Università di Trieste: FISICA SPAZIALE

"Laboratorio di Astrofisica Spaziale"

Analisi dell'ambiente spaziale: studio del Sole, dell'atmosfera terrestre e della loro interazione; astrodinamica con studio particolareggiato delle orbite e delle caratteristiche di una missione spaziale (propulsione, trasmissione dati, …)

Anna Gregorio
anna.gregorio@ts.infn.it
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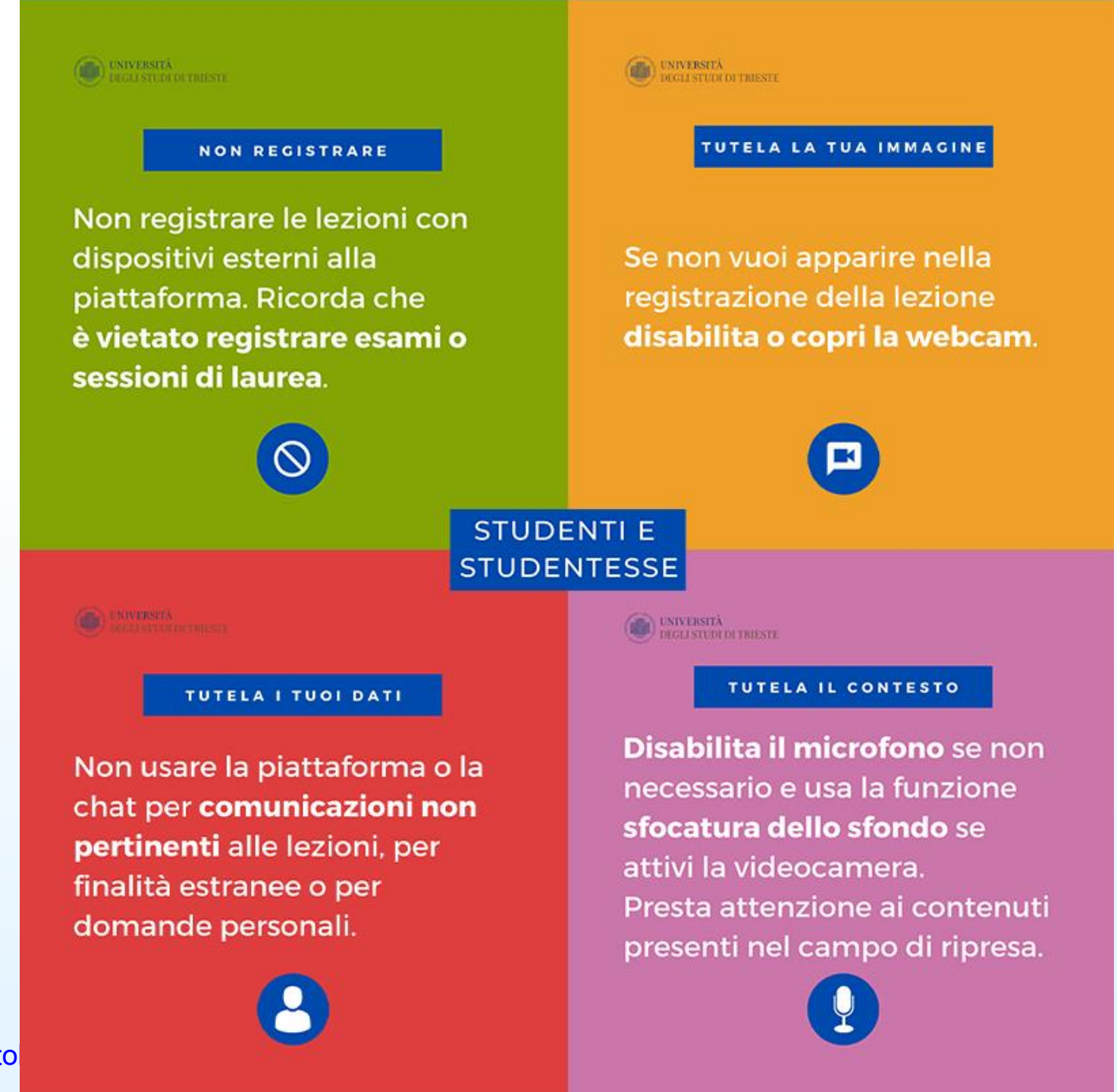

UNIVERSITÀ DEGLI STUDI DI TRIESTE
NON REGISTRARE
Non registrare le lezioni con dispositivi esterni alla piattaforma. Ricorda che **è vietato registrare esami o sessioni di laurea**.
UNIVERSITÀ DEGLI STUDI DI TRIESTE
TUTELA LA TUA IMMAGINE
Se non vuoi apparire nella registrazione della lezione **disabilita o copri la webcam**.
STUDENTI E STUDENTESSE
UNIVERSITÀ DEGLI STUDI DI TRIESTE
TUTELA I TUOI DATI
Non usare la piattaforma o la chat per **comunicazioni non pertinenti** alle lezioni, per finalità estranee o per domande personali.
UNIVERSITÀ DEGLI STUDI DI TRIESTE
TUTELA IL CONTESTO
Disabilita il microfono se non necessario e usa la funzione **sfocatura dello sfondo** se attivi la videocamera.
Presta attenzione ai contenuti presenti nel campo di ripresa.

Sommario

- Corso:
  - Programma, orario, materiale, esami, disponibilita'
- Motivazioni & Storia
- Astrofisica
- Astronomia
- Fisica della Terra
- Programmi Commerciali
- Programmi Educativi
- Conclusioni

Programma del Corso 1/2

1. INTRODUZIONE ALLA FISICA SPAZIALE
   - Scopi dell'esplorazione spaziale
   - Storia dell'esplorazione dello spazio
2. IL SOLE E L'AMBIENTE CIRCOSTANTE LA TERRA
   - Il Sole
   - L'atmosfera
   - La ionosfera
   - La magnetosfera
   - Le fasce di radiazione di Van Allen
3. INTRODUZIONE ALL'ASTRODINAMICA
   - Orbite kepleriane
   - Generalità sulle orbite
   - Cambiamenti d'orbita
   - Scelta dell'orbita per un satellite astronomico

Programma del Corso 2/2

4. GEOMETRIA DI UNA MISSIONE SPAZIALE
   - Geometria sulla sfera celeste
5. PROPULSIONE E POTENZA NELLO SPAZIO
   - Caratteristiche dei motori per razzi
   - Sistemi di propulsione
   - Sistemi di potenza
6. SISTEMI D'ASSETTO
   - Guida e controllo d'assetto
   - Sensori d'assetto
7. ULTERIORI SISTEMI DI UN SATELLITE
   - Sistema termico di un satellite
   - Struttura di un satellite
   - Telecomunicazioni di un satellite
8. LABORATORIO CON ARDUINI

Orario & materiale

- Mattino:
  - Lunedì 11-13 Ed. F – Aula C
  - Martedì 11-13 Ed. F – Aula C
- Pomeriggio:
  - Lunedì 14-18 Ed. F – Aula C
  - Martedì 14-18 Ed. F – Aula B

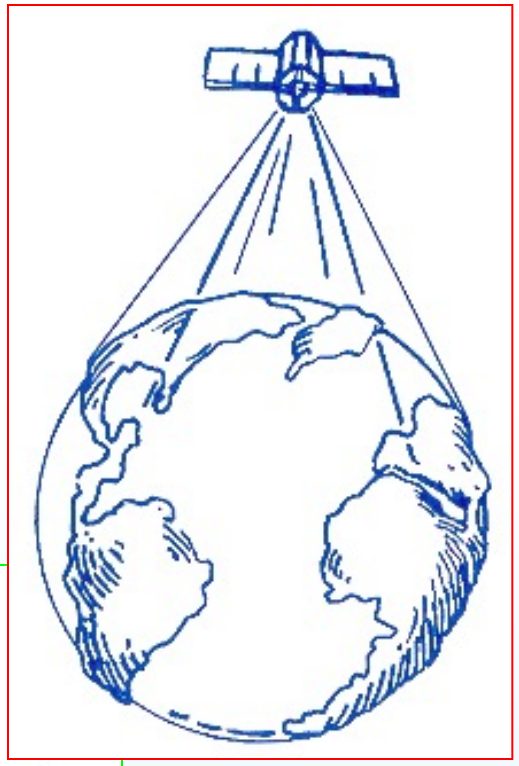
- Materiale
  - Dispense (Italiano)
  - Tutto su “Moodle” https://moodle2.units.it/
  - Libro di riferimento: “Space Mission Analysis and Design” (SMAD), J.R. Wertz and W.J. Larson, 3rd edition, Space Technology Library (in biblioteca)

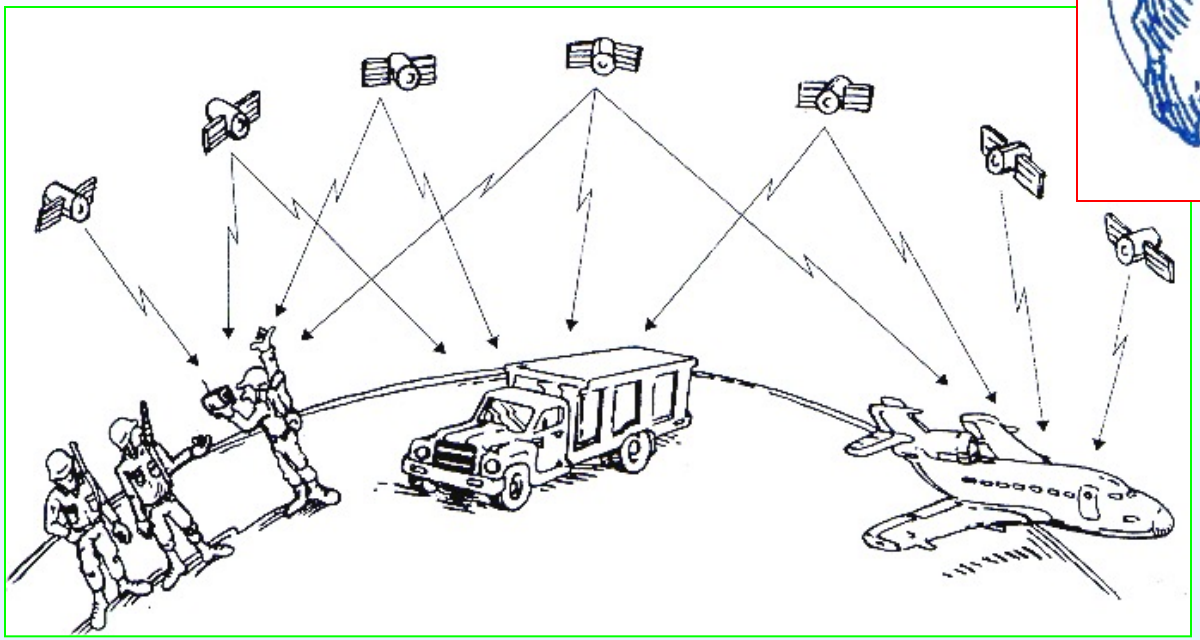
Esame & disponibilità

- Esame:
  - Seminario di 20 minuti con un approfondimento di un argomento a piacere (consiglio: venite a parlarne prima)
  - Due o tre domande sul programma
  - Avvisare almeno una settimana prima
- Disponibilità:
  - E.mail o telefono, ~~ricevimento all'Università (mer. 9-10)~~
  - Richiesta: lista e-mail e un cellulare di (almeno) una persona di riferimento
- Altro:
  - PC a disposizione? E.mail & mac-address

