1) SMART-1 situation
2) SMART-1 Mission Extension

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**SMART-1 project team

**Science Technology Working Team & ESOC Flight Control Team

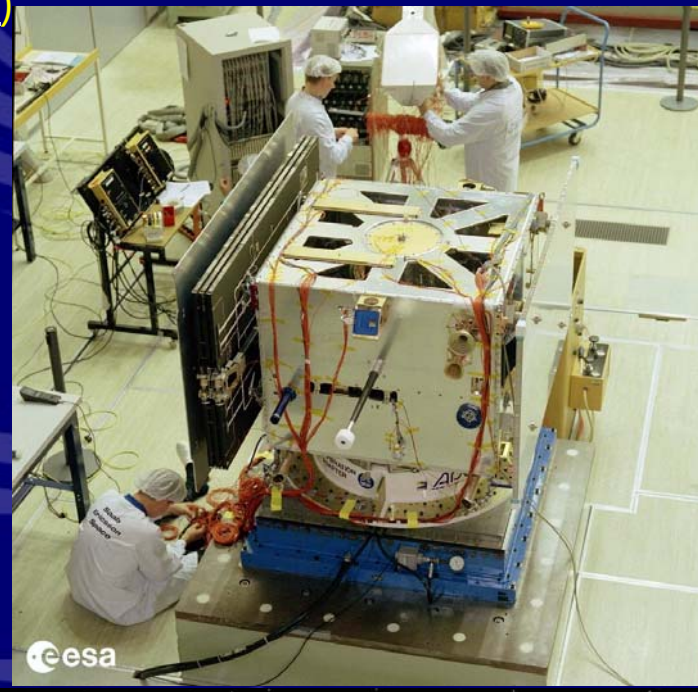
SMART-1 Mission

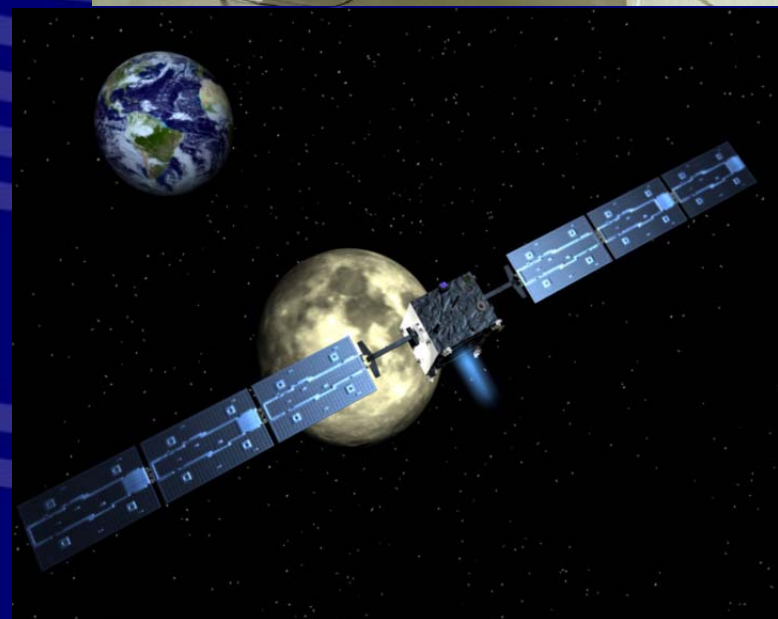
SMART-1 web page (http://sci.esa.int/smart-1/)

- ESA SMART Programme: Small Missions for Advanced Research in Technology
  - Spacecraft & payload technology demonstration for future cornerstone missions
  - Management: faster, smarter, better (& harder)
  - Early opportunity for science

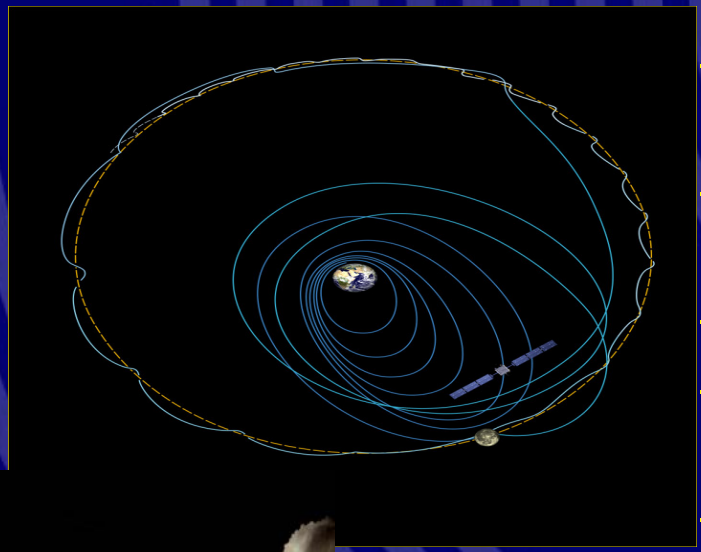
SMART-1 Solar Electric Propulsion to the Moon

- Test for Bepi Colombo/Solar Orbiter
- Mission approved and payload selected 99
- 19 kg payload (delivered August 02)
- 370 kg spacecraft
- launched Ariane 5 on 27 Sept 03, Kourou

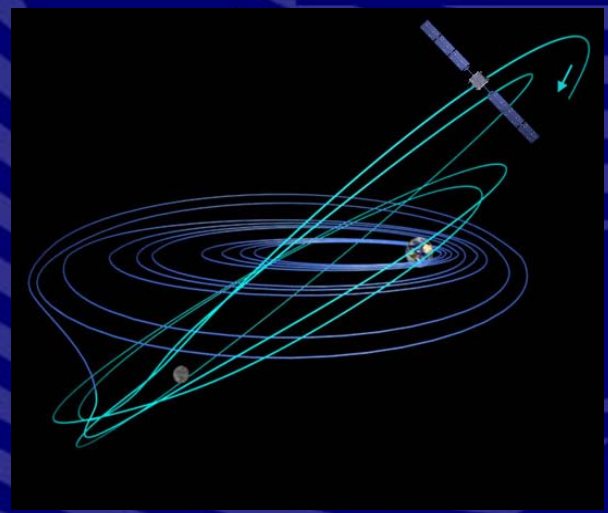


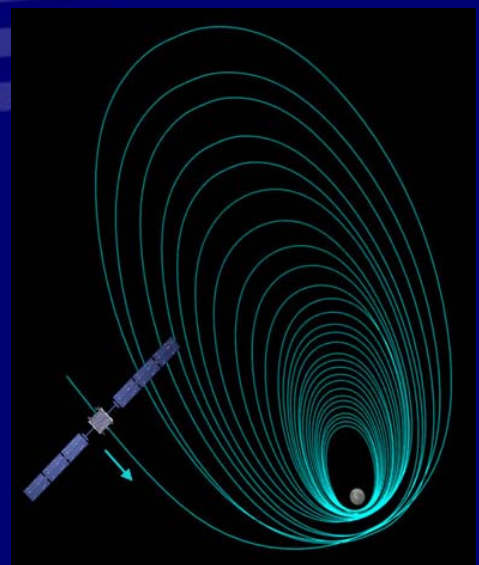


Solar Electric Propulsion to the Moon



- Launched 27 Sept 2003 as Auxiliary passenger on Ariane 5 into Geostationary Transfer Orbit
- Spiral out cruise (13.5 month): SPT/coast arcs, 3 lunar resonance approaches
- lunar capture 15 November 2004
- lunar science orbit (perilune 300 to 3000 km) arrival 28 February 2005
- Lunar science/exploration: 6 month + requested extension 1 year





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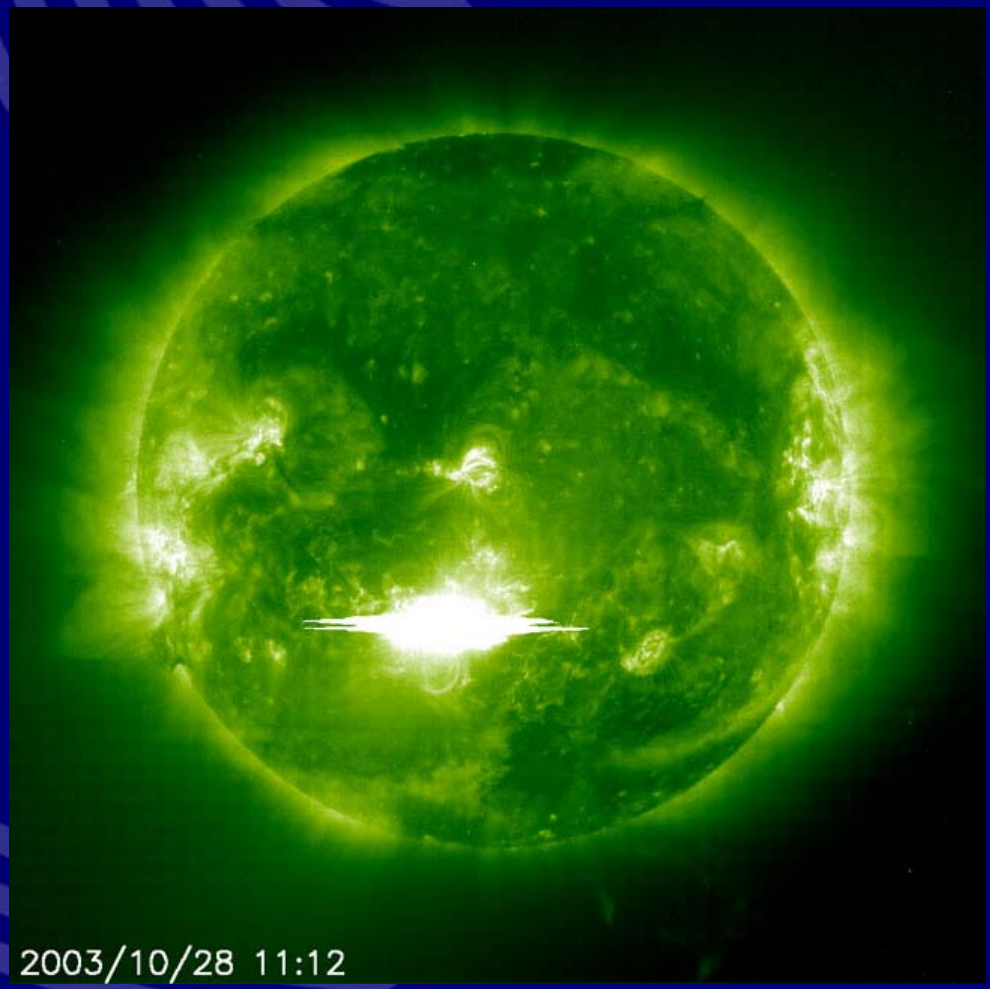
Hard Travel through Radiation belts and Exceptional Solar Activity: Halloween storm

- In the last days of October and early November 03 intense radiation environment
- This was caused by the exceptional solar and geomagnetic activity
- A series of intense solar flares occurred exciting the van Allen radiation belts: proton flux 100,000 higher than normal !!
- impact on spacecraft operations and cost



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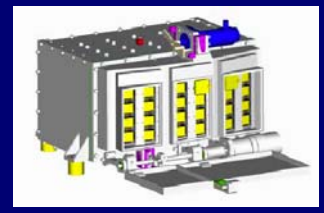
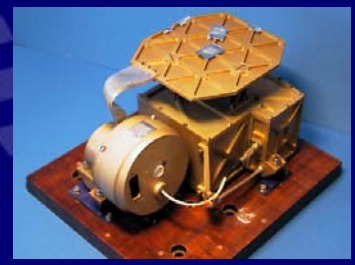
European Technologies
Successful tests of Mini-Instruments (19 kg)

- D-CIXS Compact Imaging X-ray Spectrometer (UK, 5.2 kg)
- + XSM solar X-ray Monitor (SF)



- SIR IR Spectrometer (D, 2.3 kg)



- AMIE High Resolution micro-Camera (CH, 2.1 kg)

- SPEDE Spacecraft Potential Electron Dust Exp. (SF, 0.8 kg)
- EPDP Electric Propulsion Diagnostics Package (I, 2.4 kg)

- KATE Deep Space X- Ka Communications (D/ESA, 6.2 kg)
- RSIS radio science (I)

