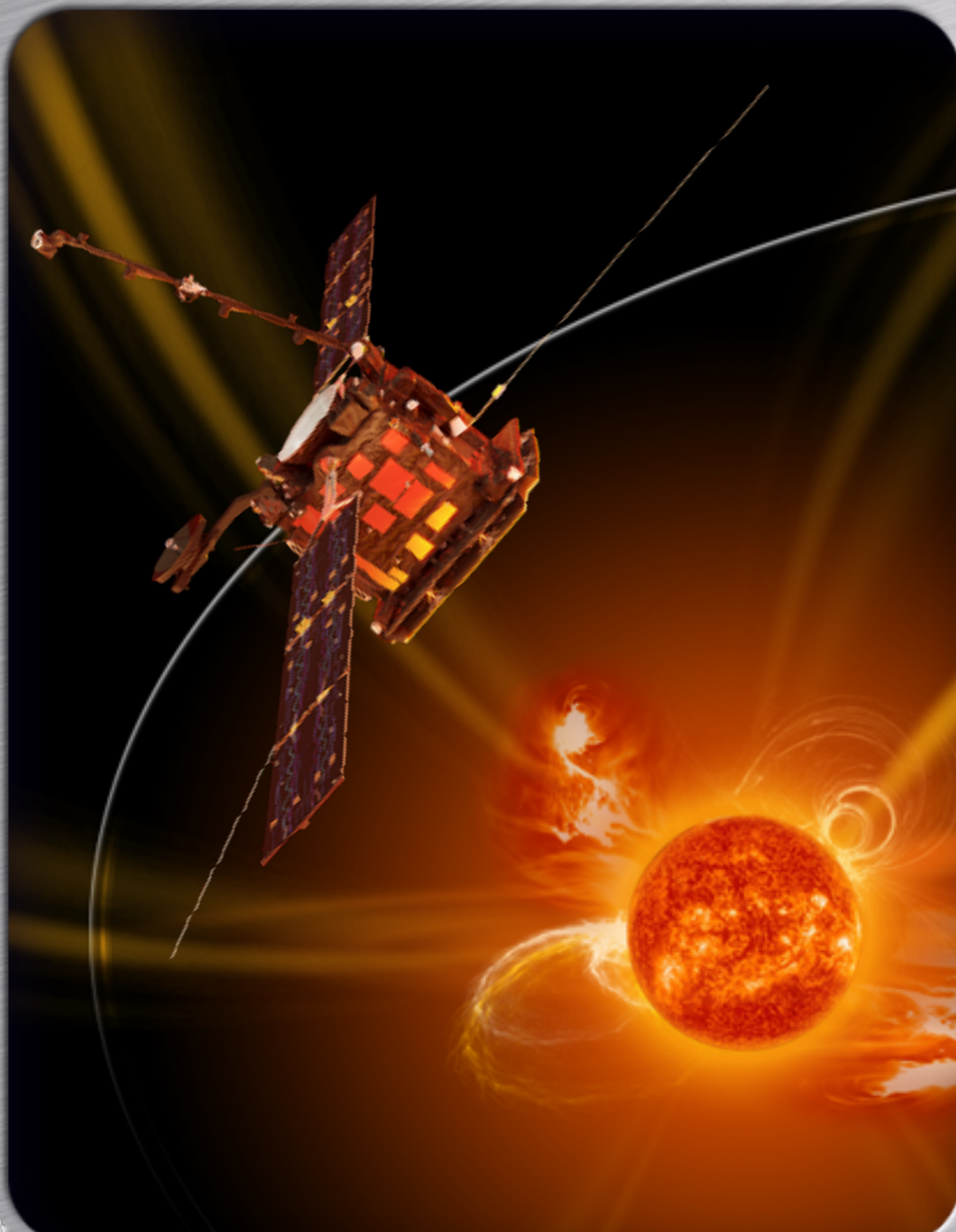
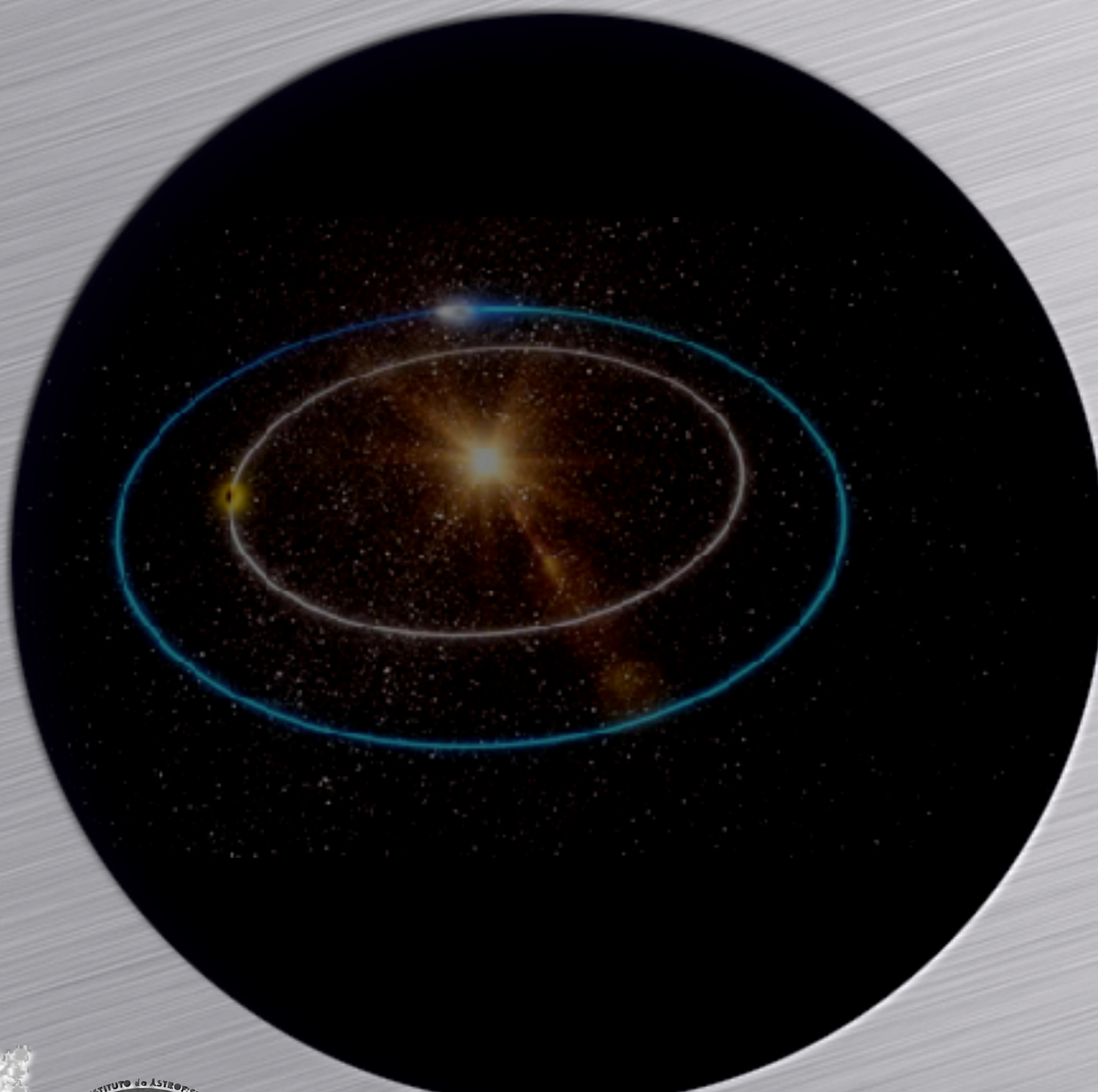
The science



- How does the Sun create and control the heliosphere and how solar activity changes with time?
    - What drives the solar wind and where does the coronal magnetic field originate?
    - How do solar transients drive heliospheric variability?
    - How do solar eruptions produce energetic particle radiation that fills the heliosphere?
    - How does the solar dynamo work and drive connections between the Sun and the heliosphere

The mission

- Launch: October 2018
- Cruise phase: 2.3 yr
- Nominal mission: 3.5 yr



- Extended mission: 2.5 yr
- Orbit: 0.28 - 0.91 AU (Period 150 - 180 days)
- Out-of-ecliptic view:
  - > 24º during nominal mission
  - > 32º during extended mission
- Reduced relative rotation
  - Observation of evolving structures for almost a complete solar rotation
- Remote sensing instrument windows
  - Three windows of 10 day each
  - Minimum distance
  - Maximum and minimum heliolatitude

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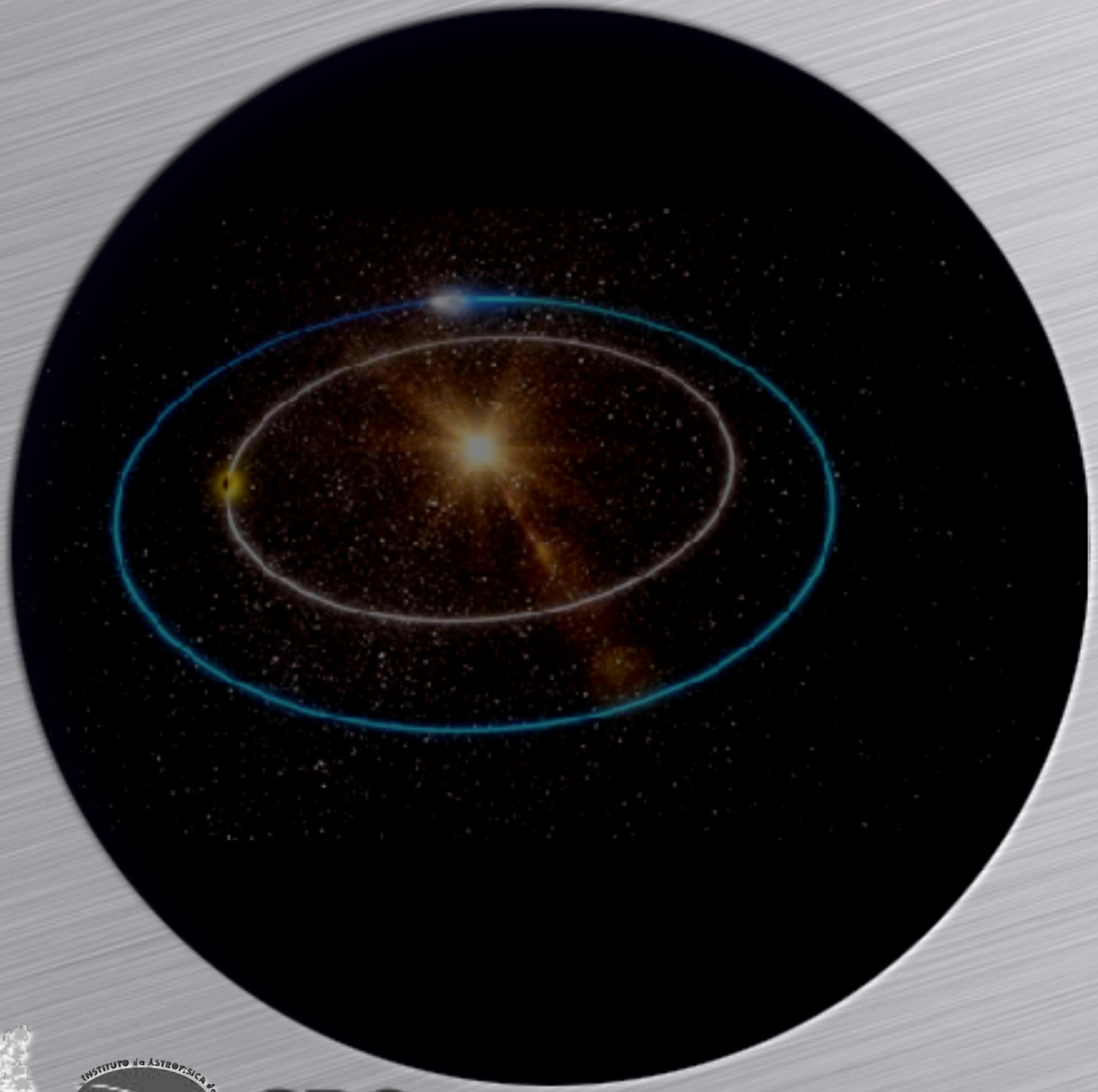

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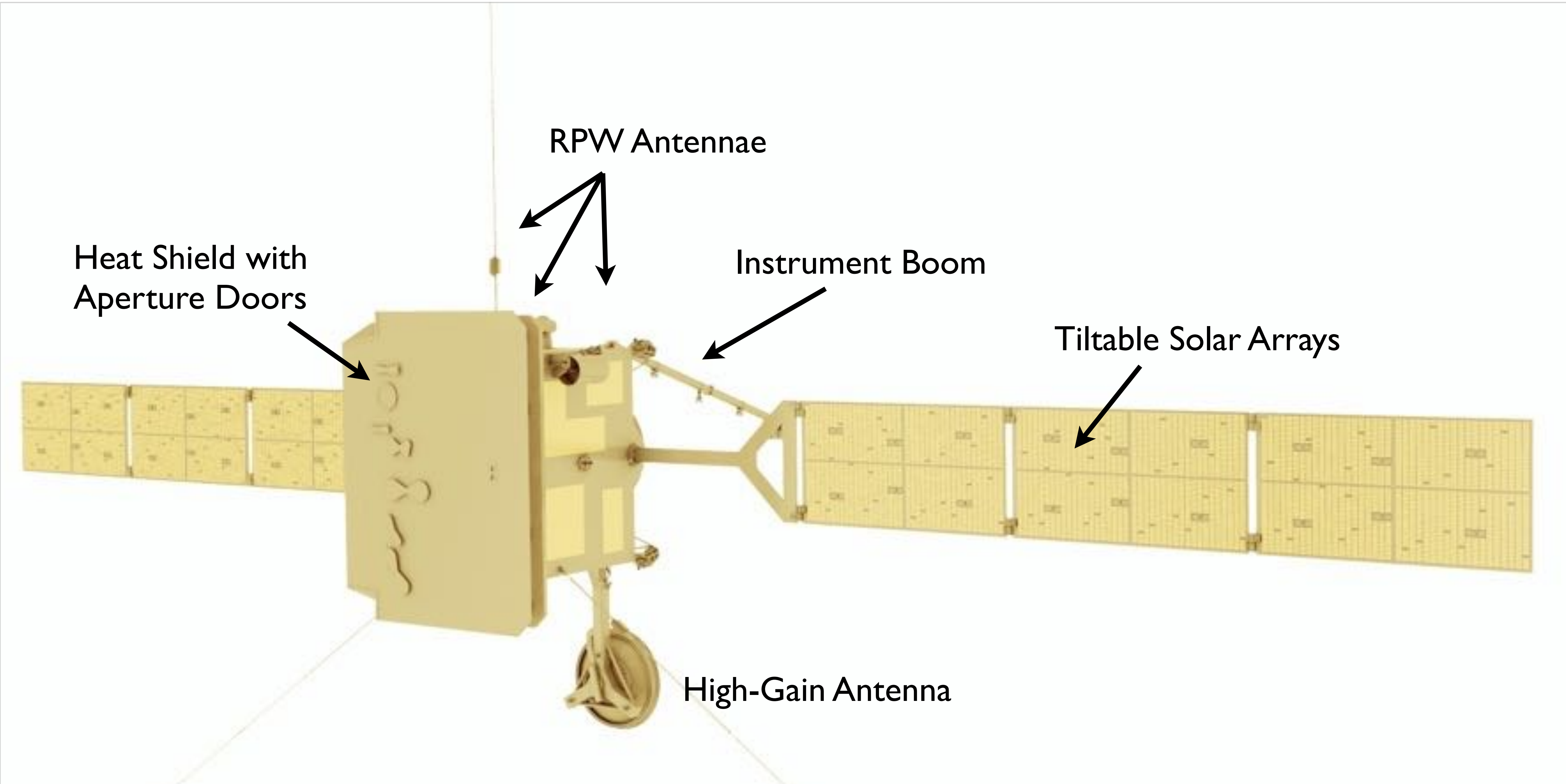
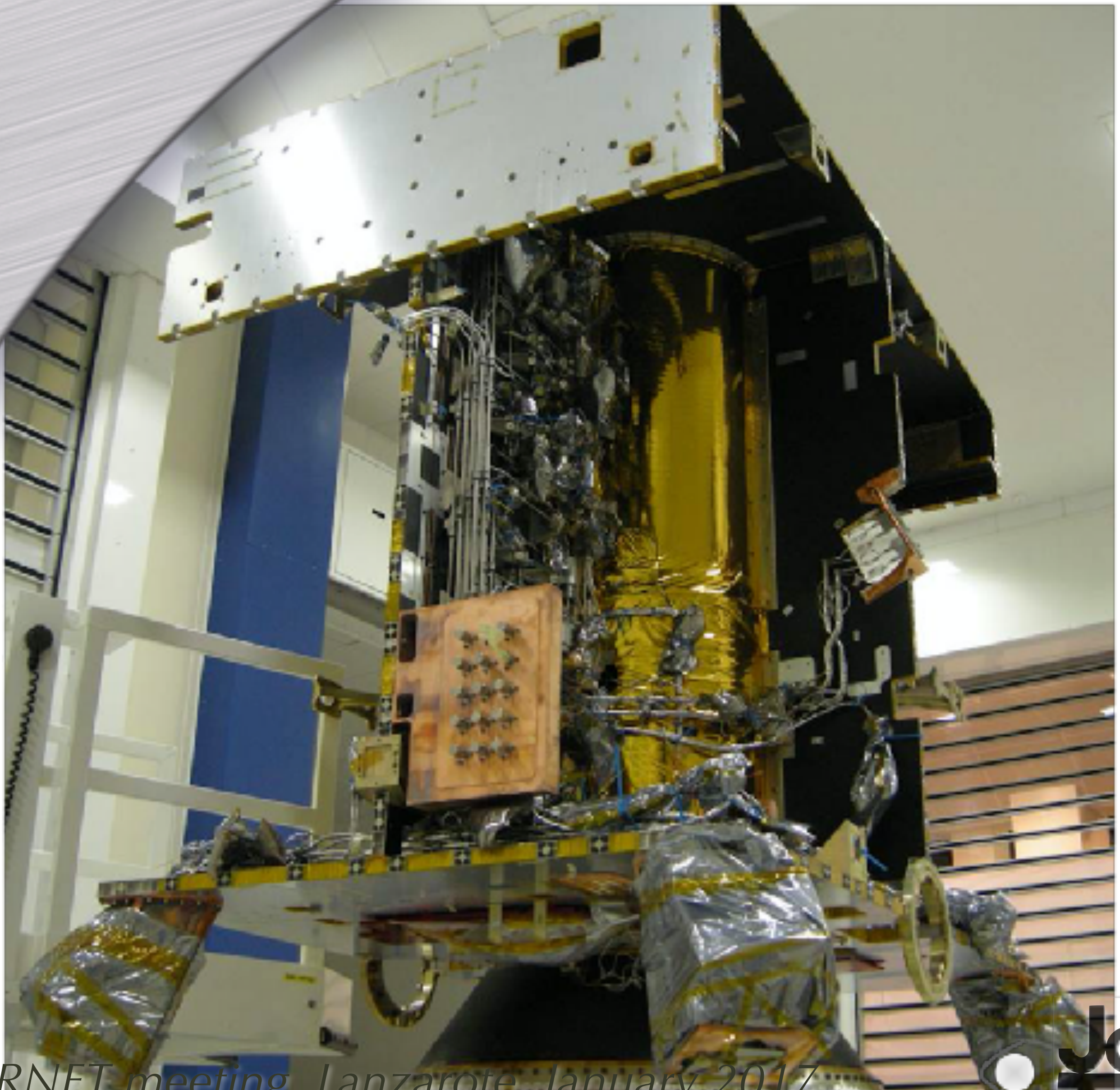
The spacecraft

