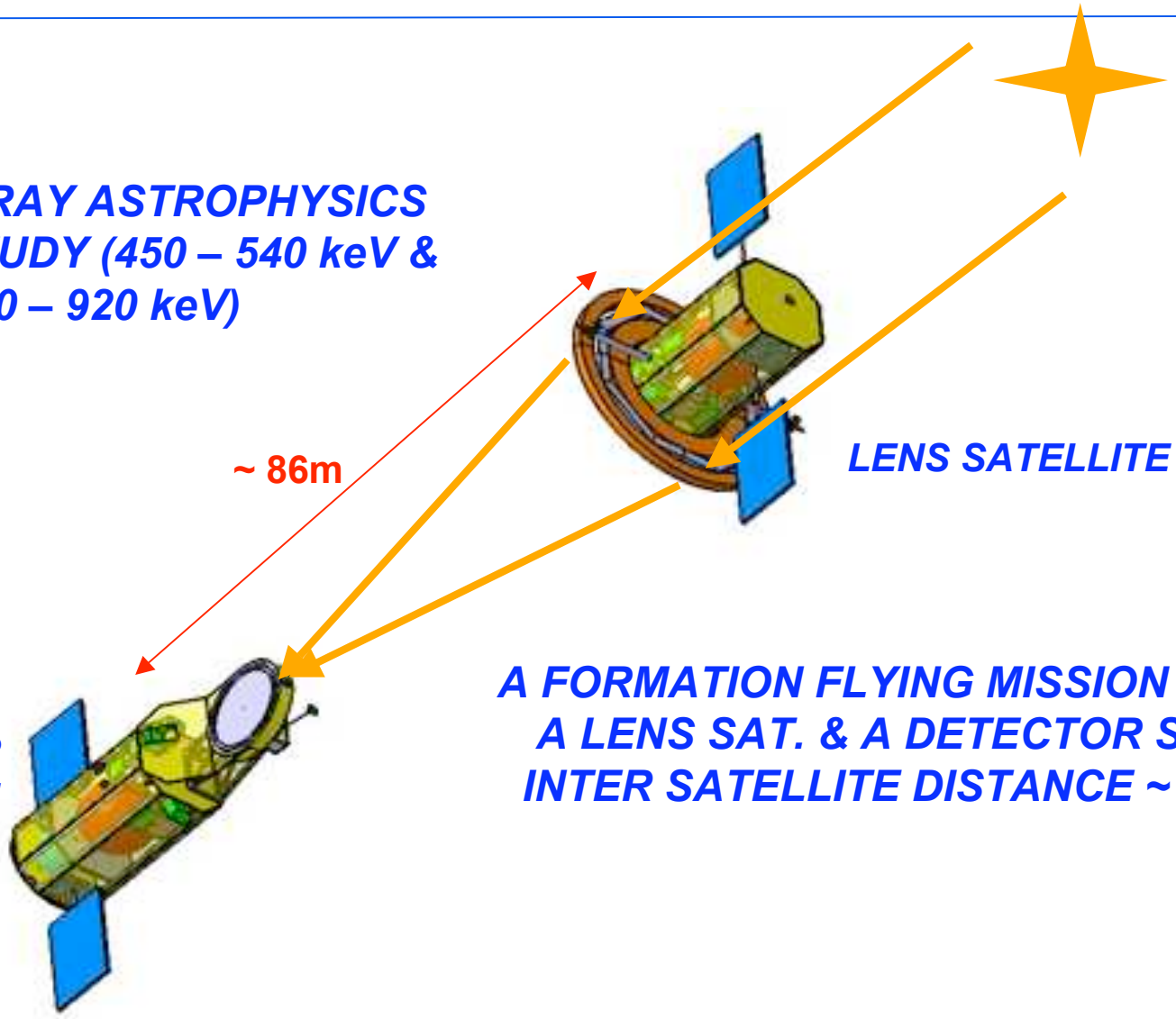
# MAX : FORMATION FLYING FOR NUCLEAR ASTROPHYSICS

***A GAMMA RAY ASTROPHYSICS MISSION STUDY (450 – 540 keV & 800 – 920 keV)***




***A FORMATION FLYING MISSION WITH A LENS SAT. & A DETECTOR SAT. INTER SATELLITE DISTANCE ~ 86M***

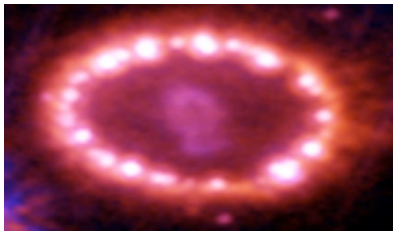
*MAX is one of the 4 formation flying astrophysics mission studied by CNES in 2005*

