Revision Lecture – PLANETS

Diversity of planets –Taking stock	*Topic #1*
Detecting and measuring their properties	*Topic #2*
Planetary missions: going *in situ*	*Topic #3*
Radar mapping of surfaces	*Topic #4*
Atmospheres	*Topic #5*
Magnetospheres and radio emissions	*Topic #6*

Problem Sheet #1
Problem Sheet #2 *Practice exam*

Topic #1 – Taking stock

You MUST remember

Basic organisation of the Solar System

Planets: which are rocky, which are not

Main basic features of each planet (atmosphere? magnetic field?)

A common technique to remember their order is mnemonics:
My Very Educated Mother Just Served Us Noodles

You can safely forget

Technical details (e.g. mass, radius, all numbers)
If needed, they will be provided.

Numbers and names of satellites of Jupiter, Saturn etc.

Topic #2 – Measuring the Solar System

You MUST remember

How to measure planetary sizes and distances
Newton's 3 Laws and how to use them
Kepler's 3 Laws and how to use them
The simple nuclear equations seen in PH20016 and now in PH20104
(radioactive decay, activity, etc.)
Wien's law

You don't need to remember the equations but need to know how to use them:

Planck's law for blackbody radiation
(but you should remember how it is used …)
Stefan-Boltzmann law

You can safely forget

Parallax effect
Rydberg's constant

Topic #3 – Planetary exploration: Tools and missions

You MUST remember

Orbital mechanics
Mission design (from power to communications)
Concept of beam pattern (main lobe vs. sidelobes – *not the need for deconvolution or the equations*)
Travel times: when to use one-way or two-way travel times

You don't need to remember the equations but <u>need to know how to use them:</u>

Hohmann transfer orbits

You can safely forget

Exact details of Magellan and Cassini-Huygens missions
(they were there to illustrate the main points in the Topic)

Question:

in lecture 3 in the 'Measuring the Basics' section, I do not understand what the radar ranging to the moon graph shows on the slides. Please could you go over exactly what it shows and how the information is used in the revision lecture?