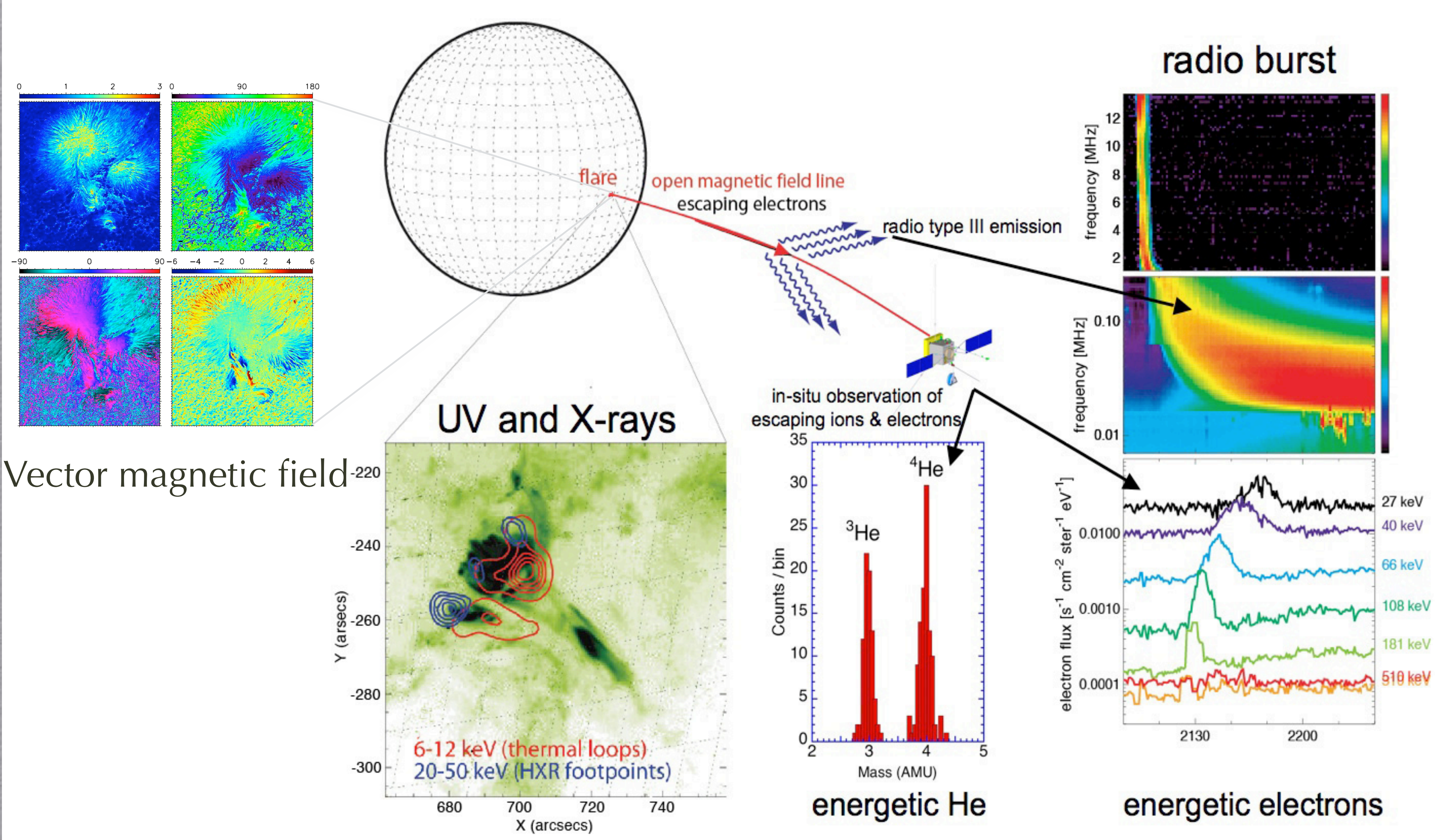


The spacecraft

- System-level CDR successfully passed
- STM tests completed
- S/C Engineering Test Bench: most of the instrument SF and FFTs completed
- Majority of FM units delivered, including the core structure
- Integration started
- Ground segment
  - Design review of Science Ground Segment completed
- Launch vehicle
  - NASA will launch SolO on an Atlas V 411
  - Launch date: October, 2018

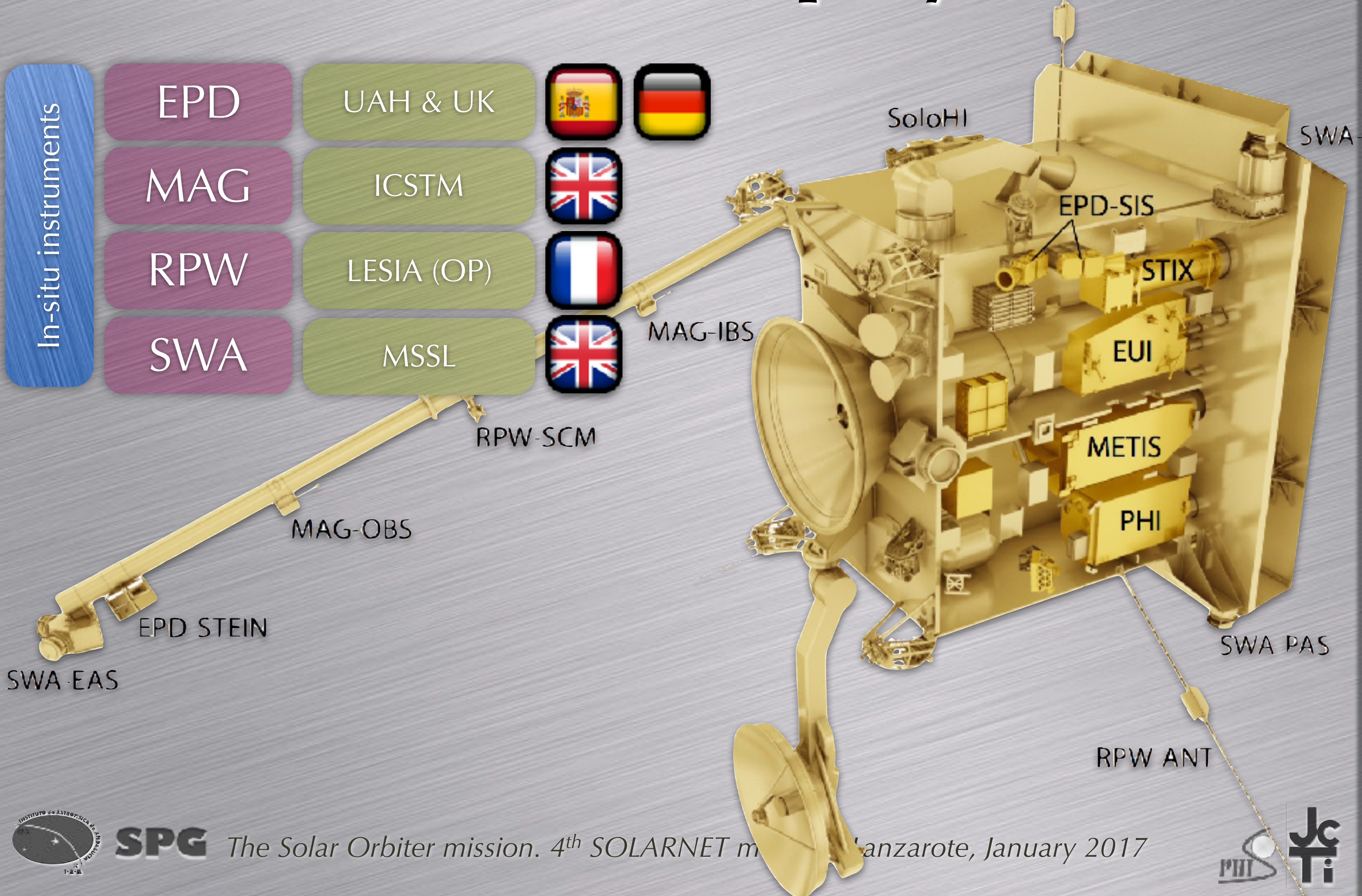


Linking in-situ with remote-sensing instruments



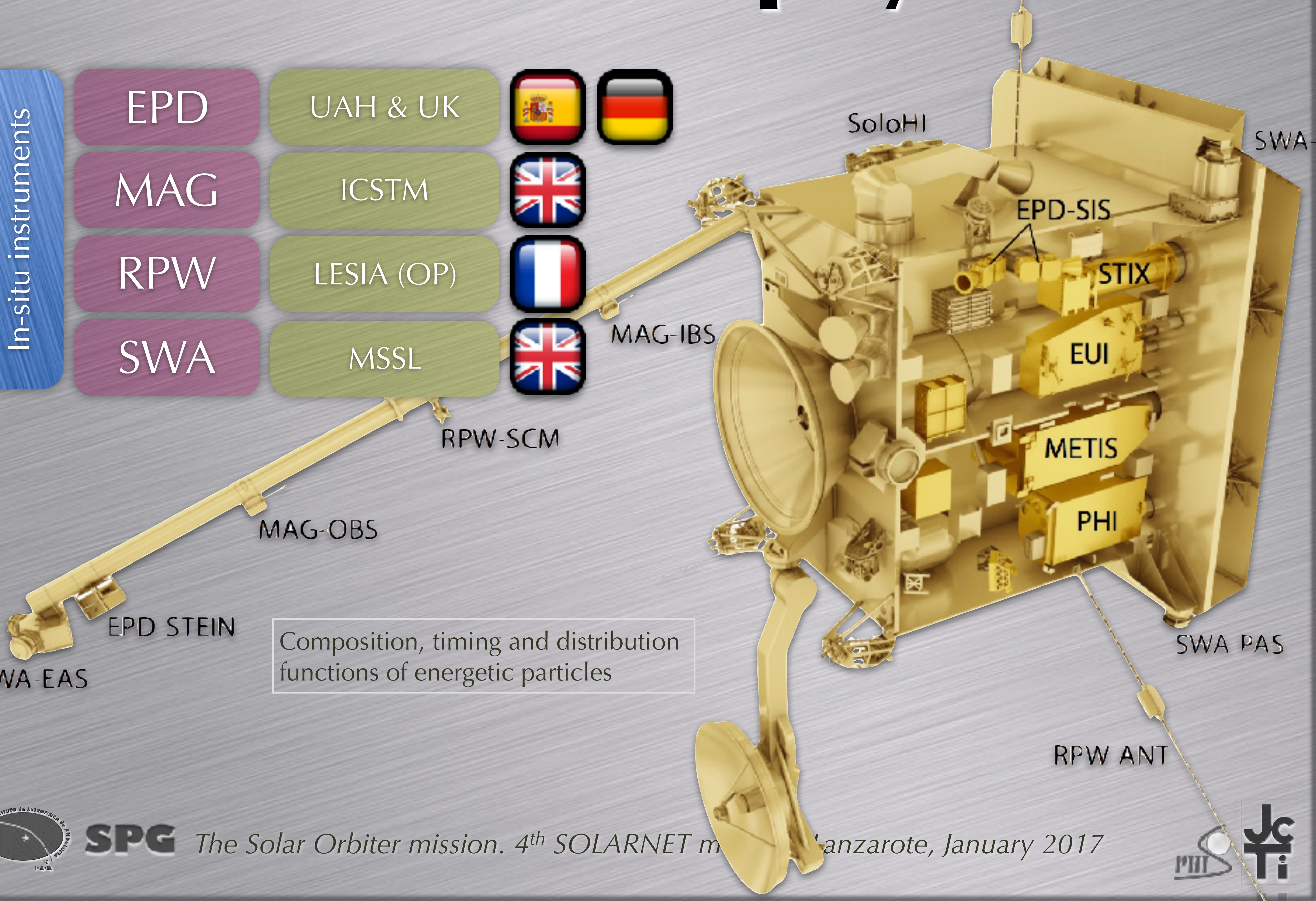
The scientific payload

In-situ instruments		
	EPD	UAH & UK
	MAG	ICSTM
	RPW	LESIA (OP)
	SWA	MSSL



The scientific payload

In-situ instruments		
EPD	UAH & UK	Spain, Germany
MAG	ICSTM	UK
RPW	LESIA (OP)	France
SWA	MSSL	UK