## SCIENTIFIC OBJECTIVES

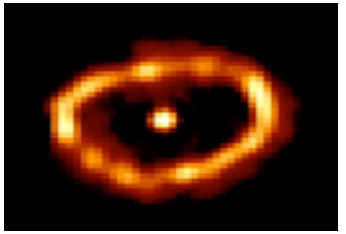
### Two main objectives and two spectral bands :

**- First band ( 800keV – 920keV) main objective :** Explosive nuclear synthesis in the **Supernovae Ia** ( $^{56}Ni \rightarrow {}^{56}Co \rightarrow {}^{56}Fe$) ===> To discriminate between various model.


**SN Ia**



**SN II (Core-collapse)**

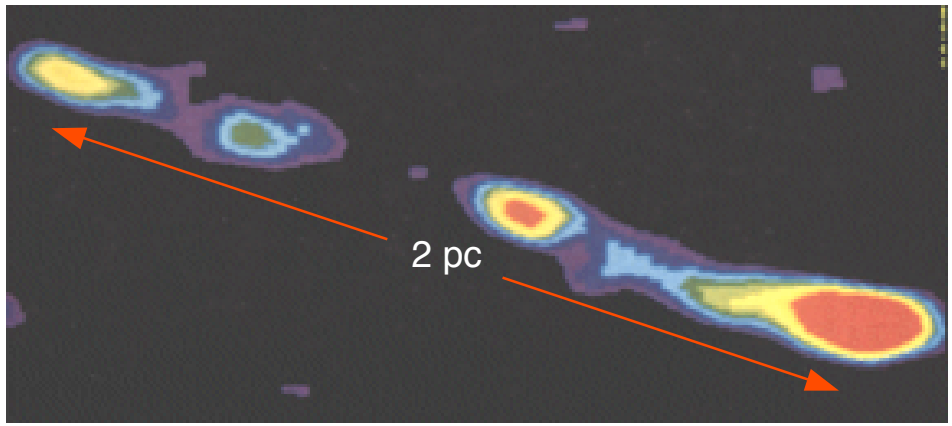


**Novae X burst**

**- Second band ( 450keV – 540keV) main objective : " 511keV annihilation ray $e^- e^+$ "** in Galactic, Dark matter, X Binaries, Microquasar,…. . Secondary objective : 478keV - $^7Li(\alpha+\alpha)$

**Microquasar**

1E1740 en radio , 1'x1': Mirabel et al. 1992




www.cesr.fr/~pvb/MAX/science

## SPACE SYSTEM STUDY - SCENARIOS

**Minimal life duration : 2.5 years with 2 years for science**

### Mission

**Science**

Instantaneous FOV:3 arc min,

Abs. Lens point. : 15 arc sec,

Observations : ~$10^6$s / target

~ 60 targets

5 kbps TM (observation)

Out of Van Allen belts,

**Spectral bands :**

450 – 540 keV
and (or) 800 – 920 keV

**Observable FOV :**

- > 2π strd (anti Sun)
- Similar to Integral or XMM,
- Similar to GAIA or Planck,

### Scientific Orbit

**HEO**

44000/253000

Low or high inclination

**L2**

Halo or Lissajous

### Launcher

Soyuz

dedicated

### Space segment

**Lens (PF~200kg) + Detector (PF~ 400kg)**

Common

Four reactions wheels on the lens spacecraft.

Cold gas propulsion on the detector spacecraft.

Hydrazine propulsion, Standard star tracker, Gyro and RF metrology for both spacecraft.