Motivazioni 1/2

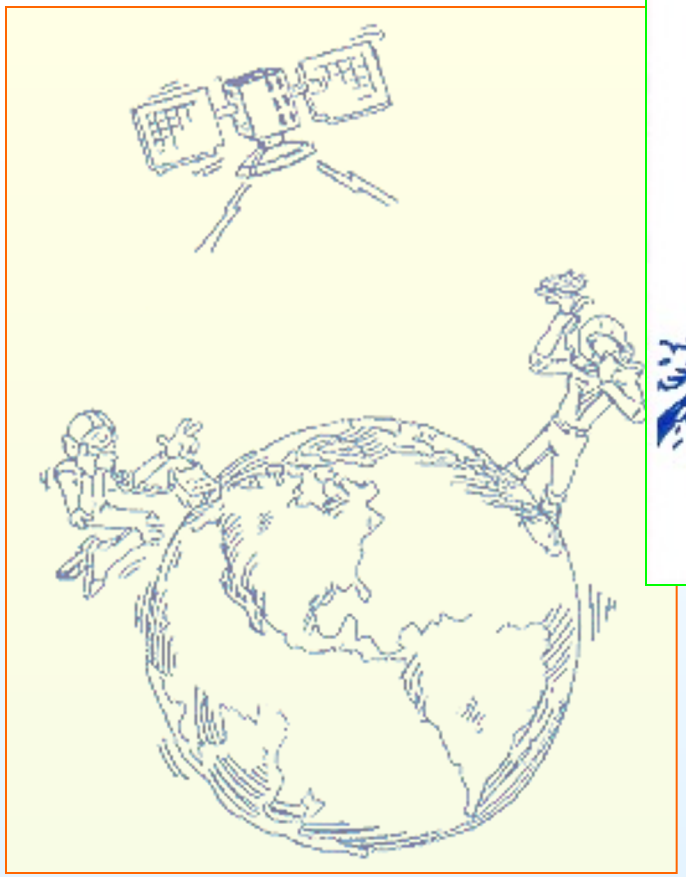
- Osservazioni della Terra
- Comunicazioni
- Navigazione





Motivazioni 2/2

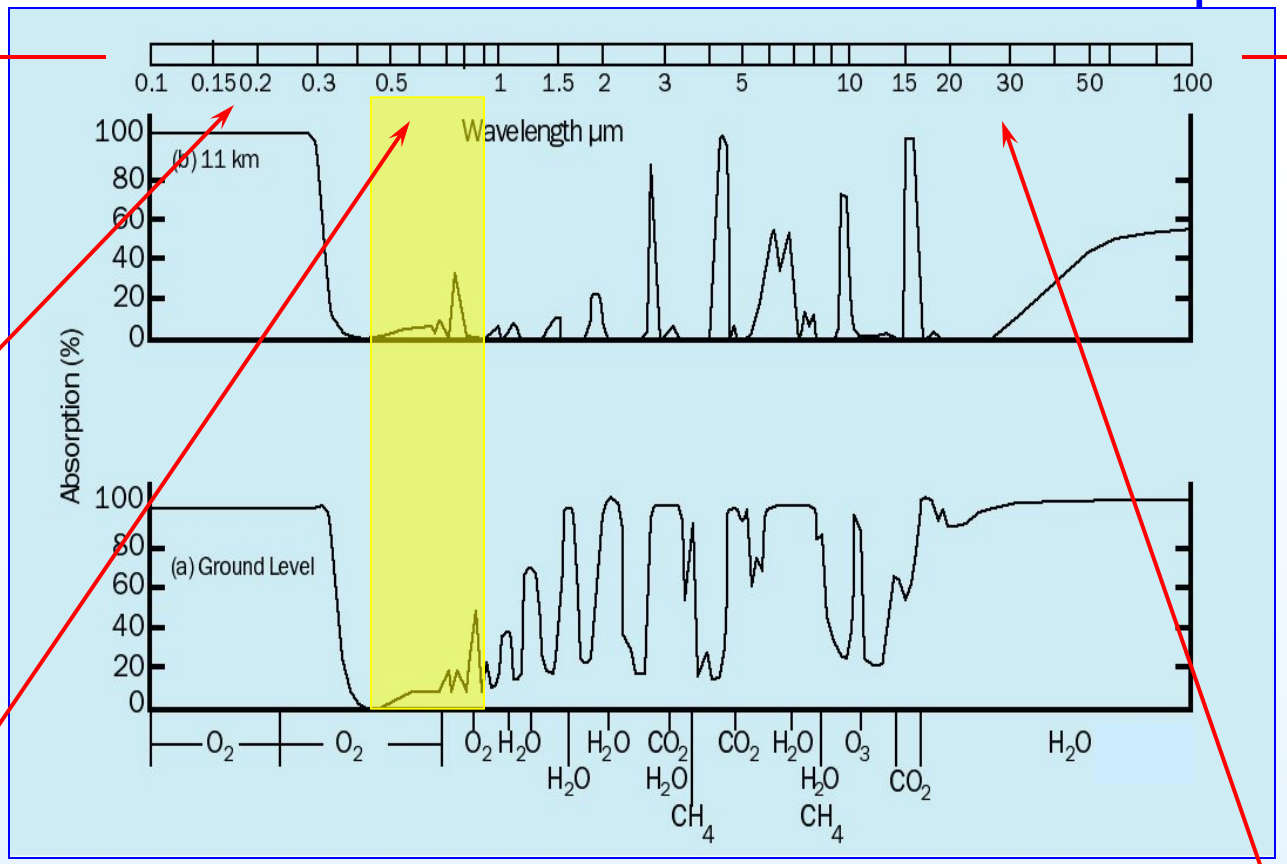
- Scienza
- Esplorazione



Atmosfera

Raggi X / γ: gas intergalattico, dischi accrescimento

Microonde / Onde Corte: fondo radiazione cosmica, elettroni in campi magnetici



UV: stelle calde

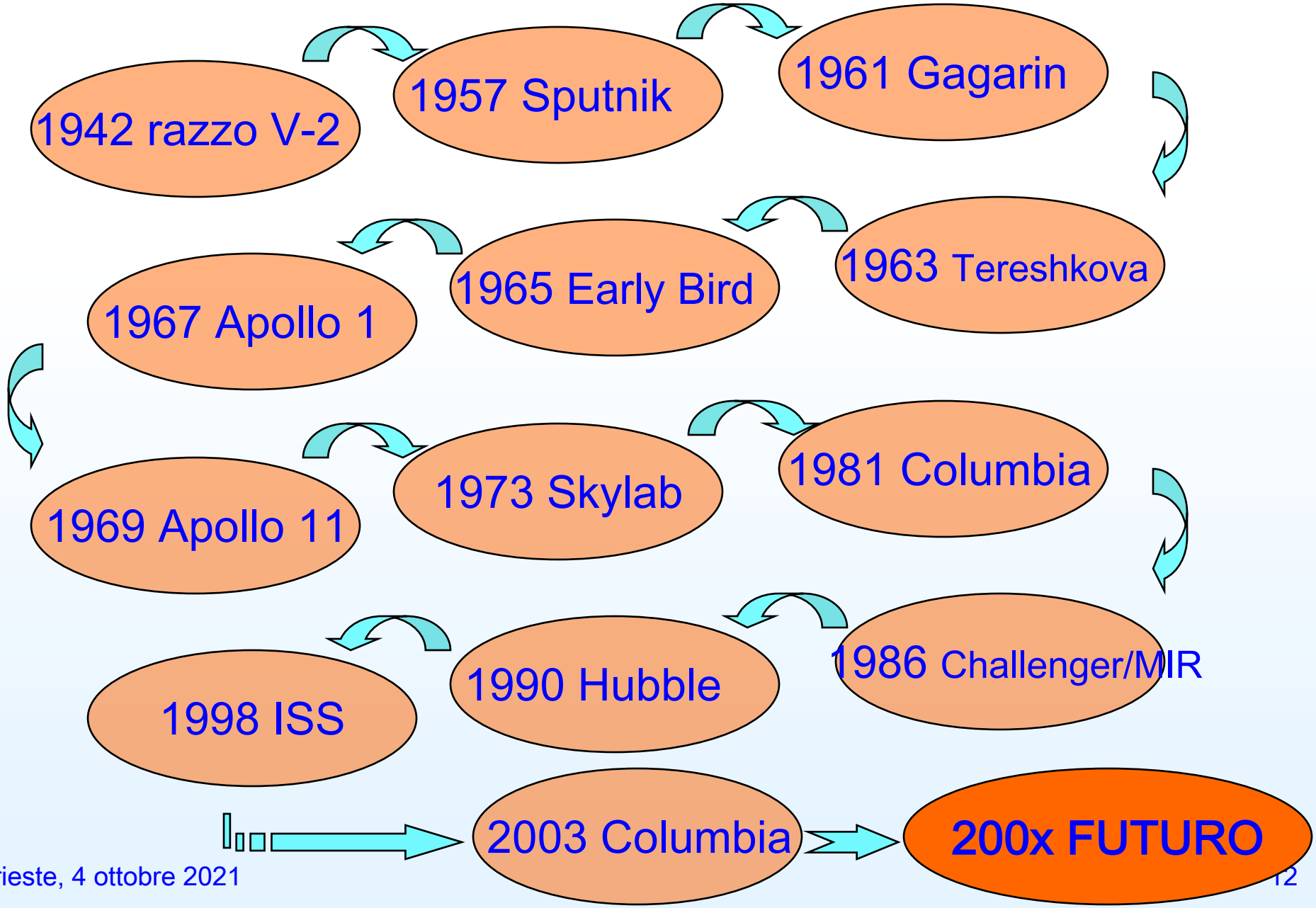
Visibile: stelle fredde

IR: polveri cosmiche, comete

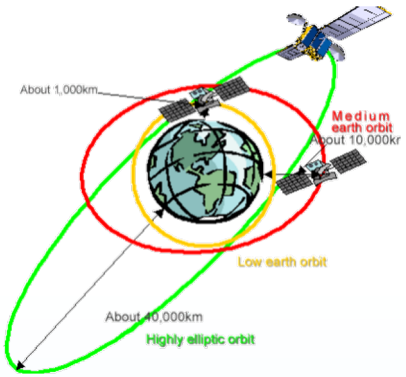
Storia 1

YouTube “Escape Velocity - A Quick History of Space Exploration”