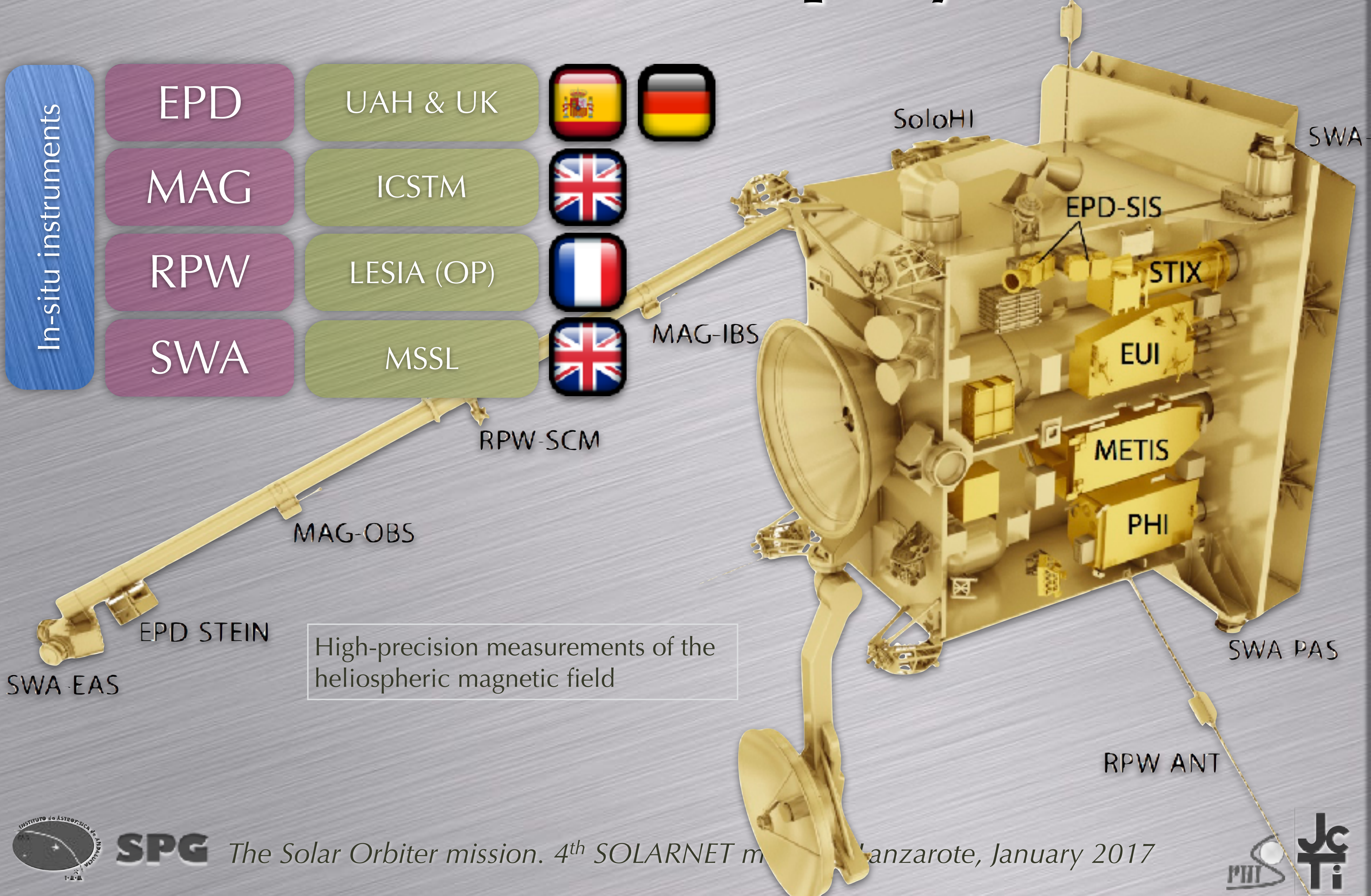


Composition, timing and distribution functions of energetic particles

The scientific payload

In-situ instruments

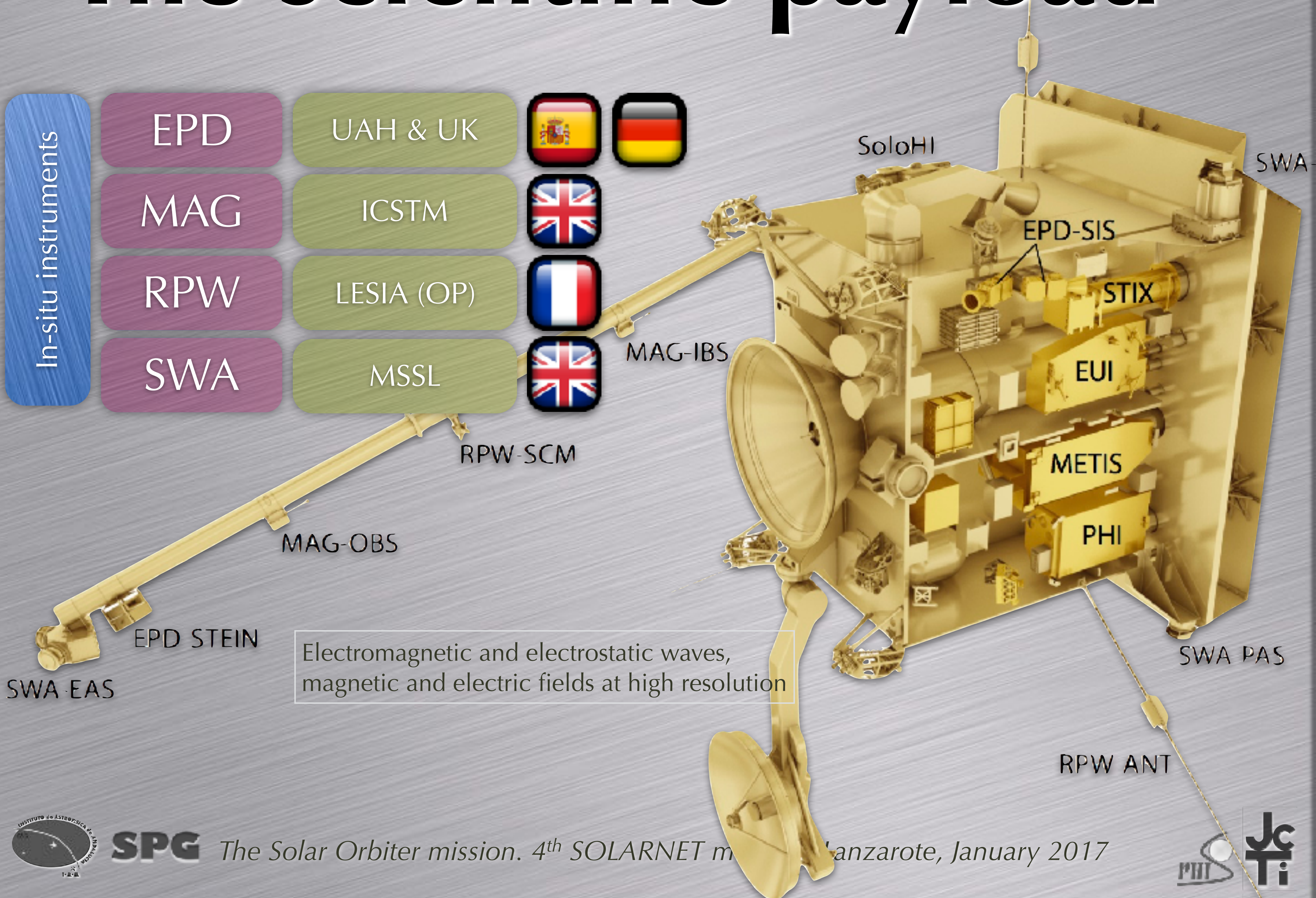
EPD	UAH & UK	Spain, Germany
MAG	ICSTM	UK
RPW	LESIA (OP)	France
SWA	MSSL	UK



High-precision measurements of the heliospheric magnetic field

The scientific payload

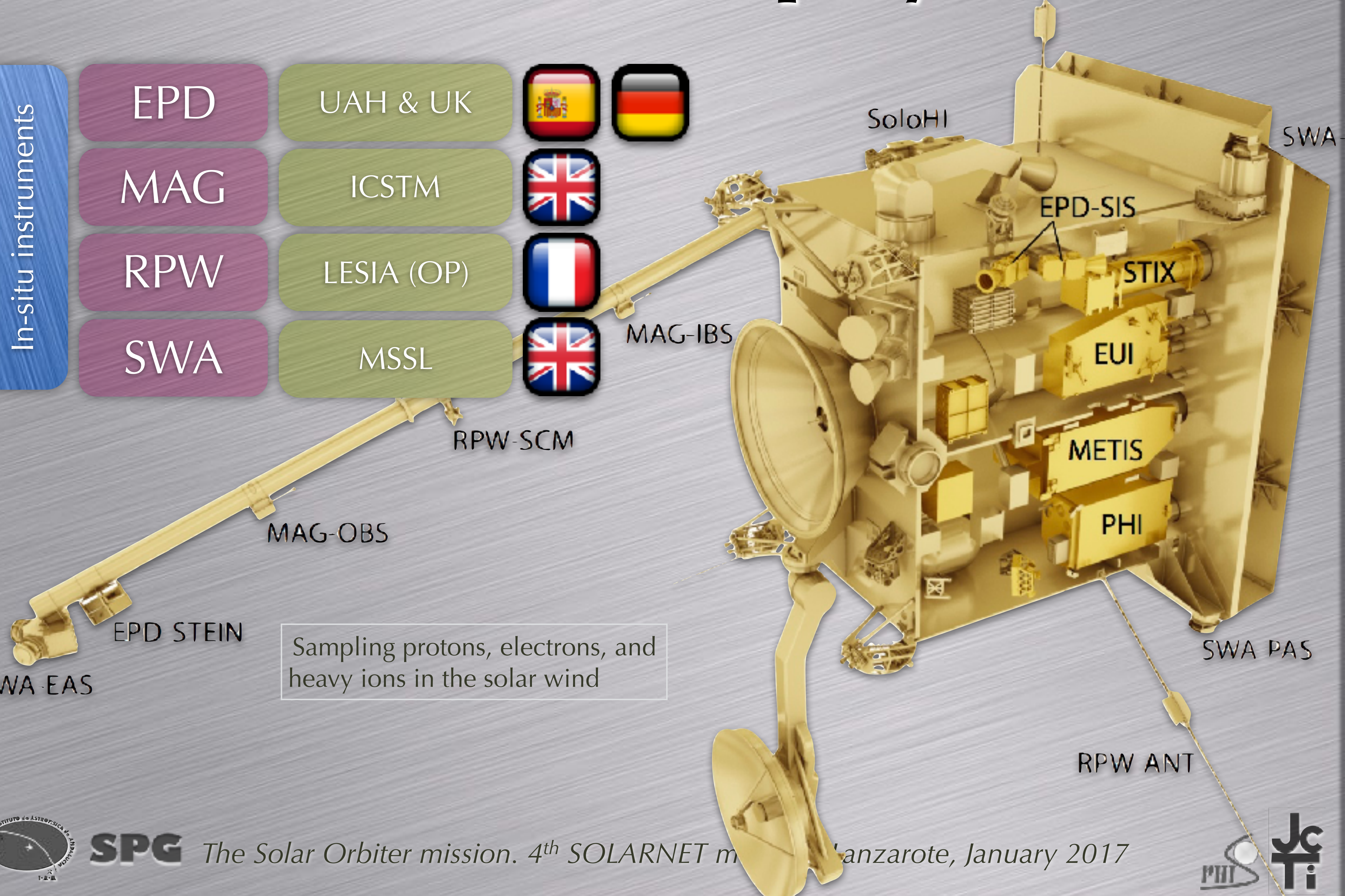
In-situ instruments		
EPD	UAH & UK	
MAG	ICSTM	
RPW	LESIA (OP)	
SWA	MSSL	



Electromagnetic and electrostatic waves, magnetic and electric fields at high resolution

The scientific payload

In-situ instruments		
EPD	UAH & UK	Spain, Germany
MAG	ICSTM	UK
RPW	LESIA (OP)	France
SWA	MSSL	UK

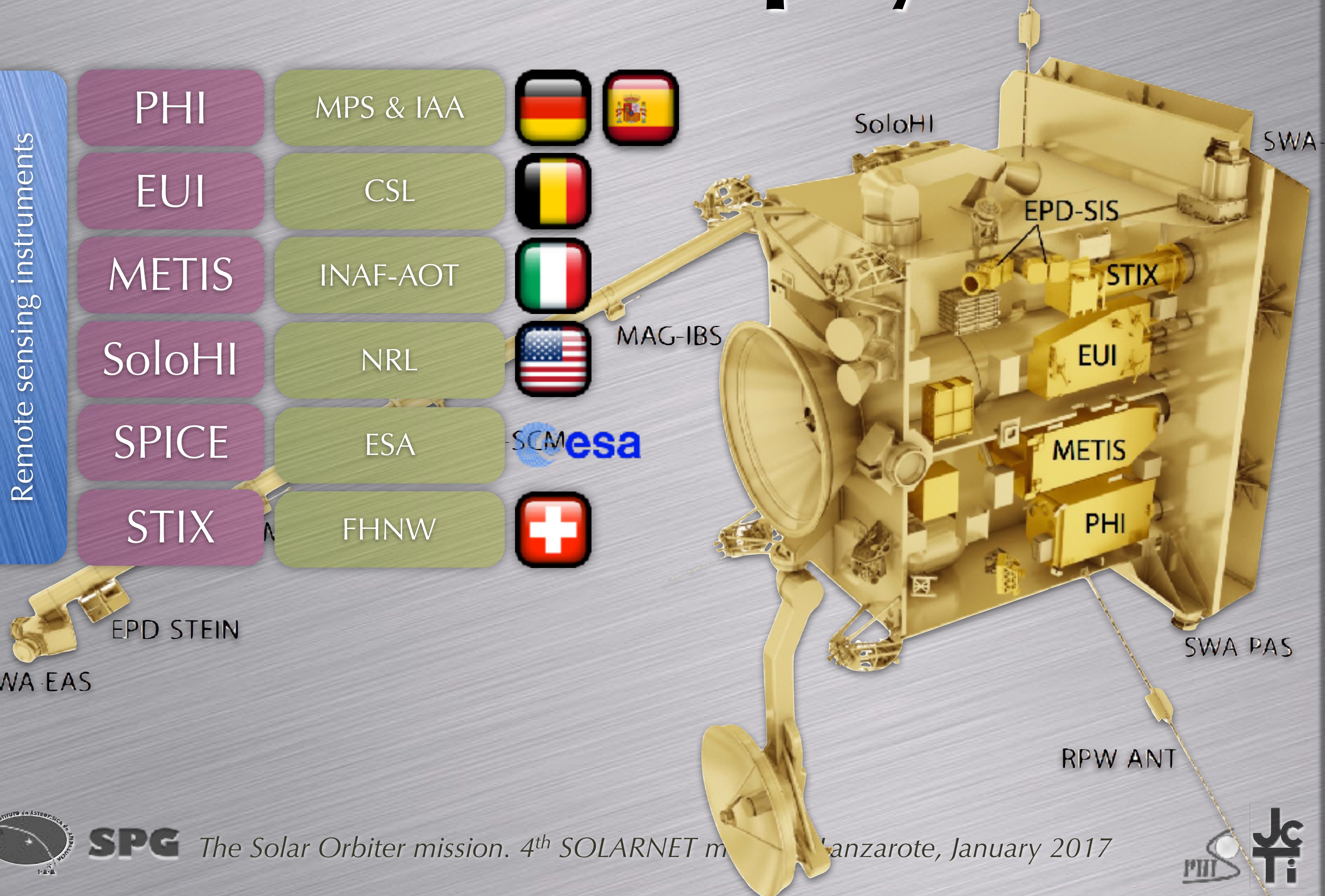


Sampling protons, electrons, and heavy ions in the solar wind

The scientific payload

Remote sensing instruments

PHI	MPS & IAA
EUI	CSL
METIS	INAF-AOT
SoloHI	NRL
SPICE	ESA
STIX	FHNW



The scientific payload

Remote sensing instruments		
PHI	MPS & IAA	
EUI	CSL	
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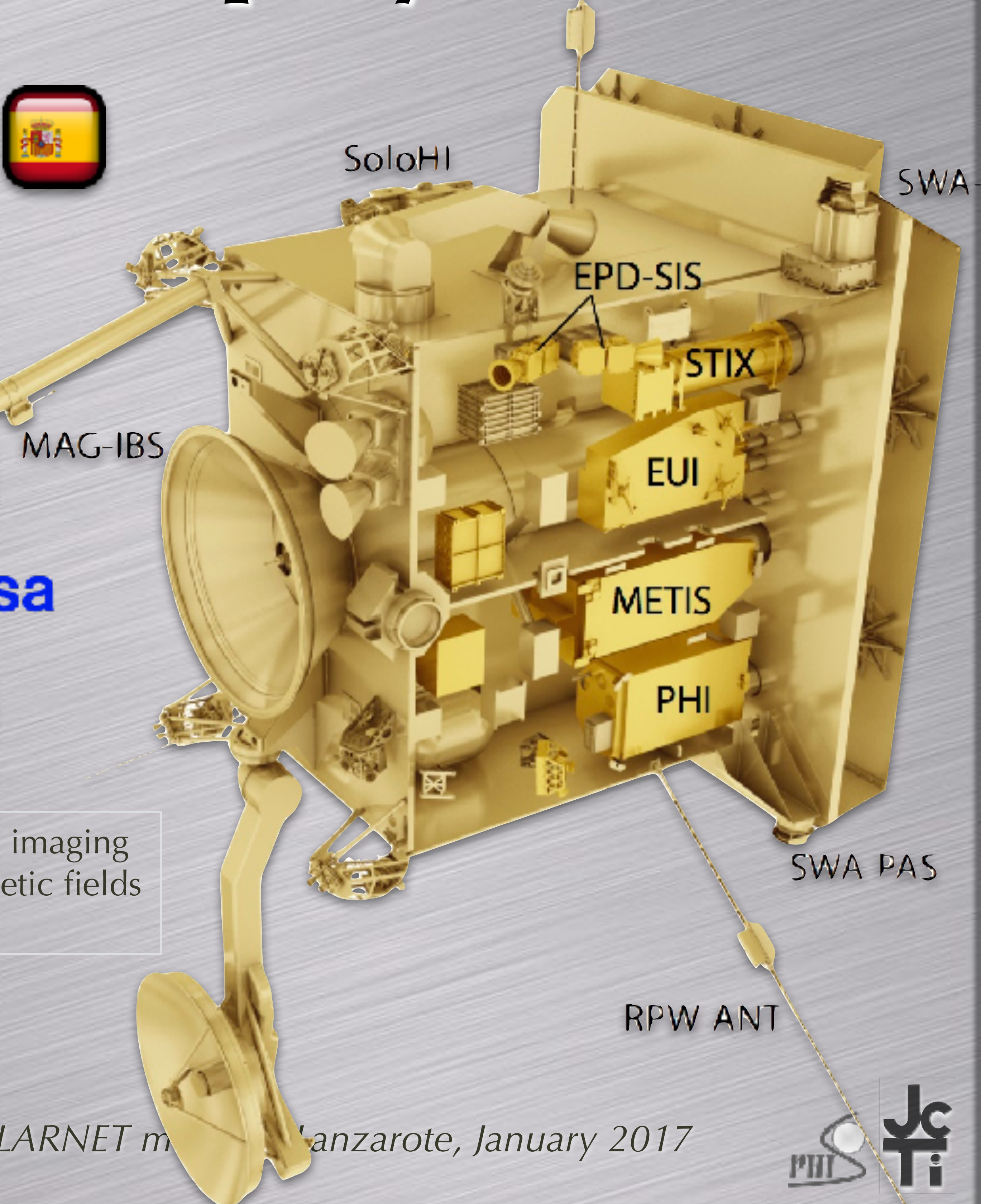
SoloHI	NRL	
SPICE	ESA	esa
STIX	FHNW	