Optical lateral sensor on the detector spacecraft

**> 2π strd (anti Sun)**

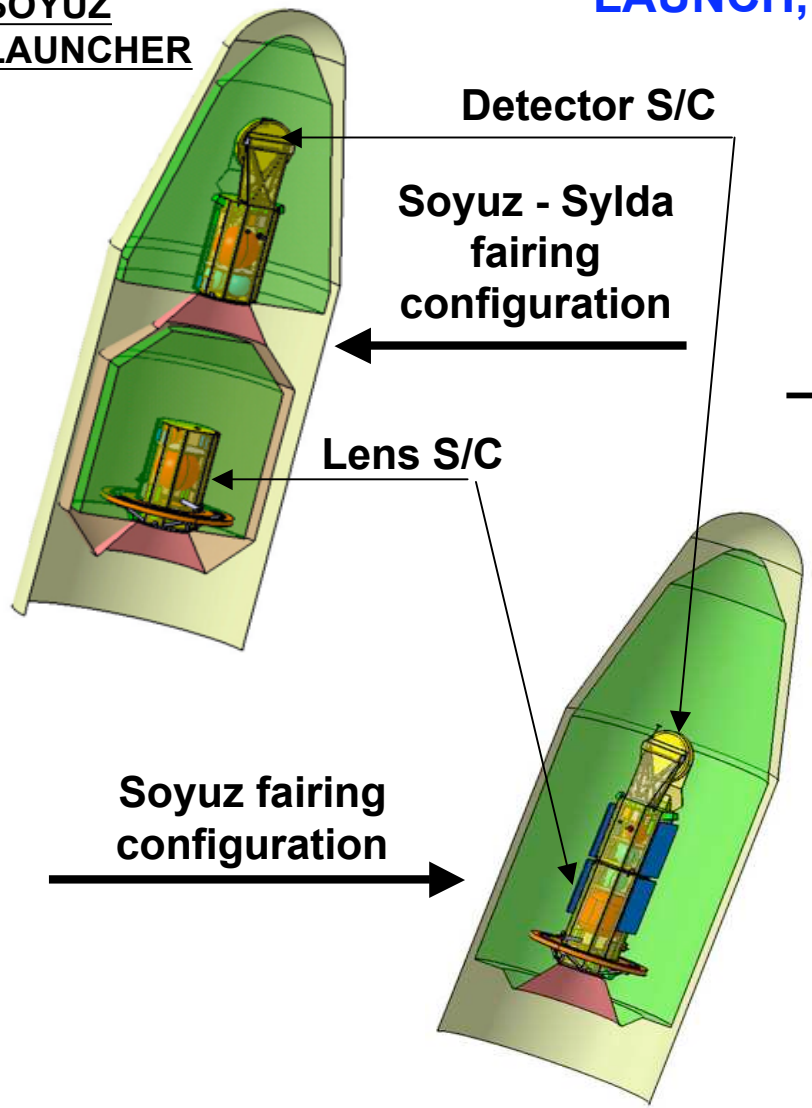
- Warm detector,
- Lens with insulation & active thermal control,
- 2 rotating Solar Generator (SG) wings
- 2 LGA 4π strd +Adjustable payload antenna or medium mass memory ( >4Gbits)

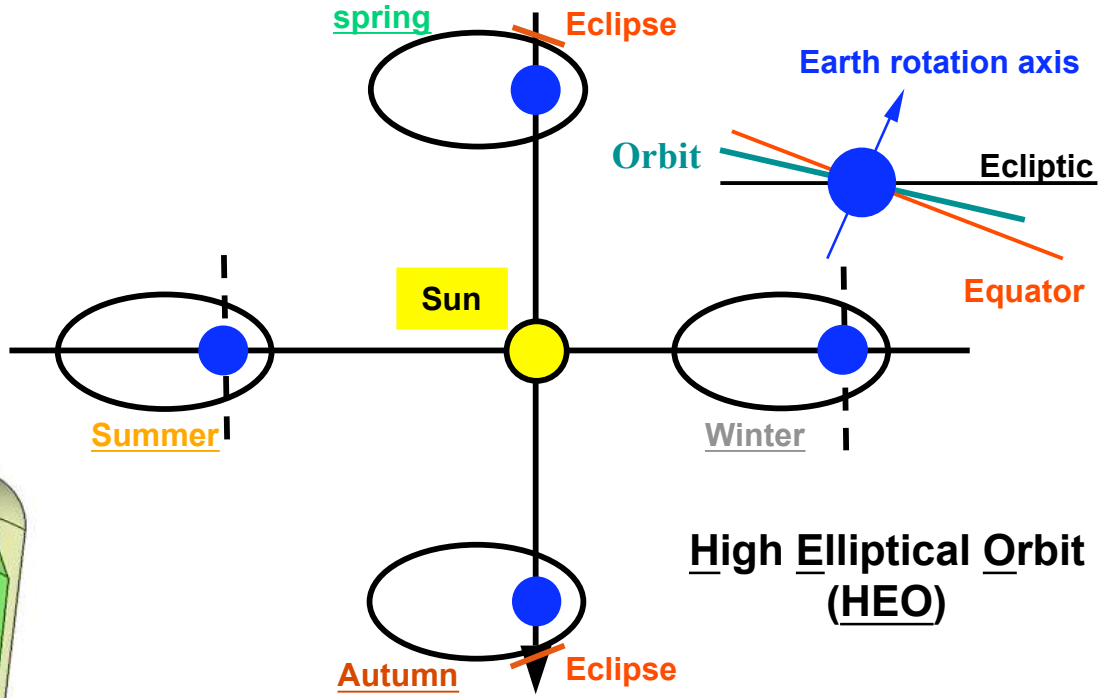
**Common Integral / XMM or GAIA / Planck**