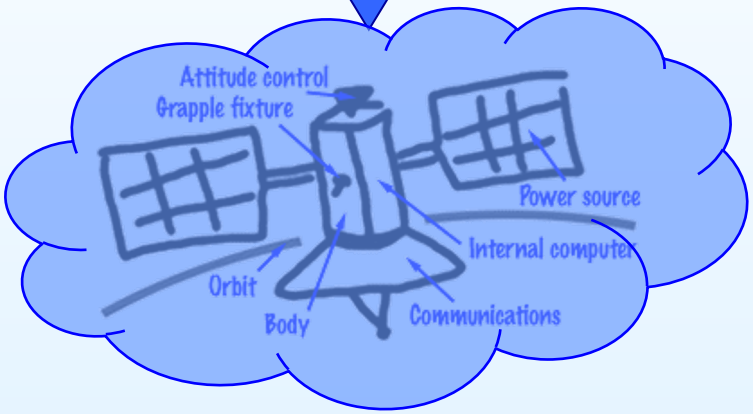
Storia 2


1942 razzo V-2
1957 Sputnik
1961 Gagarin
1963 Tereshkova
1965 Early Bird
1967 Apollo 1
1969 Apollo 11
1973 Skylab
1981 Columbia
1986 Challenger/MIR
1990 Hubble
1998 ISS
2003 Columbia
200x FUTURO

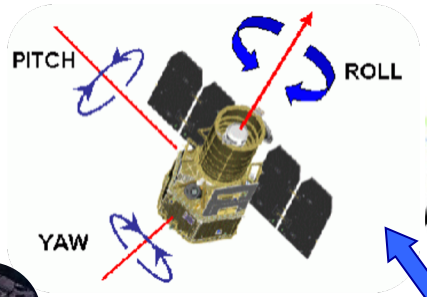
Una Missione Satellitare

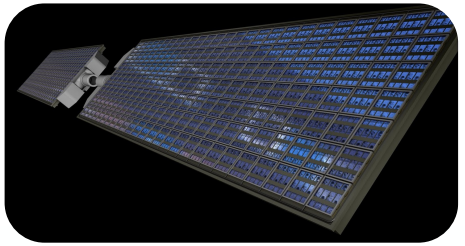


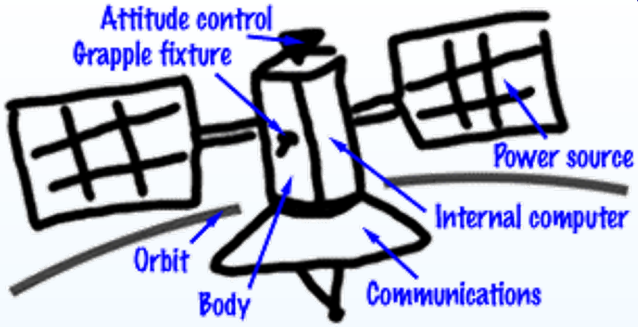
Missione Satellitare

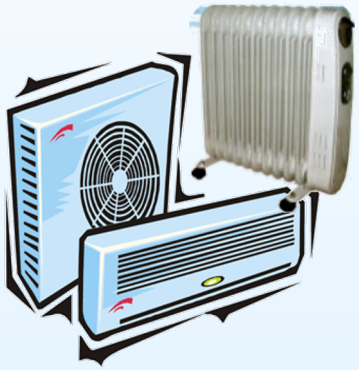


I Sistemi di un Satellite 1/2



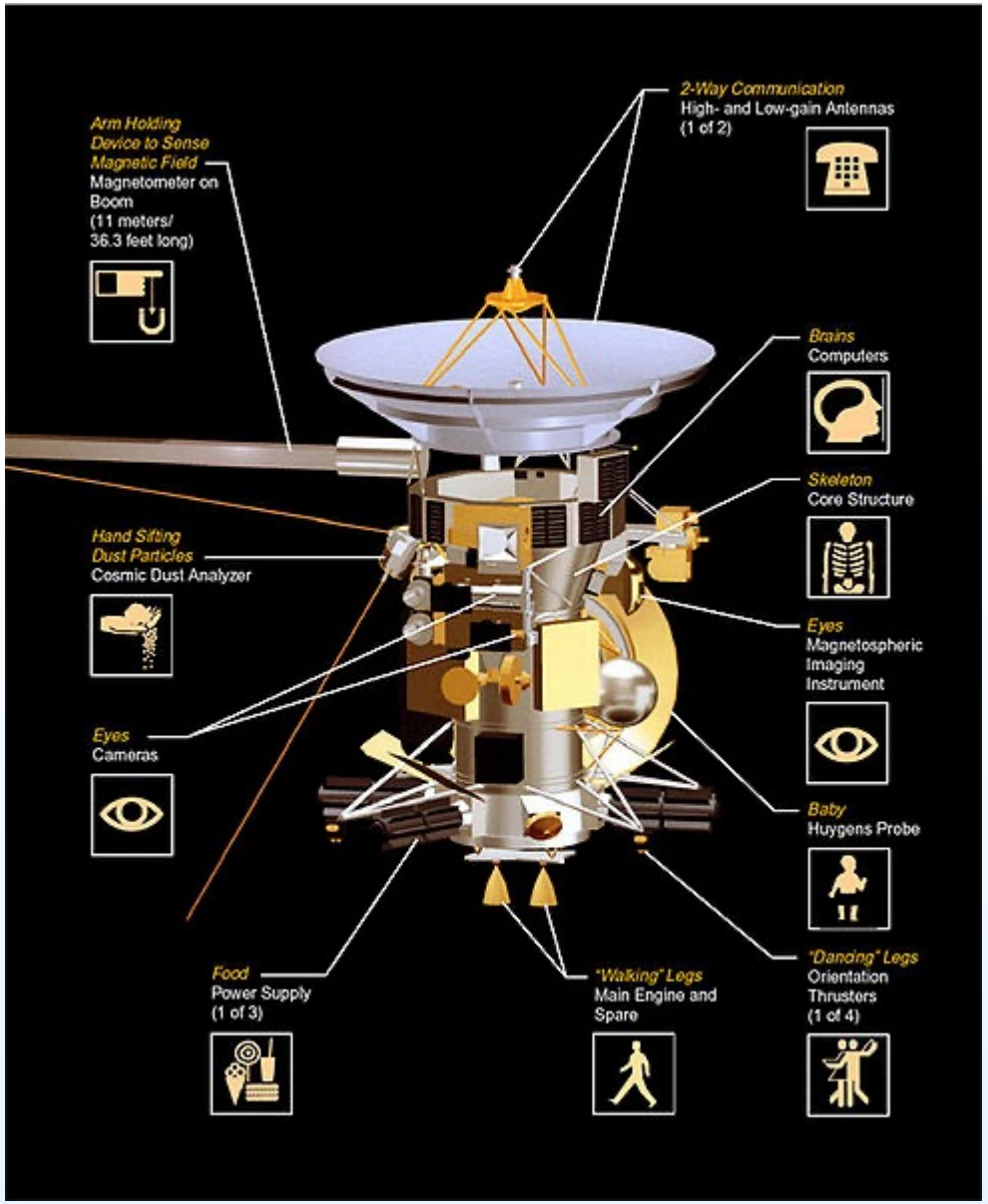






I Sistemi di un Satellite 2/2

Cassini – Huygens



Difficoltà Tecniche 1/2

- Condizioni ostili ambiente spaziale:
  - escursioni termiche
  - vuoto
  - dosi di radiazione cosmica
  - particelle e frammenti
- Problematiche al lancio (vibrazioni)
- Strumentazione di dimensioni, massa e consumi ridotti

Difficoltà Tecniche 2/2

Radiazione nello Spazio (esempio)

Componenti Primarie

- Raggi Cosmici – particelle provenienti dallo spazio profondo
- Particelle Solari – particelle provenienti dal Sole
- Cinture di Radiazione – cinture di particelle energetiche che circondano la Terra

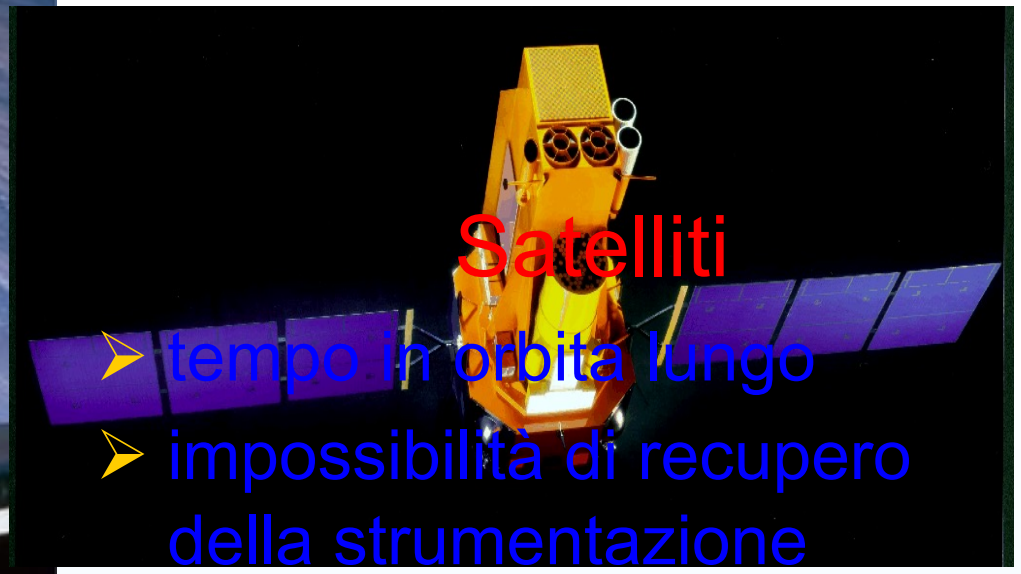
Componenti Secondarie

- Sciami Elettromagnetici – raggi cosmici nell'atmosfera
- Bremsstrahlung – elettroni attraverso un materiale/atmosfera
- Scintillazione (fluorescenza) particelle attraverso l'azoto atmosferico o componenti ottiche
- Radiazione Cherenkov – flash prodotti da particelle ad alta velocità attraverso materiali

Strategia

Navette Spaziali (Shuttle)