Radar ranging to the Moon

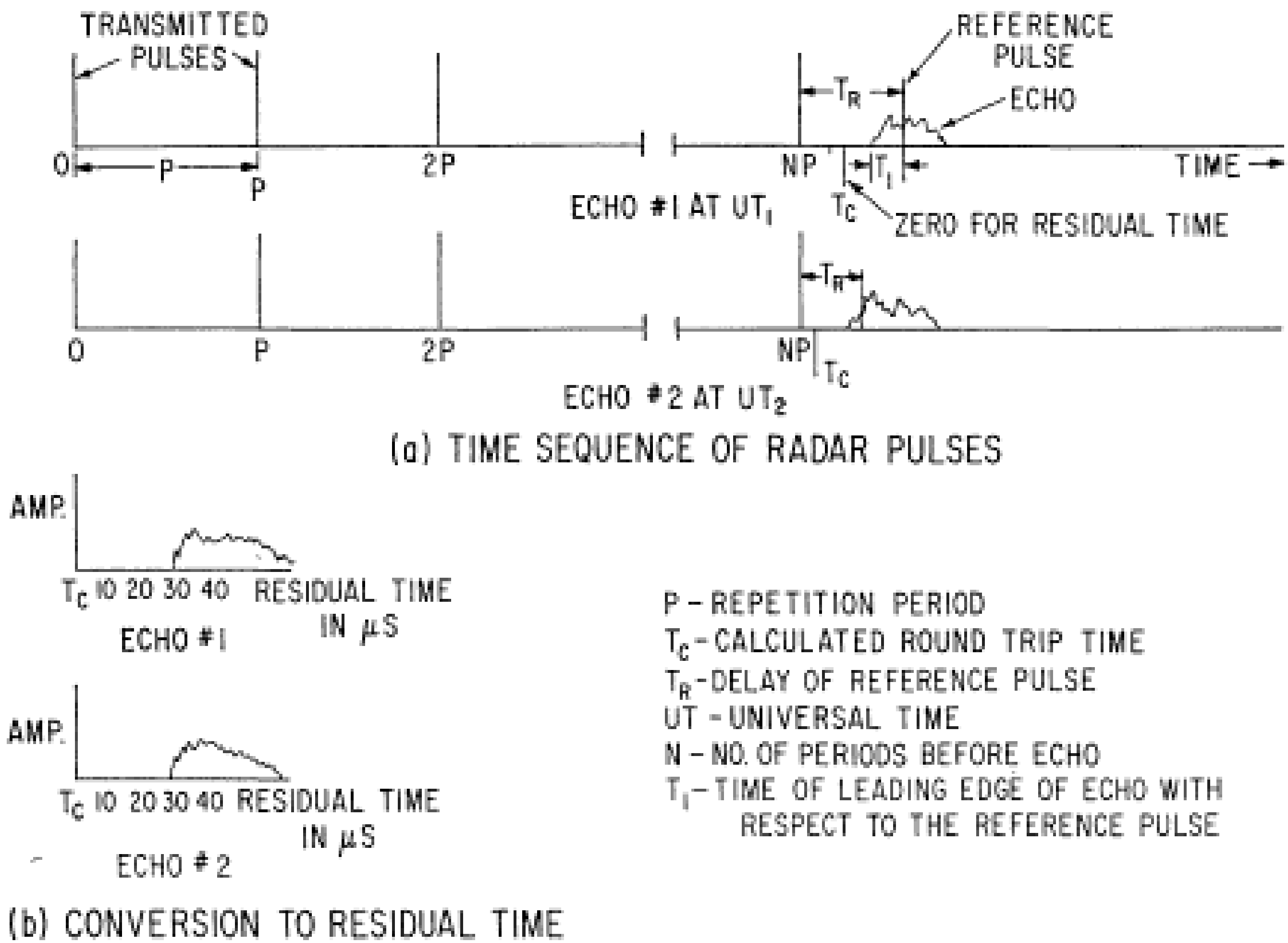


Fig. 2. — Time sequences of radar pulses and conversion to residual time.

Topic #4 – Radar Mapping of Surfaces

You MUST remember

Basics of EM scattering and propagation (only the very basics)
Concept and use of scattering and penetration in planetary surfaces
Concept and use of Fourier and fractals to measure heights
Role of surface and its properties (topography, dielectric constant, content, …)

You don't need to remember the equations but need to know how to use them:

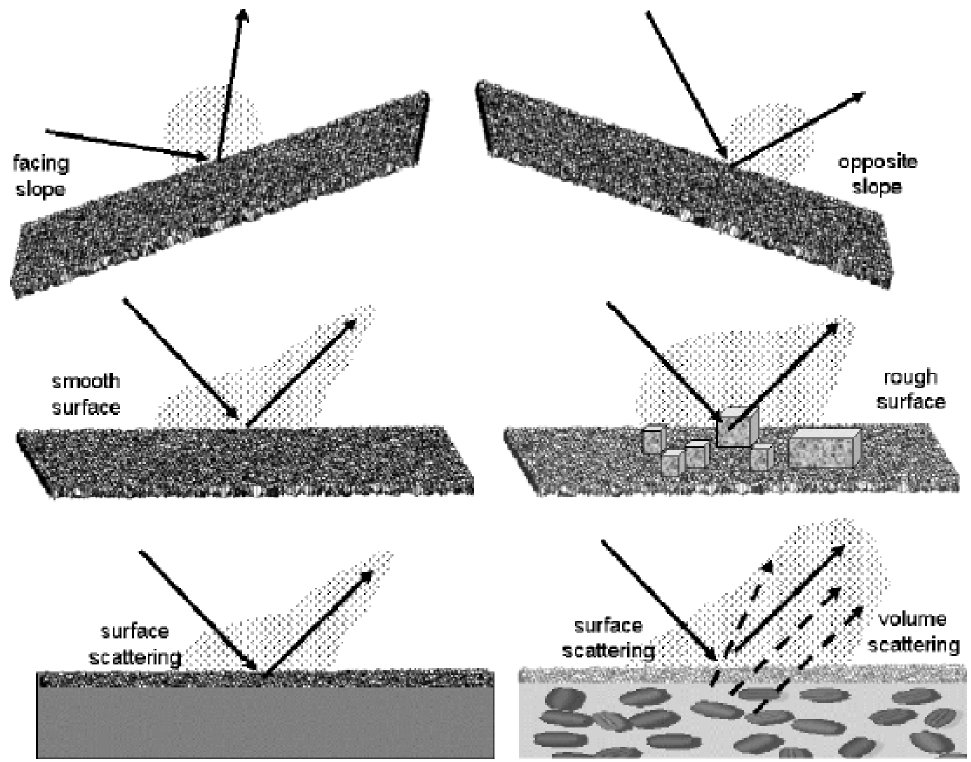
Reflectivity/transmissivity (if you need them, they will be provided)
Auxiliary orientation angle
Penetration depth – Skin depth
Average height, roughness and tilt
Mixing formulas (e.g. PVL, Lichtenecker, Lorentz-Lorenz)

