INTERHELIOPROBE

Science, synergies, and French implications

3 November 2014, Solar Orbiter workshop, Toulouse

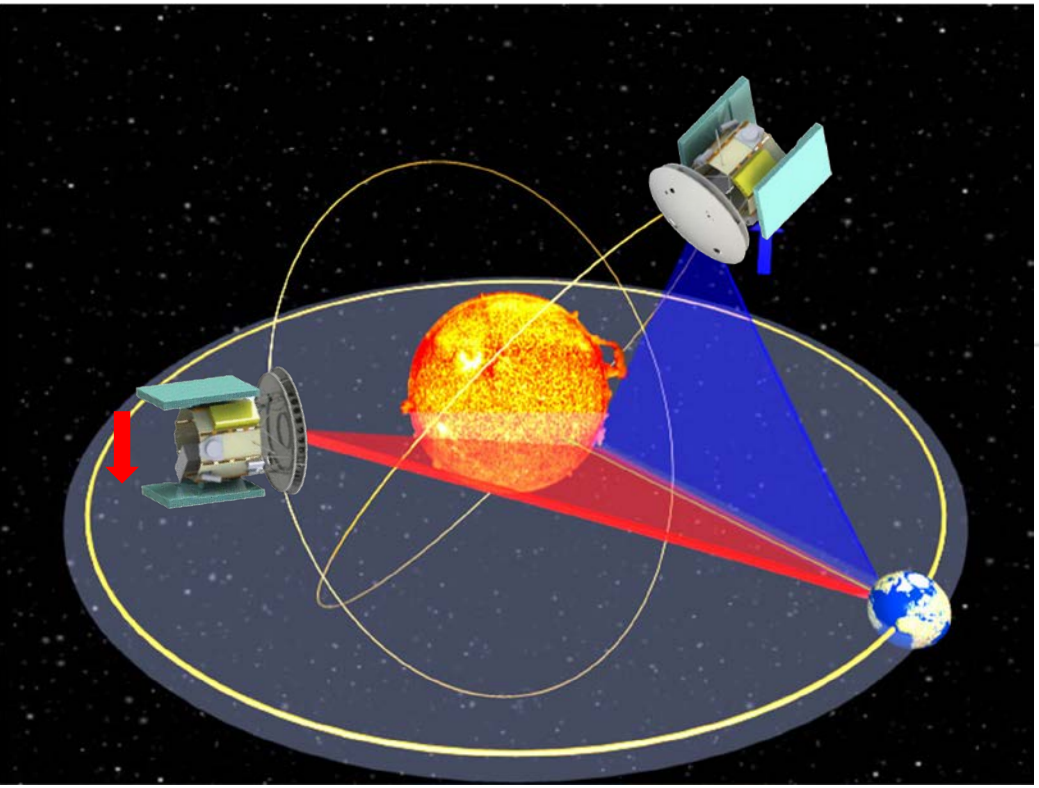
Summary of mission concept

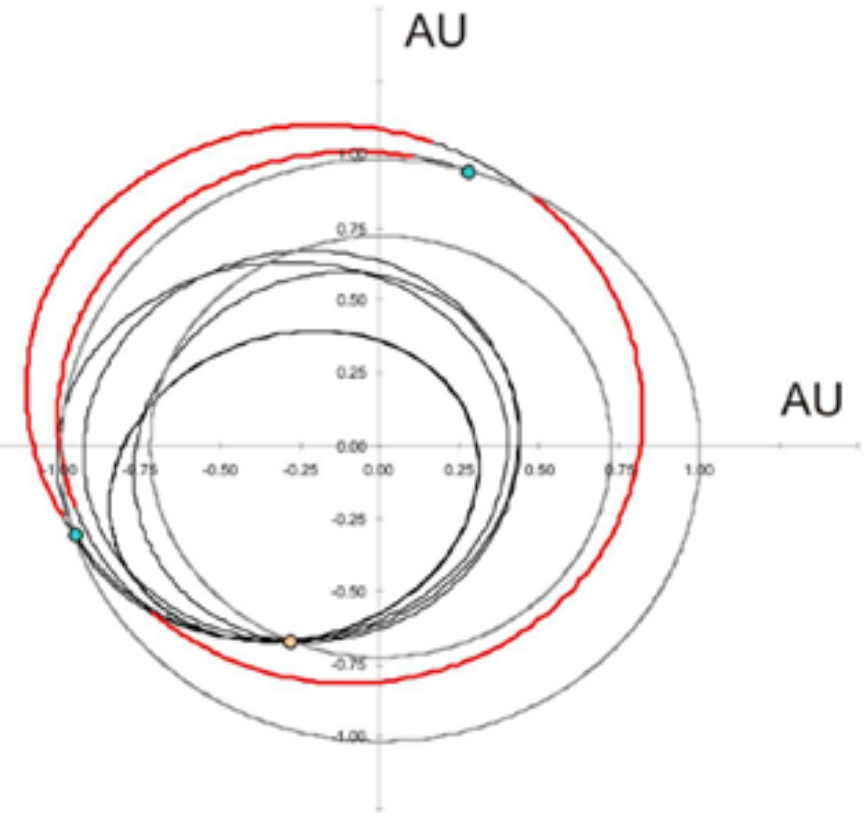
Funding	The Russian Federal Space Agency (Roscosmos)
Principal Investigators	L.M. Zeleny (IKI), V.D. Kuznetsov (IZMIRAN)
Spacecraft design	The Lavochkin Scientific Association, Russia
Number of Spacecraft	2 **Only 1 as new baseline**
Spacecraft	3-axis stabilized platform, circle-shaped shield with windows, ≈3.7×4.5×3.7 m^3
Orientation	Sun-pointing
Launcher	"Soyuz-2/1b" rocket with "Fregat" rocket stage
Cosmodrome	Baikonur, Republic of Kazakhstan
Launch date	2020 (№1), 2021 (№2) **Now 2022-2023**
Orbit	Venus resonance orbits with multiple gravity assists. Perihelion: 60-70 Rs. Aphelion: 250-260 Rs. Inclination: up to 30° to the ecliptic.
Mission active operation time	5 years