- "Cold or warm" detector
- Fixed SG & antennas (with 2 LGA : Safe mode)

## LAUNCH, LAUNCHER & ORBIT

**SOYUZ LAUNCHER**




**High Elliptical Orbit (HEO)**

**SCIENTIFIC ORBIT PARAMETERS (Out of Van Allen belts # 90% time above 73000km)**

**Perigee Altitude : 44000 km - Apogee Altitude : 253000 km**

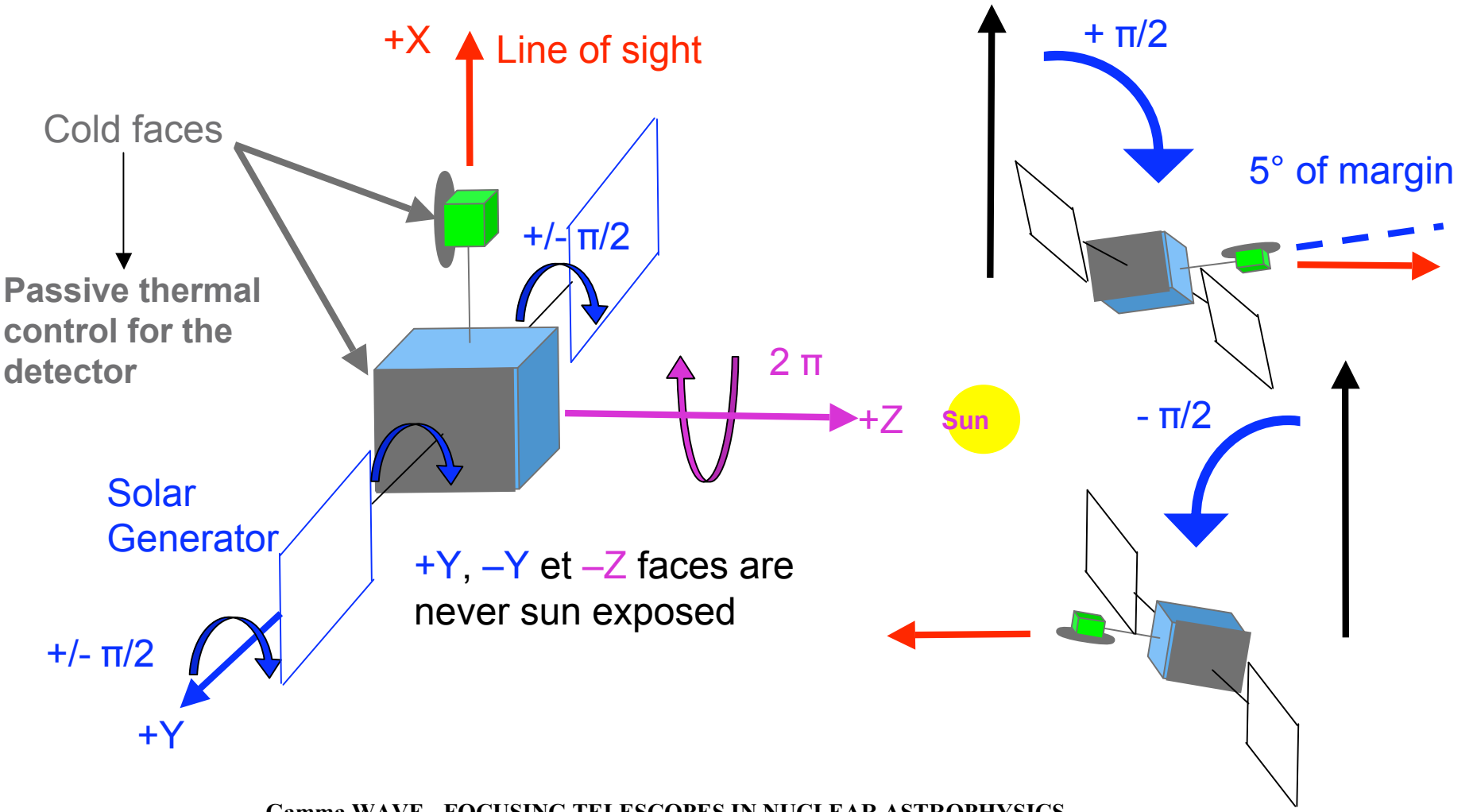
**Inclination : between 5° to 10° - Period : 7 sidereal days**