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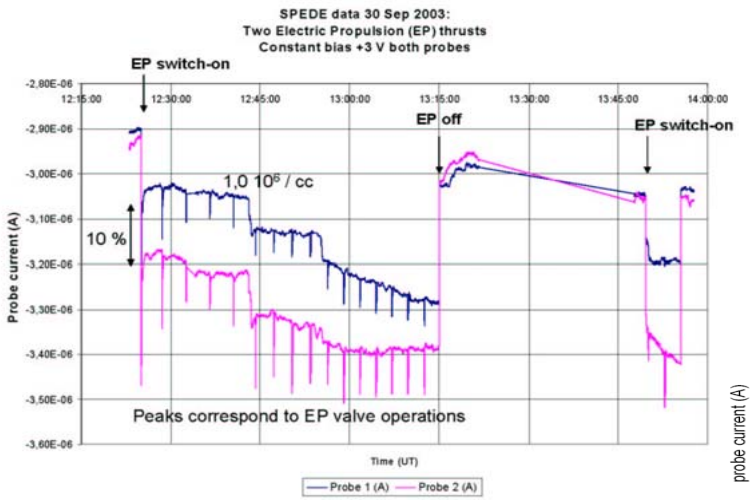
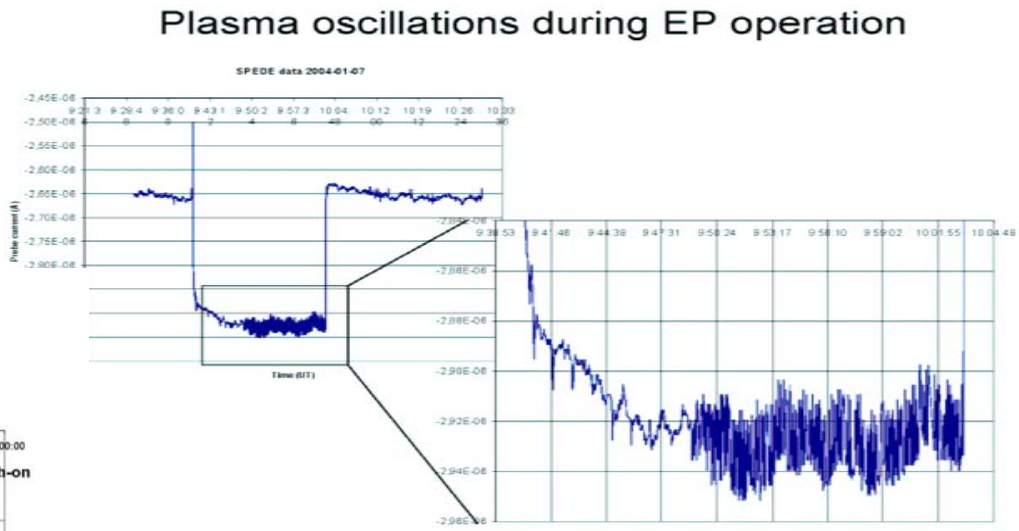
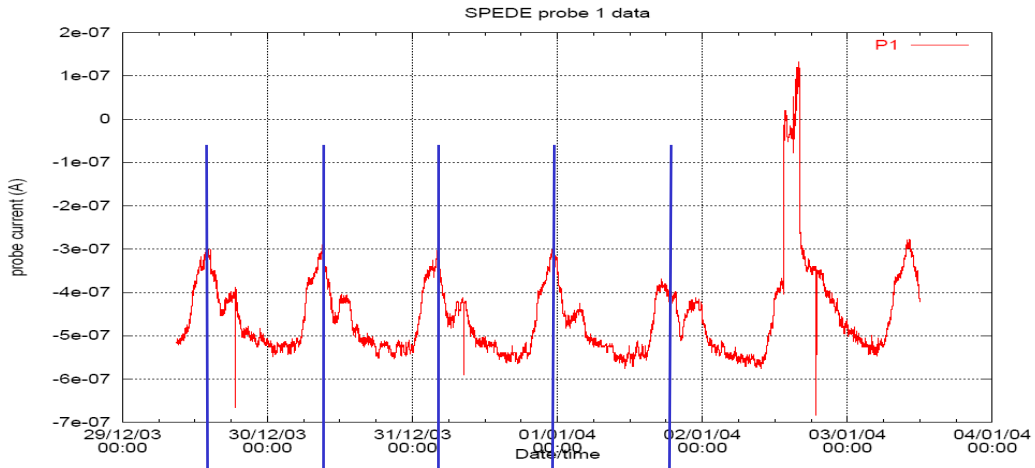
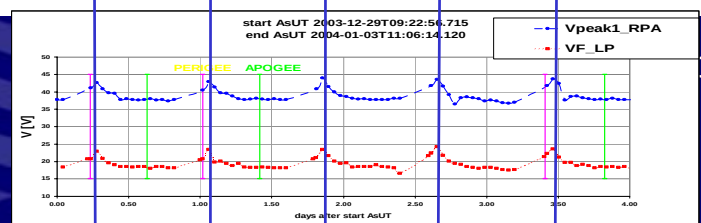
SMART-1 smelling nose: SPEDE plasma diagnostics







SPEDE probe current Monitoring during EP valve operations



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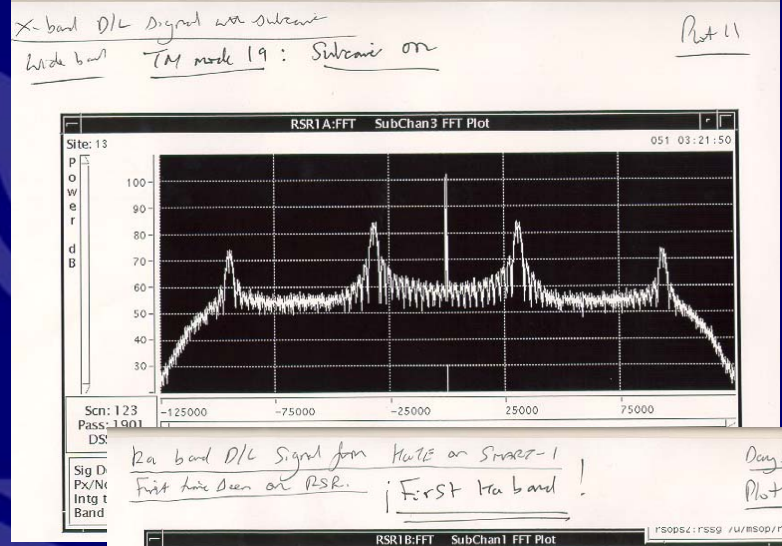
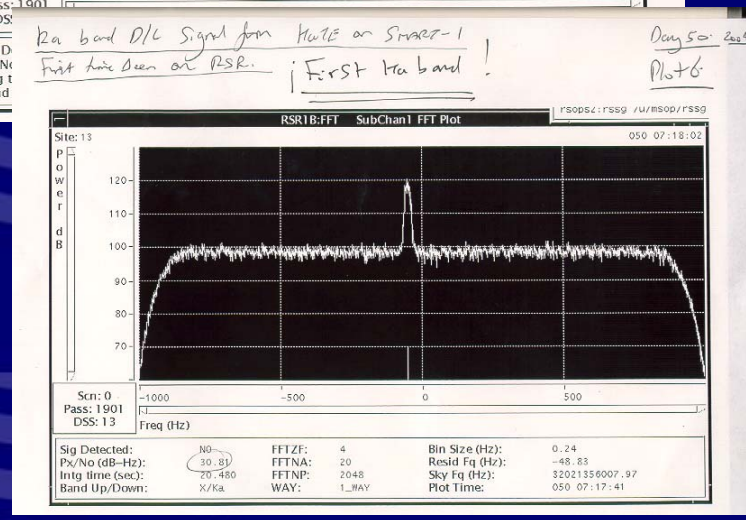
SMART-1 KATE Deep Space X Ka communications

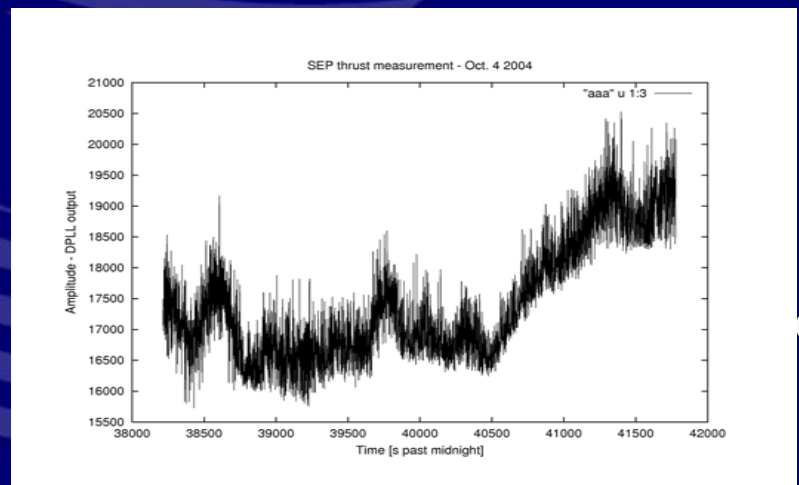
- X band experiment first detection

- First detection of an European Ka experiment

- RSIS thrust monitoring : 1% dispersion stability measurement







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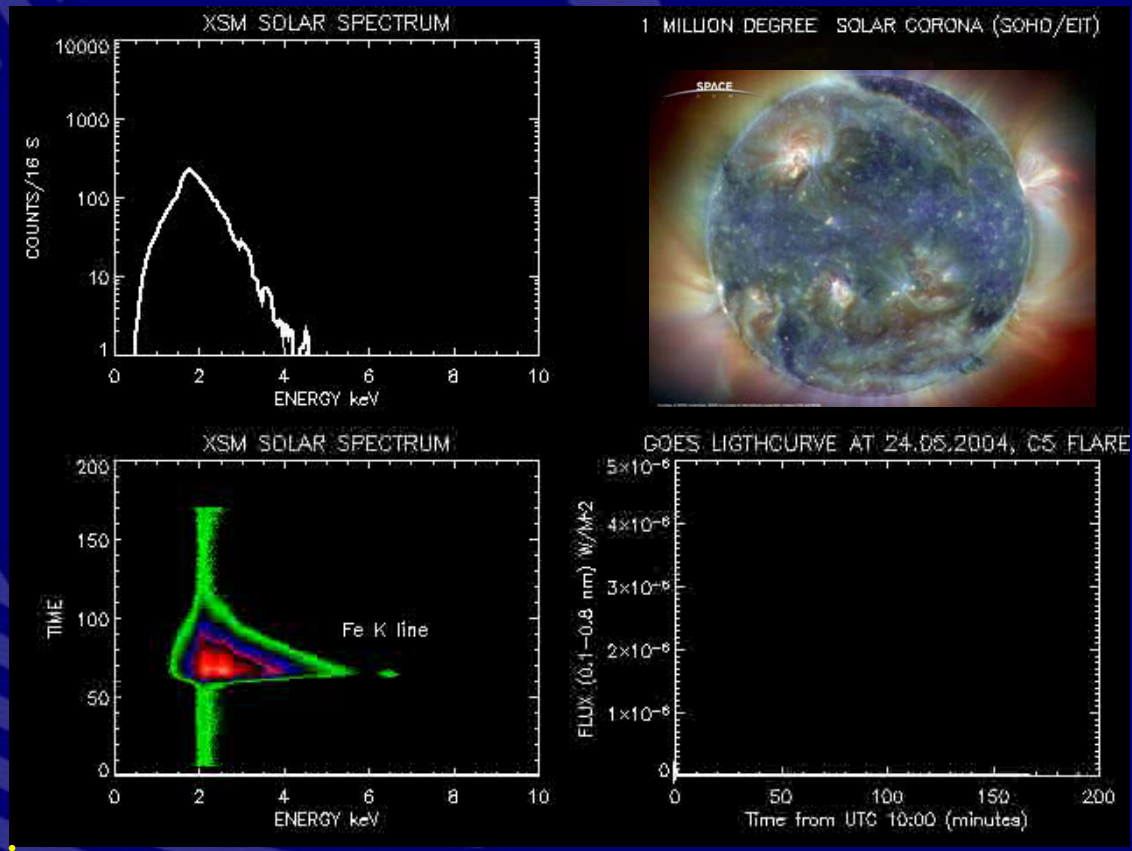
X-ray Solar Monitor (XSM)

- Variable solar corona
- Cruise results until 15 Nov 04:
  - **16500 X-ray spectra**
  - **125 hr: Many solar flares**
- Coordination RHESSI, SOHO (solar physics)
- XSM will measure solar X-rays hitting the Moon
- Already detected solar X flares since lunar capture (e.g. 15 jan X2)