- tempo in orbita breve
- recupero della strumentazione



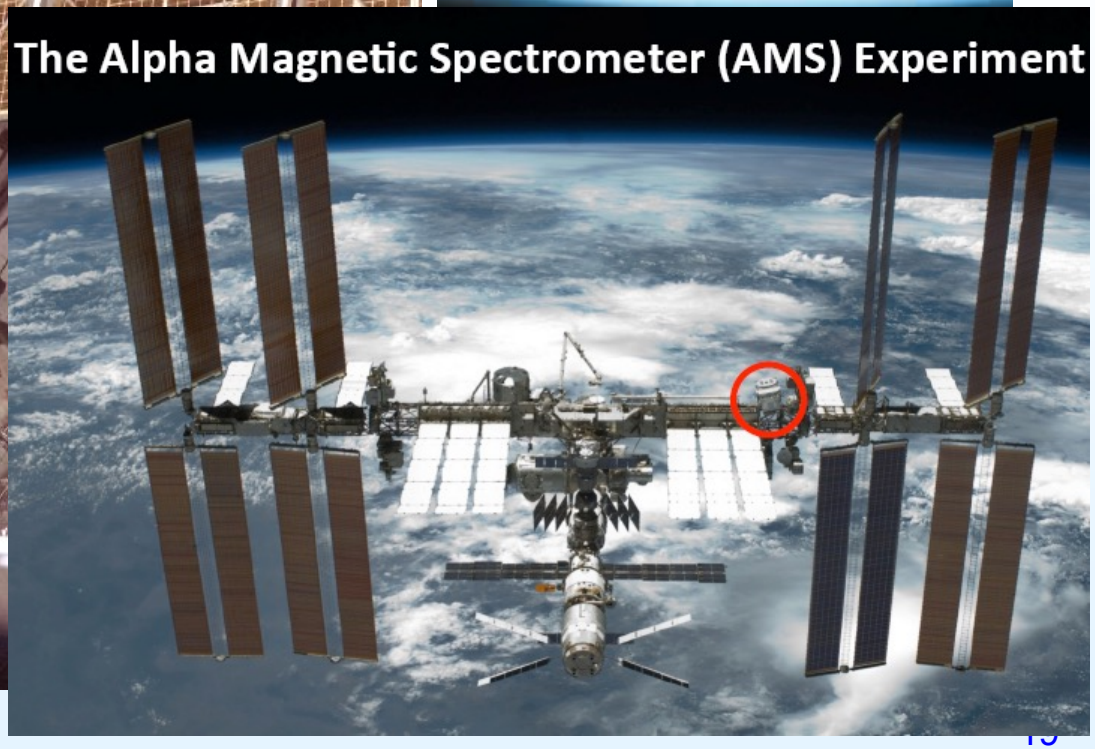
Satelliti

- tempo in orbita lungo
- impossibilità di recupero della strumentazione

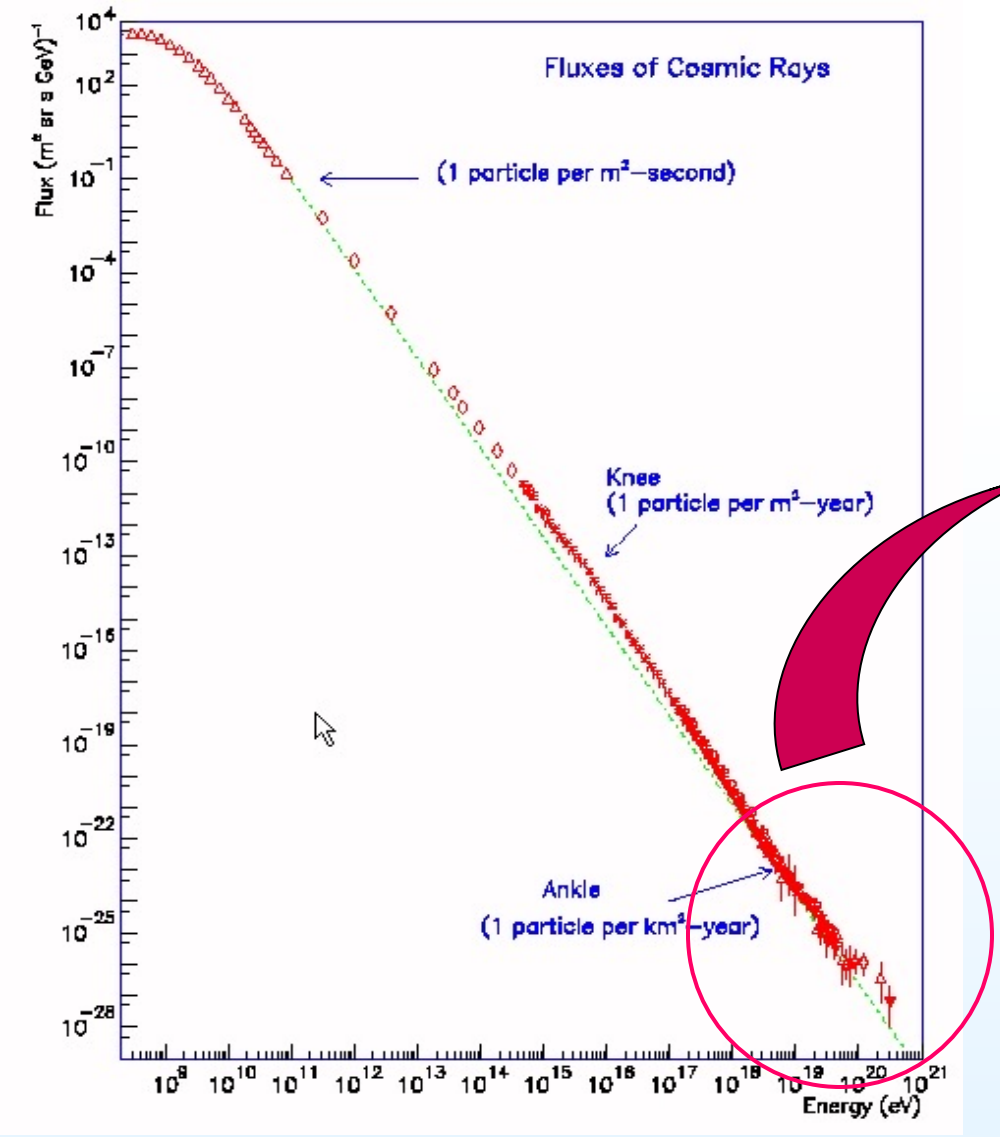
Stazione Spaziale Internazionale (ISS)