Total mass of scientific payload	160 kg
Number of scientific instruments	19
Flight Operation Center	The Lavochkin Scientific Association, Russia
Science Operation Center	IKI, Moscow, Russia
Ground stations	"Medvezgyi Ozera" (70-m antenna), Moscow Region, Russia "Ussuriysk" (70-m antenna), Russia
Scientific traffic	Up to 1 GB/day

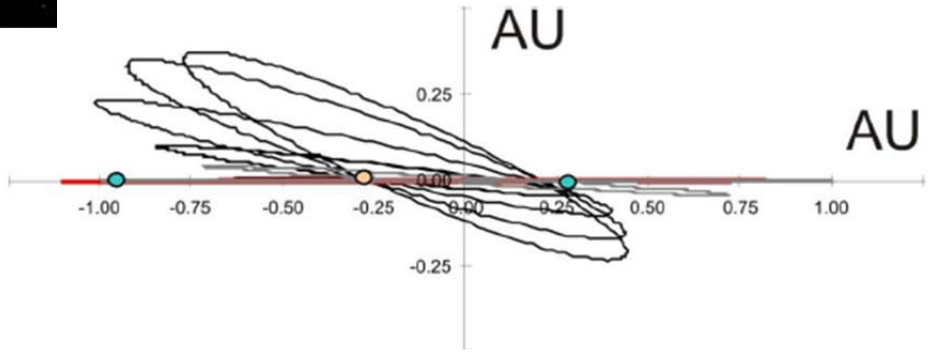
Science objectives

- Magnetic field in the solar polar regions to contribute to the understanding of the solar dynamo mechanism and solar cycle
- Fine structure and dynamics of the solar atmosphere
- Mechanisms of solar corona heating and acceleration of the solar wind
- Nature and global dynamics of the most powerful manifestations of the solar activity – solar flares and coronal mass ejections – and their influence on the heliosphere and space weather
- Processes of generation and transport of energetic particles at the Sun and in the heliosphere