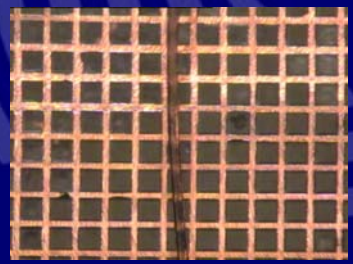
U. of Helsinki

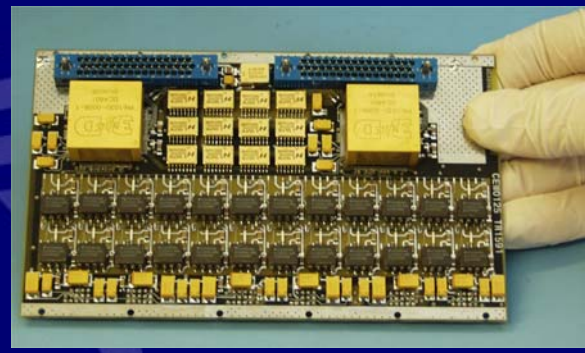
D-CIXS Compact X-ray Spectrometer

New X-ray Detector

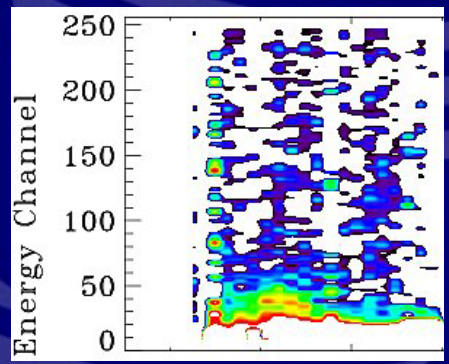
Miniaturised electronics

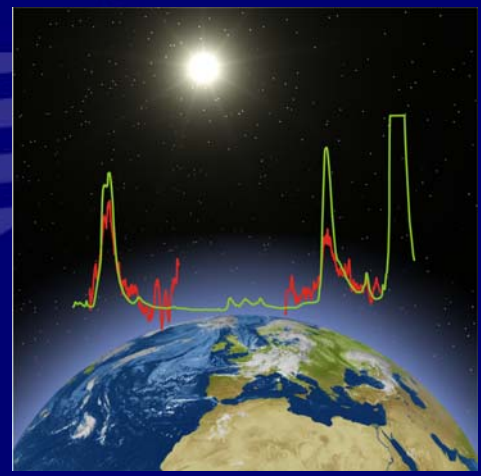
New X-ray micro-optics





- Nominal performances,
- Cruise observations of cosmic X-ray sources



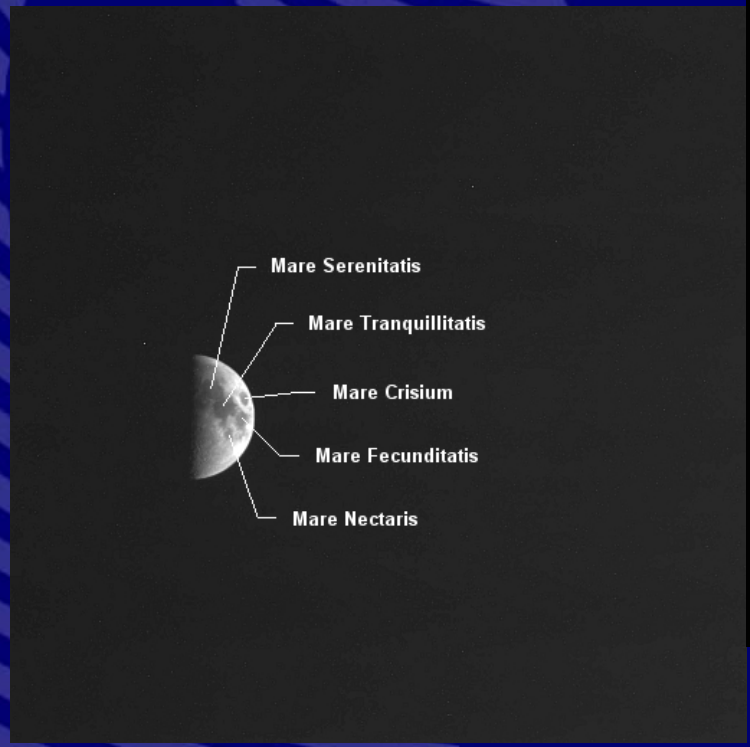


- Earth scans
- Detection of Earth X-ray fluorescence, Ar line

PI (RAL, UK), Co-Is (UK, F, SF, S, E, ESA, US, J, India)

AMIE multicolour microcamera

- CCD cam & micro-electronics packed in 3-D
- 3 colour filters (red to near infrared)
- Mass 2.1 kg , optics 400 g , 5.3° view
- Support laser-link, OBAN, RSIS, SIR



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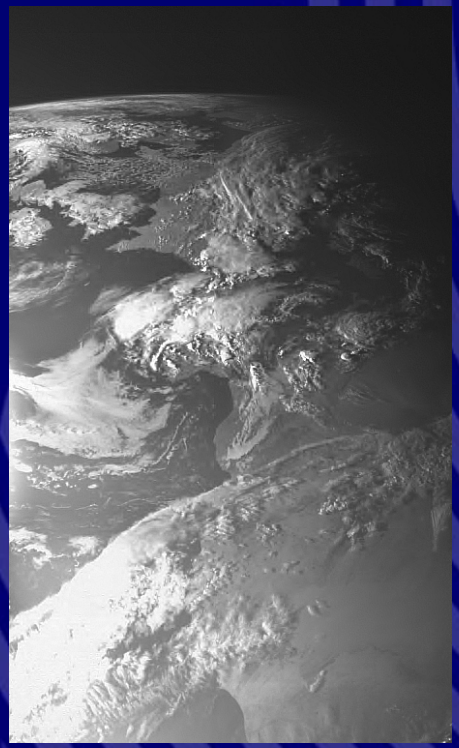
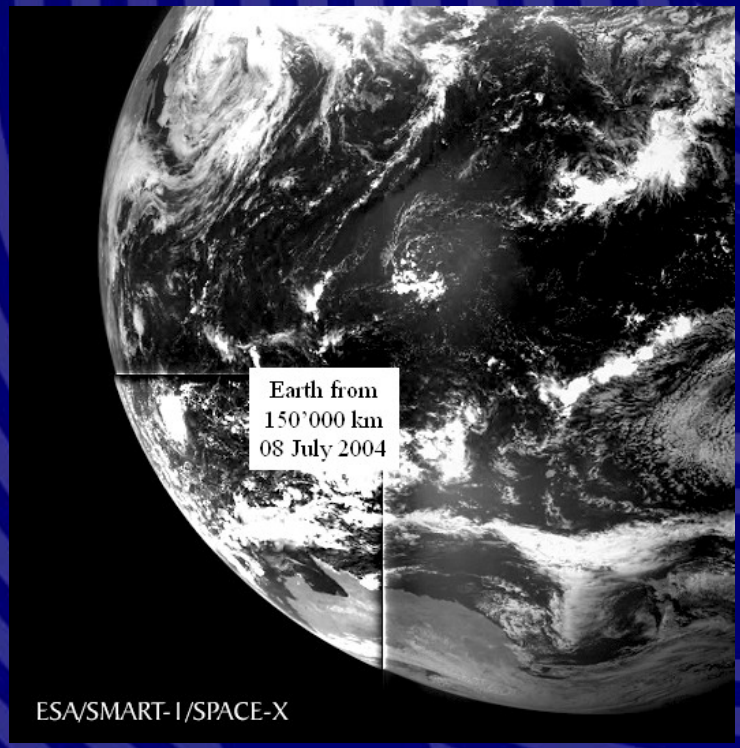
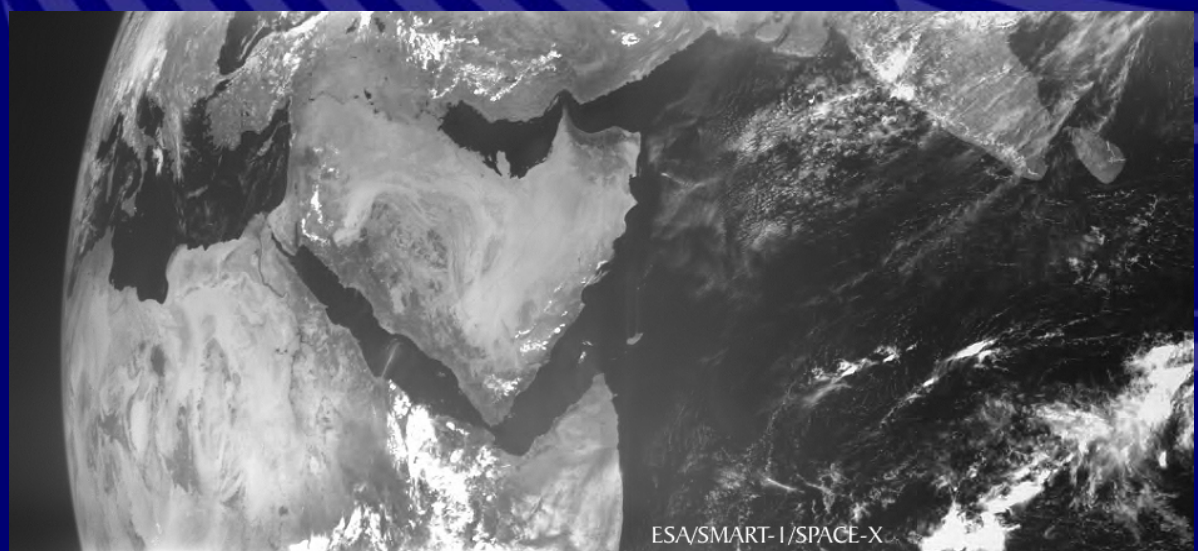
amarini/ppt

PI:Space-X, CH; Co-I's I,F,CH, Fin, NL, ESA

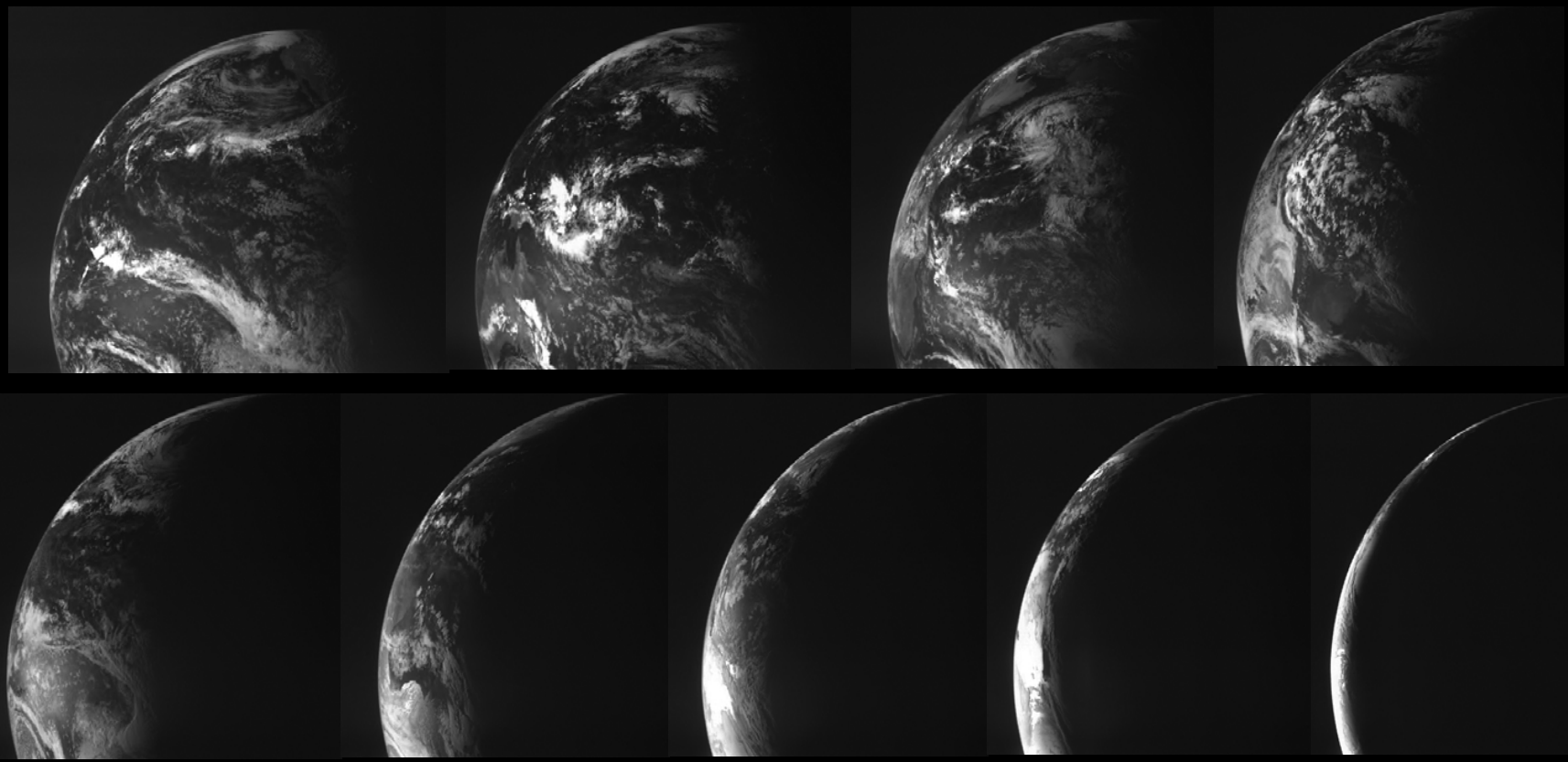
SMART-1 views planet Earth







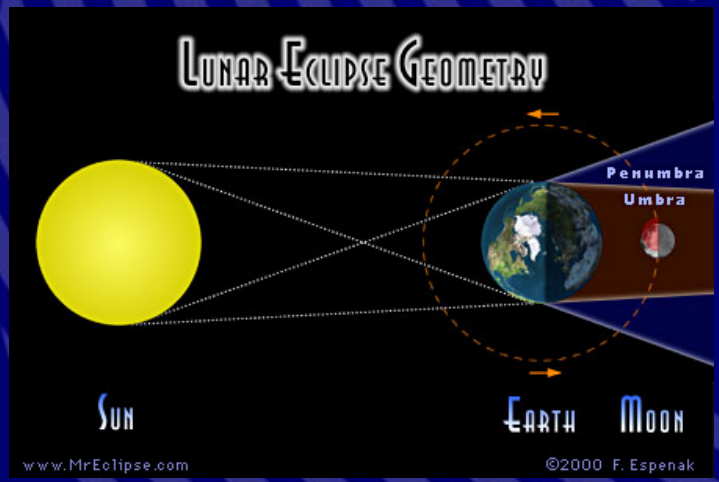
Earth taken by AMIE /SMART-1 on 1-2 Nov. 2004