You can safely forget

Hagfors model equation
Wave propagation equation
Radar equation
Exact frequency bands (apart from orders of magnitude for radar wavelengths in general)
Exact values of ε and μ for specific targets (just an order of magnitude is good enough)
SAR concepts and how it works
Radar scattering models: from the integral equation to workable approximations

Question: what is the difference between optical and radar albedo?

Albedo is how reflective a target is at a particular wavelength



Radar albedo is not the same as the dielectric constant (but they are related)

A high radar albedo can result from either large surface roughness, a very dense surface composed of rock, or even a porous metallic surface

Topic #5 – Planetary Atmospheres

You MUST remember

Vertical stability conditions
Lapse rate, at least the key equations used in Problem Sheet #2
The key components of a typical planetary atmosphere
Concepts of cloud formation and evolution/movements
Remote sensing of planetary atmospheres: reflected/scattered/thermal components

You don't need to remember the equations but need to know how to use them:

Saturated lapse rate
Hydrostatic equation and hydrostatic equilibrium (and how to derive them)
(the full derivation is available on Moodle, drawing on Year 1 material)
Coriolis force and geostrophic flow
Vertical wind shear
Optical thickness

You can safely forget

Margules' formula
Jean's flux of thermal escape
Exact names of the zones and belts of Jupiter (e.g. NPR, SEB, NNTZ)
(just remember there are different bands and why)

Topic #6 – Planetary Magnetospheres

You MUST remember

Solar activity and types of interaction with planets (e.g. with magnetic field or without,
with atmosphere or without)

Synchrotron emission – Radio emissions in general

You don't need to remember the equations but need to know how to use them:

Chapman-Ferraro distance

You can safely forget

Plasma frequency

Exact speeds of solar wind in different conditions (it will be provided if needed)

Question: *I'd quite like it if at some point you could discuss magnetic pole reversals on earth*

The positions of the magnetic North and South poles are reversed.

Normal polarity: the direction same as now

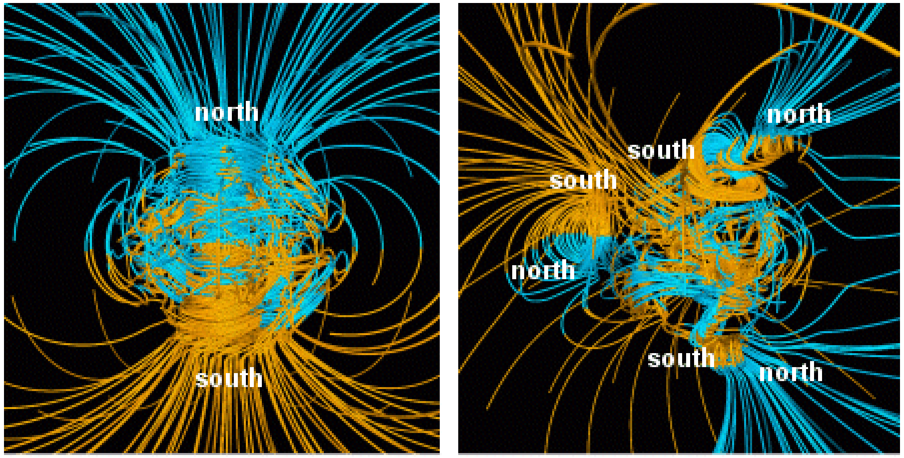
Reverse polarity: pointing in the other direction