Spacecraft orbits







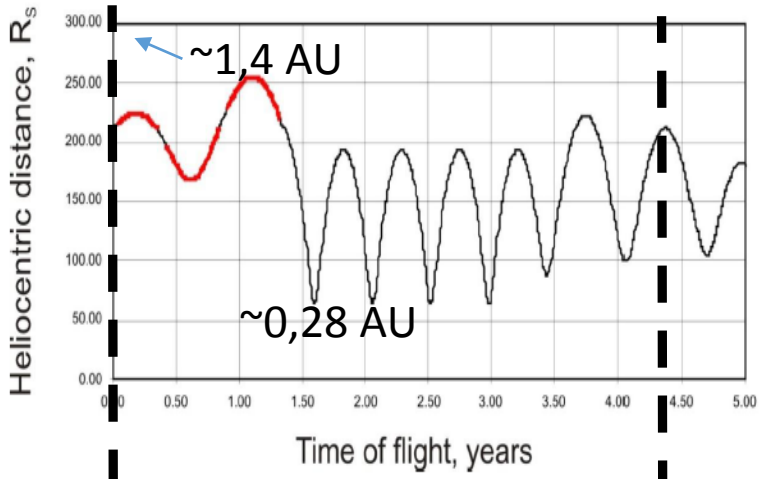
Similar to Solar orbiter:

- Down to 0.3 AU
- Up to 30° latitude

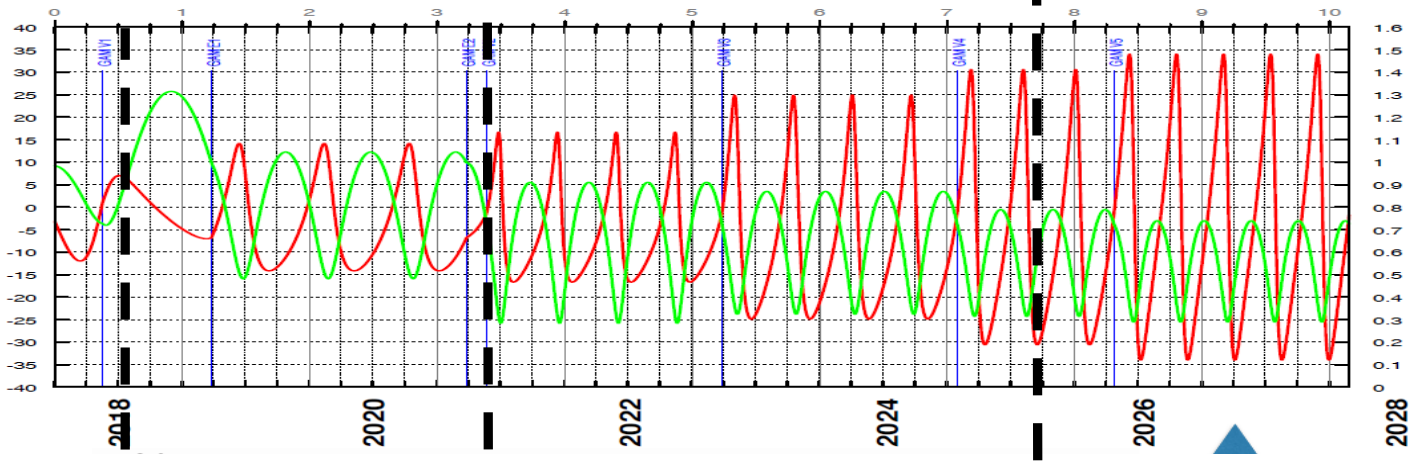
Synergies

INTERHELIOPROBE

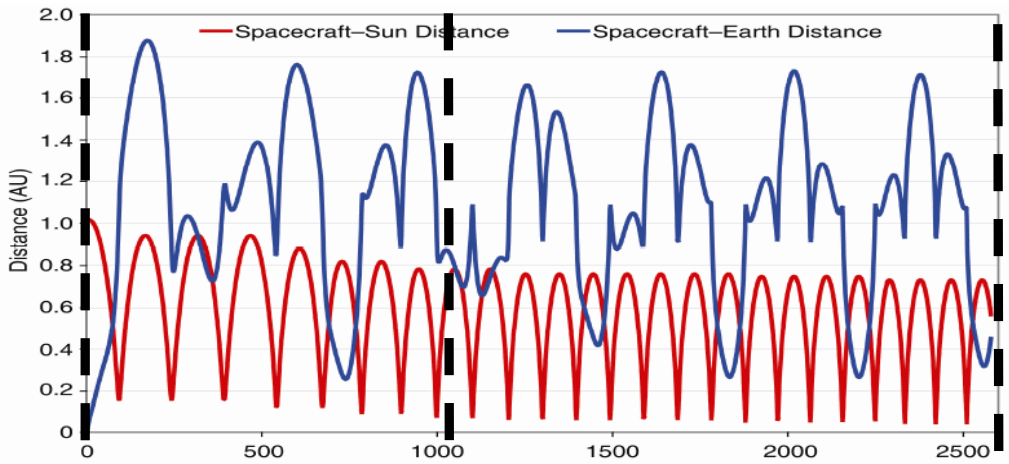
faster inward cruise
→ allows synergy



SOLAR ORBITER



SOLAR PROBE



Solar Orbiter payload

Interhelioprobe payload

Remote-Sensing Instruments	
Polarimetric and Helioseismic Imager	PHI
EUV full-Sun and high-resolution Imager	EUI
X-ray spectrometer/telescope	STIX
Coronagraph	METIS
Heliosphereic Imager	SoloHI
EUV spectral Imager	SPICE

In-situ Instruments	
Solar Wind Analyser	SWA
Magnetometer	MAG
Radio and Plasma Wave analyser	RPW
Energetic Particle Detector	EPD

From Muller et al. (Sol. Phys., 2012)

Remote-Sensing Instruments	
TAHOMAG	Multi-functional optical telescope
PHOTOSKOP	Multi-channel solar photometer
TREK	Imaging EUV and SXR telescope
SORENTO	Solar HXR telescope-spectrometer
OKA	Solar coronagraph
HELIOSPHERA	Heliosphereic Imager
CHEMIX	X-ray spectrometer
PING-M	Hard X-ray polarimeter
HELIKON-I	Scintillation gamma-spectrometer
SIGNAL	Gas gamma-ray spectrometer

In-situ Instruments	
HELIES	Analyzer of solar wind electrons
HELION	Analyzer of solar wind ions
PIPLS-B	Energy-mass-analyzer of solar wind plasma
PIPLS-A	Dust particle analyzer
HELIOMAG	Magnetometer
IMVE	Electromagnetic wave complex
RSD	Rasiospectrometer
SKI-5	Charged particle telescope
INTERSONG	Neutron detector

Payload

18 instruments:

10 remote sensing

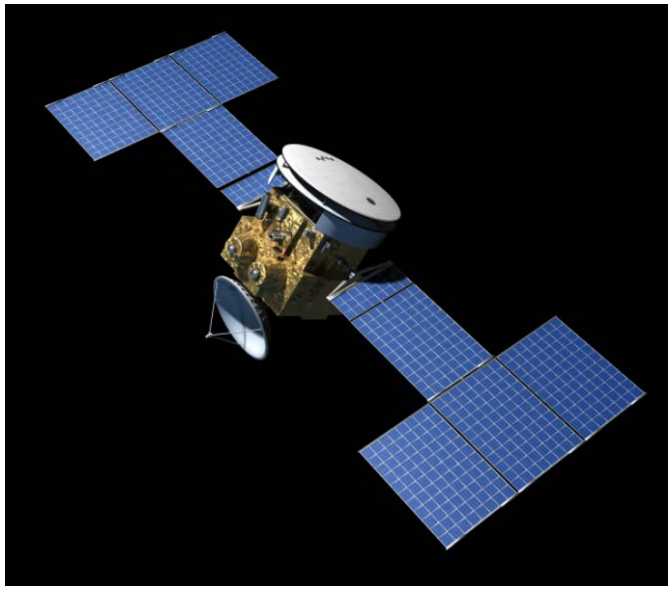
8 in situ

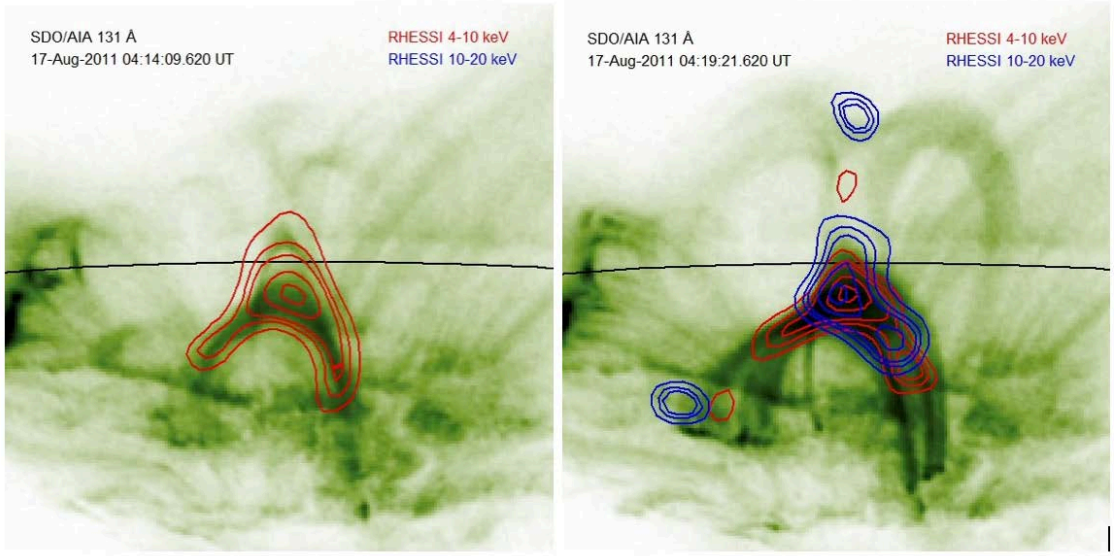
4 potential French implications

Instrument	Principal Investigator (Institution)	Collaboration
Multi-functional optical telescope **TAHOMAG**	V.N. Obridko (IZMIRAN)	IZMIRAN, NIRPHI
Multi-channel solar photometer **PHOTOSKOP**	V.D. Kuznetsov (IZMIRAN)	IZMIRAN
Imaging EUV and SXR telescope **TREK**	S.A. Bogachev (LPI)	LPI, HSCfA, CSL, IAS
Solar HXR telescope-spectrometer **SORENTO**	S.A. Bogachev (LPI)	LPI, IKI, FHNW, CEA Saclay, SSL, CBK PAN (Wroclaw)
Solar coronagraph **OKA**	S.V. Shestov (LPI)	LPI
Heliosphereic Imager **HELIOSPHERA**	S.V. Shestov (LPI)	LPI
X-ray spectrometer **CHEMIX**	J. Sylwester (CBK PAN), V.D. Kuznetsov (IZMIRAN)	CBK PAN, IZMIRAN, LPI, KKNU
Hard X-ray polarimeter **PING-M**	Y.D. Kotov (NRNU "MEPhI")	NRNU "MEPhI", IPTI, IAP
Scintillation gamma-spectrometer **HELIKON-I**	R.L. Aptekar' (IPTI)	IPTI
Gas gamma-ray spectrometer **SIGNAL**	S.E. Ulin (NRNU "MEPhI")	NRNU "MEPhI", WU
Analyzer of solar wind electrons **HELIES**	R.A. Kovrazhkin (IKI)	IKI, IRAP, ONPU
Analyzer of solar wind ions **HELION**	M.I. Verigin (IKI) V. Truhlik (IAP)	IKI, IAP, IGEP TUB, MPS, ONPU
Energy-mass-analyzer of solar wind plasma **PIPLS-B**	O.L. Vaisberg (IKI)	IKI, "Astron Electronics" (Russia)
Dust particle analyzer **PIPLS-A**	O.L. Vaisberg (IKI)	IKI
Magnetometer **HELIOMAG**	V.A. Styazhkin (IZMIRAN)	IZMIRAN, IGEP TUB, IWF, PIC GRI
Electromagnetic wave complex **IMWE**	A.A. Skalsky (IKI)	IKI, LPC2E, CU, IAP
Radiospectrometer **RSD**	V.V. Fomichev (IZMIRAN)	IZMIRAN, CBK PAN (Warsaw)
Charged particle telescope **SKI-5**	M.I. Panasyuk (SINP MSU)	SINP MSU, JAXA, KU, NU, "Arsenal" (Russia), "Idea-Medica" (Norway), "Maraphon" (Russia), NILAKT DOSAAF (Russia), NRNU "MEPhI", IKI
Neutron detector **INTERSONG**	M.I. Panasyuk (SINP MSU)	SINP MSU, JAXA, KU, NU, "Arsenal" (Russia), "Idea-Medica" (Norway), "Maraphon" (Russia), NILAKT DOSAAF (Russia), NRNU "MEPhI", IKI