**TRANSFER ORBIT**

**Injection by Soyuz on "200 km x 253000 km" orbit from Kourou**

## OBSERVABLE FIELD OF VIEW

### OBSERVATION > 3_ STERADIANS



# FORMATION FLYING GUIDANCE NAVIGATION & CONTROL (FFGNC) (REQUIREMENTS)

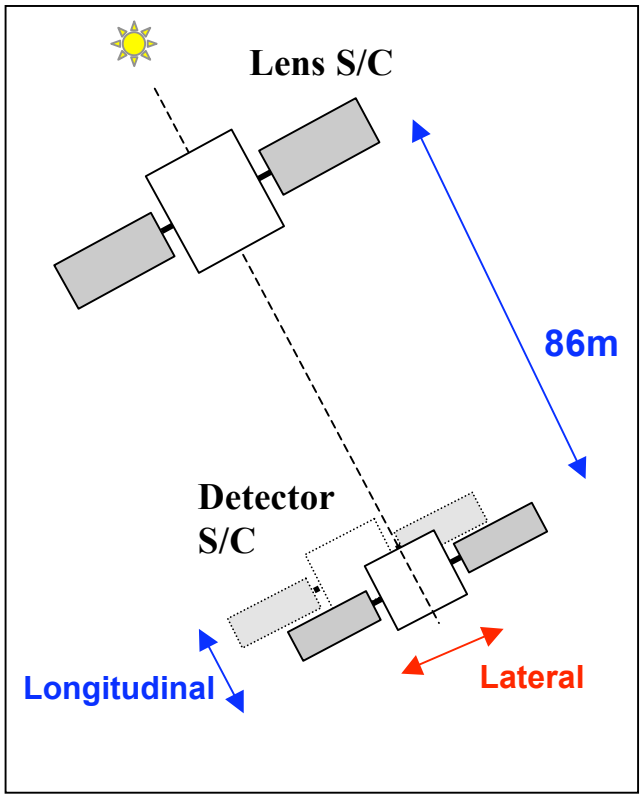
**Relative positioning :**
- lateral control (formation L.O.S.) : +/- 1 cm (+/- 24'')
- longitudinal control : +/- 10 cm
- lateral position knowledge : 1 mm (or 2'' L.O.S.)

➔ **Constraint on inertial and relative metrology :**
lateral sensor + star tracker (1'' accuracy range)