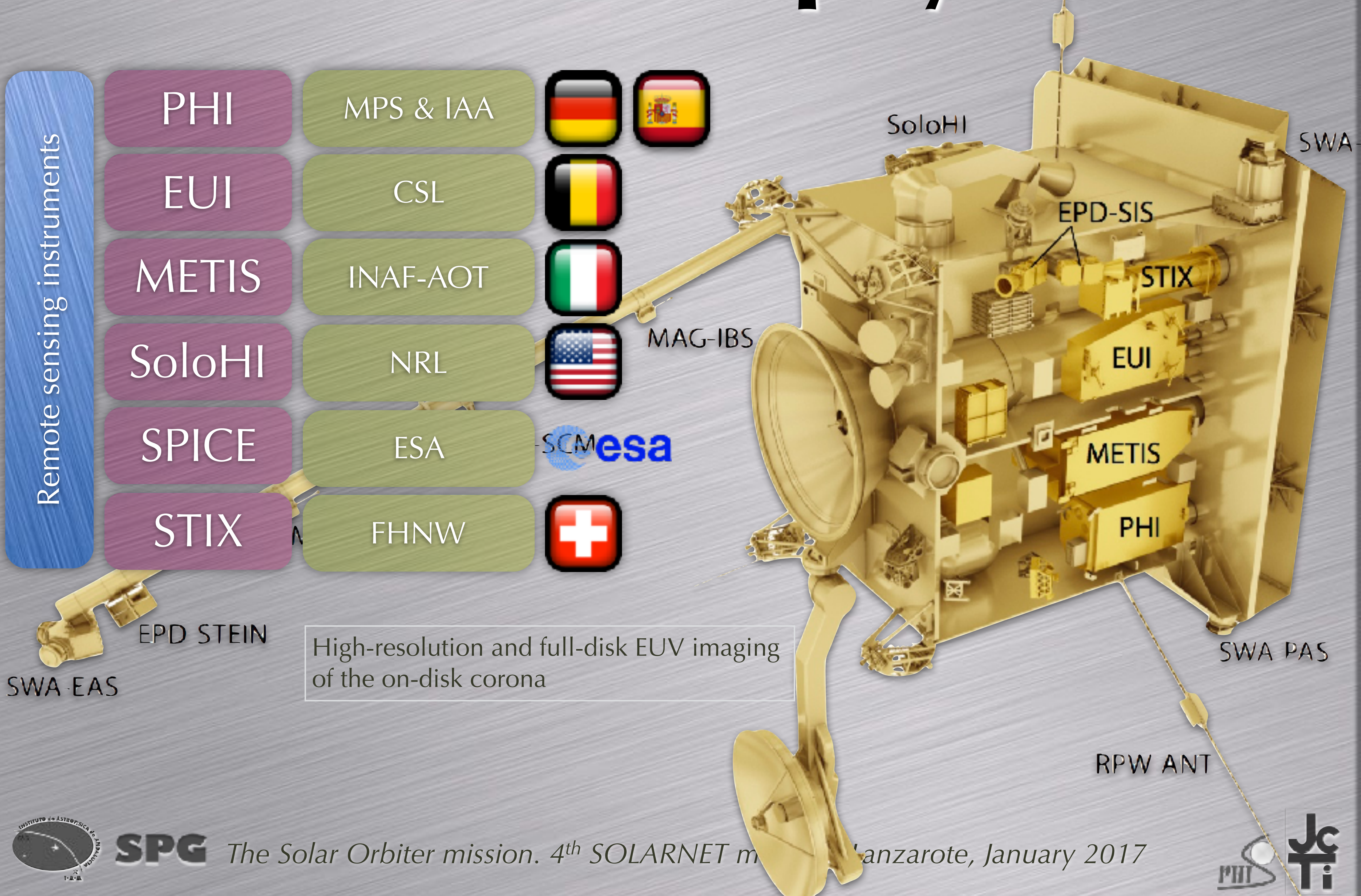


High-resolution and full-disk imaging of photospheric vector magnetic fields and line-of-sight velocities

The scientific payload

Remote sensing instruments

PHI	MPS & IAA	Germany, Spain
EUI	CSL	Belgium
METIS	INAF-AOT	Italy
SoloHI	NRL	USA
SPICE	ESA	esa
STIX	FHNW	Switzerland

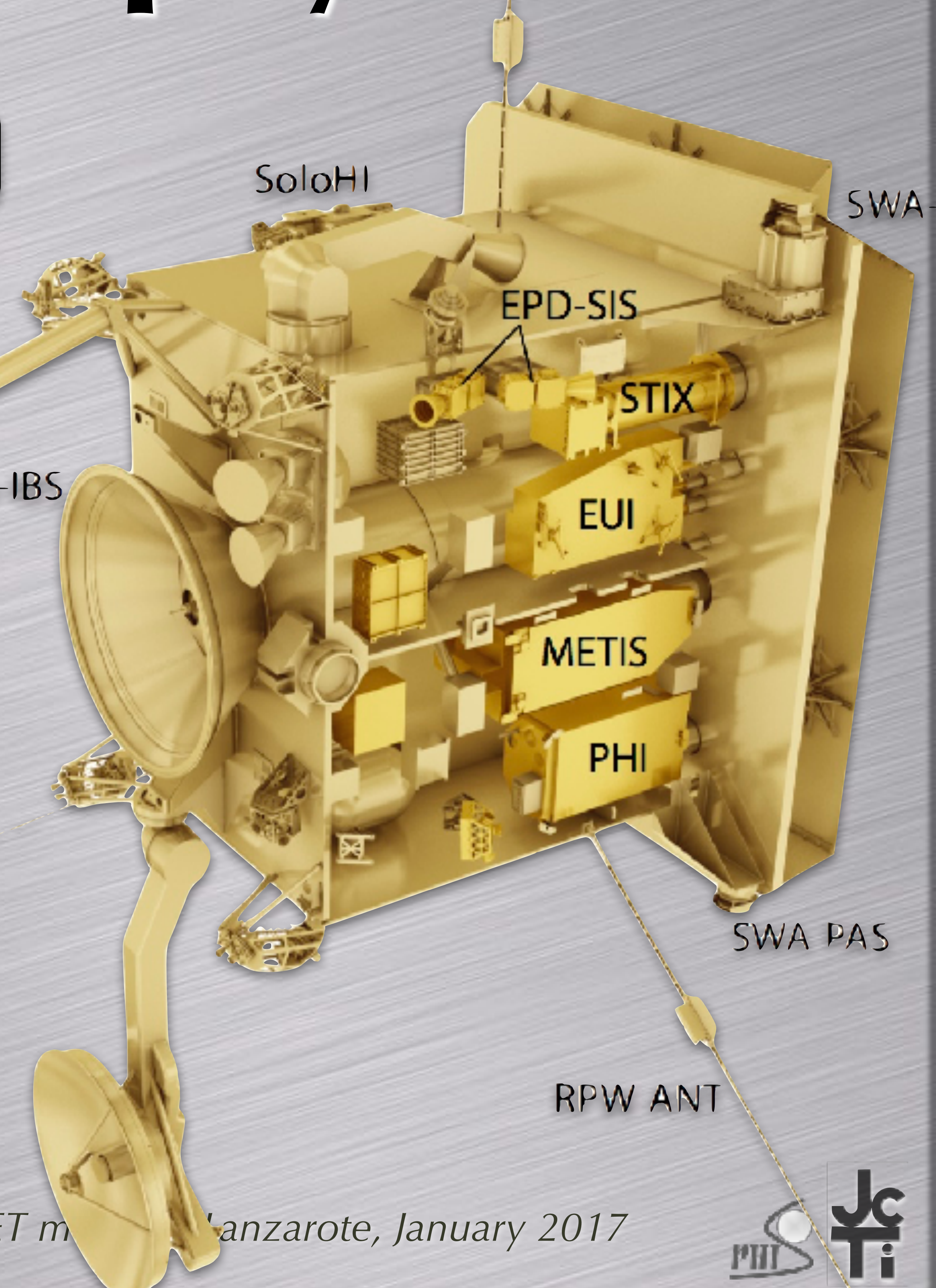


High-resolution and full-disk EUV imaging of the on-disk corona

The scientific payload

Remote sensing instruments

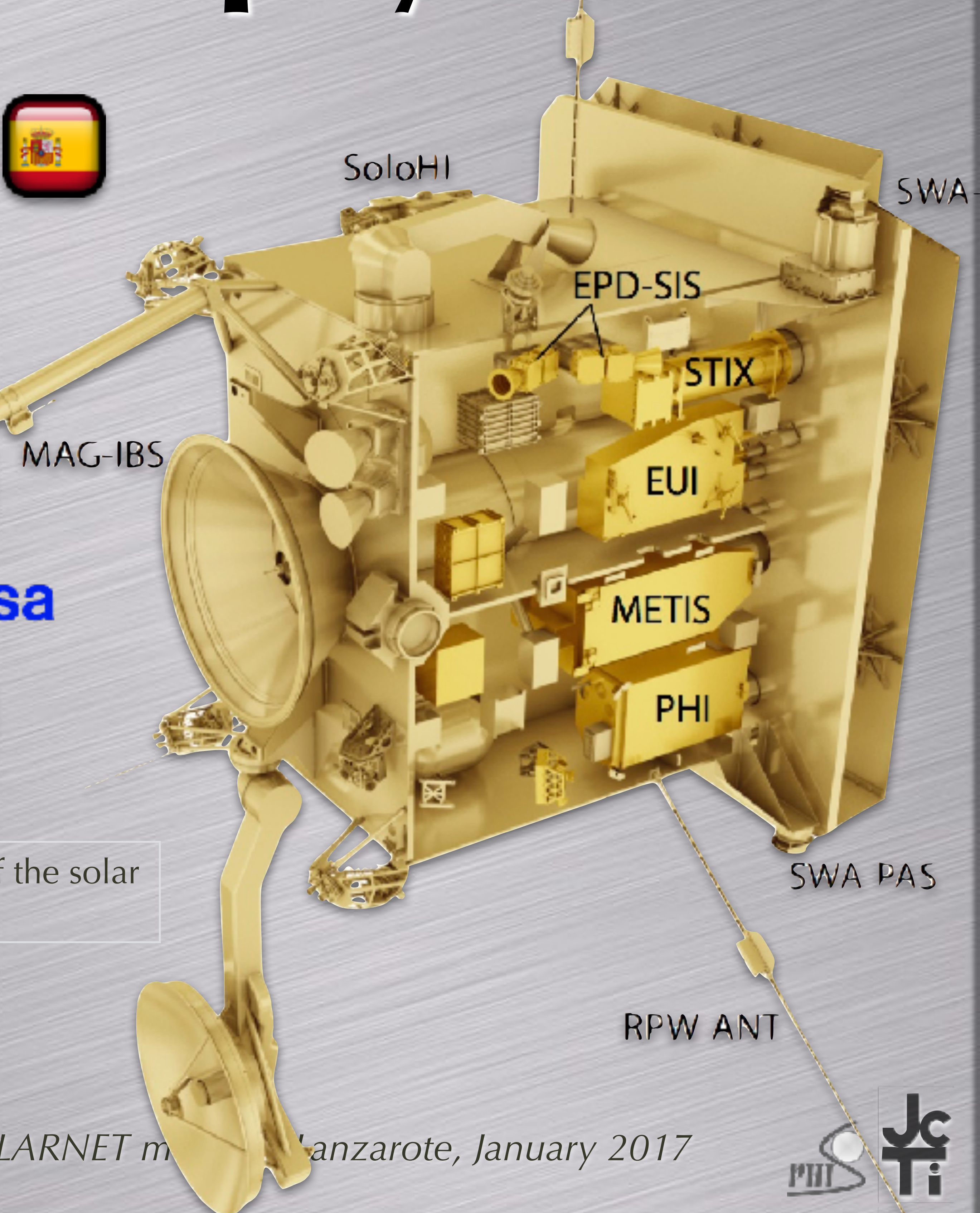
PHI	MPS & IAA
EUI	CSL
METIS	INAF-AOT
SoloHI	NRL
SPICE	ESA
STIX	FHNW



Visible and (E)UV imaging of the off-disk corona

The scientific payload

Remote sensing instruments		
	PHI	MPS & IAA
	EUI	CSL
	METIS	INAF-AOT
	SoloHI	NRL
	SPICE	ESA
	STIX	FHNW