28 October 2004 lunar eclipse: unique Earth-Moon family portrait

- movie sequence over 4 hours: Earth, Moon covering partial eclipse, Earth
- SMART-1 was 660 000 km from the Moon (farthest ever), 300 000 km from Earth

(Earth real size is 3.7 bigger than Moon)



From gateway to lunar capture

- 11 Nov 10:30 UT SMART-1 crossed fuzzy Earth-Moon gravity gateway
- 12 Nov lunar approach images of north pole far side from 60000 km
- 15 Nov 17h48 UT 1st Perilune at 5000 km

28 Oct from 600,000 km

1st European view of North pole and far side 12 Nov from 60,000 km

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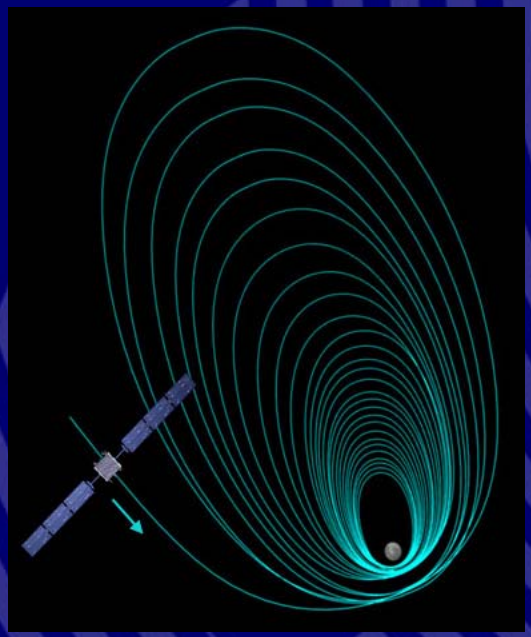
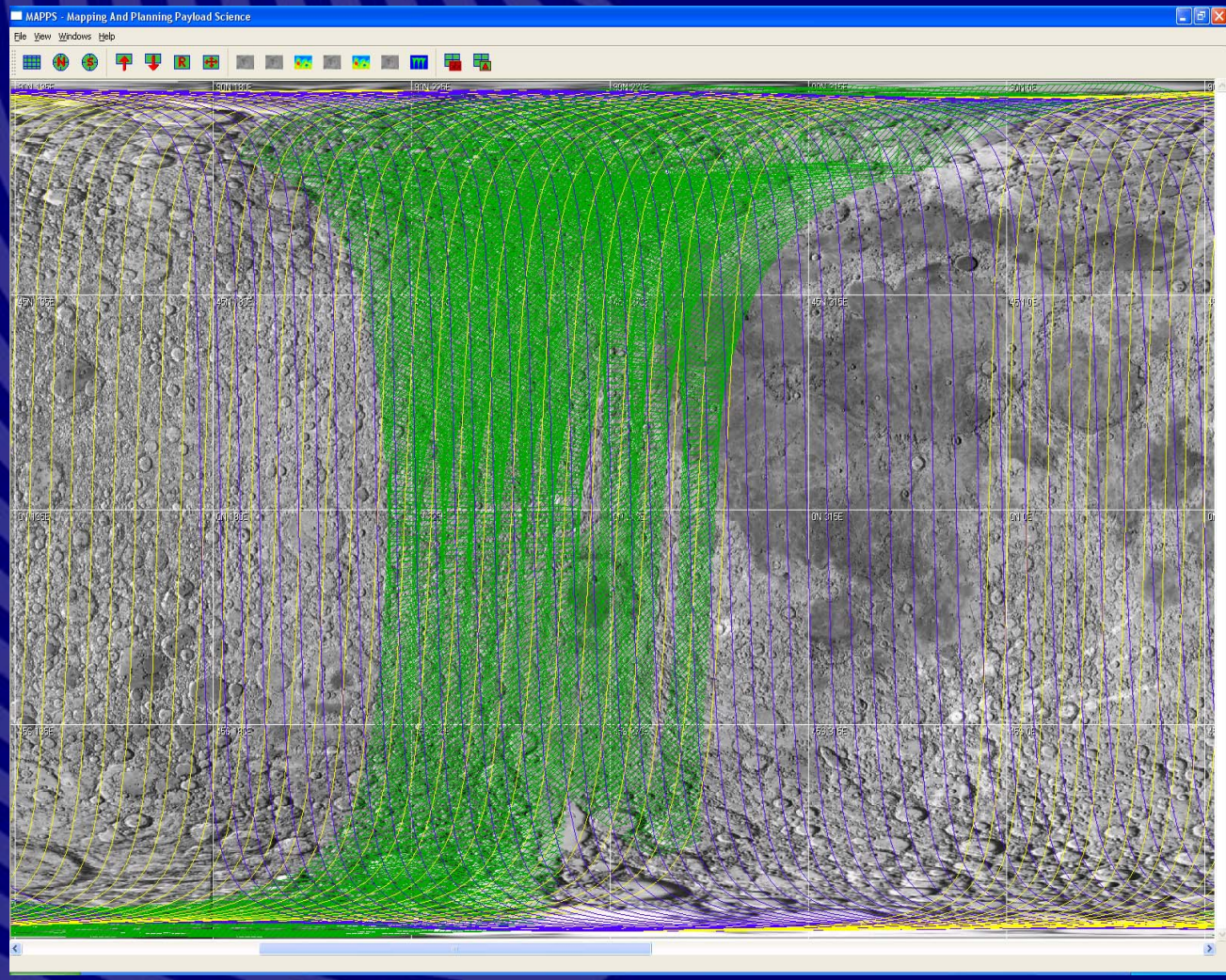
EP Off New Year – Jan 05





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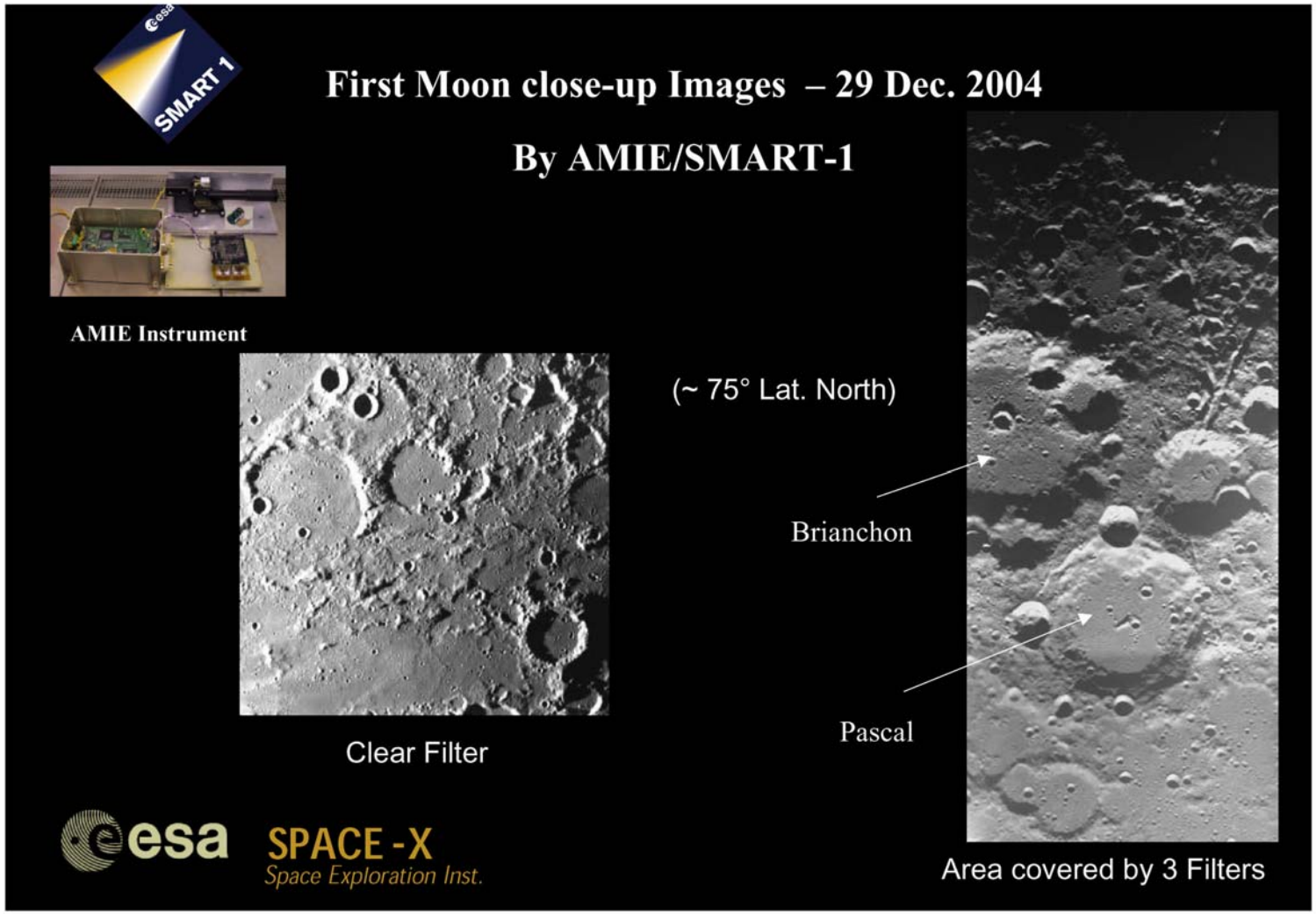
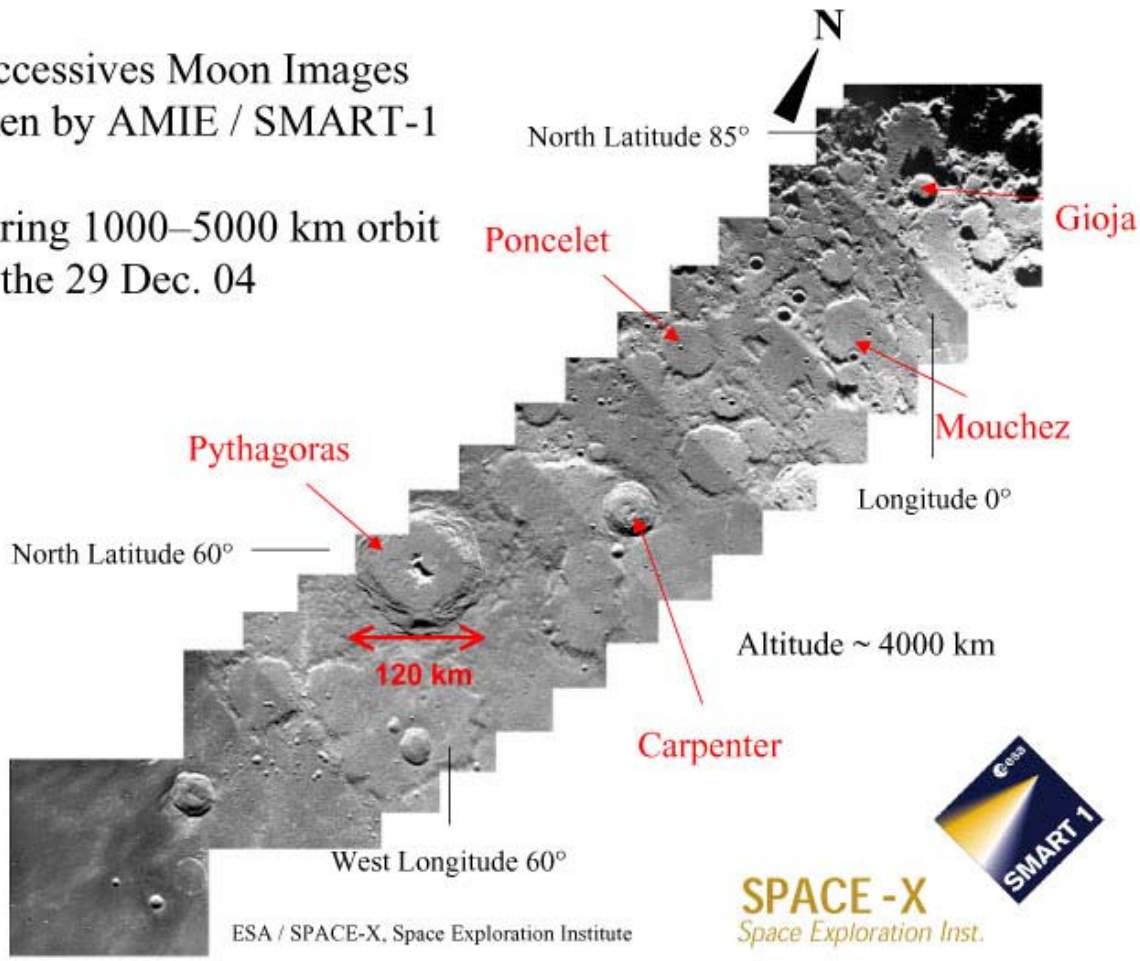
First Moon close-up images from SMART-1 AMIE



