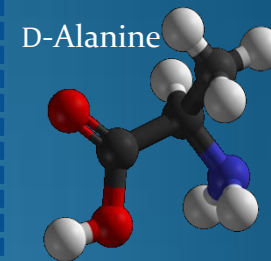
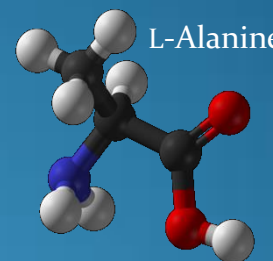
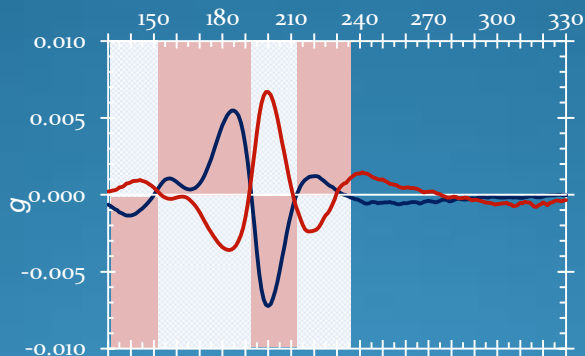


Chirality in life



Søren Vrønning Hoffmann

IFA, Januar 2017
vronning@phys.au.dk

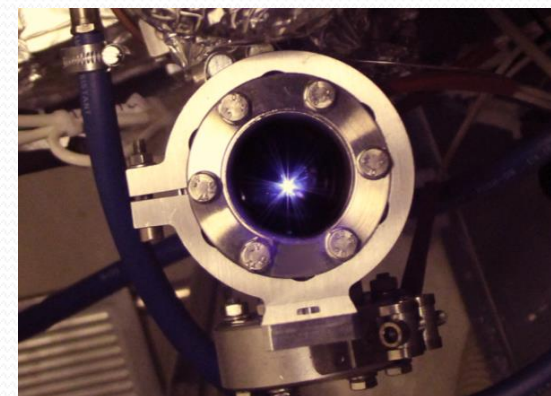
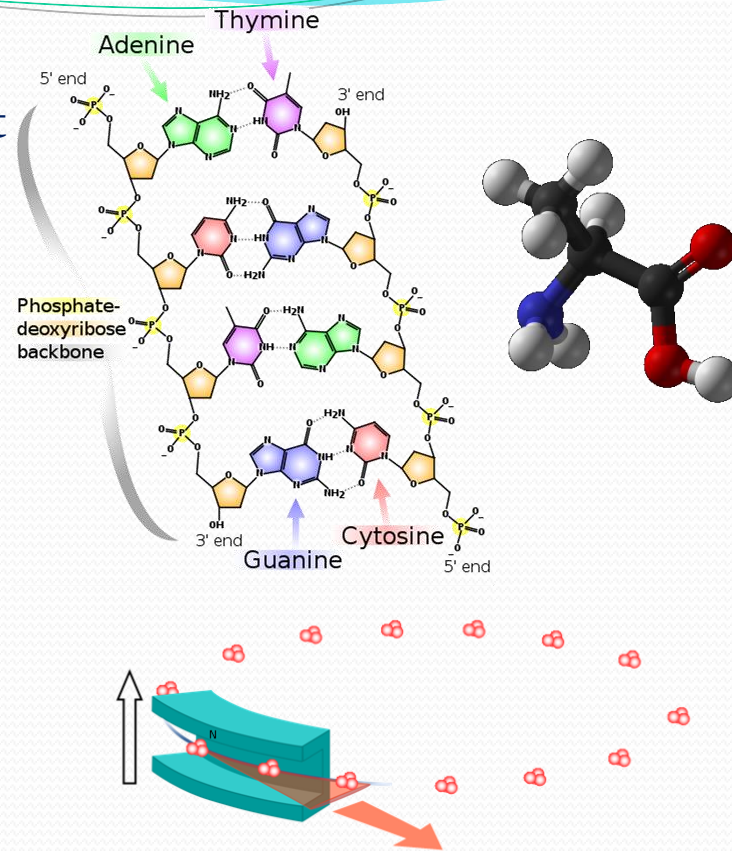