SORENTO (FROM O. LIMOUSIN)

- French participation to the imaging complex of IHP1&2
  - The Hard X-ray imaging spectrometer SORENTO
  - A very similar instrument to STIX
    - From science prospective – Solar flare physics
    - From imaging principle (Fourier Transform X-ray imager)
    - From technology: Preferably precisely the same detectors
  - Participating would enable 3D observation of eruptive events
- French participation would consist of the procurement of Focal planes equipped with Caliste-SO detector units. This procurement would be a joint effort of CEA / LESIA and FHNW)



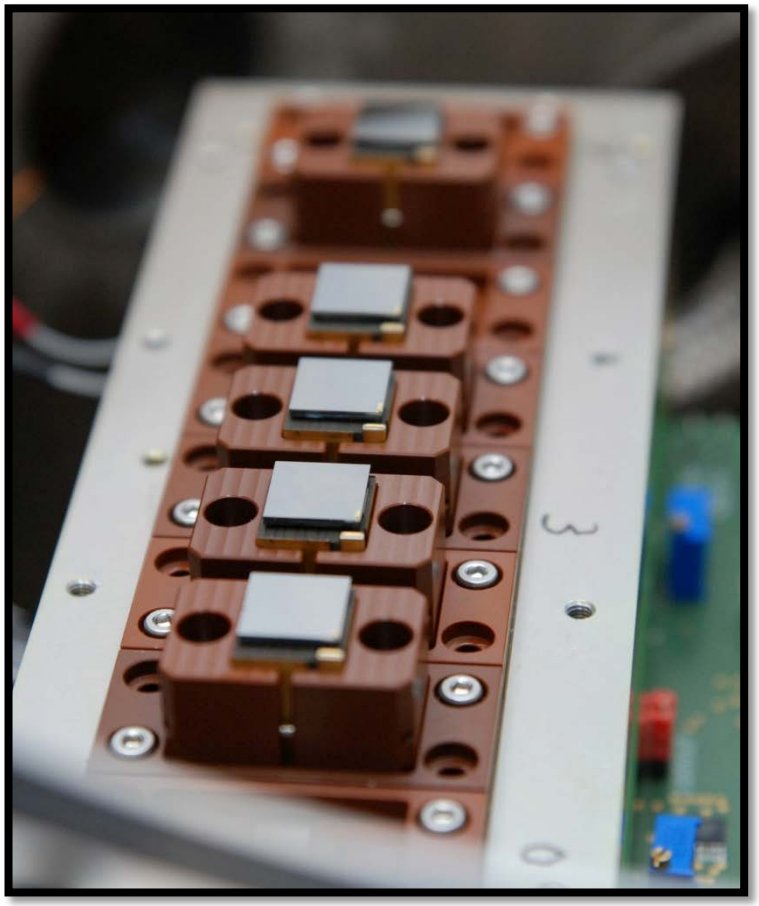


CALISTE-SO – DETECTEURS X-DURS QUALIFIÉS