Mosaic of images along SMART-1 orbit 1000-4500 km



SPC

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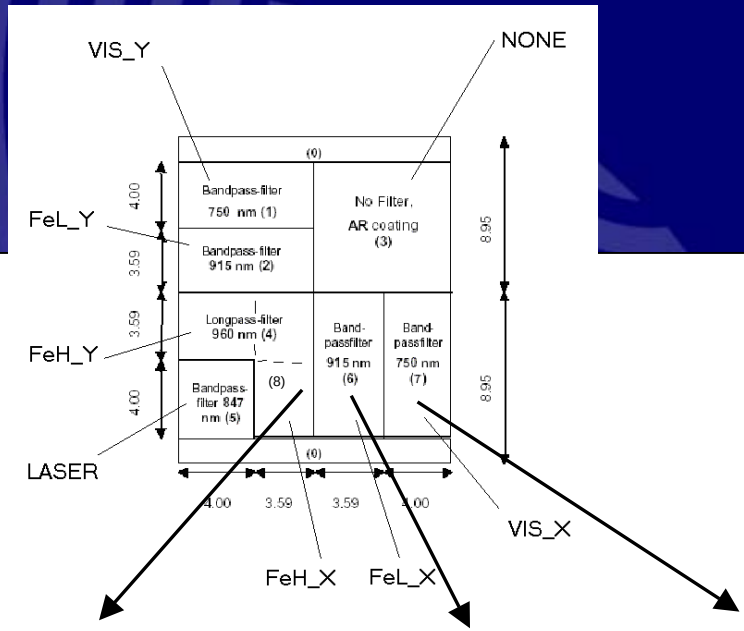
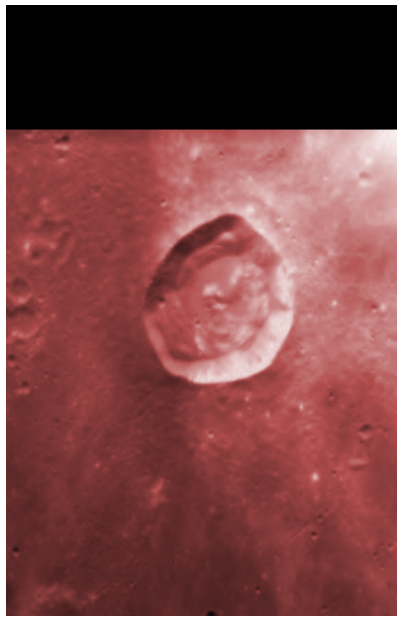
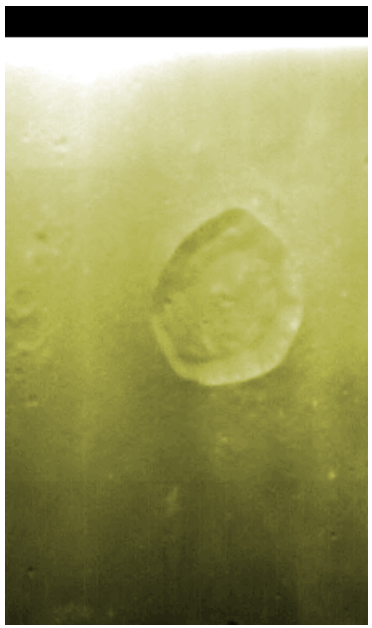
AMIE filter images, orbit 41





29 Dec 2004, 00h36m06s



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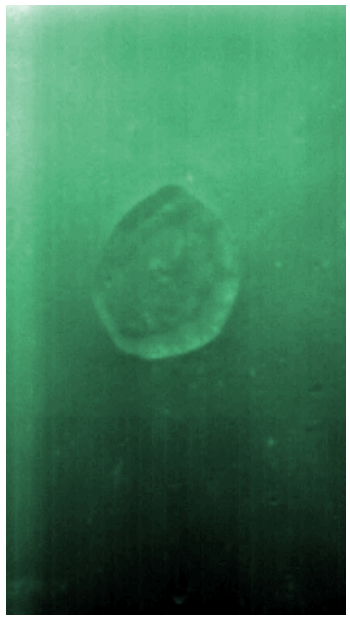

29 Dec 2004, 00h38m05s

What' s next for SMART-1:
Science and Exploration Themes

A) TECHNOLOGY AND DEMONSTRATION (draw lessons learned)

B) CRUISE PHASE SCIENCE (analysis and interpretation)

C) *HOW DO EARTH-LIKE PLANETS WORK?*

GEOPHYSICS: volcanism, tectonics, cratering, erosion, space weather , ices

D) *HOW DO ROCKY PLANETS FORM AND EVOLVE?*

GEOCHEMISTRY: chemical composition, Earth-Moon origin, Moon evolution

accretion and collisions, giant bombardment

E) PREPARING FUTURE LUNAR/PLANETARY EXPLORATION

survey lunar resources (minerals, volatiles, illumination)

high resolution maps for future landing sites and outposts

support to future exploration and coordination with other missions

F) PUBLIC OUTREACH AND EDUCATION: INSPIRING PUBLIC AND YOUTH

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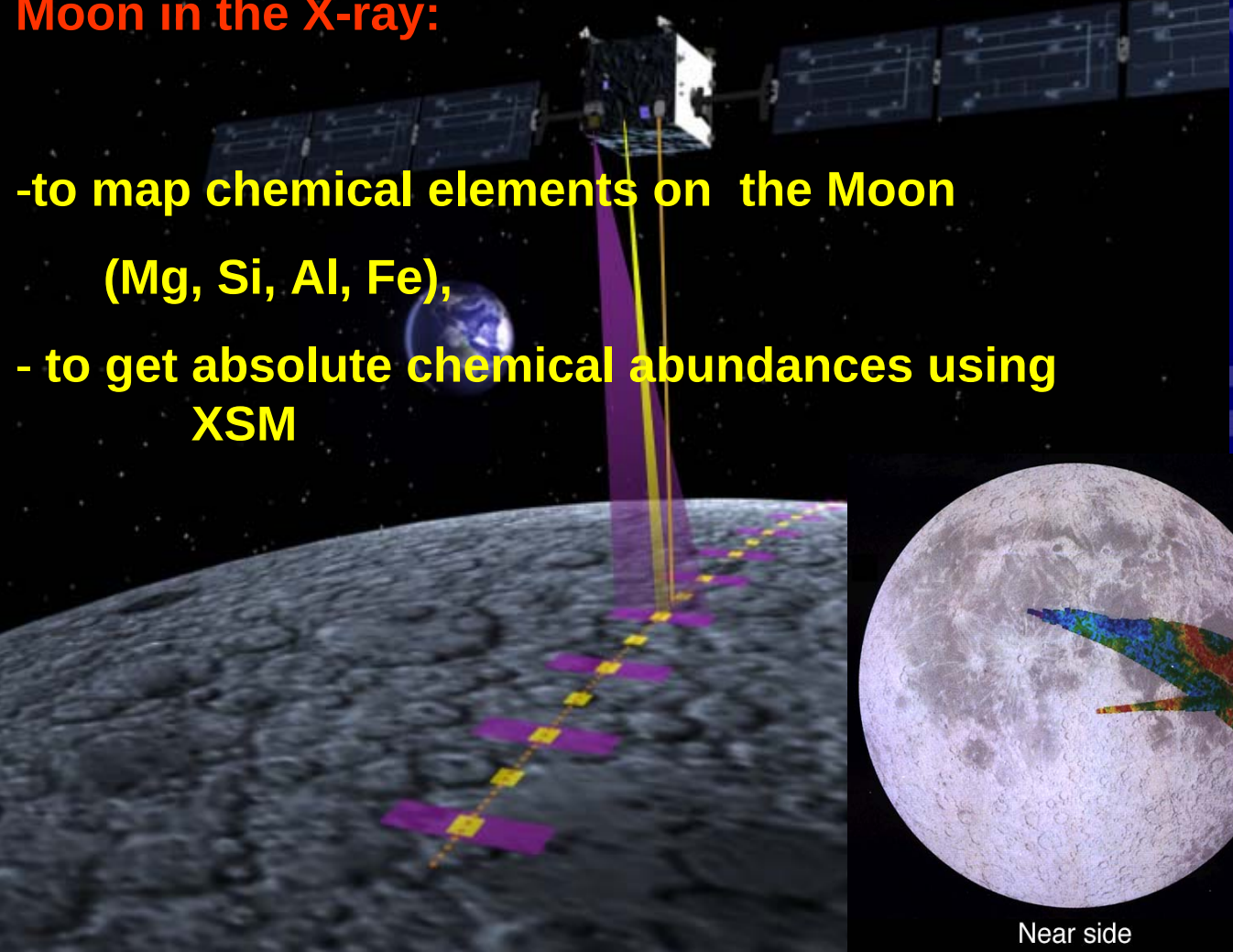
SMART_1 D-CIXS & the X-ray Moon: tracing violent Earth-Moon beginnings

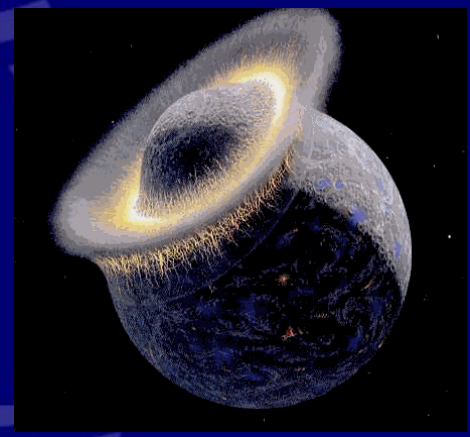
The D-CIXS spectrometer will look at the “invisible” Moon in the X-ray:

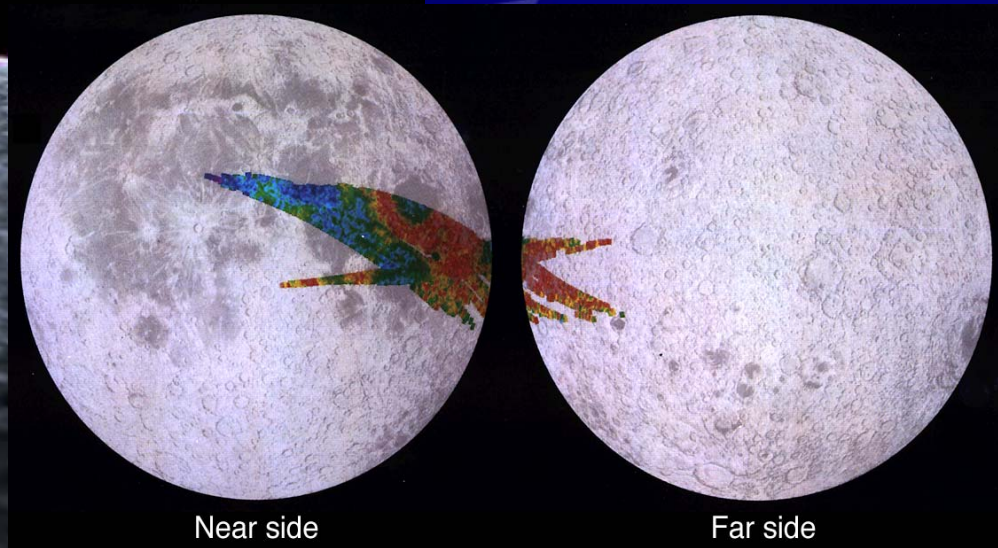


-to map chemical elements on the Moon

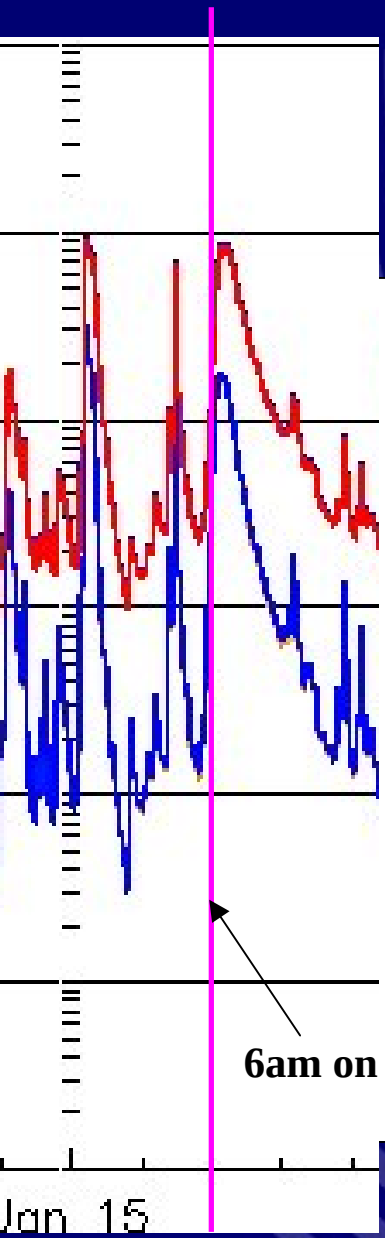
(Mg, Si, Al, Fe),

- to get absolute chemical abundances using XSM

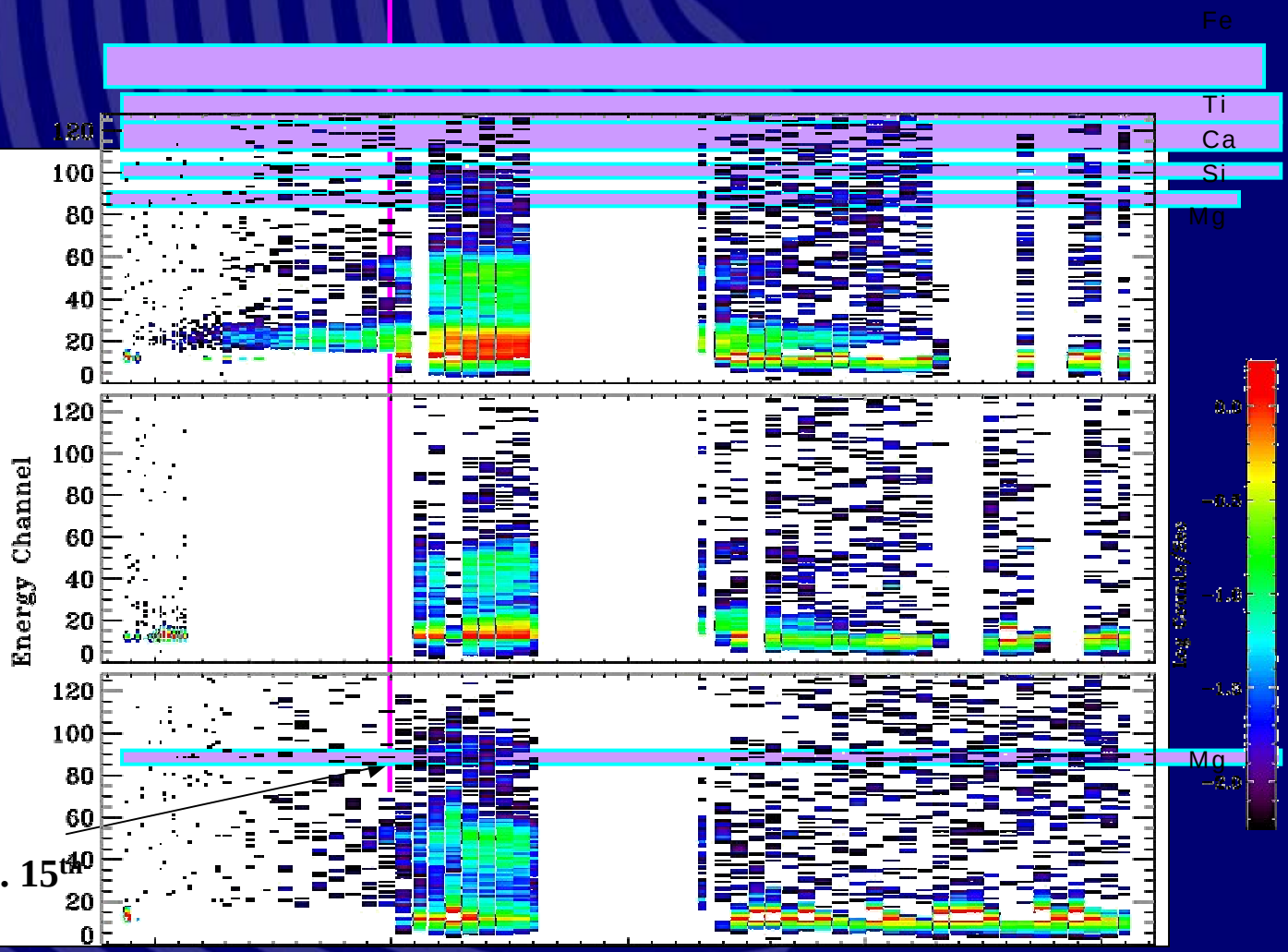




SMART-1/D-CIXS first lunar X spectra



6am on Jan. 15th

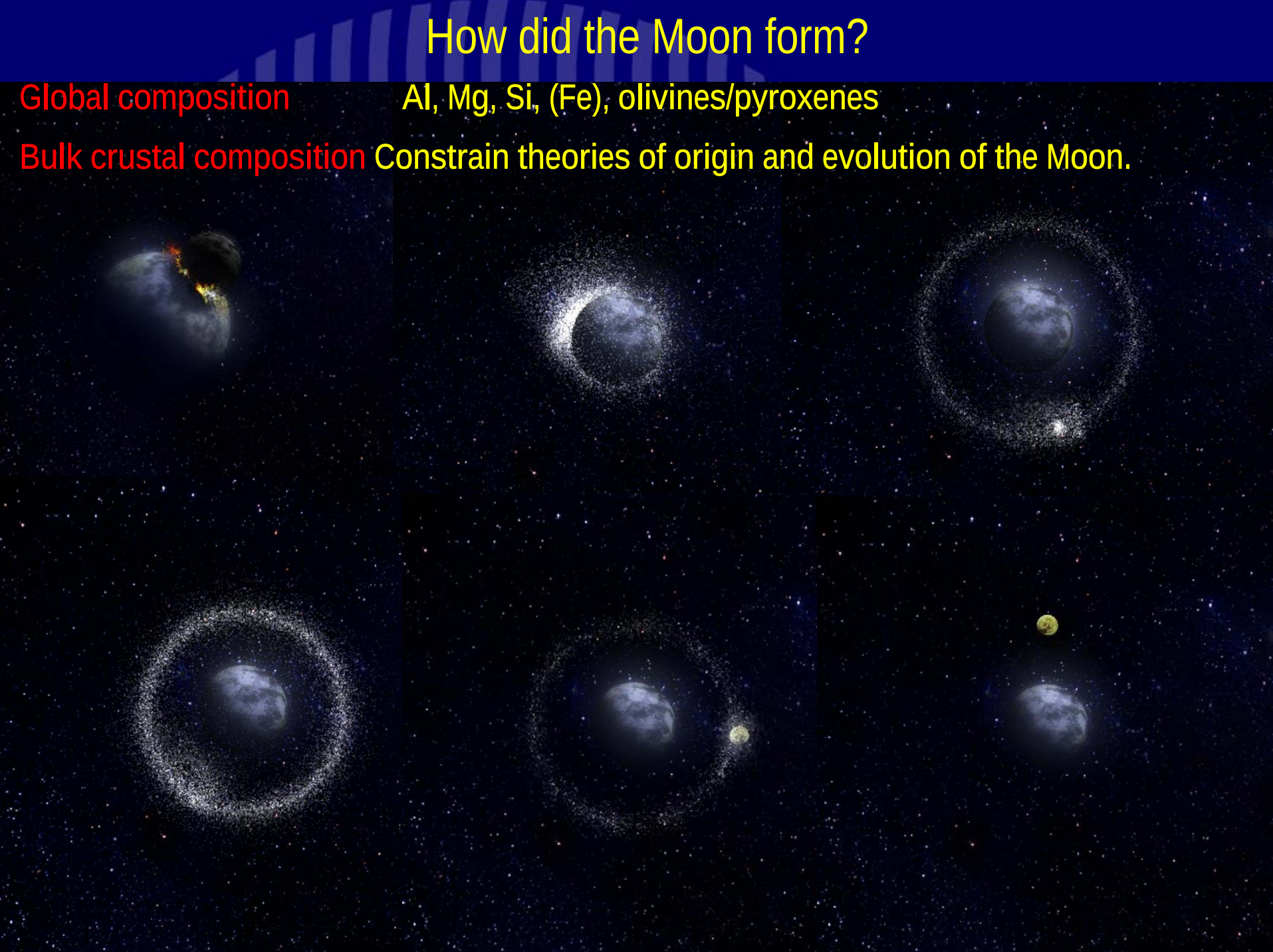


SMART-1 was flying over the Sea of Fertility when the flare went off. We see clear evidence for the magnesium rich Mare basalt (notice only the Mg line appears in the bottom D-CIXS panel – not silicon. This is the purpose of this panel – to eliminate "contamination" from silicon [and aluminium]). Silicon, calcium and titanium are also clearly detected plus iron is almost certainly present at the peak of the flare.

How did the Moon form?

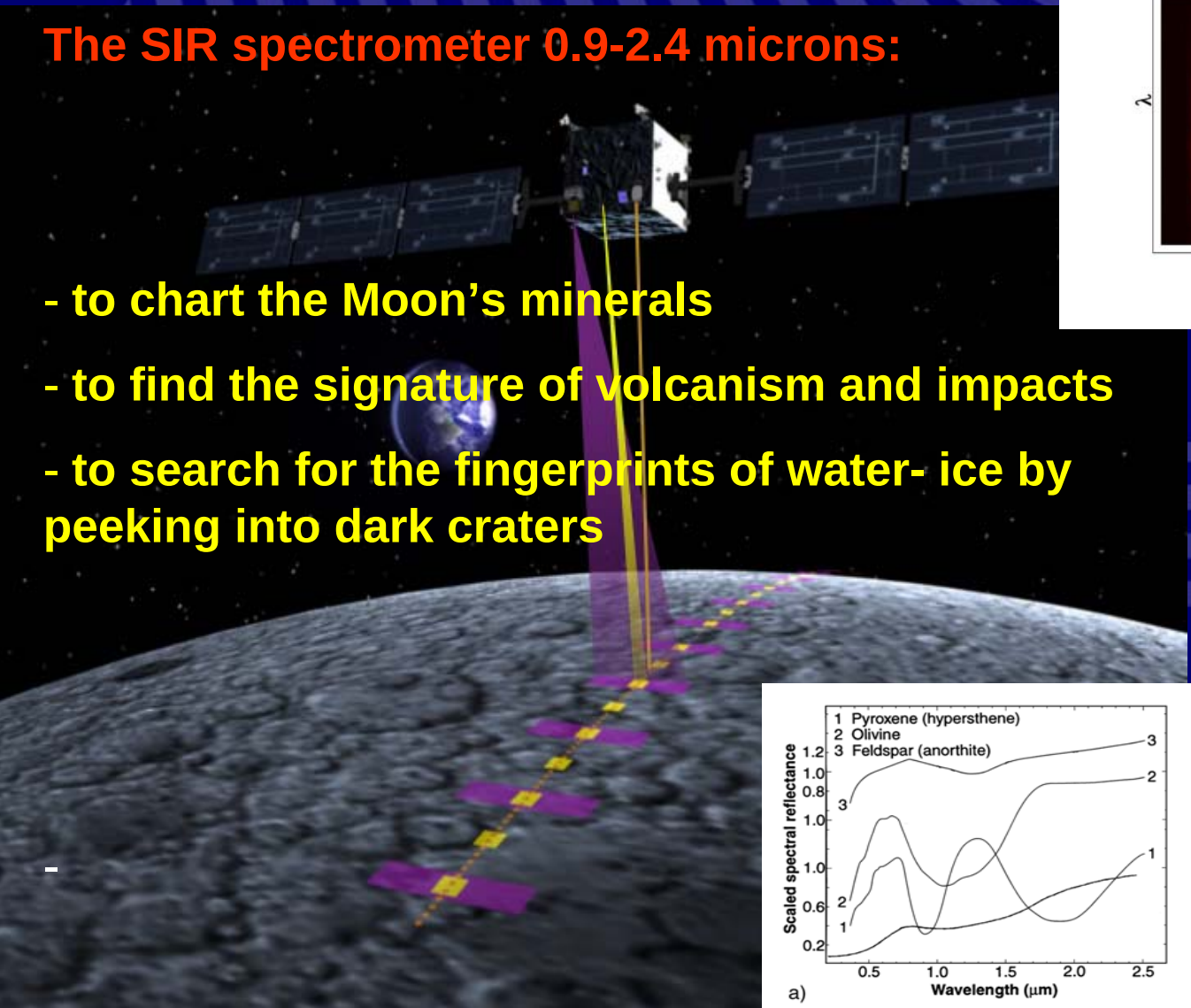
Global composition Al, Mg, Si, (Fe), olivines/pyroxenes

Bulk crustal composition Constrain theories of origin and evolution of the Moon.