Reversals are statistically random: > 183 reversals in last 83 million years

(on average once every ~450,000 years)

The latest is the Brunhes–Matuyama reversal, 780,000 years ago

We do not know how long a reversal takes (up to thousands of years???)



between reversals | during a reversal

NASA simulation (Glatzmaier & Roberts)

Related to changes in Earth's dynamo (convection of molten iron in planetary core)

Confirmed by simulations and experiments (e.g. with liquid metal) (sodium)

Triggers: still heavily debated (plate tectonics? impacts? instabilities?)

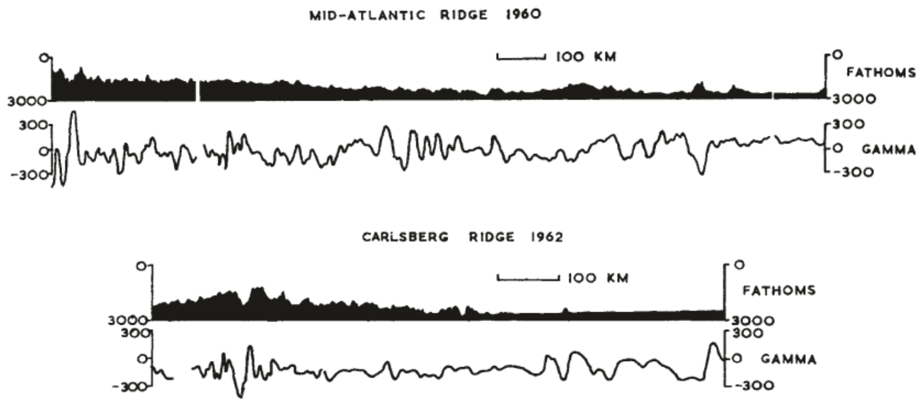
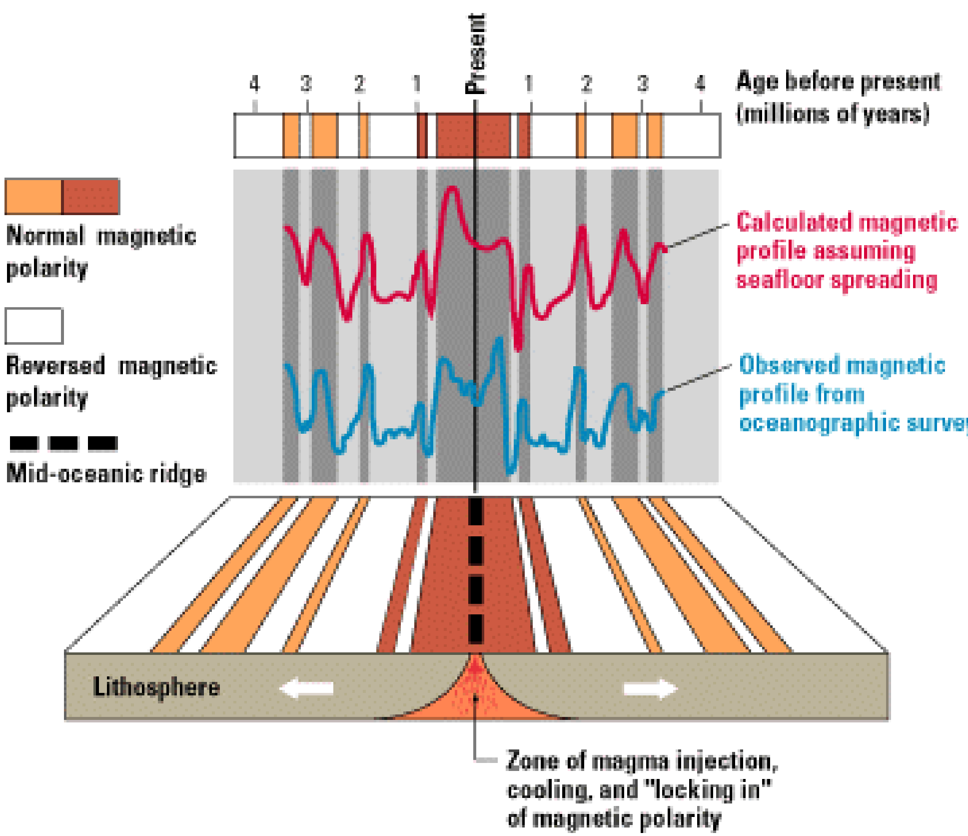