Introduktion

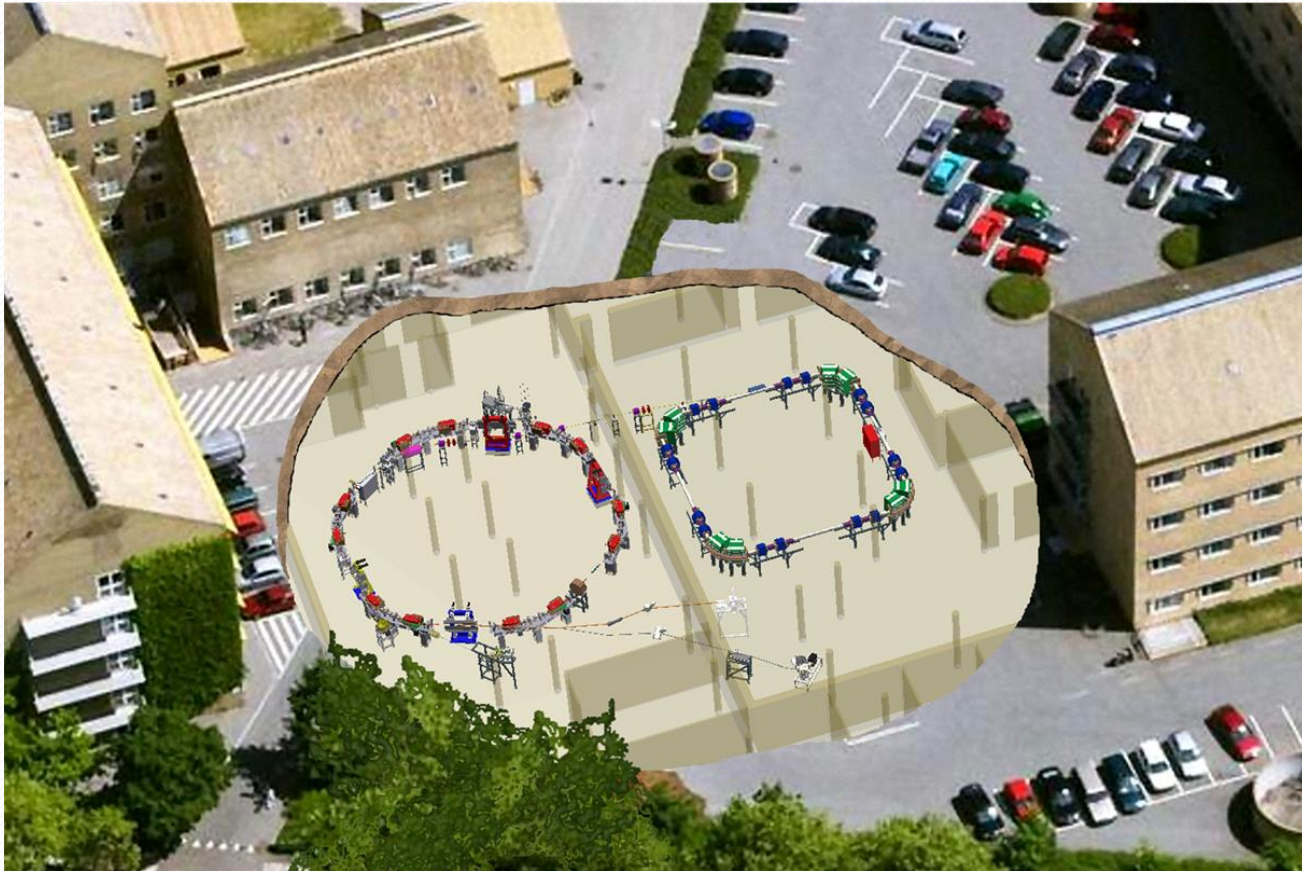
- Livets molekyler (f.eks. proteiner og DNA) er et fascinerende komplekst system.
- Rigtigt mange elektroner og mange mulige tilstande.