Smart-1/SIR & the infrared Moon: minerals and ice

The SIR spectrometer 0.9-2.4 microns:

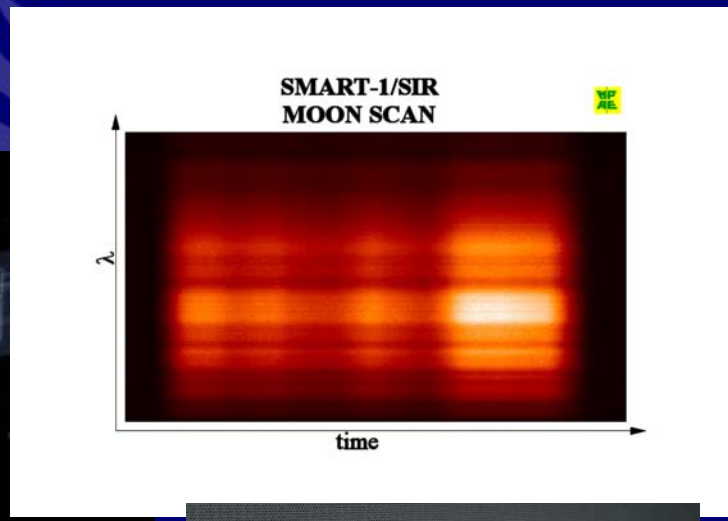


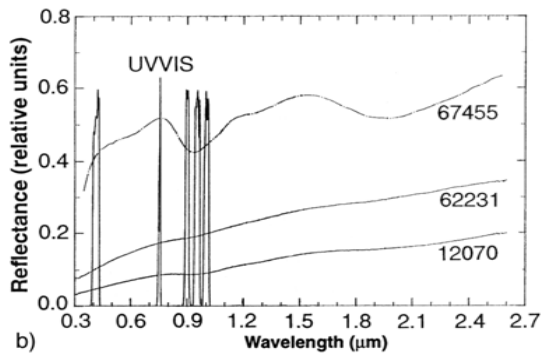
- to chart the Moon's minerals

- to find the signature of volcanism and impacts

- to search for the fingerprints of water- ice by peeking into dark craters

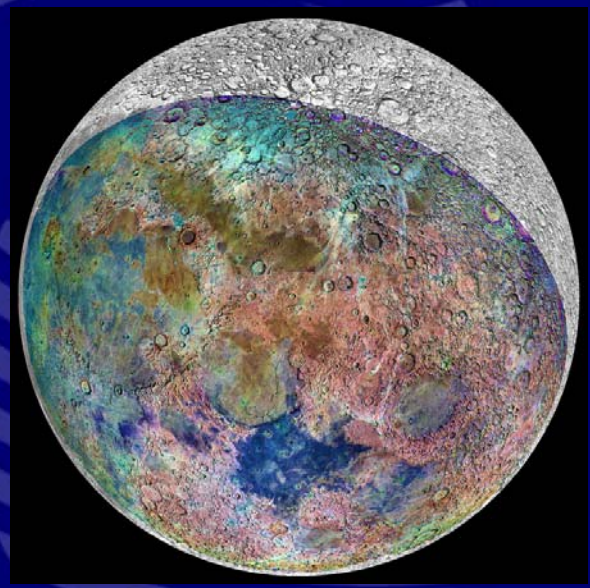
-

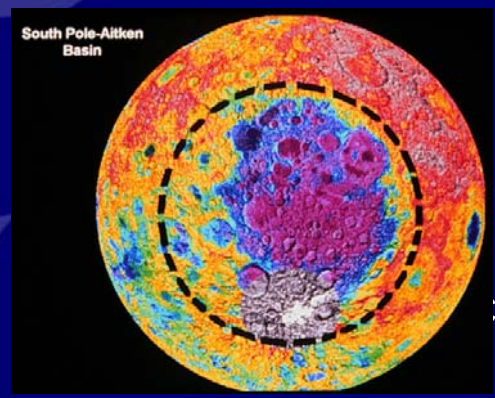




SMART-1 survey phase 1 March- 31 July

- Nadir observations
- D-CIXS global map
- SIR coverage 10 %
- Multicolour imaging
  - 750, 900 and 960 nm + White light
  - Southern colour map at better than 80 m/pixel
- Geology Context of targets
- Orbital / Telemetry/ illumination constraints





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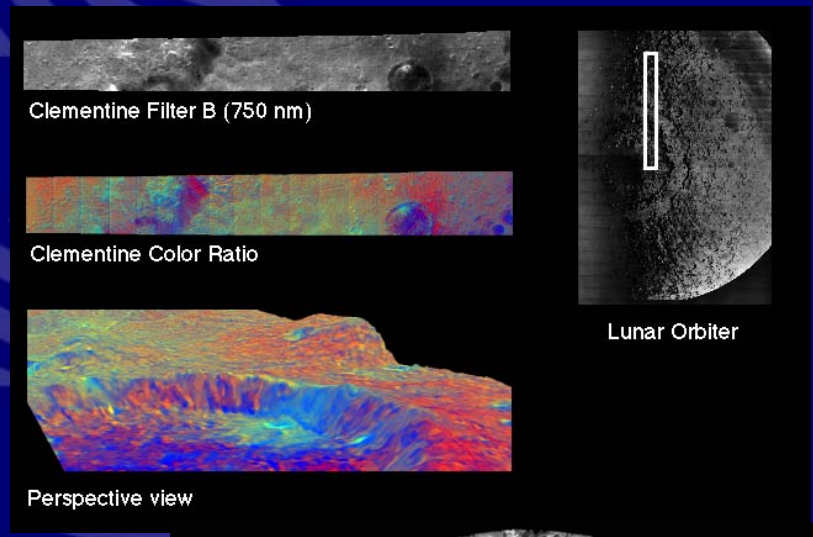
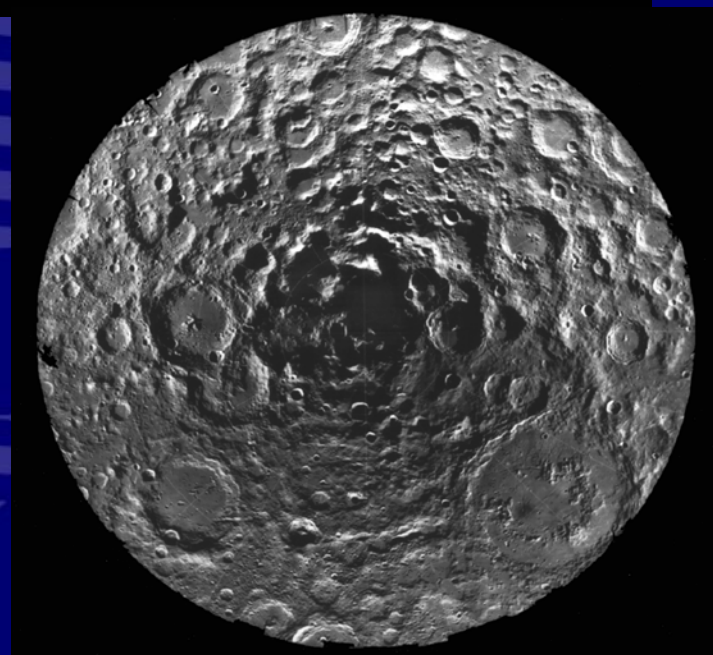
SMART-1 extension: 1st 6 months after reboost

- Fill gaps in survey
- Extend SIR/AMIE coverage, D-CIXS flare events
- Multi-angle, tracked, stereo maps
- Polar peaks of light
- Extended search for ice
- Dark side observations
- Mapping potential landing sites for future missions (South pole Aitken sample return, polar ice missions)
- Targeted observations SIR Central peaks of craters





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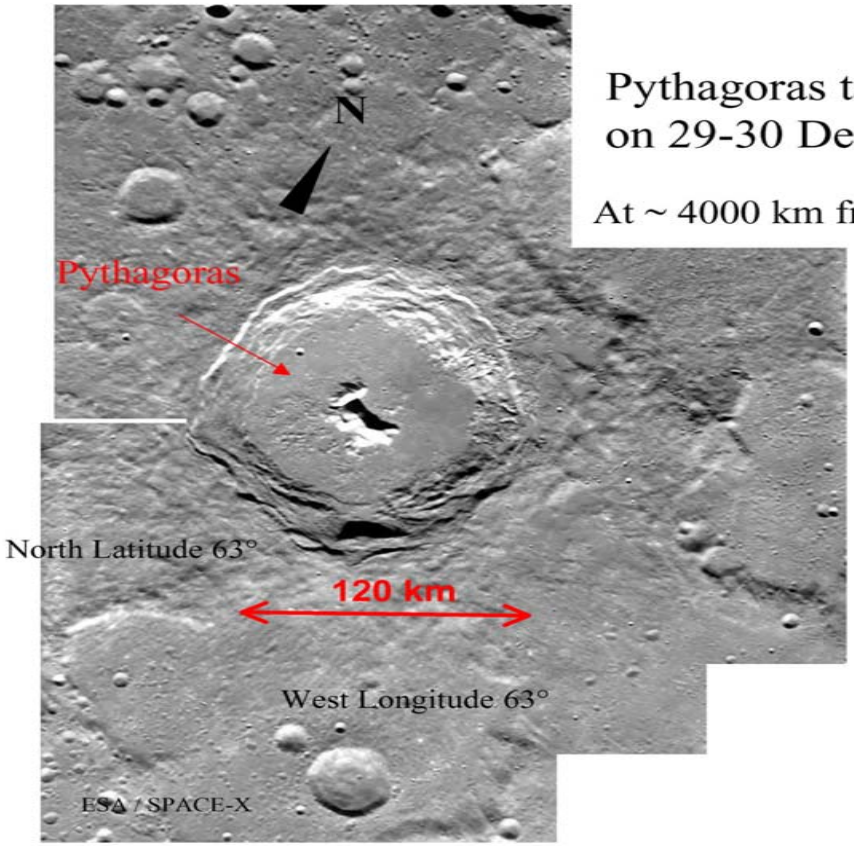
Pythagoras test images



Pythagoras taken by AMIE / SMART-1 on 29-30 Dec. 04

At ~ 4000 km from the Moon Surface

This mosaic view of Pythagoras is composed of images taken during two successives orbits. Pythagoras is a 120 km diameter complex lunar crater characterized by a relatively flat crater floor, a central peak and terraced walls. The terraced walls height reaches 5000 m.

SPACE -X
Space Exploration Inst.

C3 Vertical lithology basins ejecta central peaks, small craters

1 Introduction

The present document summarises the actual targets so far identified for SIR pointing requests. A new target list will be released this summer/autumn when details of the individual orbits are known.

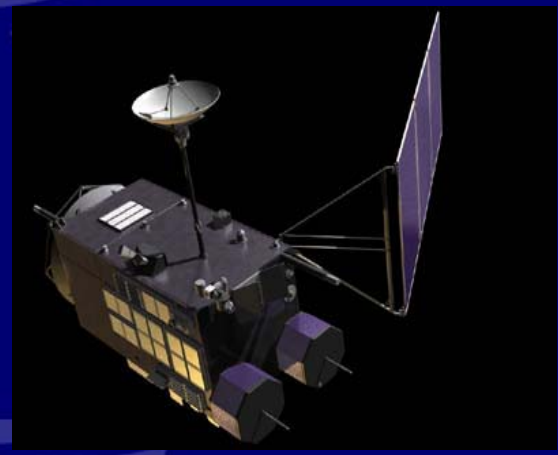
2 Preliminary Target Lists

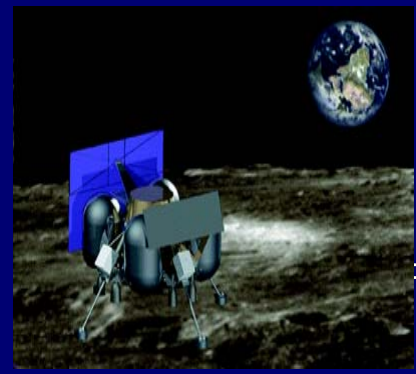
Table 1. Central-peaked craters of the Moon selected as potential targets for SIR

No	Name	Lat., deg	Long., deg	Dia., km	No	Name	Lat., deg	Long., deg	Dia., km
1	Schomberger	-76.7	24.9	85	32	Vavilov	-0.8	-137.9	98
2	Hale	-74.2	90.8	83	33	King	5	120.5	76
3	Moretus	-70.6	-5.8	111	34	Moiseev	9.5	103.3	59
4	Antoniadi	-69.7	-172	143	35	Copernicus	9.7	-20.1	93
5	Hausen	-65	-88.1	167	36	Lobachevskiy	9.9	112.6	84
6	Lyman	-64.8	163.6	84	37	Sharonov	12.4	173.3	74
7	Zucchius	-61.4	-50.3	64	38	Eratosthenes	14.5	-11.3	58
8	Fizeau	-58.6	-133.9	111	39	Ohm	18.4	-113.5	64
9	Tycho	-43.4	-11.1	102	40	Olcott	20.6	117.8	81
10	Fabricius	-42.9	42	78	41	Robertson	21.8	-105.2	88
11	Jenner	-42.1	95.9	71	42	Morse	22.1	-175.1	77
12	Finsen	-42	-177.9	72	43	Jackson	22.4	-163.1	71
13	Stevinus	-32.5	54.2	74	44	Plutarch	24.1	79	68
14	O'Day	-30.6	157.5	71	45	Kovalevskaya	30.8	-129.6	115
15	Birkeland	-30.2	173.9	82	46	Posidonius	31.8	29.9	95
16	Piccolomini	-29.7	32.2	87	47	Nusl	32.3	167.6	61
17	Mariotte	-28.5	-139.1	65	48	Geminus	34.5	56.7	85
18	Werner	-28	3.3	70	49	Cantor	38.2	118.6	81
19	Scaliger	-27.1	108.9	84	50	Von Neumann	40.4	153.2	78
20	Humboldt	-27	80.9	189	51	Eudoxux	44.3	16.3	67
21	Tsiolkovsky	-21.2	128.9	185	52	Atlas	46.7	44.4	87
22	Bullialdus	-20.7	-22.2	60	53	Hercules	46.7	39.1	69
23	Sklodowska	-18.2	95.5	127	54	Aristoteles	50.2	17.4	87
24	Aitken	-16.8	173.4	135	55	Pythagoras	63.5	-63	142
25	Lowell	-12.9	-103.1	66	56	Hayn	64.7	85.2	87
26	Friedmann	-12.6	-126	102	57	Kirkwood	68.8	-156.1	67
27	Theophilus	-11.4	26.4	110	58	Carpenter	69.4	-50.9	59
28	La Perouse	-10.7	76.3	77	59	Schjellerup	69.7	157.1	62
29	Langemak	-10.3	118.7	97	60	Philolaus	72.7	-32.4	70
30	Langrenus	-8.9	61.1	127	61	Ricco	75.6	176.3	65
31	Schluter	-5.9	-83.3	89	62	Plaskett	82.1	174.3	109