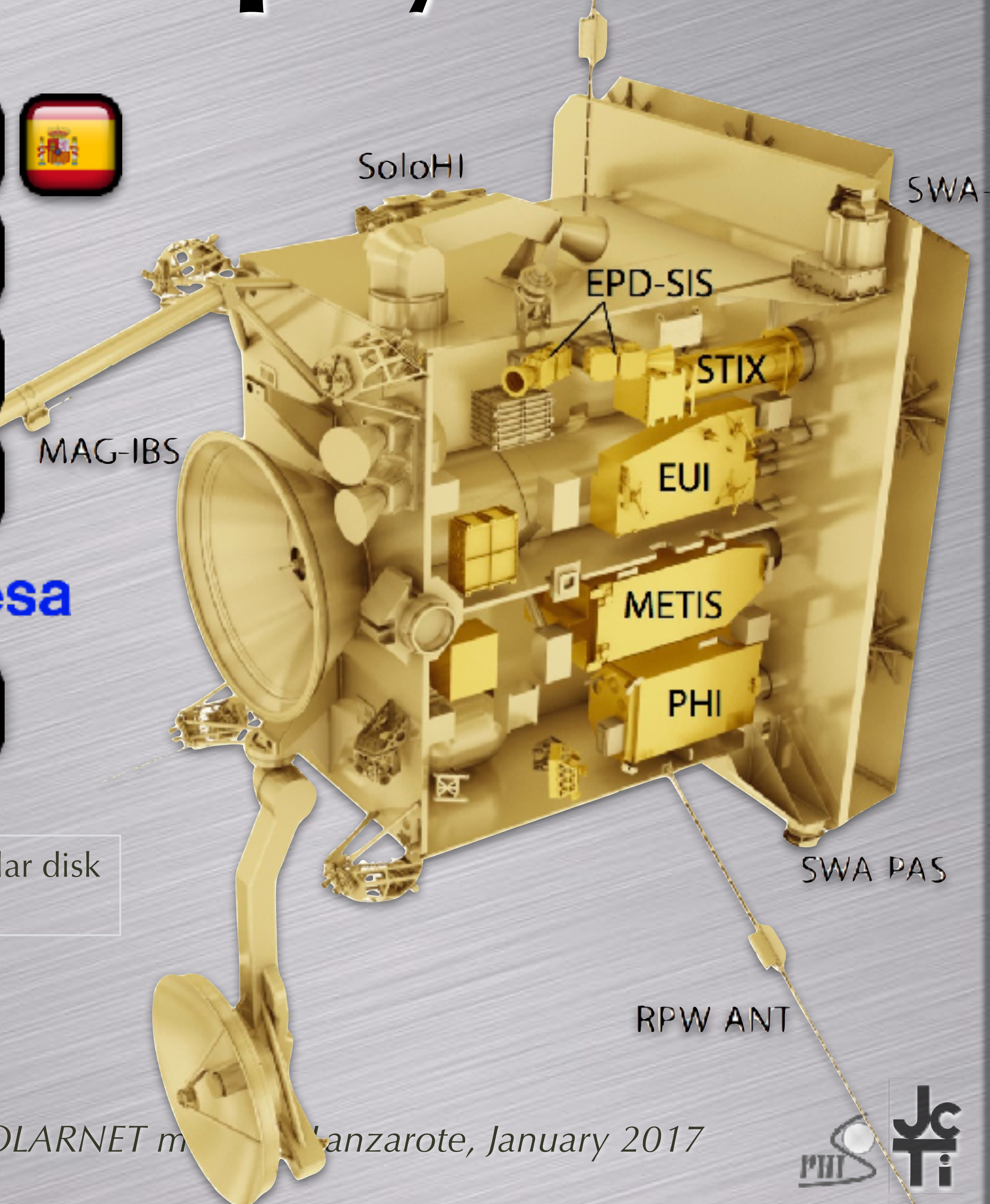


Wide-field visible imaging of the solar off-disk corona

The scientific payload

Remote sensing instruments

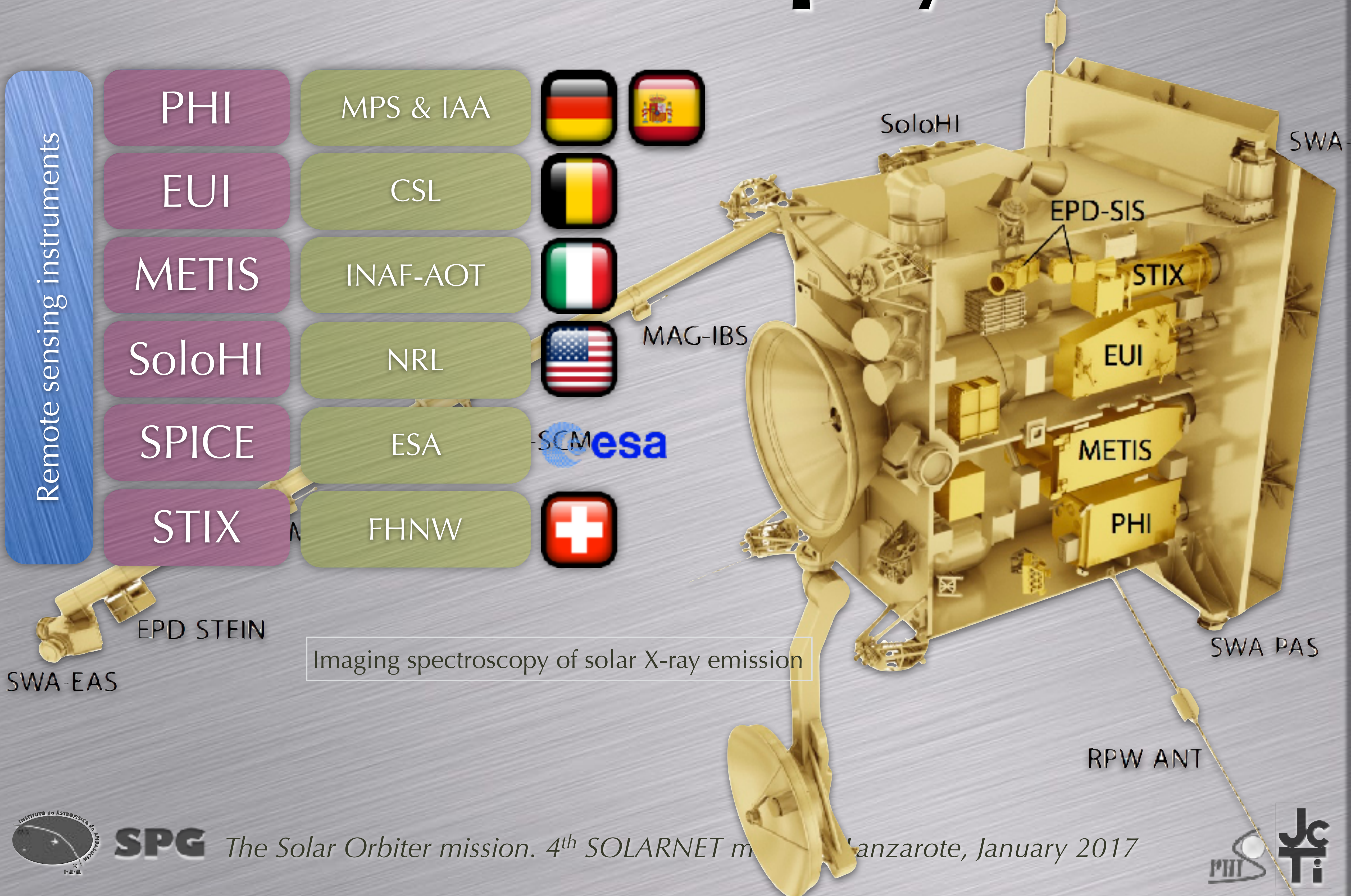
PHI	MPS & IAA
EUI	CSL
METIS	INAF-AOT
SoloHI	NRL
SPICE	ESA
STIX	FHNW



EUV spectroscopy of the solar disk and near-Sun corona

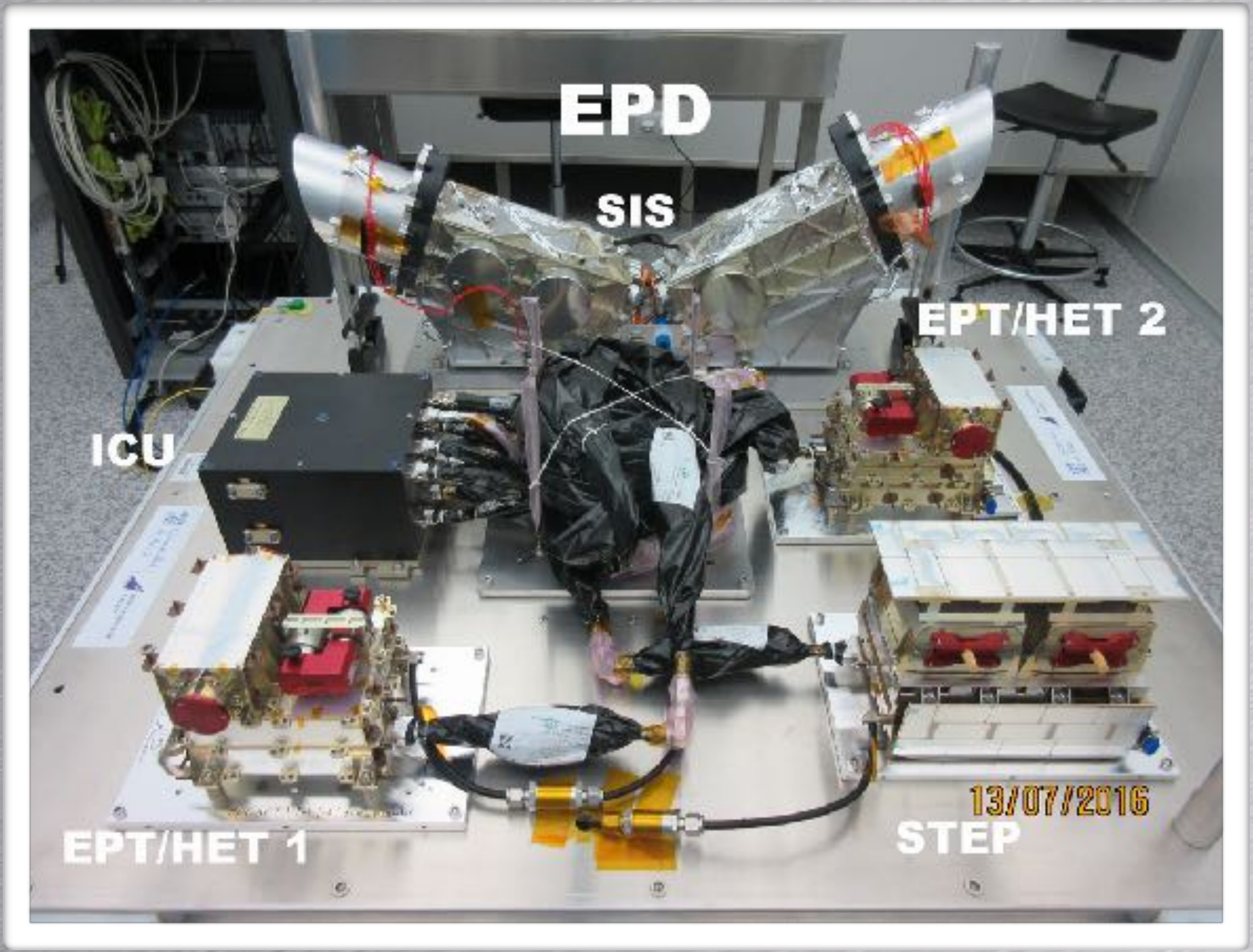
The scientific payload

Remote sensing instruments		
PHI	MPS & IAA	
EUI	CSL	
METIS	INAF-AOT	
SoloHI	NRL	
SPICE	ESA	esa
STIX	FHNW	



Imaging spectroscopy of solar X-ray emission

EPD



- SIS: Supra-thermal Ions spectrograph
- STEP: Supra-thermal Electrons and Protons
- EPT: Electron Proton Telescope
- HET: High Energy Telescope
- ICU: Instrument Control Unit

Electrons, protons, and heavy elements from few keV up to 400 MeV/n

(PI: J. R.-Pacheco, Spain; co-PI: R. Wimmer-Schweingruber, Germany)

METIS

- Observables
  - Coronal density
  - Coronal outflow velocity
- Where
  - Solar wind is accelerated
  - CMEs first propagate
  - Shock fronts accelerate particles

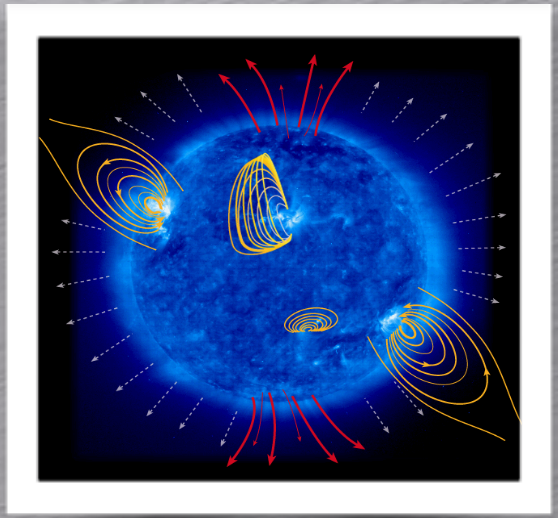
- Externally occulted coronograph
  - Annular FOV: 1.5º-2.9º (1.6 - 3.0 $R_\odot$ @ 0.28 AU)
- Simultaneous imaging in two channels
  - Broadband polarized, visible light (580 - 640 nm)
  - Narrow band UV @ $Lyman_\alpha$ (121.6 ± 10 nm)
- Spatial resolution
  - ≥ 20″ (vis. and UV phot. cont.); ≥ 4000 km @ 0.28 AU
- Temporal resolution: ≥ 1 min typically

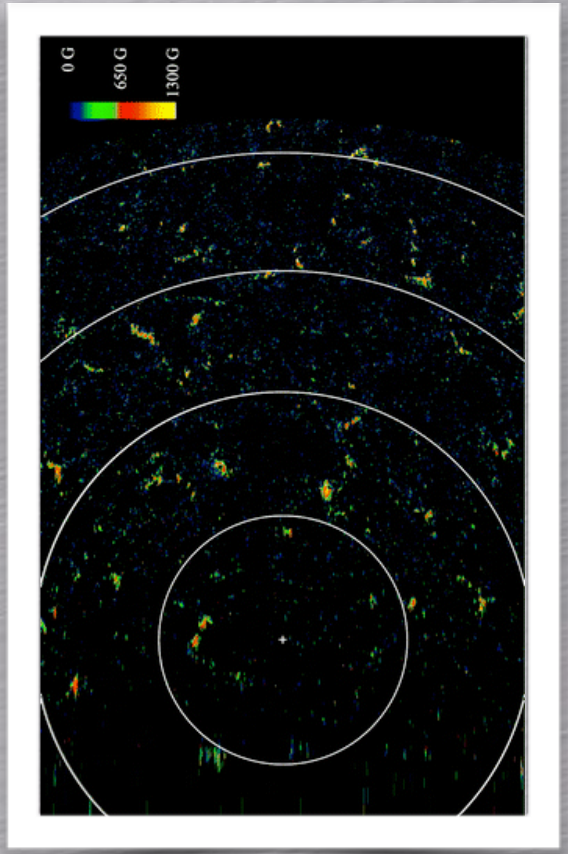
The corona as a link to the heliosphere

(PI: E. Antonucci, Italy)

SO/PHI

- Science goals
  - Links between the surface and higher layers
    - Mapping ***B*** in the photosphere (HR & FD to be extrapolated where necessary; in combination)
  - Energetics, dynamics, and fine structure of the magnetic field (… poles)
    - Mapping ***B*** and v_{LOS} (HR; in combination)
  - Probe the solar dynamo
    - Uninterrupted series of ***B*** and v_{LOS} (HR & FC; stand-alone)





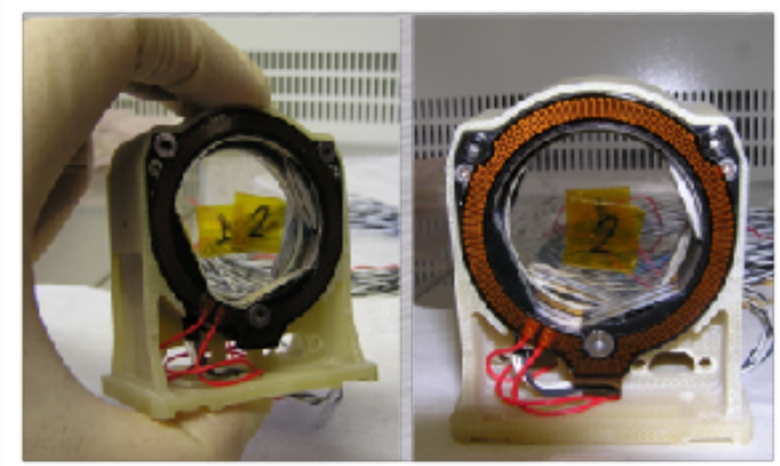
SO/PHI

Mapping | Imaging

- HRT & FDT
- Image stabilization system

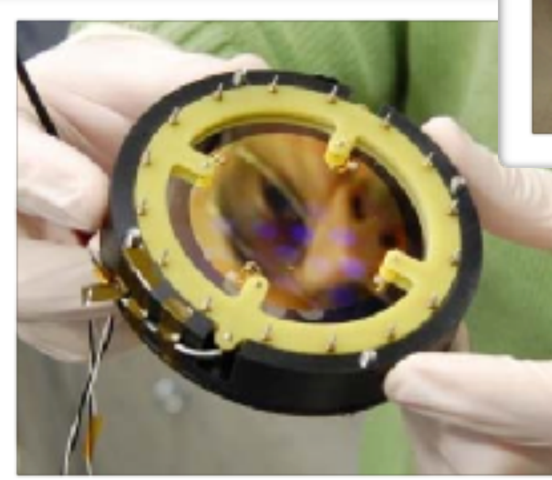
Magnetometry | Polarimetry

- LCVR-based polarimeters



Tachography | Spectroscopy

- LiNb O_3 etalon

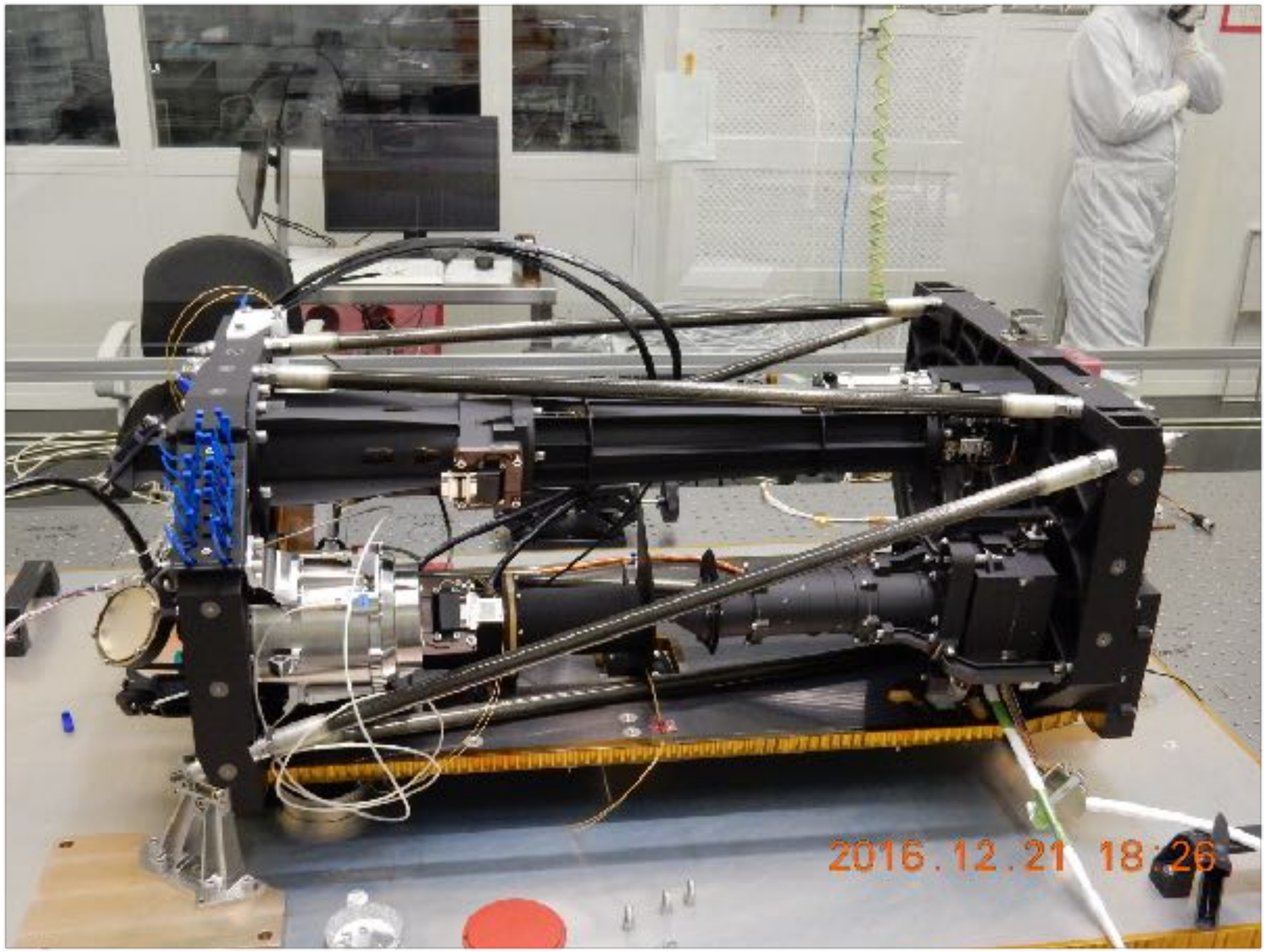


(PI: S.K. Solanki, Germany; co-PI: J.C. del Toro Iniesta, Spain)