Fact Sheet

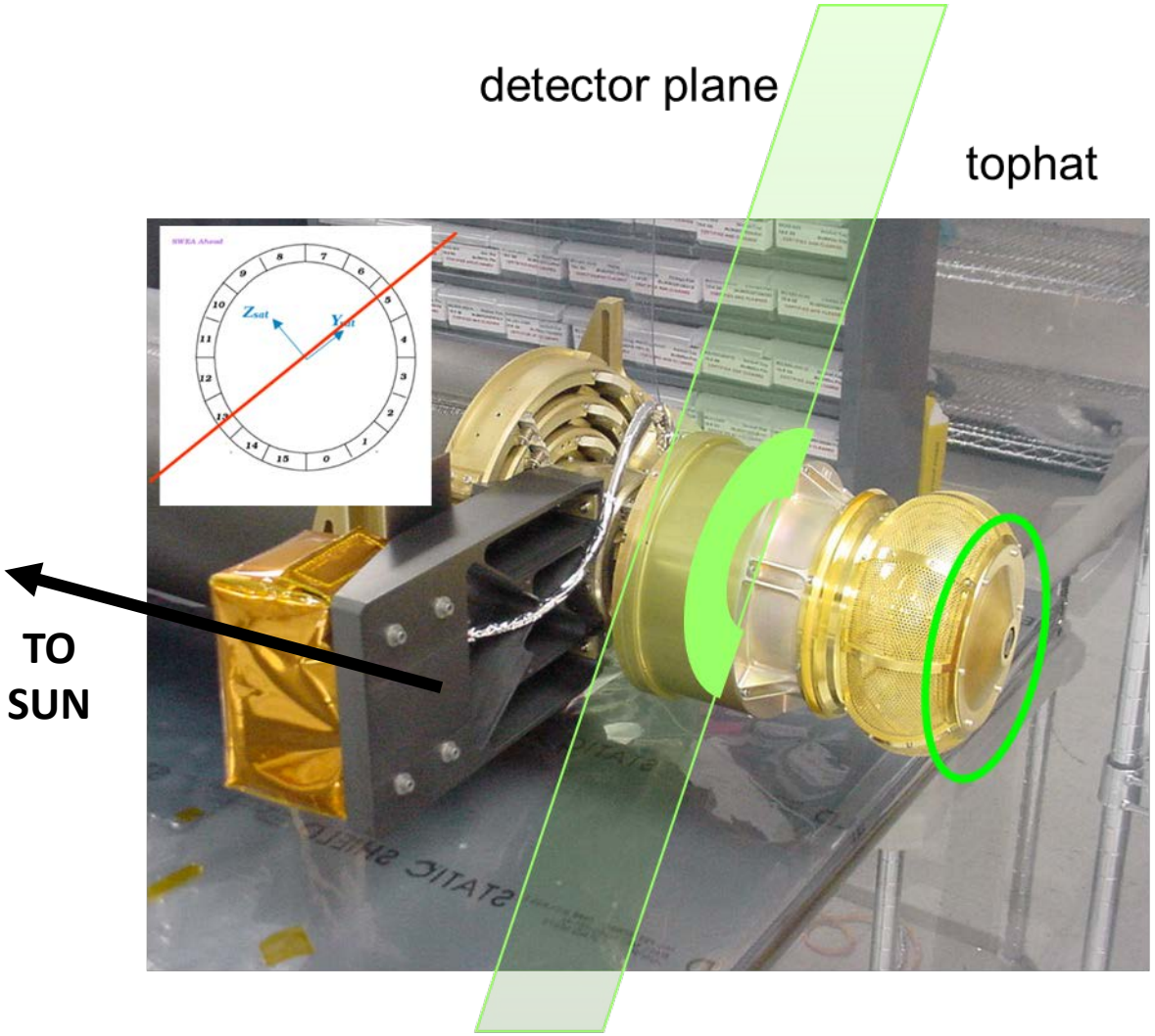
Imaging system with time-resolved spectroscopy capability

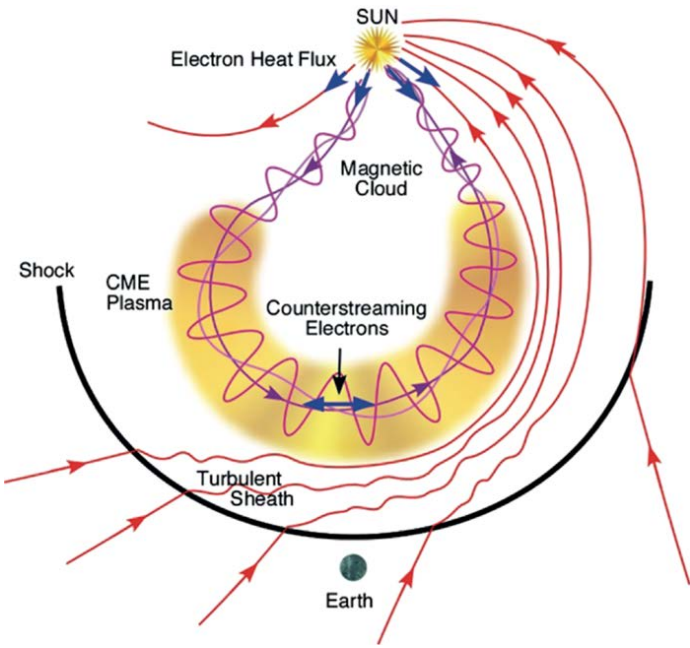
- **1 cm² detection array of 1 mm-thick CdTe**
- **12 pixels in 4 bands**
  - **Combine large and small pixels**
  - **Guard ring event rejection**
- Low dead time (10 µs)
- **High rate capability > 20 000 counts/s/cm2**
- Optimized for 2 - 250 keV energy range
- High voltage routing included
- **Low noise**
  - **<80 el. rms**
  - **Energy resolution**
  - **< 1 keV FWHM at 6 keV**
  - **~2 keV threshold**
- **Low Power per Caliste-SO, 17 mW**
- **Radiation hard, Space qualified**