- Amino syrer og sukre absorberer først i det dybe UV område (~200 nm).
- Vi bruger for en kraftig og tunebar UV kilde: Synkrotron stråling.

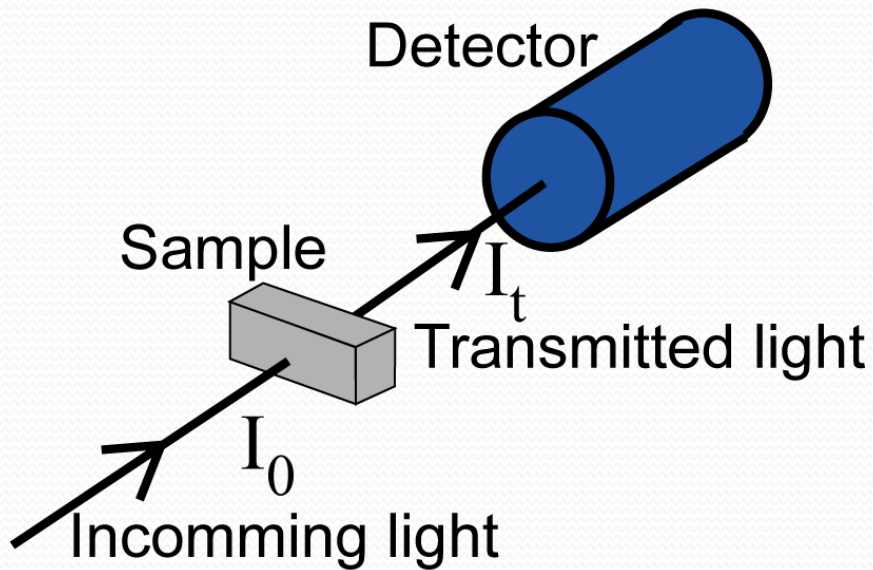


The ASTRID accelerator complex



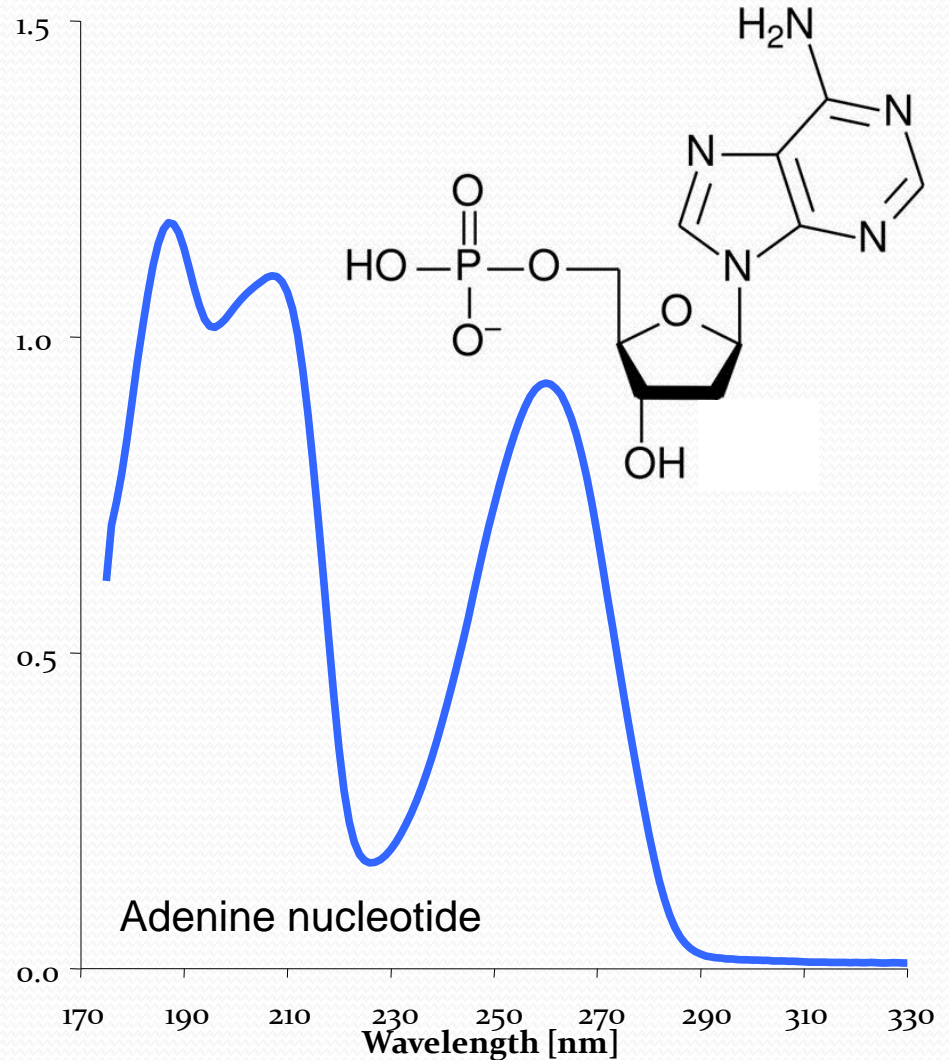
The ASTRID and ASTRID2 complex is situated under the parking lot between physics and chemistry