SO/PHI

Mapping
Magnetometry
Tachography

Imaging
Polarimetry
Spectroscopy



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Imaging
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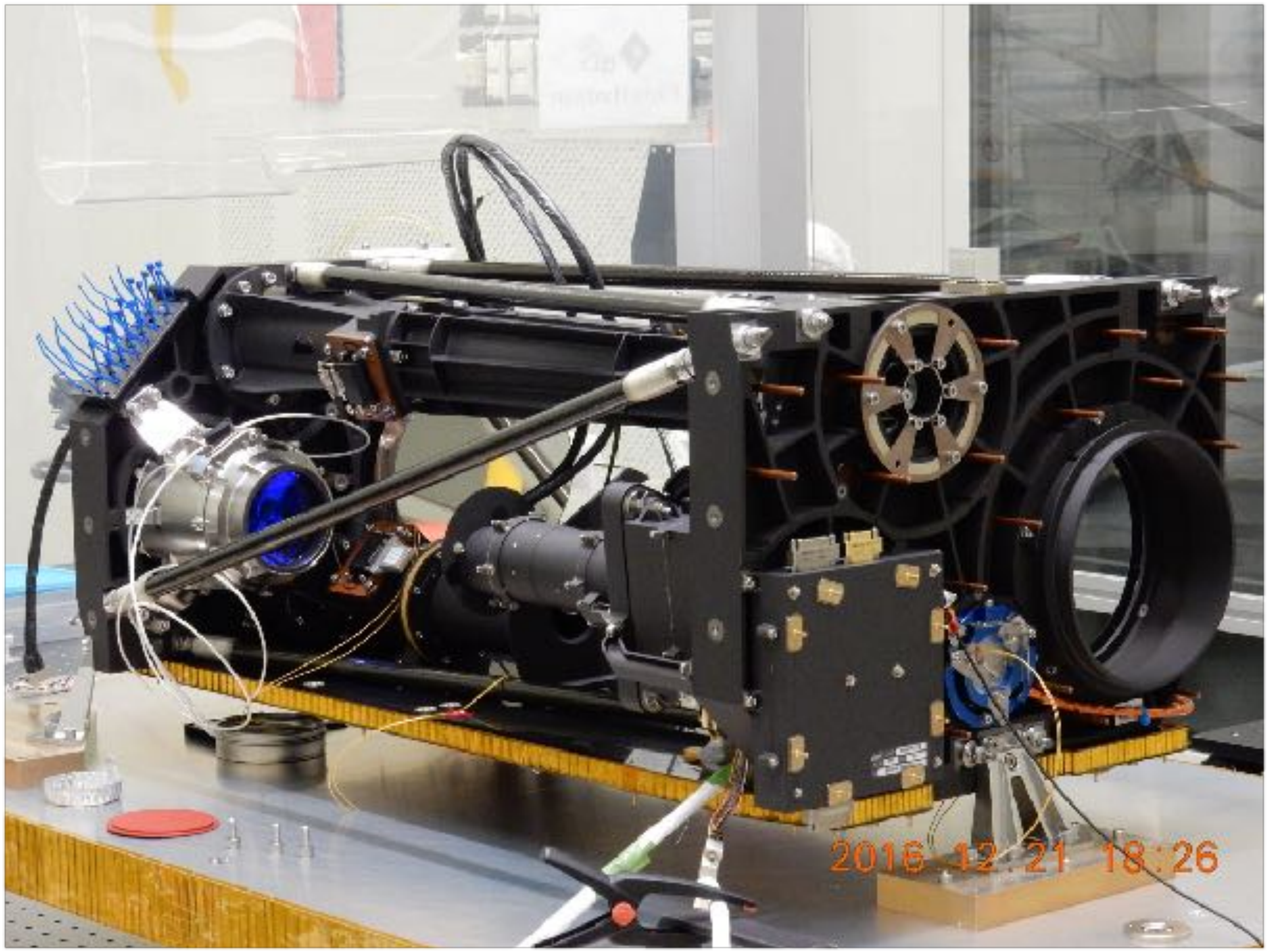

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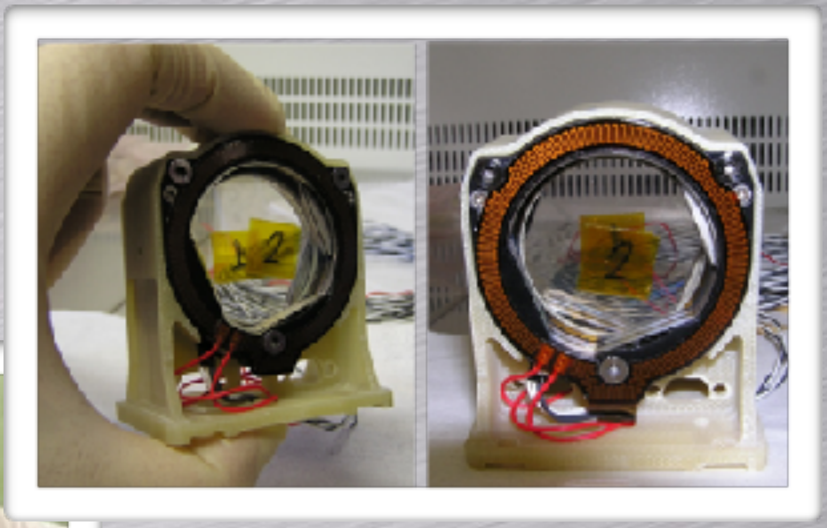

Tachography | Spectroscopy
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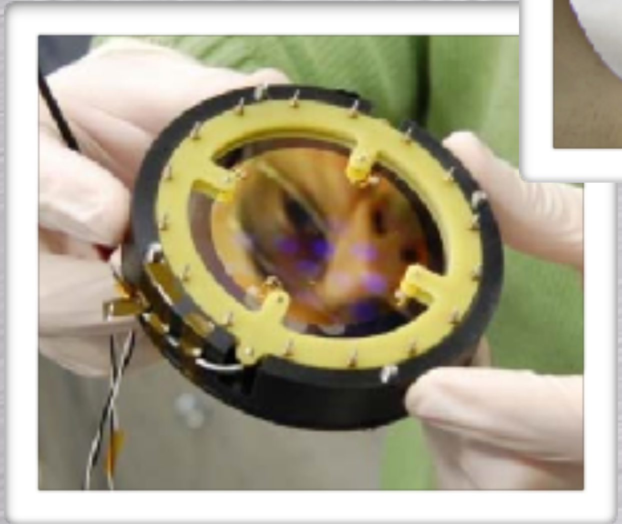


(PI: S.K. Solanki, Germany; co-PI: J.C. del Toro Iniesta, Spain)