- tempo in orbita lungo
- recupero della strumentazione

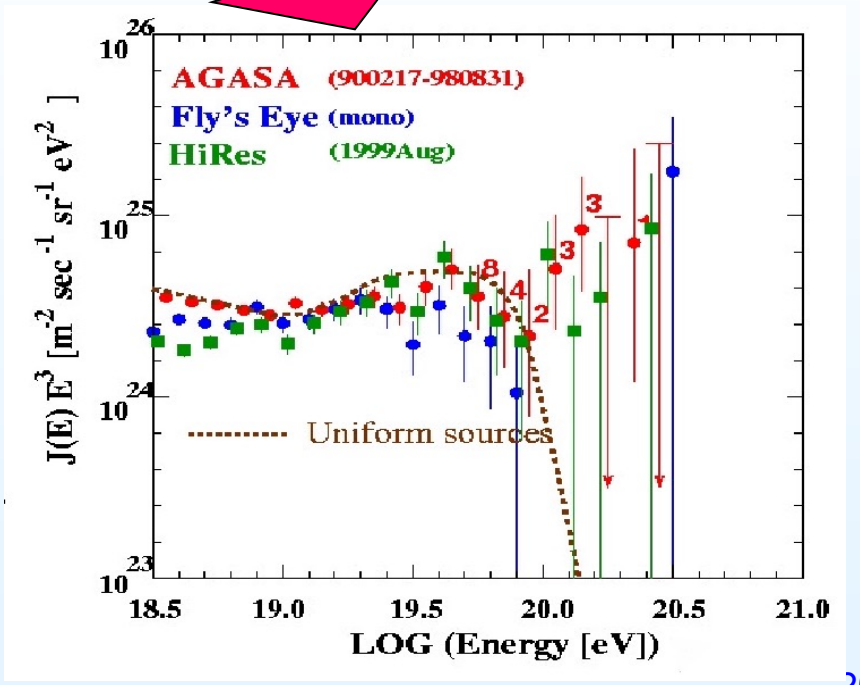
Astrofisica: XMM - GLAST – AMS



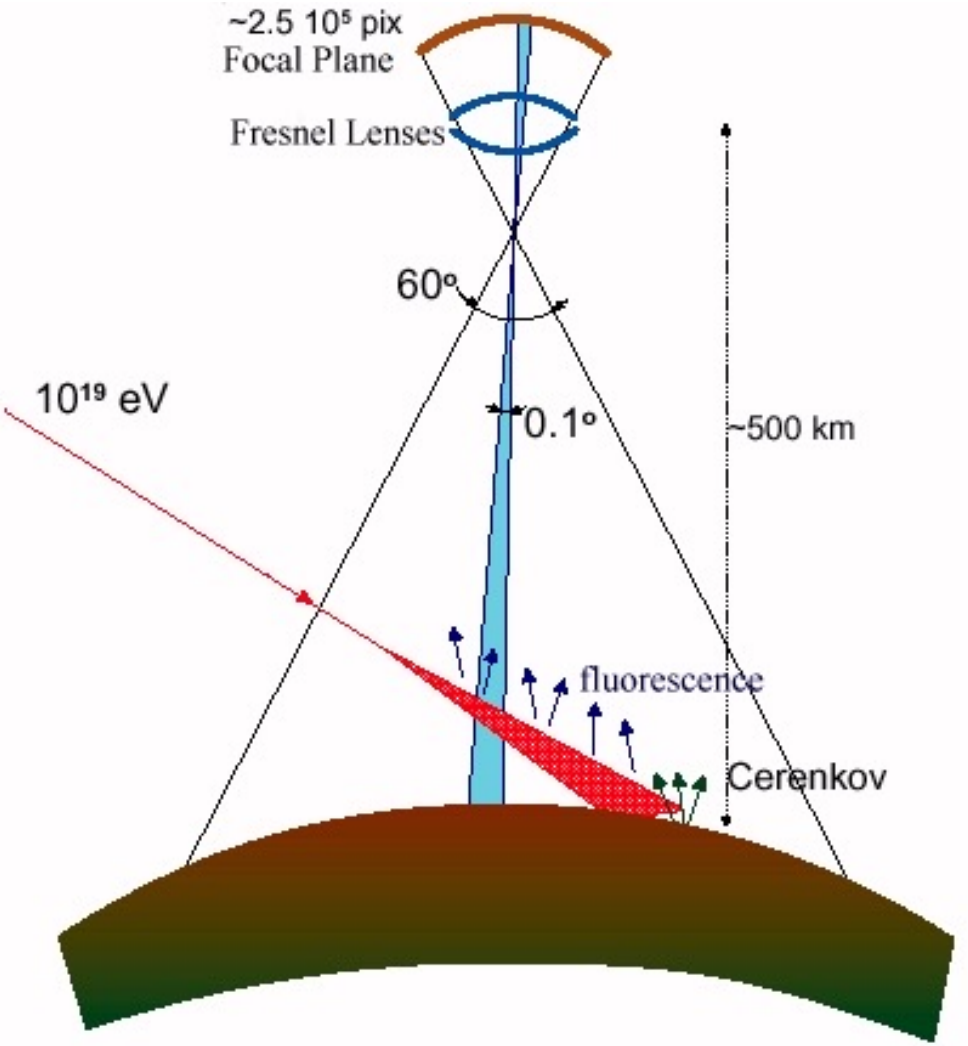
EUSO 1/2



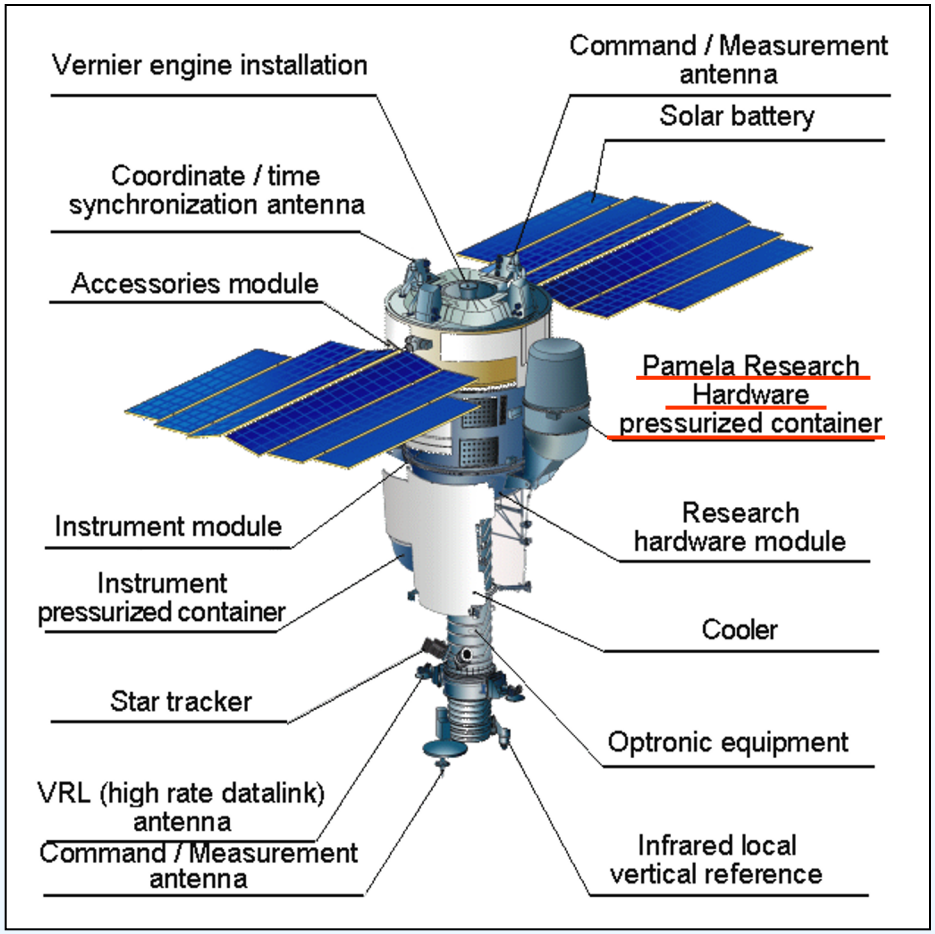
Flusso estremamente basso:
≈1 evento/sr/km²/secolo
⇓
300 eventi



EUSO 2/2

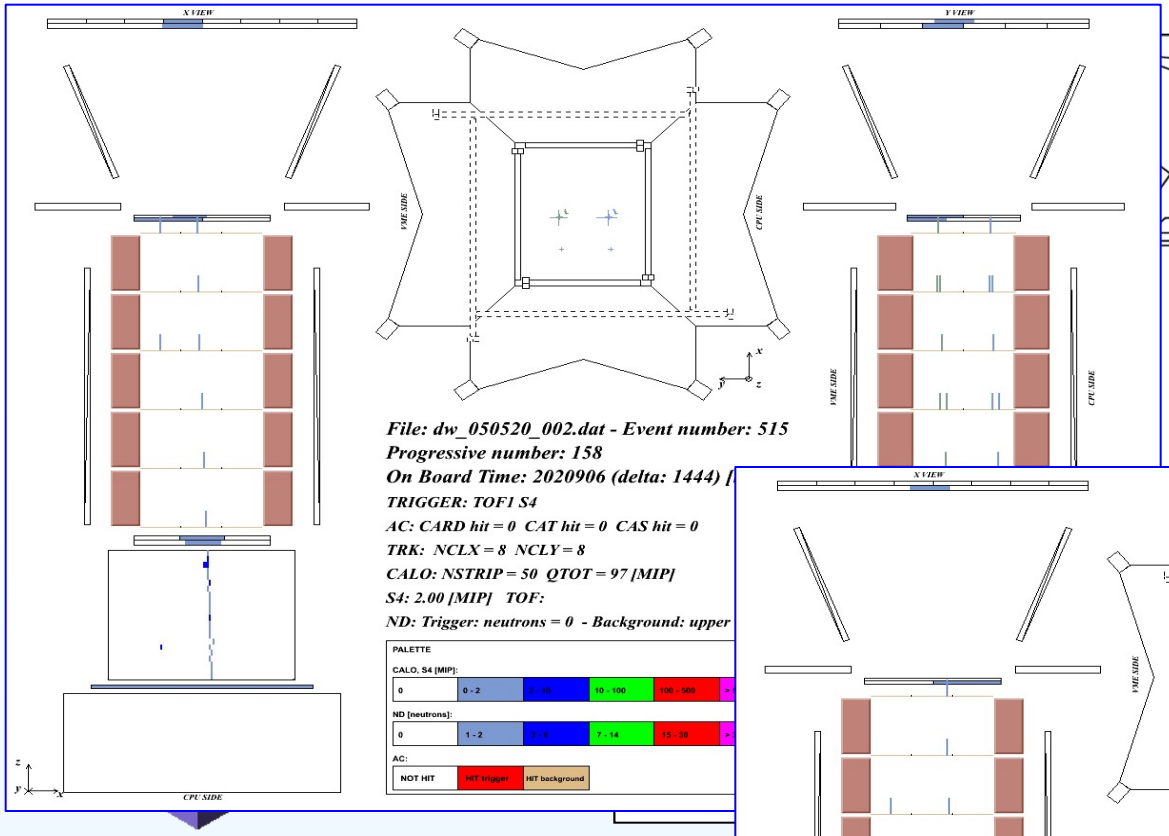

~2.5 10⁵ pix
Focal Plane
Fresnel Lenses
60°
10¹⁹ eV
0.1°
~500 km
fluorescence
Cerenkov

PAMELA 1/4

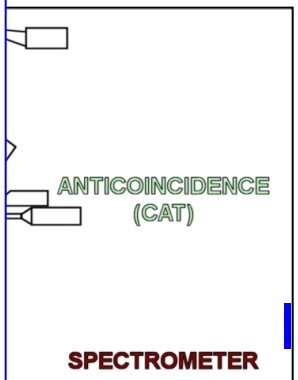


- Multi-spectral remote sensing of earth's surface
  - → near-real-time high-quality images
- Built by the Space factory TsSKB Progress in Samara (Russia)
- Operational orbit parameters:
  - inclination ~70°
  - altitude ~ 360-600 km (elliptical)
- Mass: 6.7 tons
- Active life >3 years
- Launch: 15/06/2006
- Data transmitted via Very high-speed Radio Link (VRL)