**Lens attitude control :**
- Pointing : 15 arc sec
- Stability: no constraint

**Detector attitude control:**
- Pointing : 1degree
- Stability: no constraint

➔ **Low constraint on attitude control**



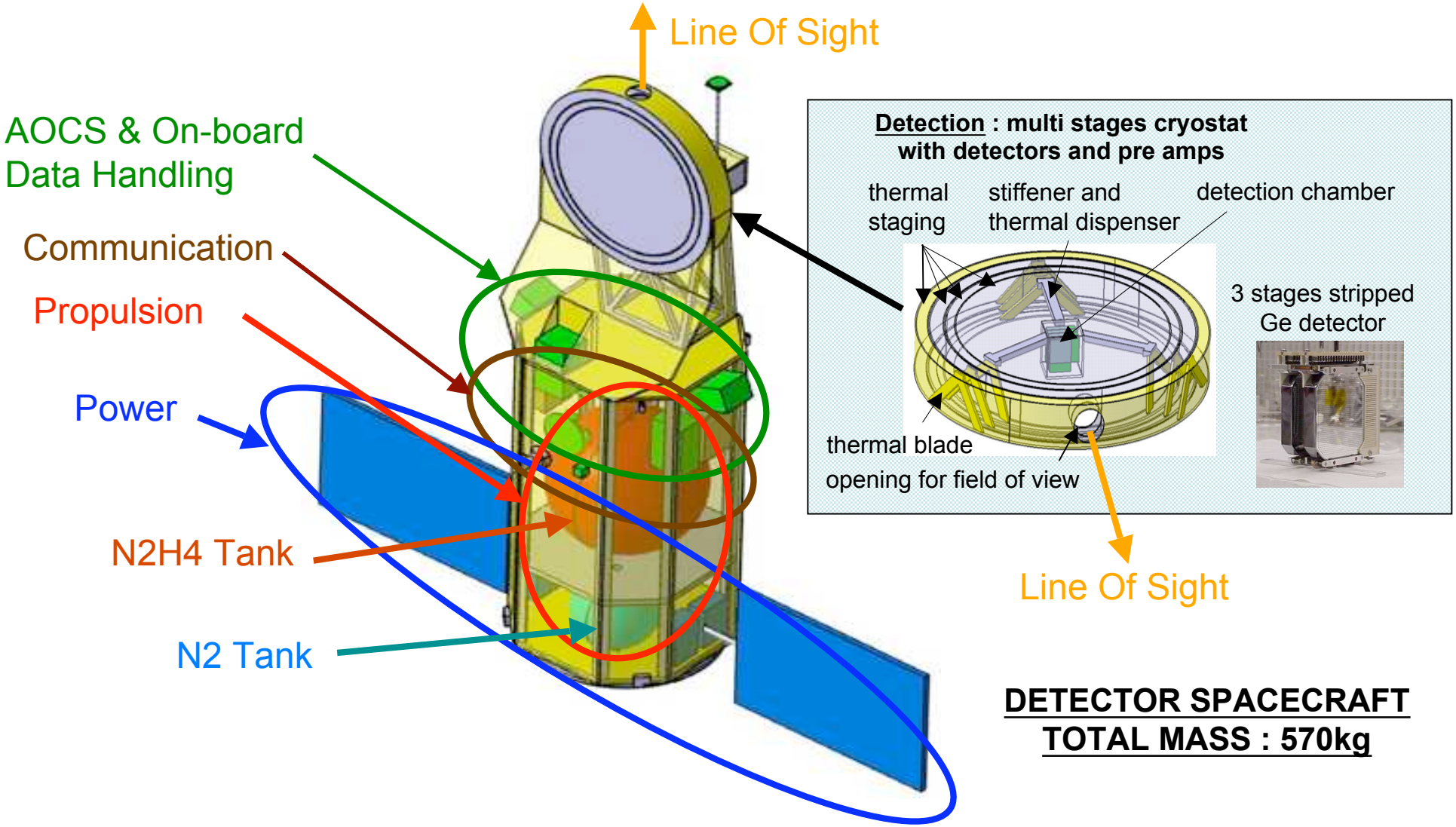
## FORMATION FLYING GUIDANCE NAVIGATION & CONTROL (FFGNC) (HARDWARE)

| | *Lens spacecraft* | *Detector spacecraft* |
|---|---|---|
| ***Metrology*** | -Standard SST (x2) + 1 gyro bloc<br><br>**- RF terminal + 1 antenna**<br>**- Corner cube** | - Fine SST (1'') + Standard SST<br>or<br>- Standard SST + accurate gyros -<br>**RF terminal + 3 antennas**<br>**- Lateral sensor** |
| ***Actuation*** | - Reaction wheels (x4) > 1 Nms<br>- Hydrazine propulsion for Orbit transfer, Station-keeping and Wheels off-loading | - Cold gas propulsion (8x2) for relative control<br>- Hydrazine propulsion for Orbit transfer and Station-keeping |

FF equipments : no critical technology in metrology (currently in development or R&D studies) and propulsion (already available)