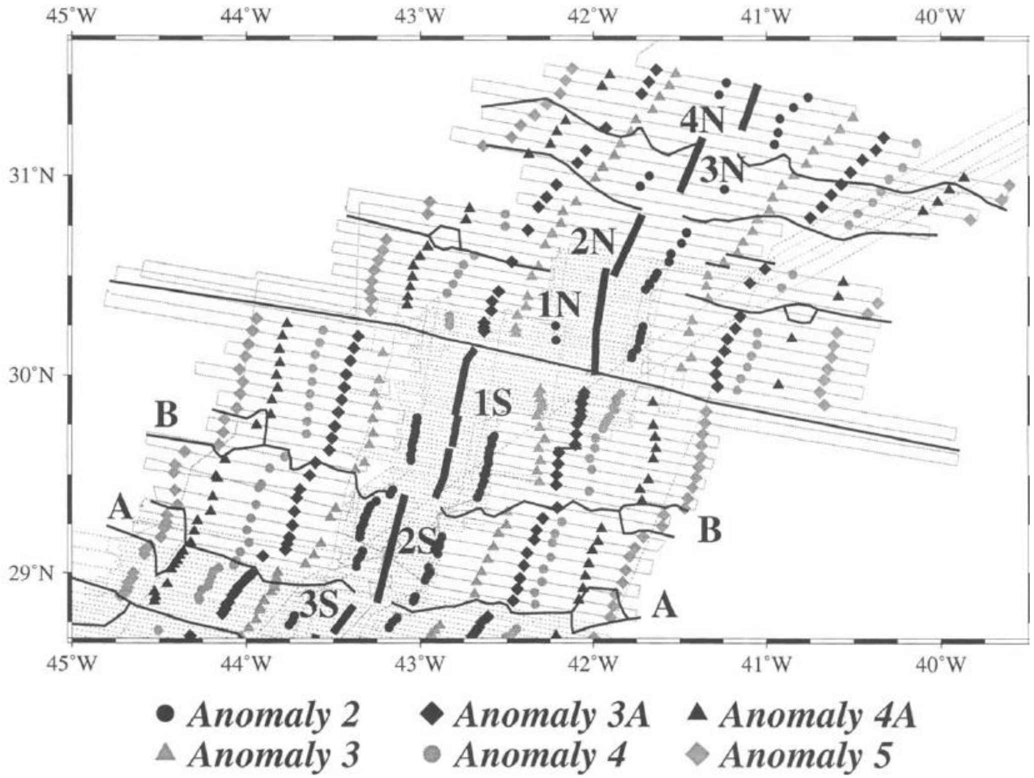
Fig. 1. Profiles showing bathymetry and the associated total magnetic field anomaly observed on crossing the North Atlantic and the north-west Indian Oceans. Upper profile from 45° 17′ N. 28° 27′ W. to 45° 19′ N. 11° 29′ W. Lower profile from 30° 5′ N. 61° 57′ E. to 10° 10′ N. 66° 27′ E.

Vine and Matthews, *Nature*, 1963

Mantle material cools as it rises convectively under a ridge and then spreads horizontally outward.

As the material cools through its Curie point, it is magnetized parallel to the contemporary local geomagnetic field.