PAMELA 2/4

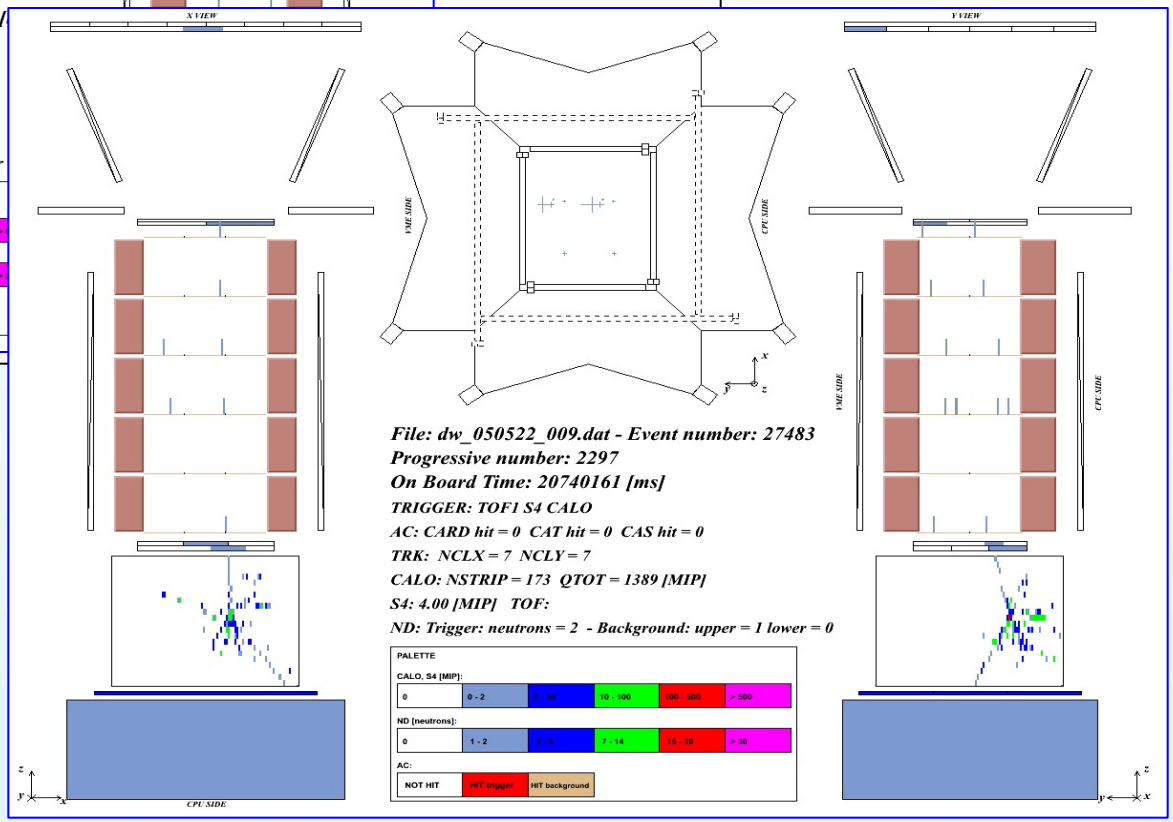


Non-interacting event



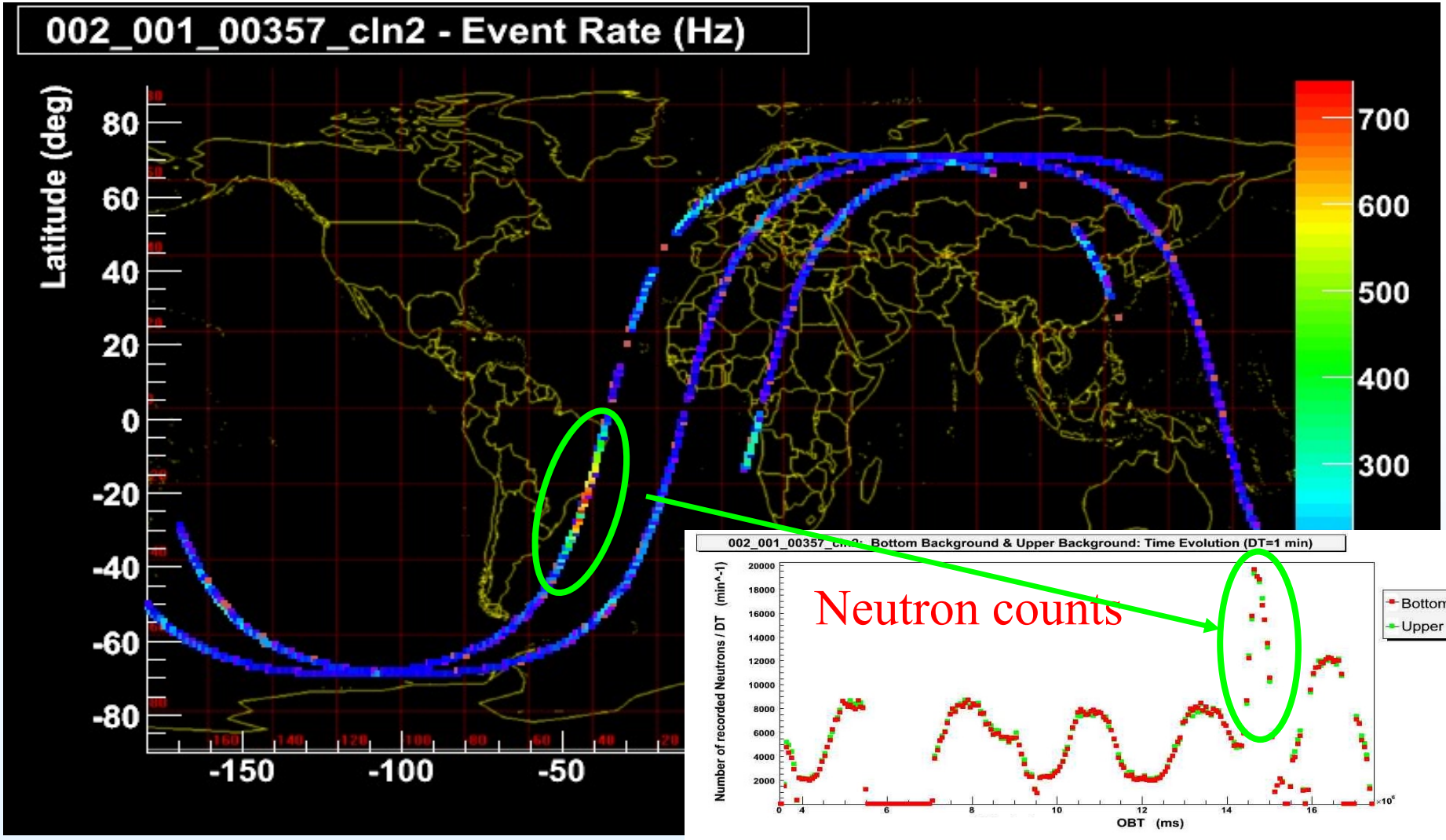
GF: 21.5 cm² sr
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360W

Interacting event



Trieste, 4 ottobre 2021

PAMELA 3/4


002_001_00357_cln2 - Event Rate (Hz)
Latitude (deg)
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
700
600
500
400
300
Neutron counts
002_001_00357_cln2: Bottom Background & Upper Background: Time Evolution (DT=1 min)
Number of recorded Neutrons / DT (min^-1)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
4
6
8
10
12
14
16
×10^6
OBT (ms)
Bottom
Upper

PAMELA 4/4

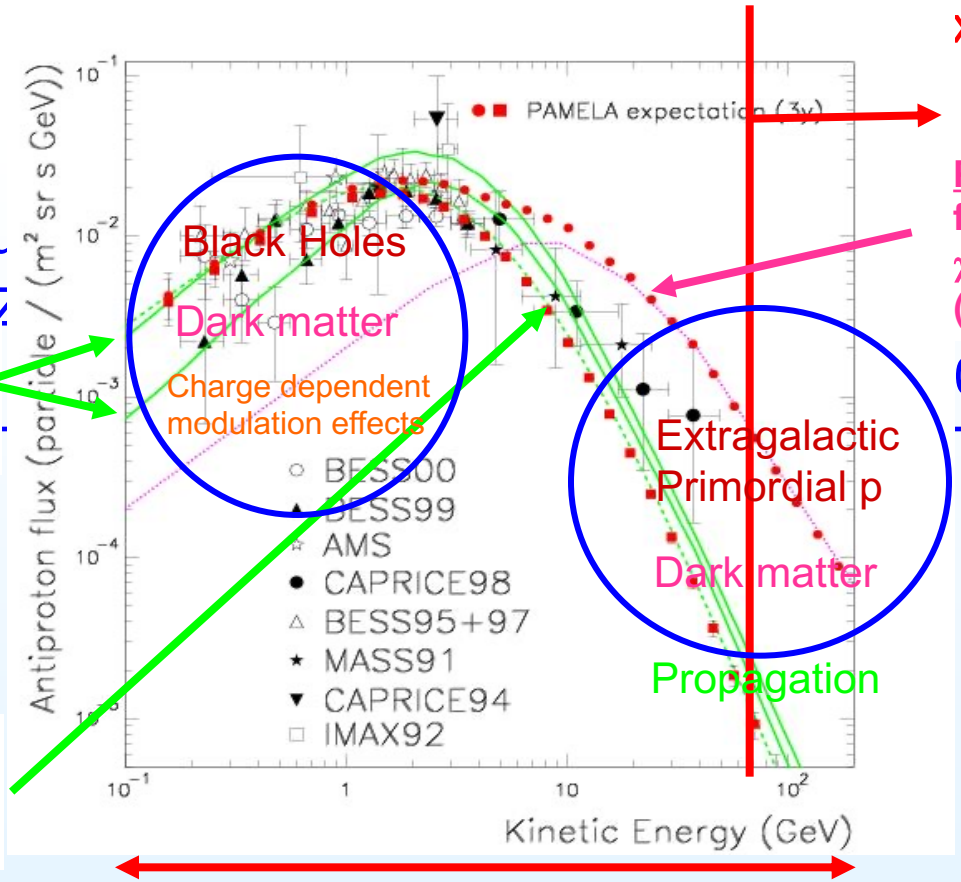
	energy range	particles/3 years
Antiproton flux	80 MeV - 190 GeV	~3×10^4
Positron flux		$\times10^5$
Electron flux		
Proton flux		
Electron/positron flu		
Light Nuclei (up to Z		

Unexplored Region

Primary production from $\chi\chi$ annihilation ($m(\chi)$ = 964 GeV)

0^{-7} in He/He)

Secondary production (upper and lower limits) Simon et al.



Secondary production (CAPRICE94-based) Bergström et al.

PAMELA energy range

AGILE 1/2

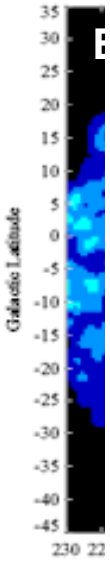
Astrorivelatore Gamma Immagini LEggero

- Missione dedicata all'astrofisica gamma
- Optimal imaging capabilities in both the gamma-ray energy range (30 MeV-30 GeV) and hard X-ray range (15-60 keV)
- Scientific Team: researchers and engineers of INAF-IASF, INFN, and several Italian Universities. The project is headed by M. Tavani (Principal Investigator) and G. Barbiellini (Co-Principal Investigator)
- Participation of several leading companies from the Italian space industry, including CARLO GAVAZZI SPACE, ALCATEL-ALENIA Space LABEN, OERLIKON-CONTRAVES Space, TELESPAZIO, and MIPOT

AGILE 2/2

Major topics are:

- Active Galactic N
- Gamma Ray Bur
- Pulsars
- Gamma-Ray Uni
- Supernova Rem
- Compact Object
- Gamma-ray Diffuse E
- TeV Sources
- Fundamental Physics



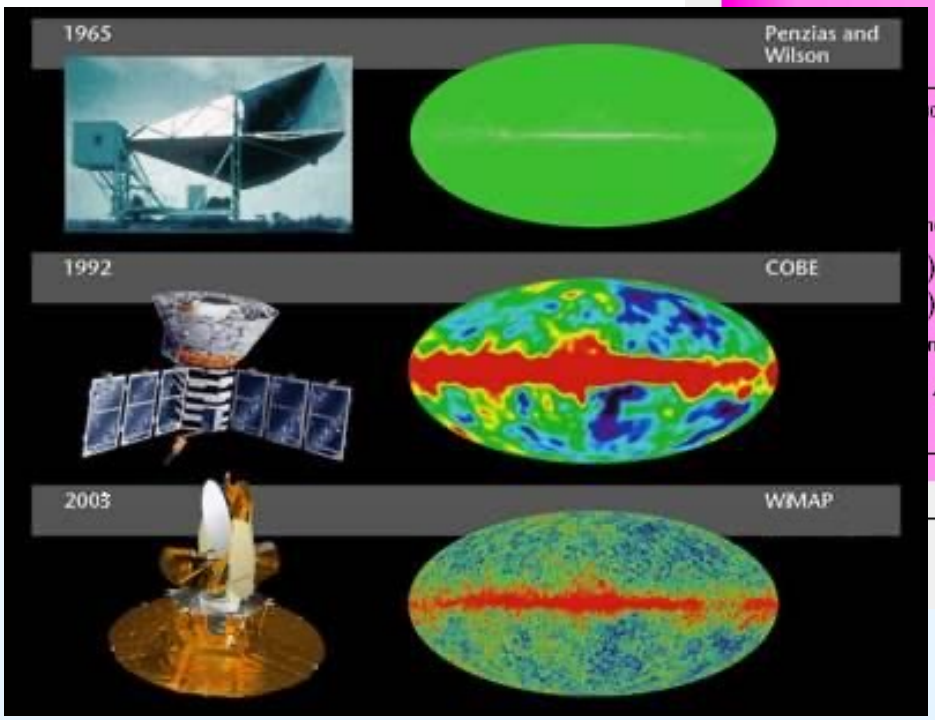
Gamma-ray Imaging Detector (GRID)		
Energy Range	30 MeV – 50 GeV	
Field of view	~ 3 sr	
Sensitivity at 100 MeV (ph cm^{-2} s^{-1} MeV^{-1})	6×10^{-9}	(5σ in 10^6 s)
Sensitivity at 1 GeV (ph cm^{-2} s^{-1} MeV^{-1})	4×10^{-11}	(5σ in 10^6 s)
Angular Resolution at 1 GeV	36 arcmin	(68% cont. radius)
Source Location Accuracy	~5–20 arcmin	S/N~10
Energy Resolution	$\Delta E/E\sim1$	at 300 MeV
Absolute Time Resolution	$\sim 1\,\mu$s	
Deadtime	$\sim 200\,\mu$s	
Hard X–ray Imaging Detector (Super-AGILE)		
Energy Range	10 – 40 keV	
Field of view	107°×68°	FW at Zero Sens.
Sensitivity (at 15 keV)	~5 mCrab	(5σ in 1 day)
Angular Resolution (pixel size)	~ 6 arcmin	
Source Location Accuracy	~2-3 arcmin	S/N~10
Energy Resolution	$\Delta E<4$ keV	
Absolute Time Resolution	$\sim 4\,\mu$s	
Deadtime (for each of the 16 readout units)	$\sim 4\,\mu$s	
Mini-Calorimeter		
Energy Range	0.3 – 200 MeV	
Energy Resolution	~ 1 MeV	above 1 MeV
Absolute Time Resolution	$\sim 3\,\mu$s	
Deadtime (for each of the 30 CsI bars)	$\sim 20\,\mu$s	