SO/PHI

Mapping

Imaging

HRT &

Image

Magnetometry

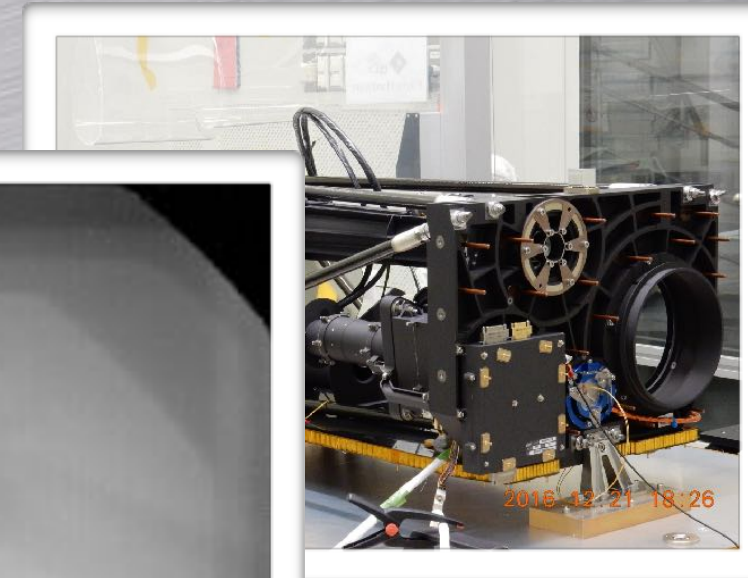
Polarimetry

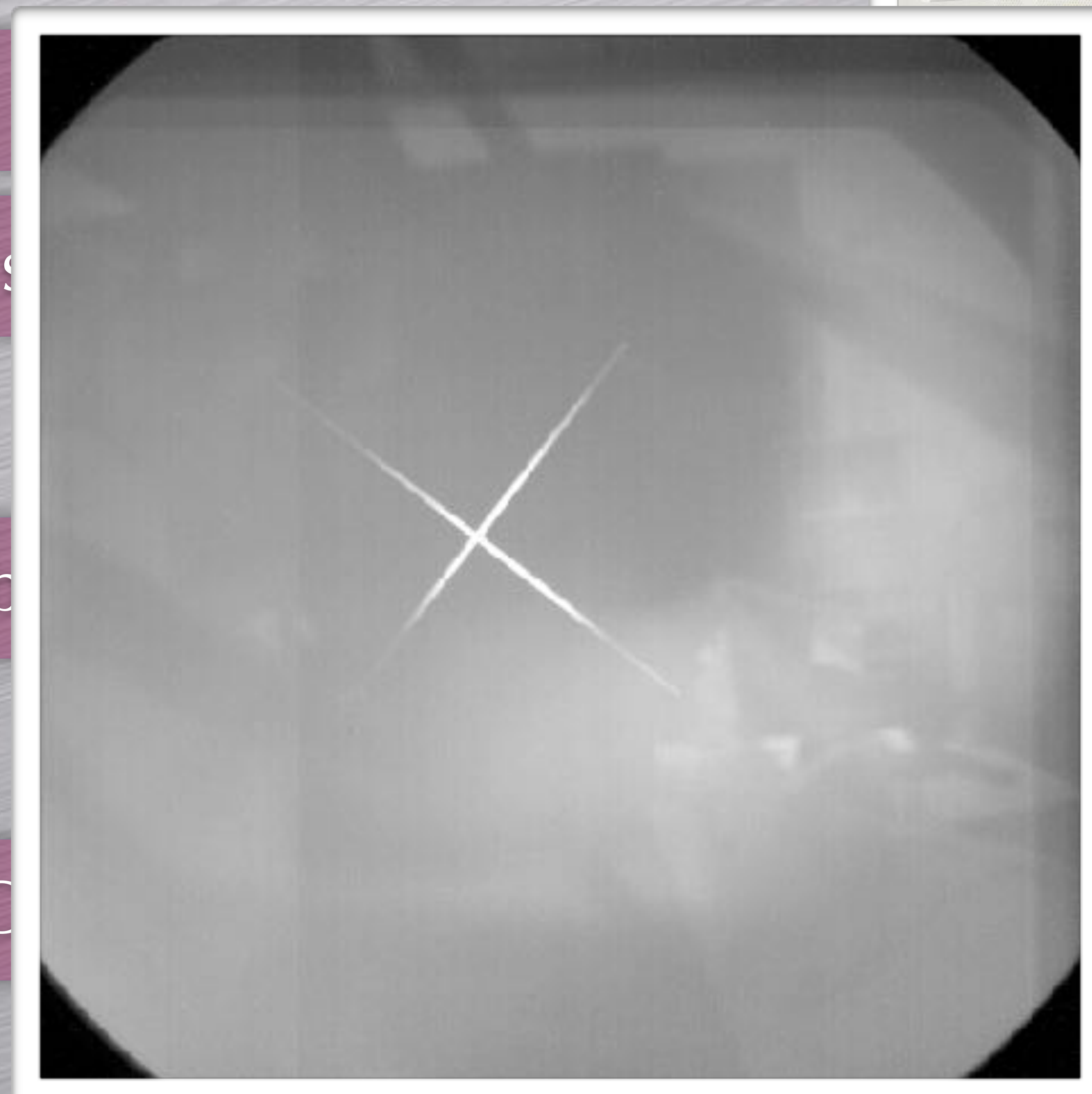
LCVR-

Tachography

Spectroscopy

LiNb





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SO/PHI

Mapping

Imaging

Magnetometry

Polarimetry

Tachography

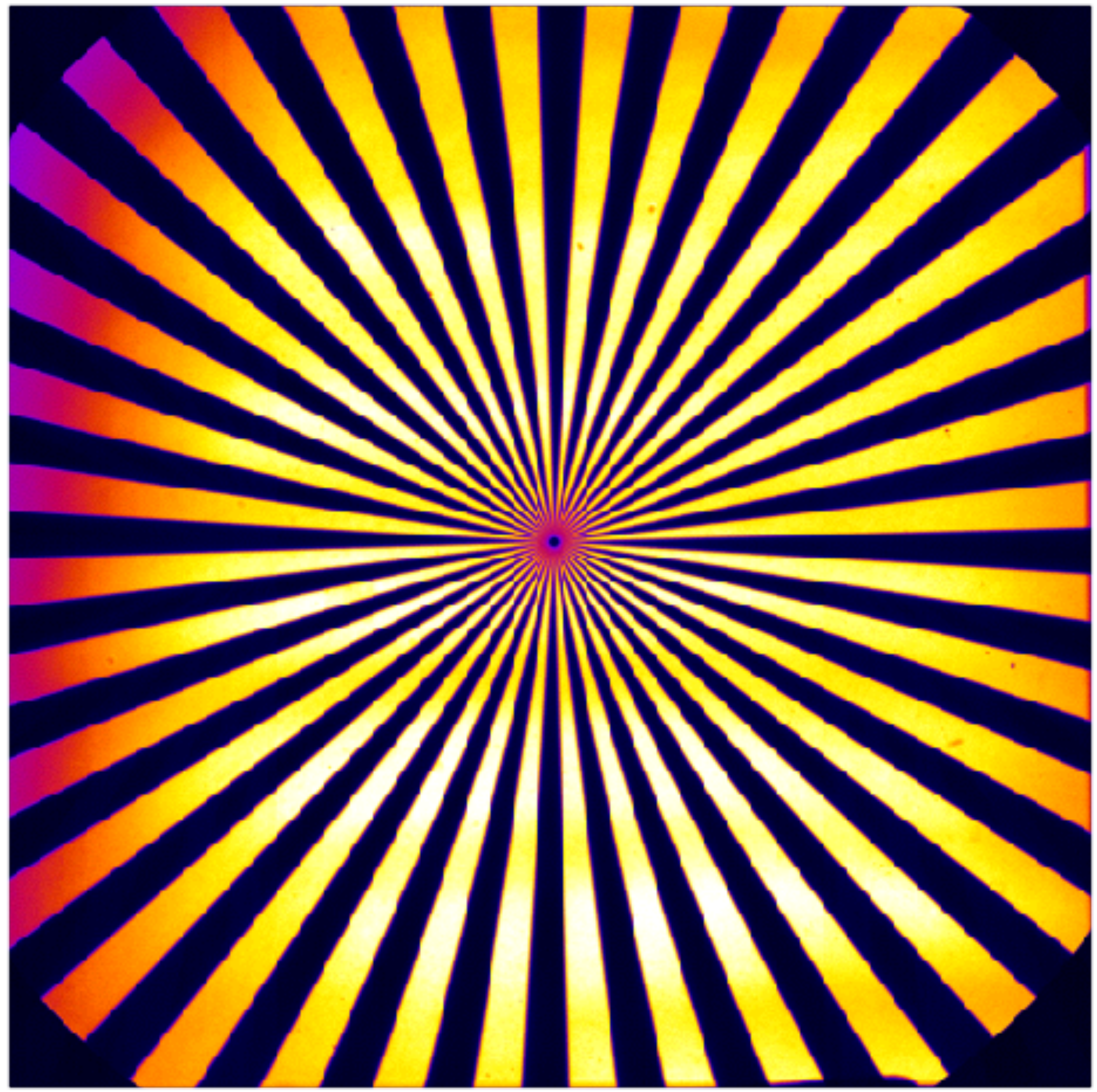
Spectroscopy

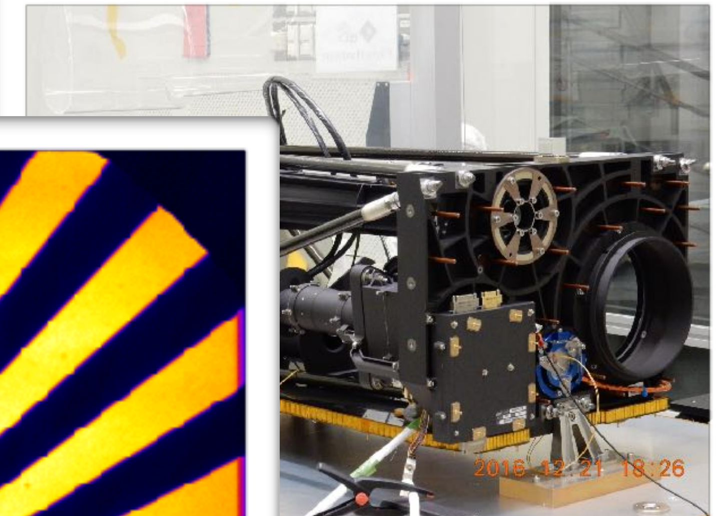
HRT &

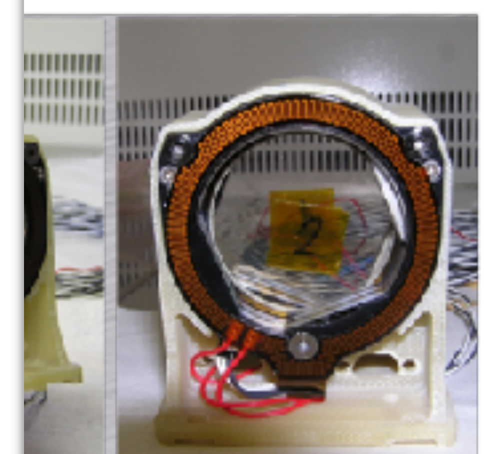
Image s

LCVR-b

LiNb O

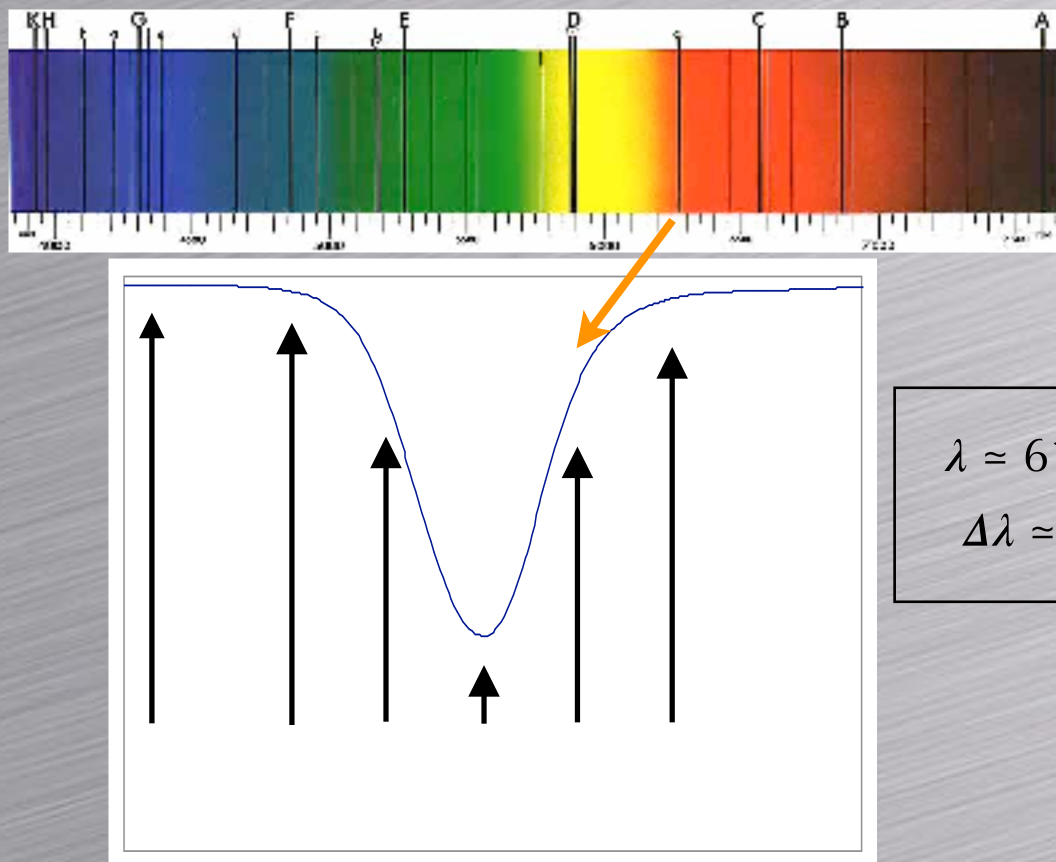






(PI: S.K. Solanki, Germany; co-PI: J.C. del Toro Iniesta, Spain)

The measurement principle

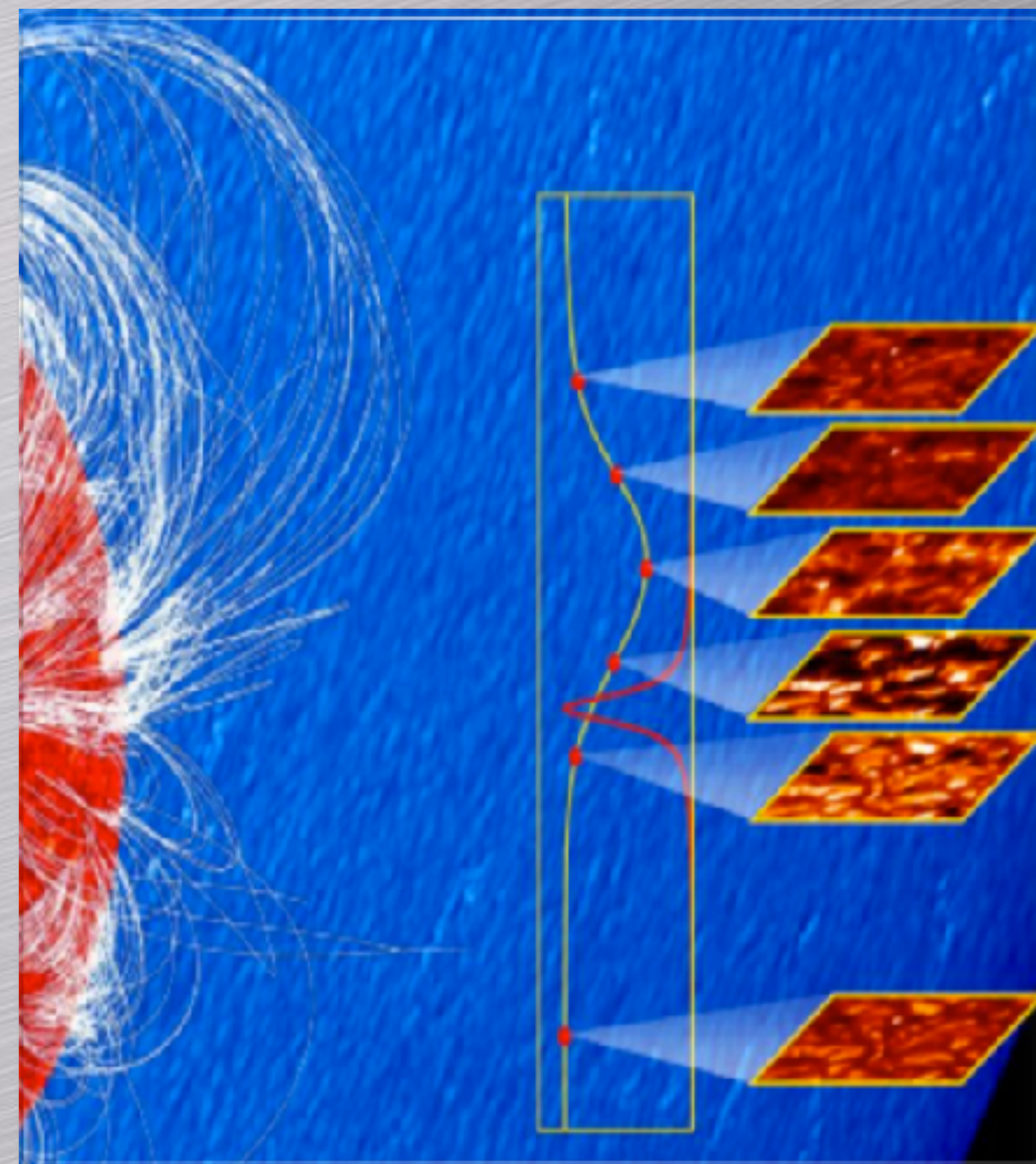


λ ≃ 617.3 nm

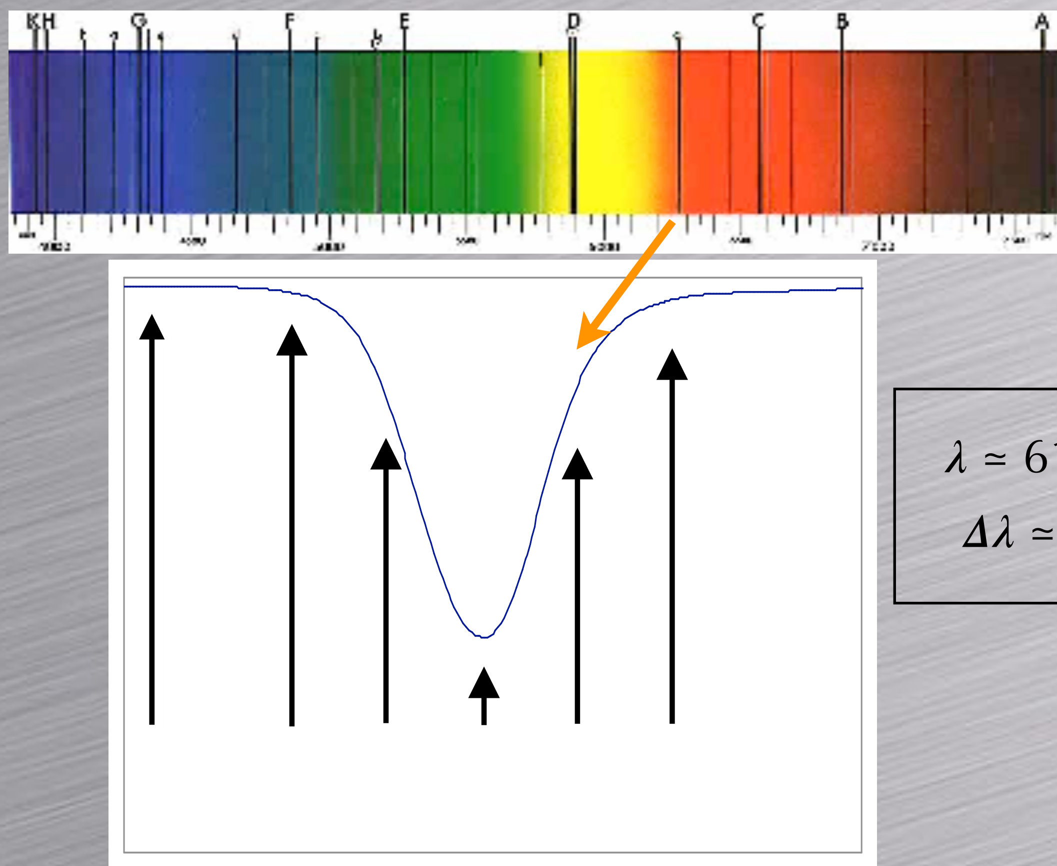
Δλ ≃ 10 nm

Polarized images in five plus one wavelengths

We infer the vector magnetic field and the LOS velocity by inverting the RTE on board by means of a special device



The measurement principle

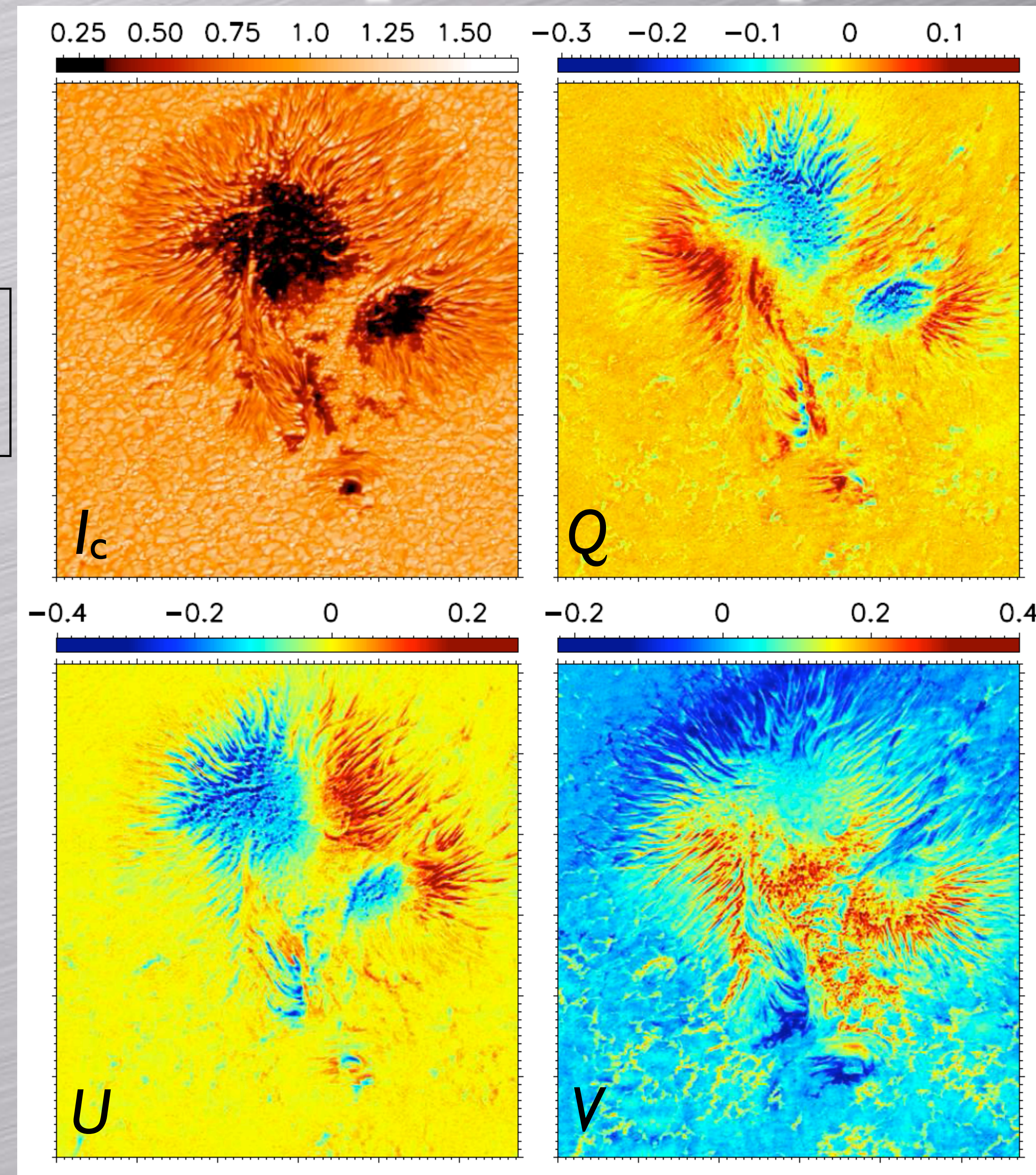


$\lambda \simeq 617.3$ nm

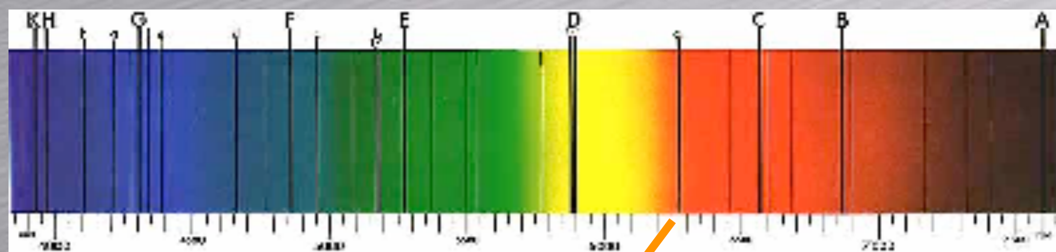
$\Delta\lambda \simeq 10$ nm

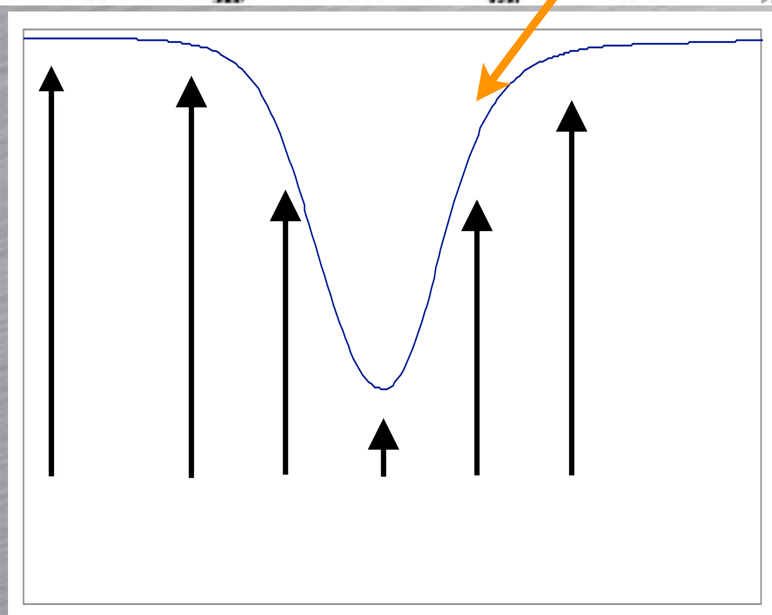
Polarized images in five plus one wavelengths