SMART-1 extension: after reboost Feb 2006

6 months: 1 end 2006
Optimal illumination, perilune 90-30 S
High res targeted pointings (SIR, AMIE)
Equator Northern hemisphere high res coverage
Winter solstices N 20 jan , S20 Jul 06
D-CIXS local coverage during flares
Coordination with Selene
Future landing sites
Support international collaborations
Prepare end of mission





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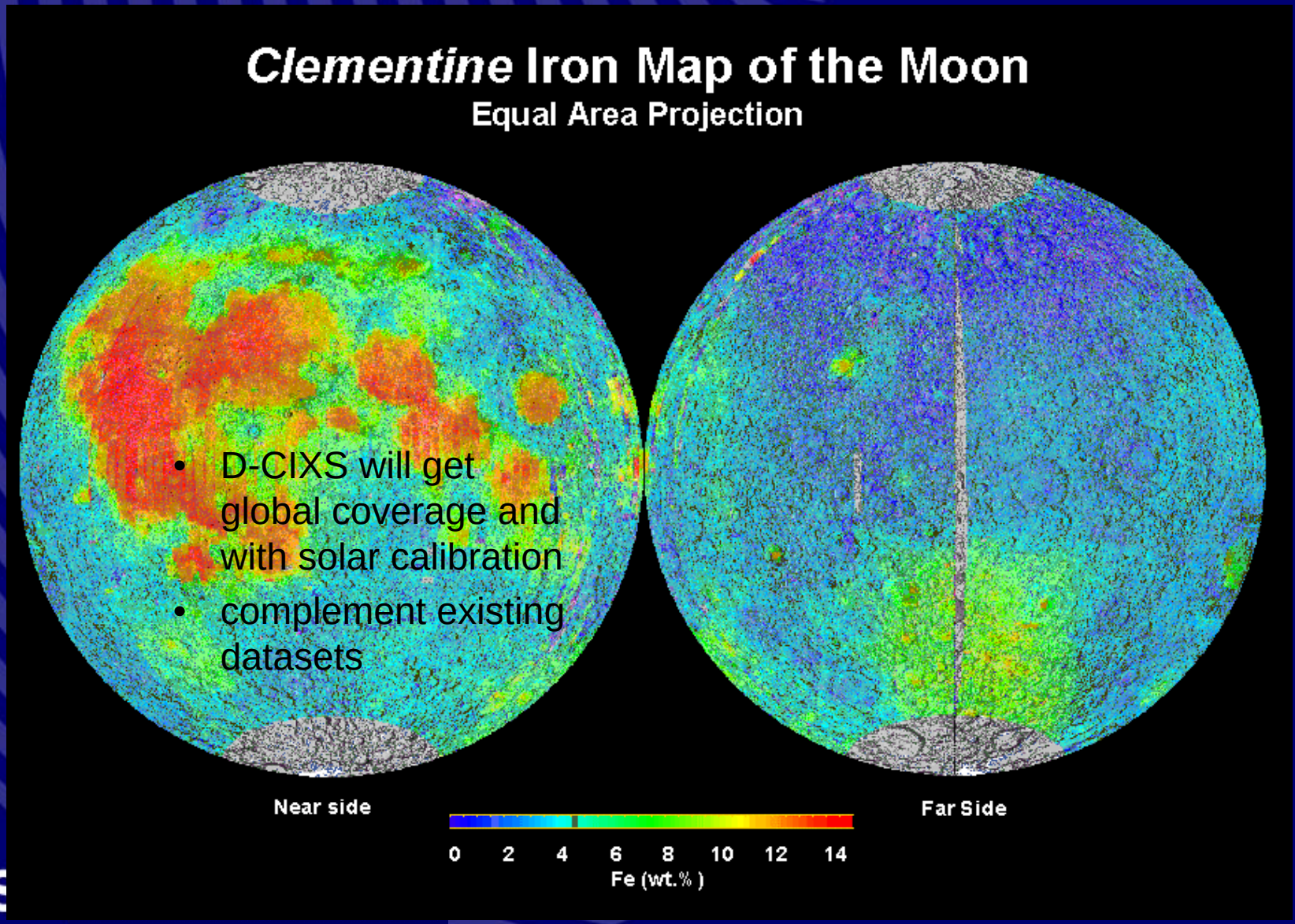
D3 Regional composition Al, Mg, Si, Fe olivines/pyroxenes Geology context



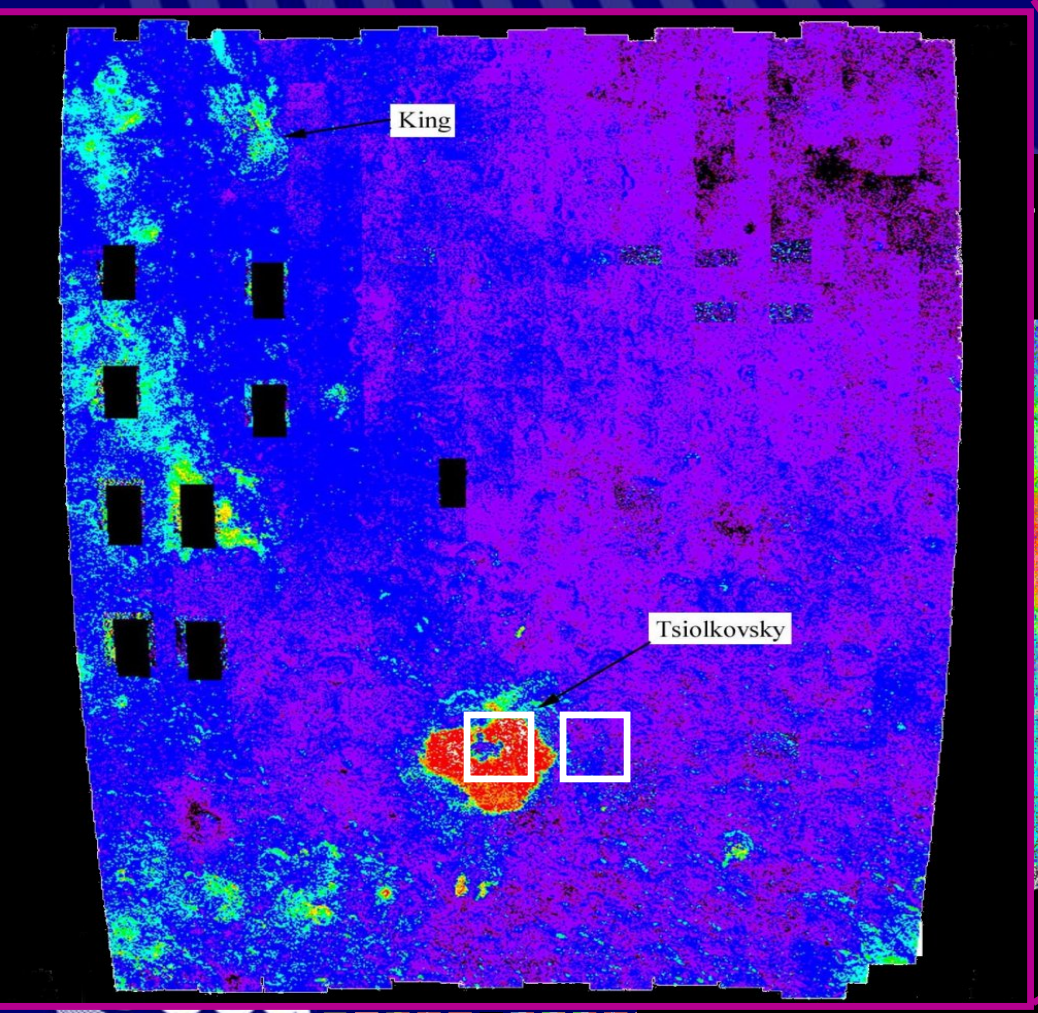
- D-CIXS will get global coverage and with solar calibration
- complement existing datasets

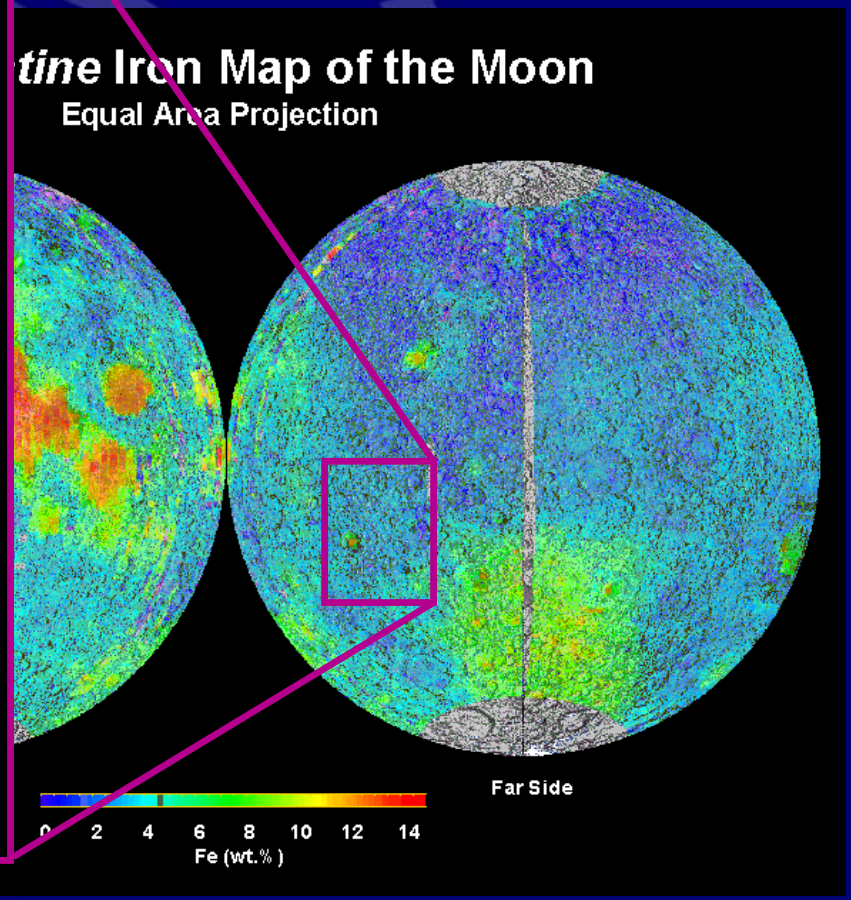
C1 Maria, volcanic

source Mg#

basalt distribution

studies of farside lunar volcanism





SMART-1 international collaborations

- Science/exploration:
  - Earth-Moon formation & evolution
  - water ice and resources
  - conditions for future sciences & life
  - sites for future robots/humans

- SMART-1 precursor for lunar fleet
- SMART-1 collaborations with future missions:

  2006 JAXA Lunar A & Selene

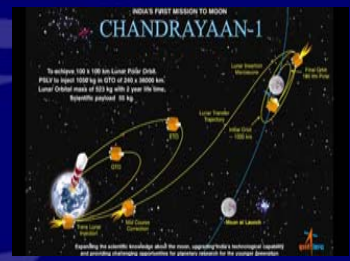
  2007 Chinese Chang'e 1

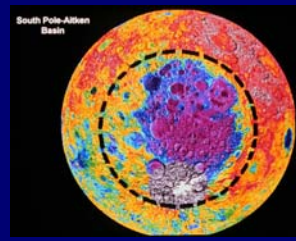
  2007 ISRO Chandrayaan-1

  2008 US Lunar Reconnaissance Orbiter

  2009 US South Pole Aitken sample return (TBC)

  2010-2012 landers, rovers, technology testbeds (US, China, Japan, Europe)





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SMART-1 9 Feb status

- Spacecraft /payload work and are ready for Moon
  - 19 Jan- 9 Feb EP off, mid- resolution pre-commission
  - 9-28 February EP on final spiral down, Star tracker blinding, limited payload ops
  - Fuel available for descent and 2 extension reboosts
- Operations
  - lunar commissioning 28 Feb
  - Baseline science ops : March 05:
    - nadir illuminated Moon pole-to-pole: 300-3000 km
    - Joint AMIE, SIR, DCIXS operations
  - Optimal illumination April-May noon-midnight orbit
- Extension:
    - Analyse cruise data + first results+ pipeline processing
    - New science, coverage, coordination other missions

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