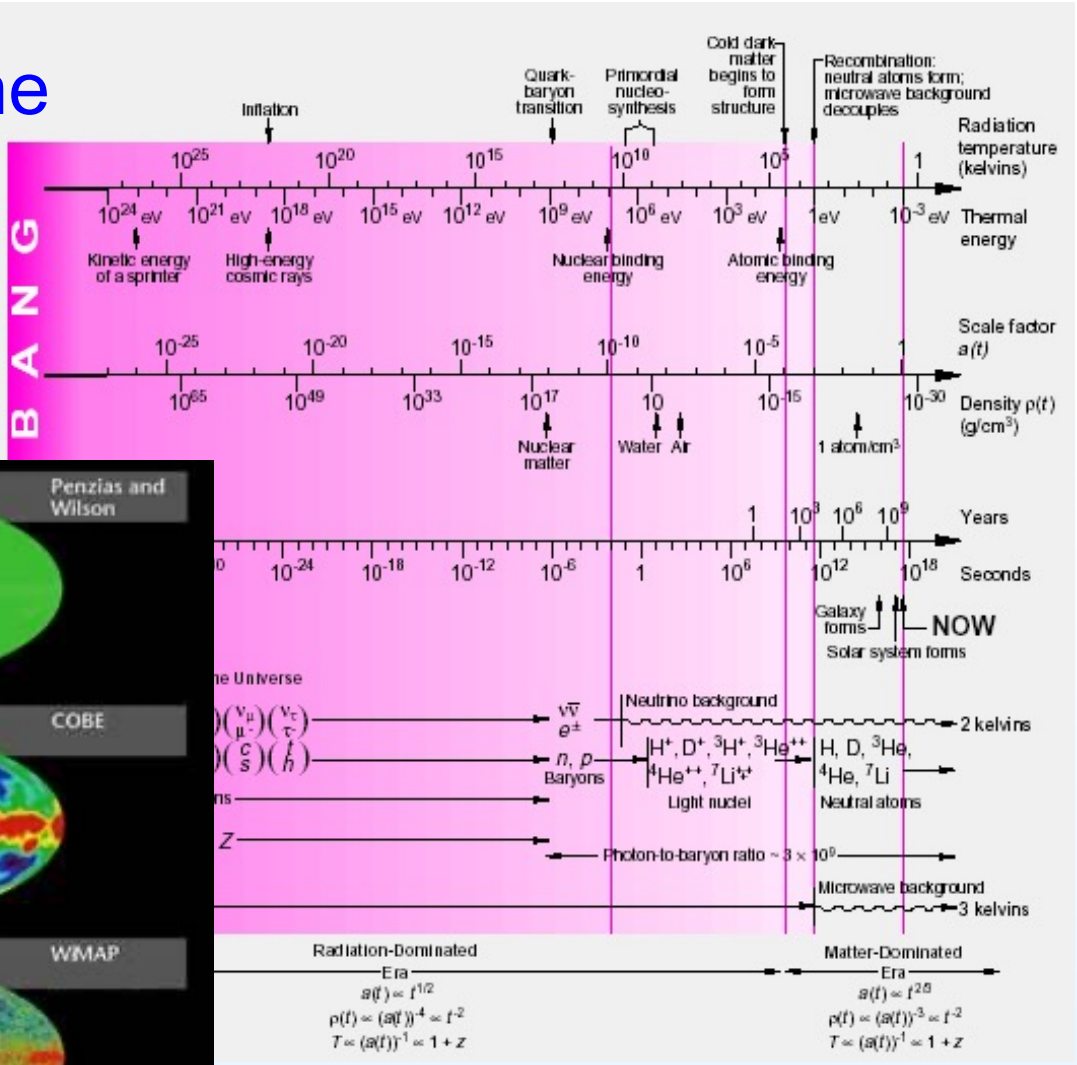
AGILE was successfully launched on April 23, 2007 by the Indian PSLV-C8 rocket from the Sriharikota base (Chennai-Madras).

The AGILE satellite was injected in the nominal equatorial orbit in agreement with the Scientific Requirements of the Mission. The satellite was tracked during its first pass over the ASI Malindi ground station in Kenya on Apr. 23rd. During its first orbit, its radio signal was also independently detected from the Sriharikota and Bangalore ground stations. The satellite is now in the initial Commissioning Phase. All test results are nominal.

PLANCK 1/3

Fondo di Radiazione

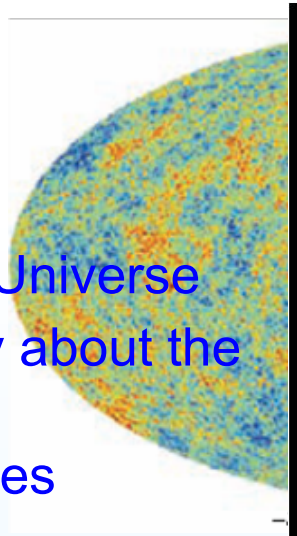


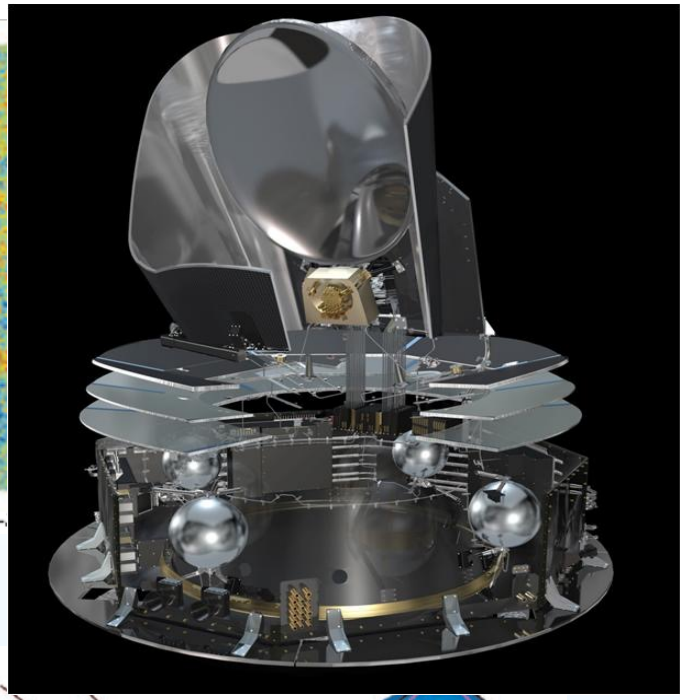


PLANCK 2/3

Planck is the third mission on CMB (first european)

- Better sensitivity ($\Delta T/T \sim 2 \times 10^{-6}$) and angular resolution (up to 5')
- Wider frequency range





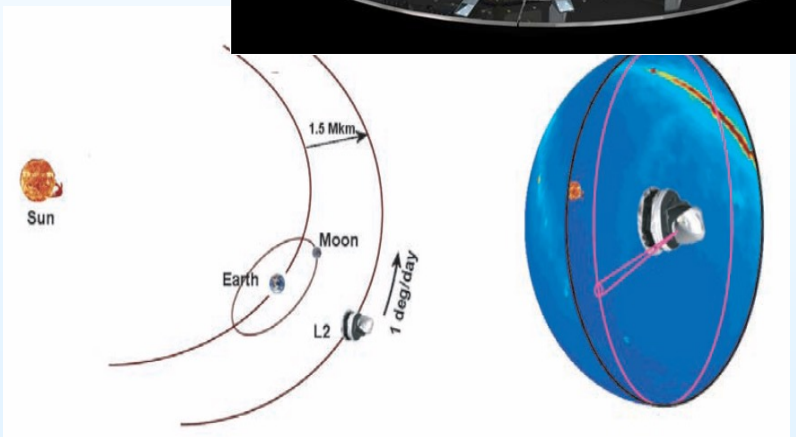
Main scientific Objectives:

- Determination of geometry of the Universe
- Determination of the correct theory about the Universe origin and evolution
- Complete map of CMB anisotrophies

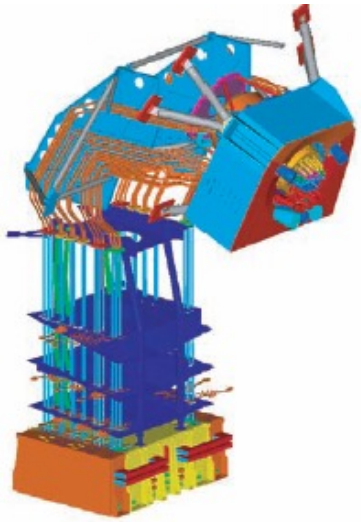
Orbit: Lissajous around Lagrangian point L2 of Earth-Sun-Moon system

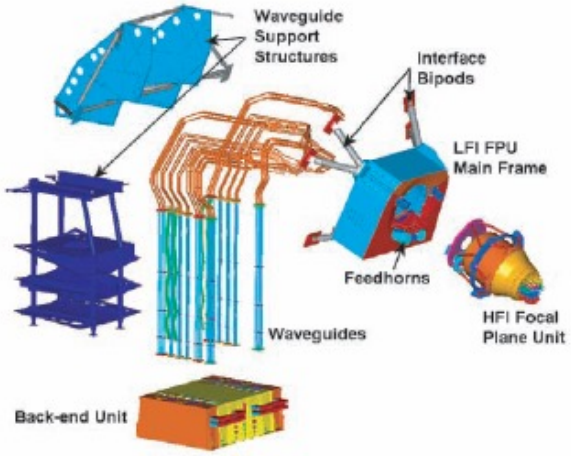
Distance from the Earth: 1.5 x 10^6 km

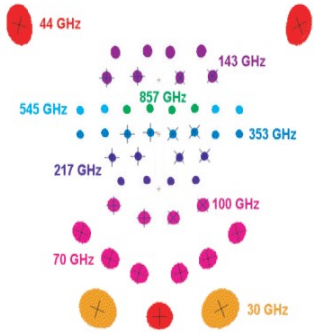
Spin axis: opposite direction respect to the Sun