FFGNC : Formation Flying control mainly on the detector spacecraft

## DETECTOR SPACECRAFT CONFIGURATION



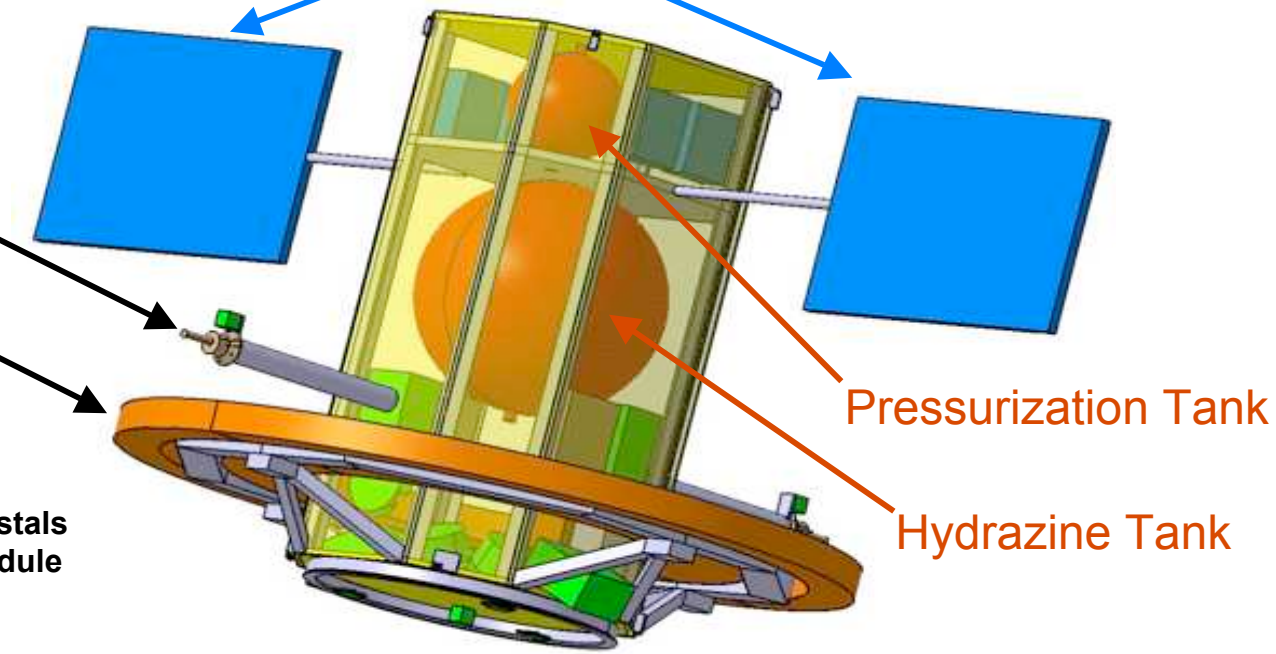

**DETECTOR SPACECRAFT TOTAL MASS : 570kg**

## LENS SPACECRAFT CONFIGURATION

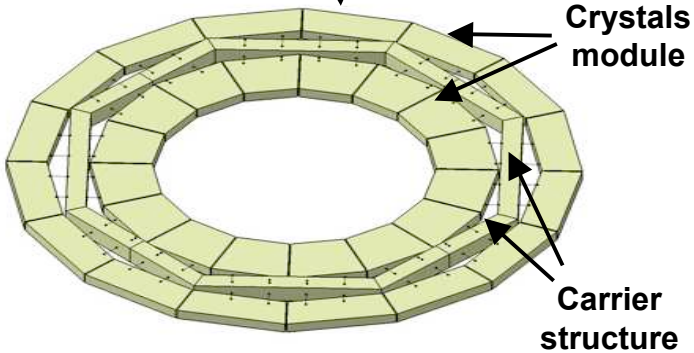
Solar Generators (+/- π/2 rotation)