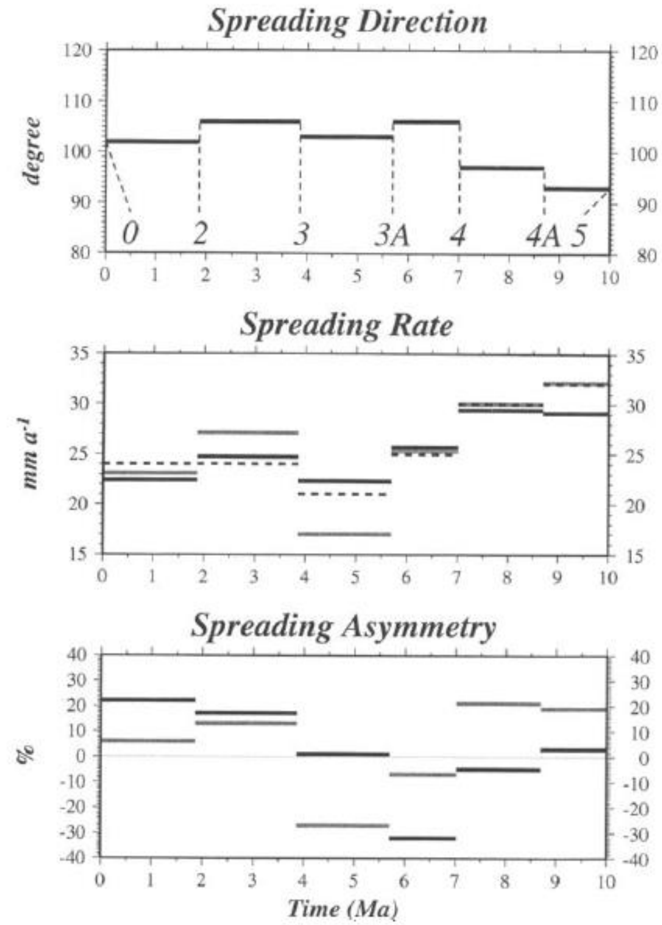


Fig. 4. Variations in spreading direction, rate and asymmetry over the last 10 Ma for segments 1S (gray) and 2S (bold). The

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Earth and Planetary Science Letters 130 (1995) 45–55

EPSL

The Mid-Atlantic Ridge between 29°N and 31°30′N in the last 10 Ma

J.-C. Sempéré [a], P. Blondel [a,1], A. Briais [1,b], T. Fujiwara [1,c], L. Géli [1,d], N. Isezaki [1,e], J.E. Pariso [1,a], L. Parson [1,f], P. Patriat [1,g], C. Rommevaux [1,g]

[a] *School of Oceanography, WB-10, University of Washington, Seattle, WA 98195, USA*

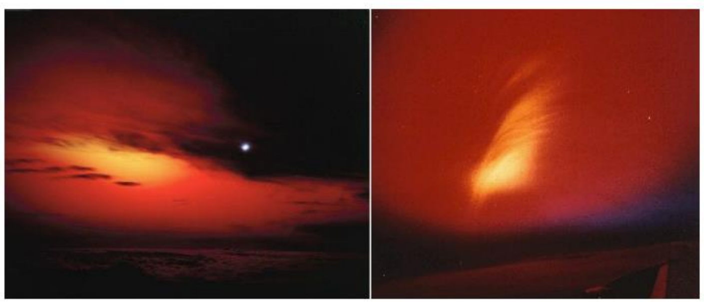
Starfish Prime: The First Accidental Geomagnetic Storm

JULY 8, 2022JULY 8, 2022 / DR.TONY PHILLIPS

July 9, 2022: Sixty years ago today, one of the biggest geomagnetic storms of the Space Age struck Earth. It didn't come from the sun.

"We made it ourselves," recalls Clive Dyer of the University of Surrey Space Centre in Guildford UK. "It was the first anthropogenic space weather event."

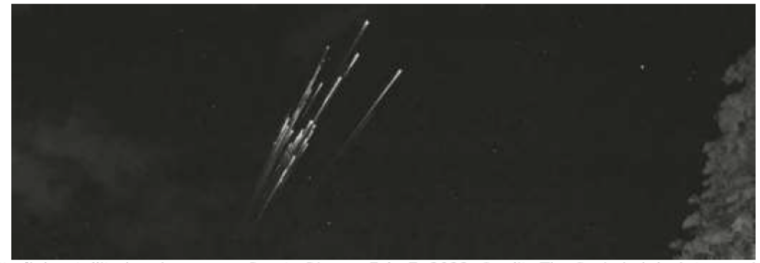
On July 9, 1962, the US military detonated a thermonuclear warhead 250 miles above the Pacific Ocean–a test called "Starfish Prime." What happened next surprised everyone. Witnesses from Hawaii to New Zealand reported auroras overhead, magnificent midnight "rainbow stripes" that tropical sky watchers had never seen before. Radios fell silent, then suddenly became noisy as streetlights went dark in Honolulu.