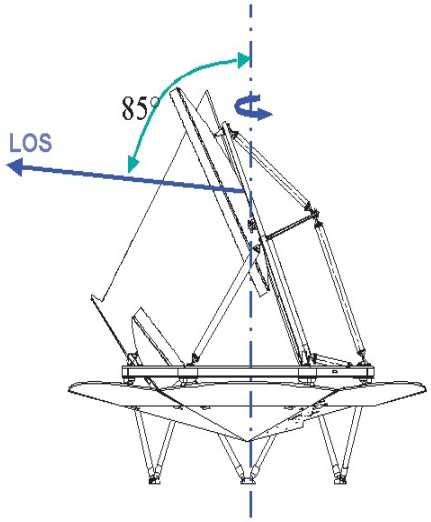


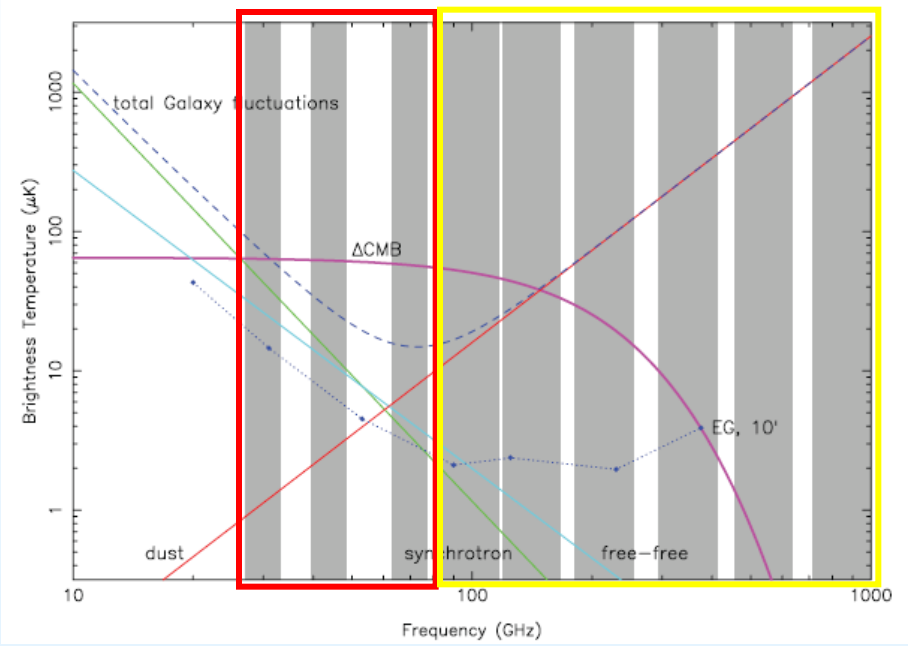
PLANCK 3/3





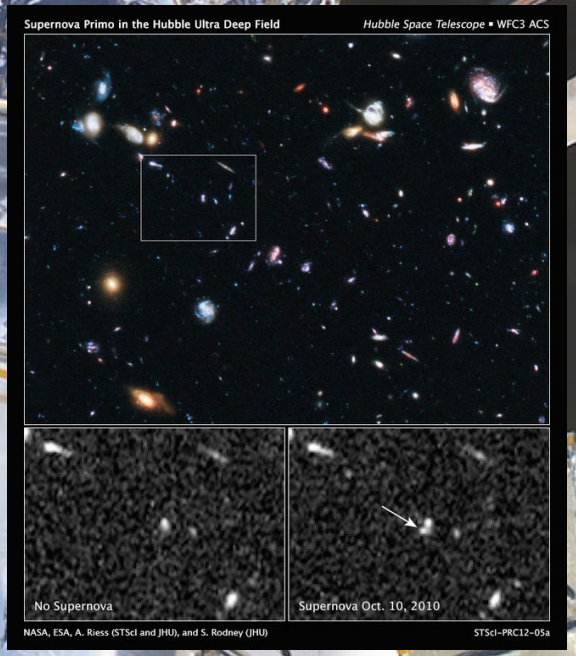




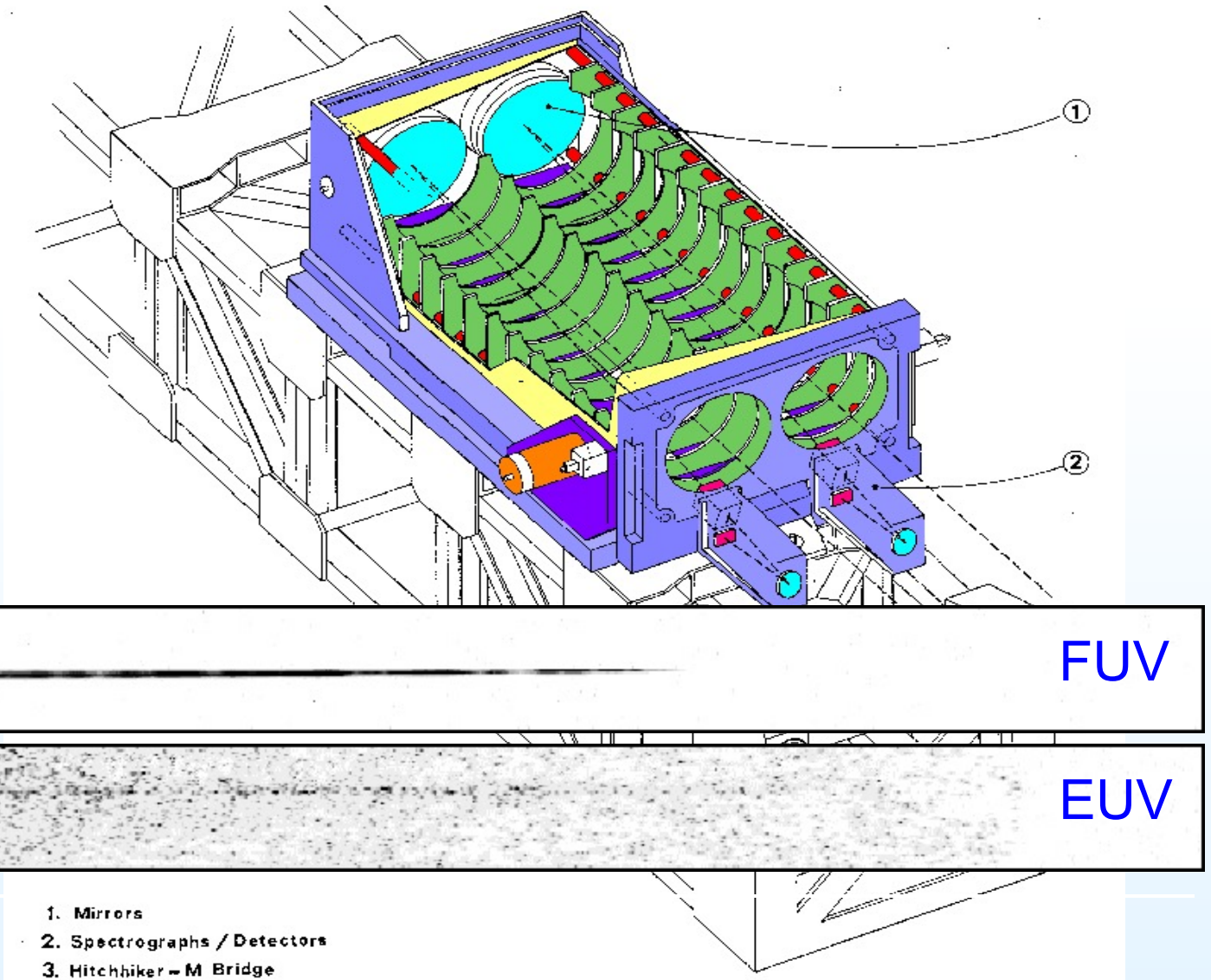


Centre frequency (GHz)	30	44	70
Bandwidth (GHz)	6	8.8	14
Angular resolution (arcminutes, FWHM)	33	24	14
Detector temperature (K)	20 K		
ΔT/T Intensity [10^{-6} μK/K]	2.0	2.7	4.7
ΔT/T polarization [μK/K]	2.8	3.9	6.7

Astronomia: Hubble



Astronomia: UVSTAR 1/4



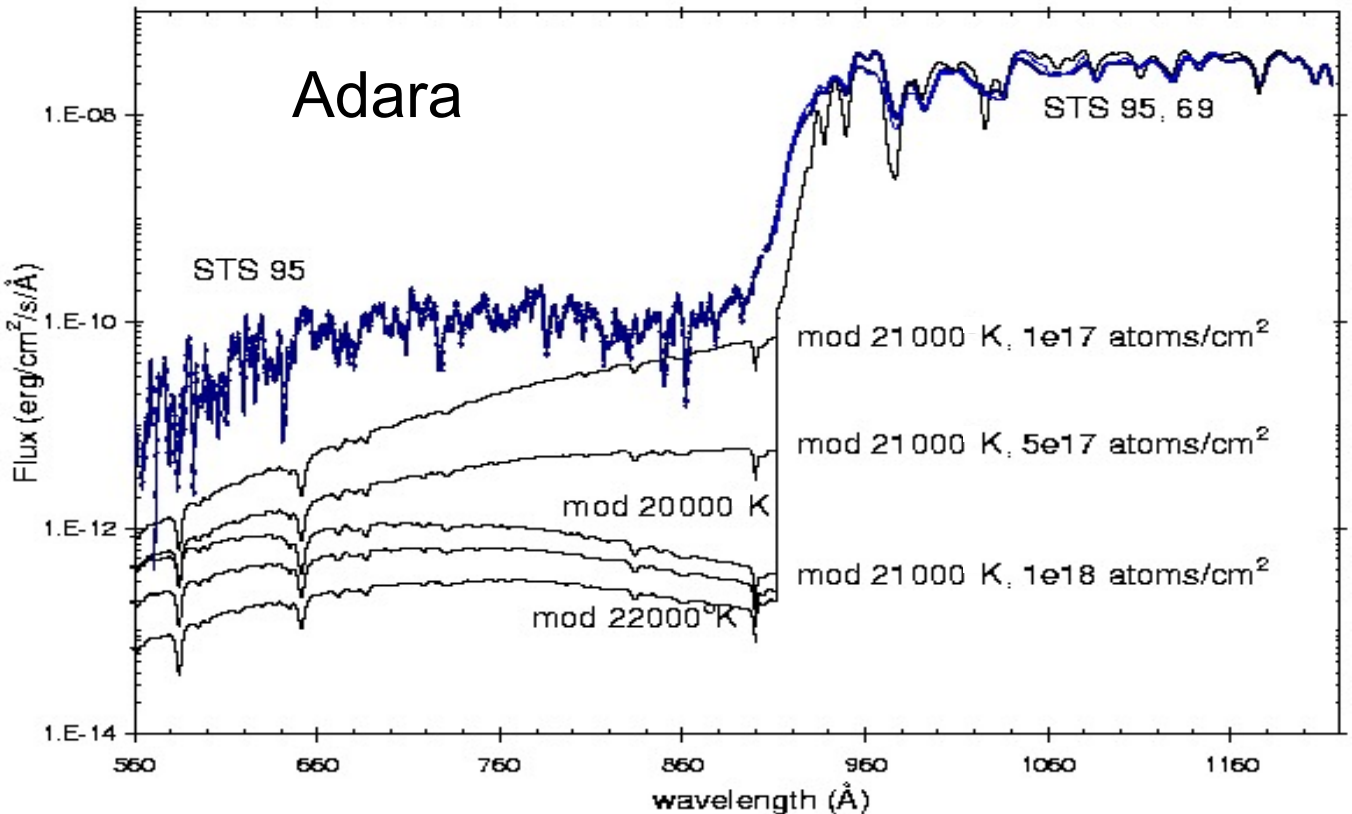
spazio

Lunghezza d'onda

Astronomia: UVSTAR 2/4

Astronomia: UVSTAR 3/4

- sistema di movimentazione autonomo munito di 2 telescopi ausiliari per la direzione di puntamento
- osserva atmosfere stellari, regioni HII, anelli di IO, comete
- analisi spettrale del flusso nelle varie componenti UV (FUV/EUV)



Astronomia: UVSTAR 4/4

Risultati tecnologici: sistema di puntamento