We infer the vector magnetic field and the LOS velocity by inverting the RTE on board by means of a special device



The measurement principle





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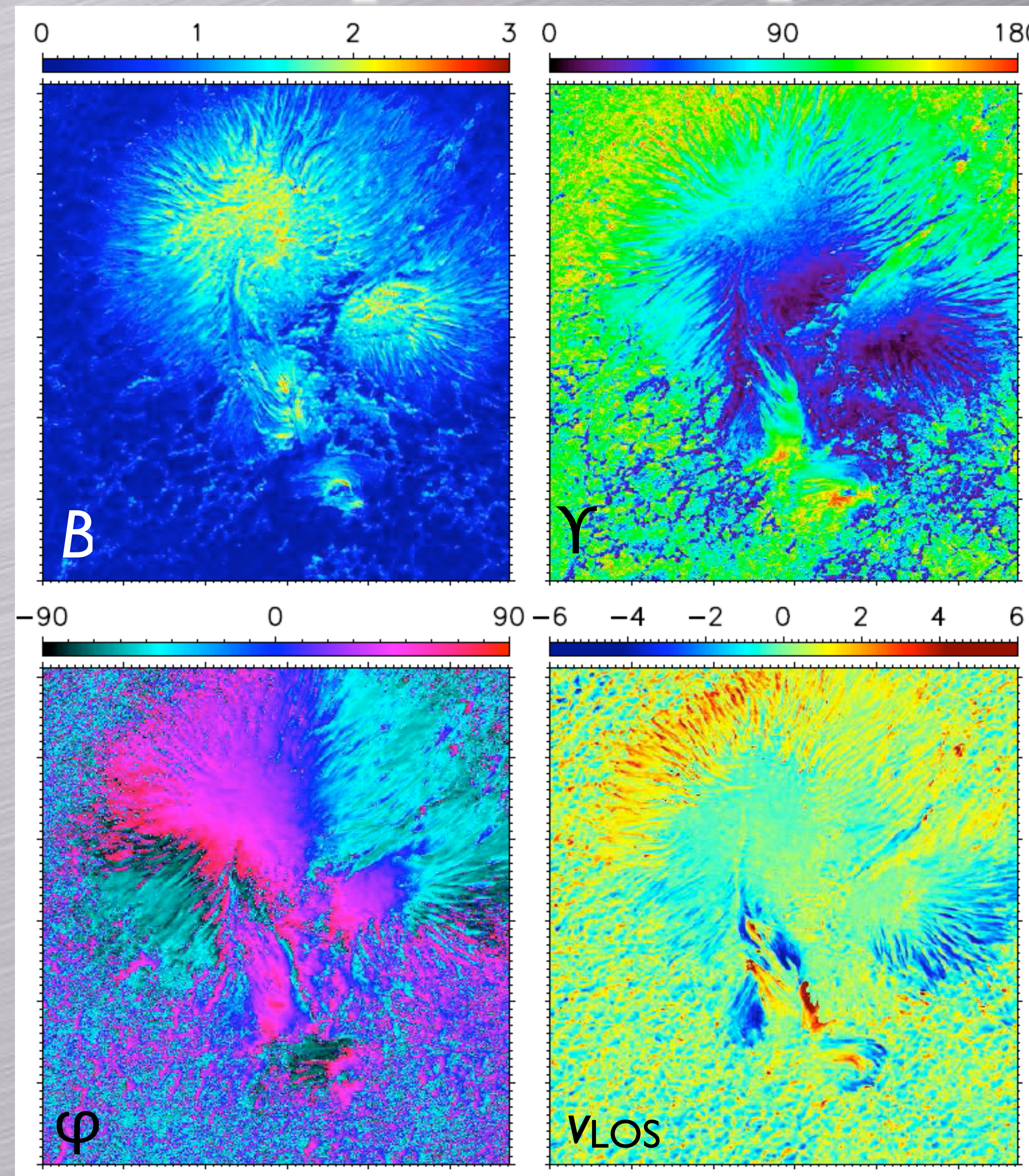
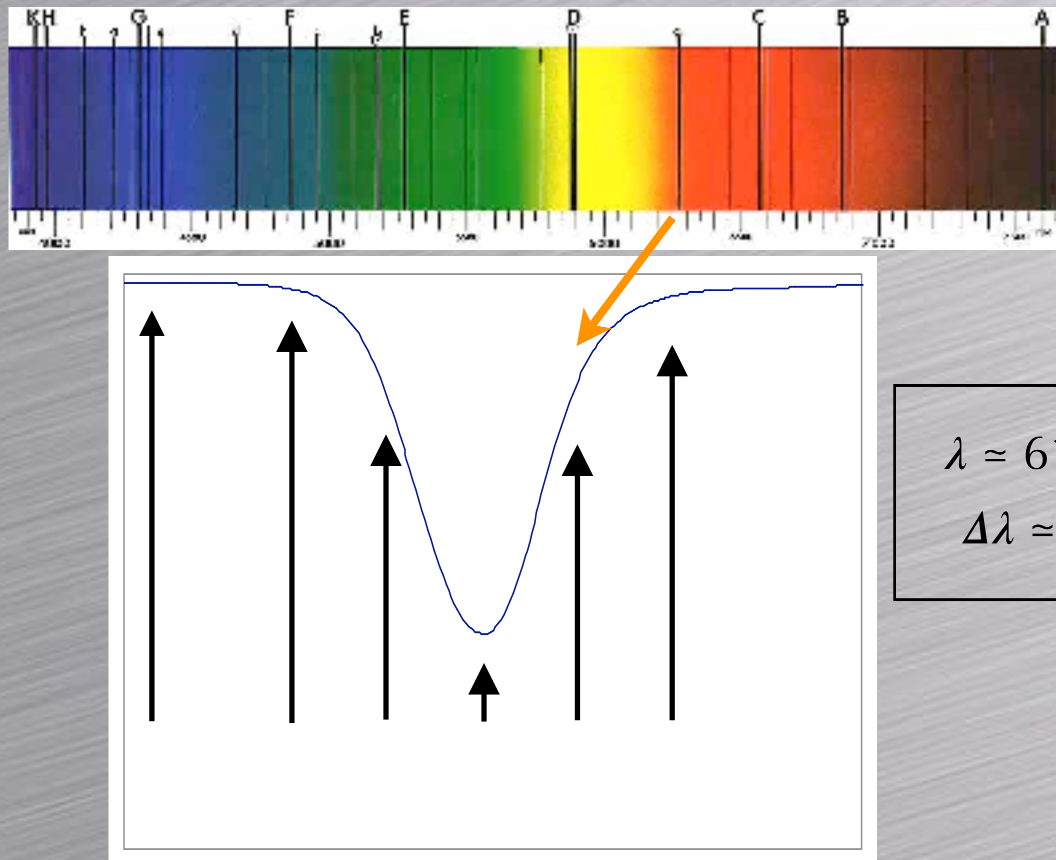


The measurement principle



$\lambda \simeq 617.3$ nm

$\Delta\lambda \simeq 10$ nm

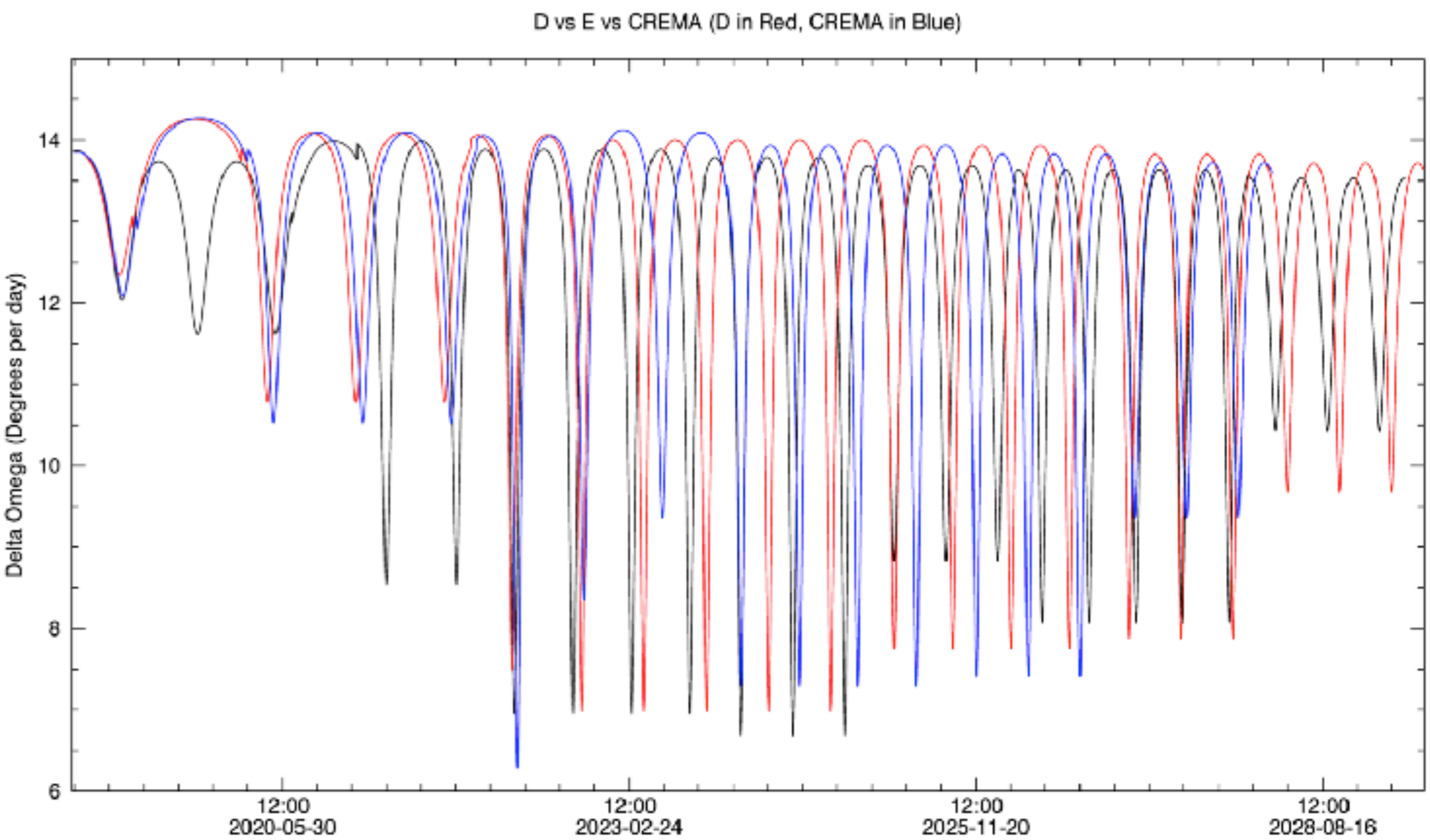
Polarized images in five plus one wavelengths

We infer the vector magnetic field and the LOS velocity by inverting the RTE on board by means of a special device

SO/PHI is
- Differential imager
- Diffraction limited
- Wavelength tunable
- Quasi monochromatic
- Polarization sensitive
- With sophisticated on-board capabilities


Invited speakers
S. Antiochos (NASA)
R. Bruno (IAPS-INAF)
P. Charbonneau (UMo)
M. Collados (IAC)
S. Cranmer (CU)
L. Gizon (MPS)
V. Hansteen (UiO)
Y. Katsukawa (NAOJ)
E. Kilpua (UH)
A. Lagg (MPS)
D. Lario (APL)
V. Martinez Pillet (NSO)
M. J. Owens (UR)
S. Parenti (IAS)
E. Priest (UStA)
J.C. Raymond (CfA)
K. Reeves (CfA)
A. Rouillard (CNES)
L. Rouppe van der Voort (UiO)
T. Shimizu (ISAS)
L. van Driel-Gesztelyi (MSSL)
M. Velli (JPL)
P. Young (NASA)
F. Zucarello (UniCT)
7th Solar Orbiter Workshop
Exploring the Solar Environs
http://spg.iaa.es/solo2017
Granada, Spain, 3-7 April 2017
esa
solar orbiter
NASA
CSIC
SPG

Relative rotation



Campaign duration

campaigns PHI (HRT or FDT)	ce s	Rate kbps	hrs	alloc % of 53.14Gb	requirements	Operational feasibility	TM feasibility	es	
Near-surface rotation, meridional circulation and solar cycle variations at high latitudes									
surface flows *seis1*	14400 (2sets/ 8h)	2,9/ 3,09	720 (30 days)	14,21	30days at **high** latitude (limited time at 'high lat')	feasible outside baseline	TM feasible	EMP high latitude periods	
supergranulation tracking *seis2*	3600 (1/hr)	0,36/0, 39	720 (30 days)	1,78	30days at **moderately high** latitude (limited time at 'high lat')	feasible outside baseline	TM feasible	NMP high latitude periods	bad comms
helioseismology & solar cycle variations *seis3*	60 (1/min)	21,85/2 3,15	720 (30 days)	106,56	**4 x 30d** campaign, **2 years** apart, at **high** latitudes (high latit. only in last 4 yrs)	**partially,** outside baseline	extra TM needed	around high lat windows, close to E	only partial cycle + data storage
Meridional circulation to 3m/s @75° *seis4*	TBD	TBD	2400 (+100 d)	**TBD**	>100d at **high** latitude (@75°)	unfeasible with current description	TBC	TBD	TBD
Deep and large-scale solar dynamics									
MDI-like medium-l & stereoscopic helioseismology *seis5*	60 (1/min)	1,37/1, 27	>1 orbit **long as possible**	37,30	to be run continuously (esp. **far side/high lat)** Continuous FDT might conflict with RSWs	feasible outside baseline	TM feasible (**)	may fit outside RSWs	RSW TM reduction mid mission
Convection at high latitudes									
helioseismology *seis6* **OR**	60 (1/min)	87,38/8 2,67	168 (7days)	99,46	7days at **high** latitudes	within RS baseline	TM limit (total alloc in 7d)	high latitude RSW, close to Earth	may need combination with seis3
local correlation tracking *seis1 short*	14400 (2sets/ 8h)	2,9/3,3 1	168 (7days)	3,32	7 days at **high** latitudes needs HRT & feature tracking?	within RS baseline	TM feasible	any high latitude RSW	
Deep convection and giant cells									
feature tracking *2x seis2*	3600 (1/hr)	0,36/0, 39	1440 (60 days)	3,55	4 repetitions of 60days OR full orbit, **high latitudes mainly** (??)	outside baseline	TM feasible	TBD	
helioseismology *seis5*	60 (1/min)	1,37/1, 27	4032 (1 orbit)	37,30	to be run continuously (esp. **far side/high lat)**	feasible outside baseline	TM feasible (**)	= MDI-like campaign	RSW TM reduction mid mission

Campaign duration

Helioseismology campaigns PHI	Cadence	TM Rate	Duration	% orbital alloc	Orbital & operational requirements	Feasibility		Opportunities	Drawback
(HRT or FDT)	s	kbps	hrs	% of 53.14Gb		Operational feasibility	TM feasibility		
Active Regions and sunspots									
AR flows and structure *seis3 short*	60	21,85/ 23,15	480 (20 days)	71,04	20 days of same AR: feature tracking @perihelion far side	within RS baseline	TM feasible	far side concat. RSWs	
sunspot oscillations *seis7*	60	262,1/ 231,5	48 (2 days)	85,25	2 days stereoscopic observations, feature tracking	within RS baseline	85% TM in 2d -> release TM in steps	RSW flying inwards	rest orbit TM low?
calibration far-side helioseismology *seis5 short*	60	1,37/1 ,74	48 (2 days)	0,44	to be repeated 5 times 2 days @ far side, AR on Earth side	within RS baseline	TM feasible	far side perihelion	
Physics of oscillations									
effect granulation on oscillations *seis8*	60	262,1 231,5	24	42,63	Stereoscopy + (clipped?) 'raw' data download	within RS baseline	TM feasible (**)	within RS window	40% TM in 1 day
two components of velocity (v) *seis3 short*	60	21,85/ 20	240 (10days)	35,52	observe several lifetimes of super-granulation	within RS baseline	TM feasible (**)	full RSW	
magnetic oscillations (MHD waves) *seis9*	60 (B at highest	1748/ 1157	24	284,17	stereoscopic observ of AR: HRT & feature tracking?	within RSbaseline	extra TM needed	last RSW before underrun	Space needed in PHI buffer
Low resolution observations									
LOI-like observations (sun-as-a-star)	60	0,088 0,003	4032 (1 orbit)	2,40	higher latitudes, continuous observations	outside baseline	TM feasible	TBD	
Shape of the sun *seis11*	3600 (1set/ hr)	0,083	12 (1 roll)	0,0068	spacecraft rolls in 12 discrete steps	TBC	TM feasible	TBD	