Arm leaving the Sun Sensor + and S Band Antenna

Laue Lens



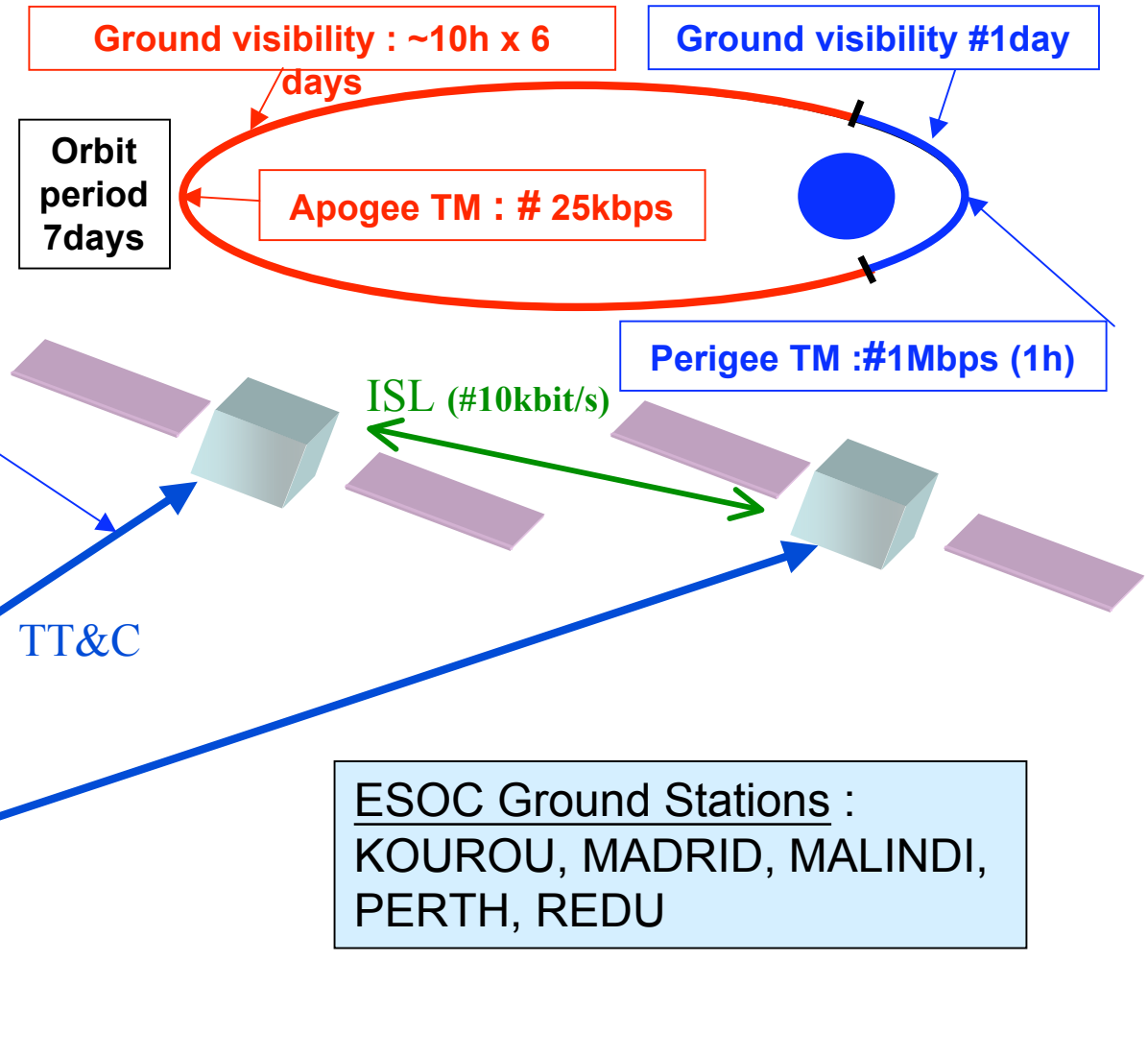

**ALCATEL**
**Structural concept**




**LENS SPACECRAFT**
**TOTAL MASS : 850kg**

## COMMUNICATION STRATEGY

- 2 communications modes
  - Housekeeping mode (TC + HKTM + ranging)
  - TMCU download (TC + TM high rate, detector only)



## SYNTHESIS

- During this study (with CESR) we shown that the accessible field of view by the MAX instrument L.O.S. (between 3π and 4πstrd) allows to maximize science observation.
- In this condition, passive cryogenics thermal system satisfies and simplifies the space system needs (lens and detector thermal subsystems).
- Special attention must be paid on the "lens quality shape". In fact, the focal of 86m requires an attitude accuracy of the germanium crystals better than 10" .
- The MAX Formation Flying performances are moderate and accessible in flight in the near future (2011- 2013 launch).
- Both orbit options (L2 & HEO) allow to release substantial mass margin (mainly for Soyuz launch in HEO : 20% + 30% system margin ) and MAX in HEO is less risky, easier and less expansive.
- The significant mass margin in HEO option could be used to add a third spectral band in addition to the "450 – 540 keV" and the "800 – 920 keV" or increase the effective area.