Above: *'Nuclear auroras' viewed from Honolulu (left) and from a surveillance aircraft (right) on July 9, 1962.*

Essentially, Starfish Prime created an artificial solar storm complete with auroras, geomagnetic activity, and blackouts. Much of the chaos that night was caused by the electromagnetic pulse (EMP)–a ferocious burst of radiation that ionized the upper

THE STARLINK INCIDENT: A minor geomagnetic storm is supposed to be *minor*. That's why even experts were surprised on Feb. 4, 2022, when dozens of Starlink satellites started falling out of the sky. A weak CME had hit Earth's magnetic field, and the resulting G1-class (minor) storm was bringing them down:



Above: A Starlink satellite breaks up over Puerto Rico on Feb. 7, 2022. Credit: The Sociedad de Astronomia del Caribe

How could this happen? A new paper published in the research journal *Space Weather* provides the answer.

"Although it was only 'minor,' the storm pumped almost 1200 gigawatts of energy into Earth's atmosphere," explains lead author Tong Dang of the University of Science and Technology of China. "This extra energy heated Earth's upper atmosphere and sharply increased aerodynamic drag on the satellites."

Problem Sheets #1, #2

You MUST remember

Everything !

You don't need to remember the equations but need to know how to use them:

See indications for the lectures.

How the questions are written gives you a fair idea of what <u>could</u> be asked at the exam, and how it <u>might</u> be asked.

You can safely forget

Nothing.

Exam

The exam is set to take 2 hours to answer.

It will have 60 marks allocated in total.

40 marks for the "Planets" part of the course

20 marks for the "Exoplanets" part of the course

Format: answer all questions

Content:

– material from lectures

– hints given during the lectures

– problems similar to those from Problem Sheets

A sample exam covering the entire course (PLANETS and EXOPLANETS) is on Moodle
Its model answers show how we would expect the answers to be written.

Example from a previous year:

4. The first interstellar object to be discovered in the Solar System was 1I/2017 U1 ('Oumuamua). There was little time to observe it after detection and astronomers have long waited for similar transits. In 2023, a similar object is discovered and named Keikikane. Observations from a space-based telescope shows it has a cylindrical shape, 1 km long and 230 m in diameter.

(a) A radio-telescope on Earth is taking radar measurements of its dielectric constant when it is 1 AU away. Assuming it sees its longest dimension, what beamwidth (in milliarcseconds) is needed to image Keikikane in full? [2]

1.378 milliarcseconds

(b) Trajectory analyses predict it will be 0.16 AU from Earth at its closest approach. If the original image was 10 pixels wide at 1 AU, what is the ground resolution of 1 pixel? Considering how many pixels can now be measured along the surface, what is the gain in spatial resolution? [3]

16 m
6.25

(c) Radar measurements show an overall dielectric constant $\varepsilon = 5.7$. The space-based telescope indicates spectral reflectance typical of a mixture of clay ($\varepsilon_1 = 8$) and chondrite material ($\varepsilon_2 = 5$). Using the Lorentz-Lorenz formula, calculate the respective volume fractions V_1 and V_2 of these materials. [3]

V1 = 30%
V2 = 70%

(d) A popular astronomer is persuaded that 10% of the clay material corresponds in fact to solar panels (whose bulk dielectric constant can be approximated as $\varepsilon_3 = 18$). Explain numerically whether the radar measurements prove or disprove this theory. [4]

Past exams are ALL on the Library website, with numerical solutions, e.g.:

https://www.bath.ac.uk/library/exampapers/solutions.bho/2018-2019/Semester2/PH/PH20104.pdf