Quelques modules en tests au CEA / CALISTE-SO FM – Lot 1

Implication IRAP: SW Electron Analyzer

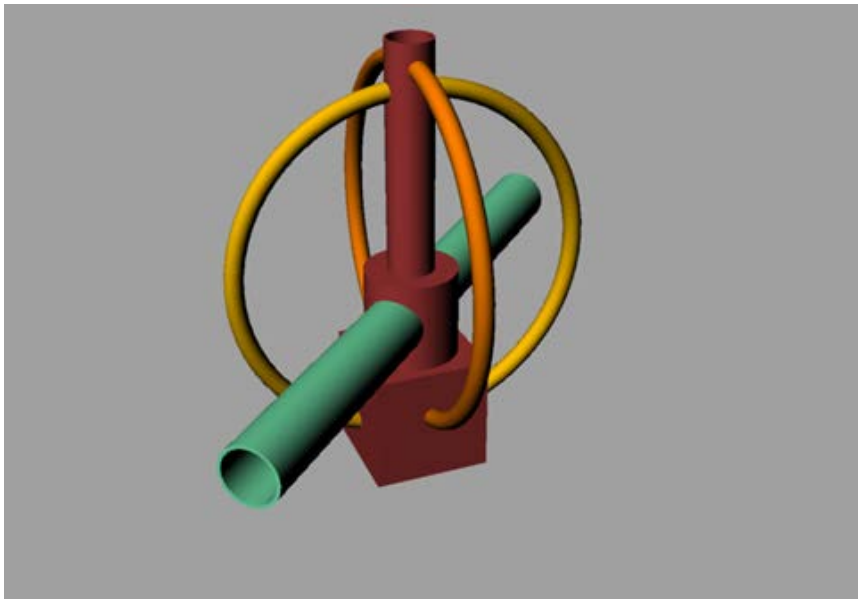




IRAP's STEREO/SWEA Solar Wind Electron Analyzer

IMWE: sensors and electronics

The “Integrated magnetic wave experiment” will measure magnetic field fluctuations at up to 40 MHZ and solar wind ion flux variations up to 32 Hz.



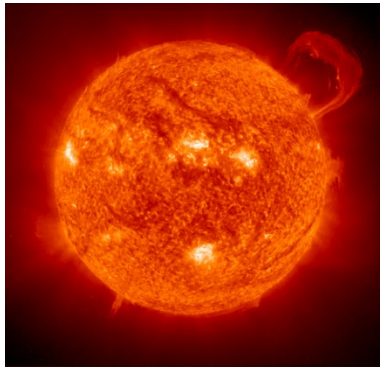
IMWE comprises:

- Double magnetic loop antenna (LPC2E Orléans)
- Flux-gate Magnetometer
- 3D search – coil magnetometer
- Set of Faraday cups
- Interface/processing unit

Vladimir KRASNOSSELSKIKH
(LPC2E/CNRS, France)

Participation de l'IAS à l'instrument TREK

Frédéric Auchère



Historique de collaboration avec l'Institut Lebedev (PI)

- Optiques EUV de CORONAS-F (identiques EIT)
- Projet de coronographe sur CORONAS Photon
- Collaboration scientifique active (publications communes)
- Données CORONAS-F archivées à MEDOC

Synergies entre EUI/Orbiter et TREK/Interhelioprobe

- S. Kuzin co-I de EUI
- Caractéristiques similaires de EUI et TREK
  - Longueurs d'onde, résolution, etc.
- Stéréoscopie / tomographie à 2 ou 3 points de vue

Etalonnage sur CaliF (IAS)

- Ligne de lumière développée à l'IAS pour Solar Orbiter
- Financement CNES / Région IDF
- Héritage SWAN, EIT/SOHO, EUVI/STEREO, EUI/Orbiter
- Deux modèles à étalonner en 2018-2019