Spectroscopy: UV-Absorption



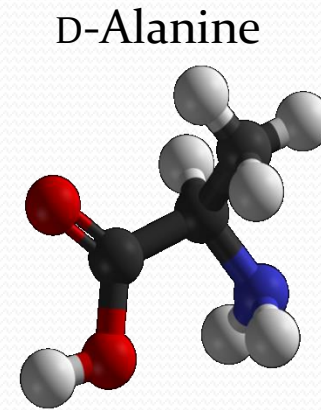
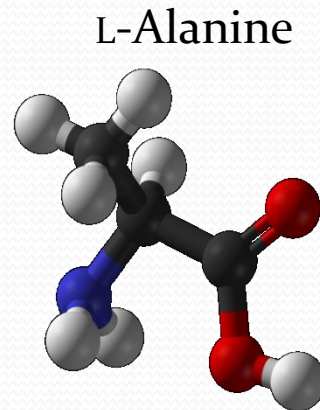
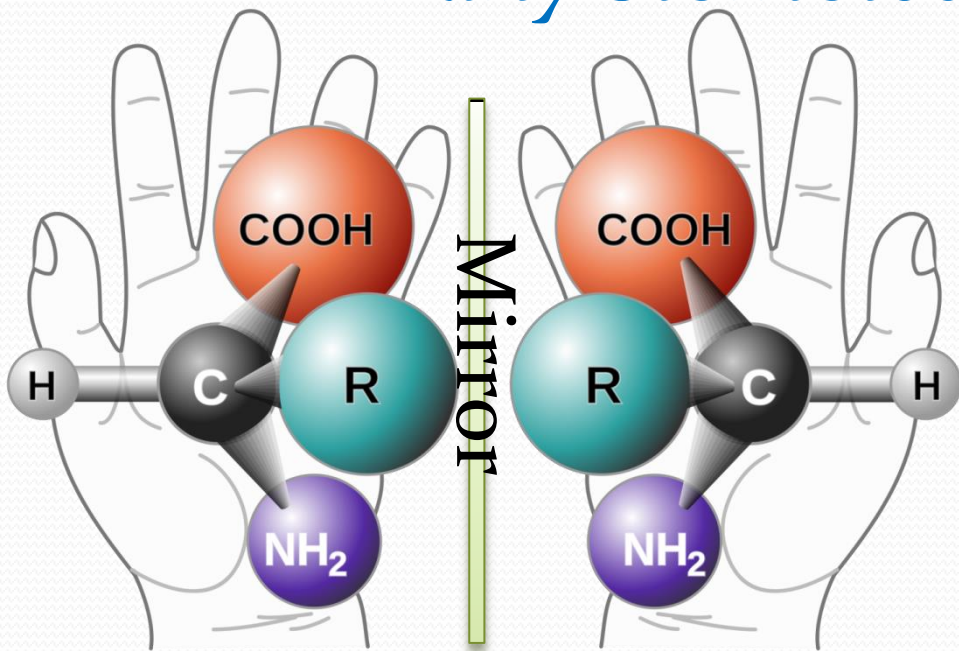
Absorbance:

$$A = \log(I_0/I_t)$$



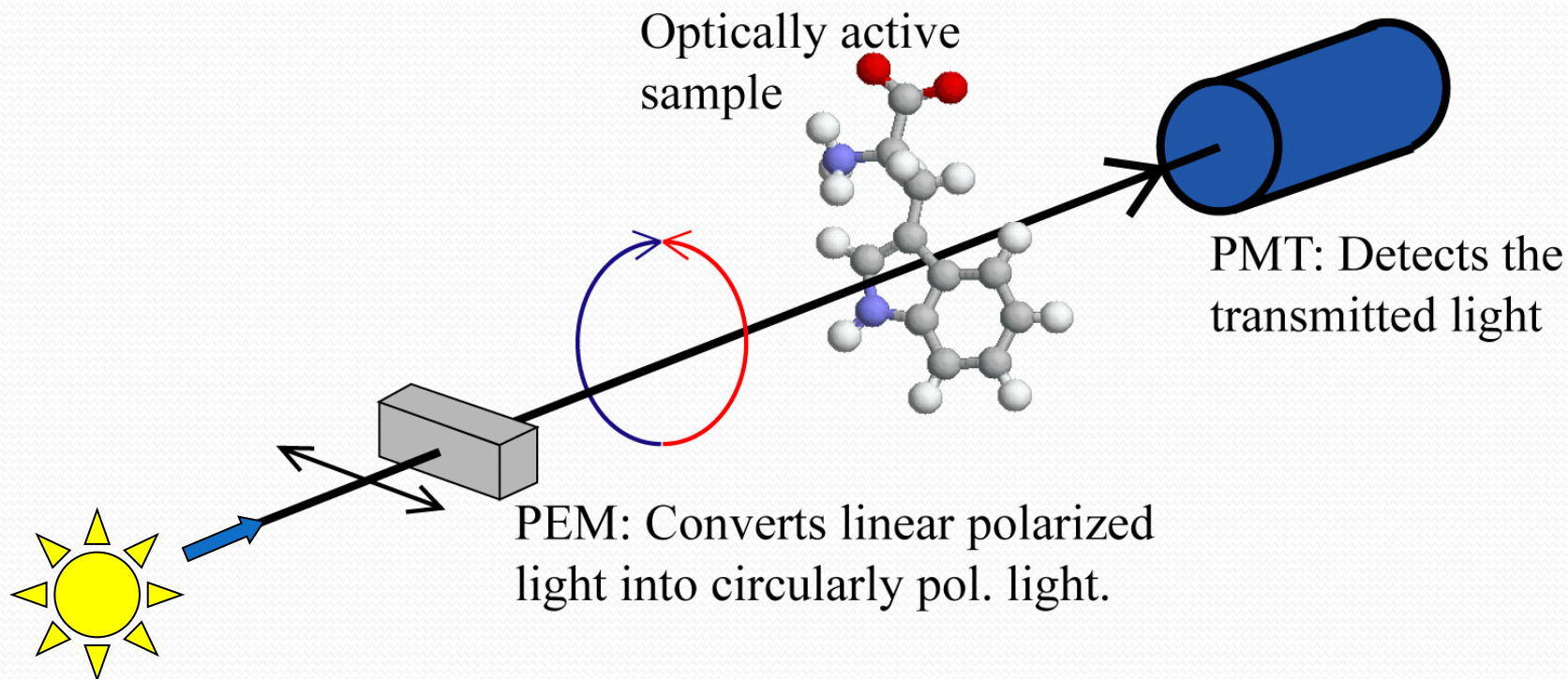
Introduction: Chirality

Many biomolecules are chiral



Circularly polarized light
is also chiral

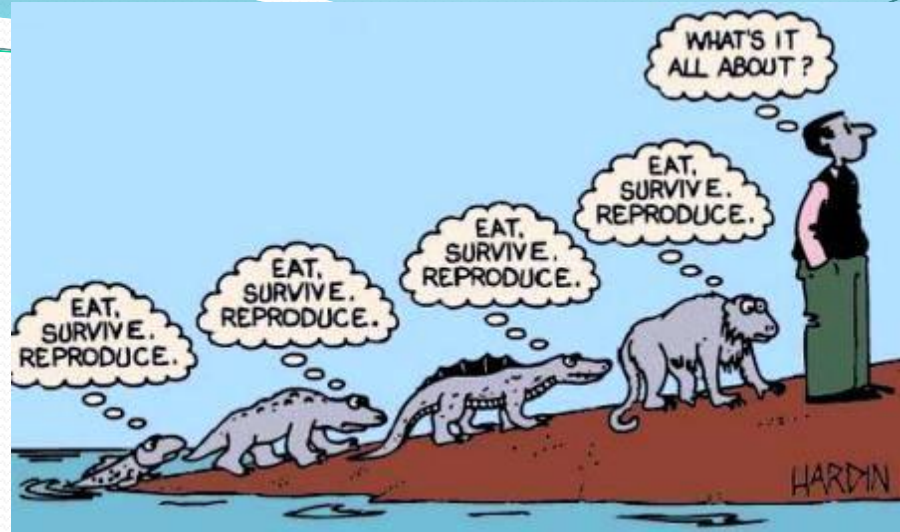
Circular Dichroism



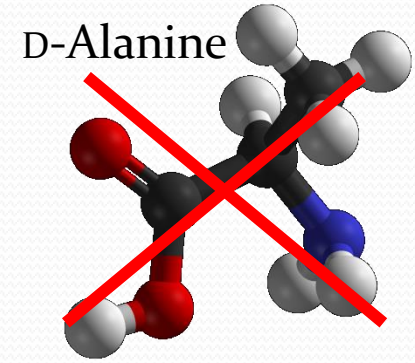
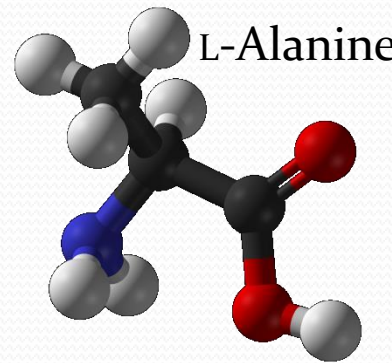
The CD signal: $CD = A_L - A_R$

Introduction

- *The origin of life is a fascinating topic.*



- Homochirality in life: Almost exclusively single enantiomers:
 - L-form of amino acids in proteins
 - D-form of sugars in DNA



Where, Why, How come....

Introduction

- Many theories for origin of this racemic symmetry breaking.

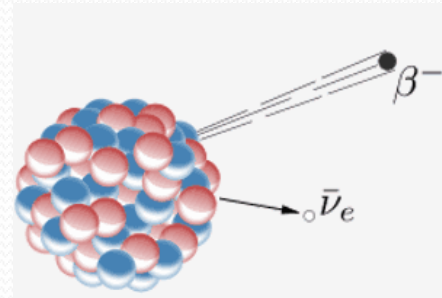
-By chance:

Stochastic fluctuations breaking symmetry

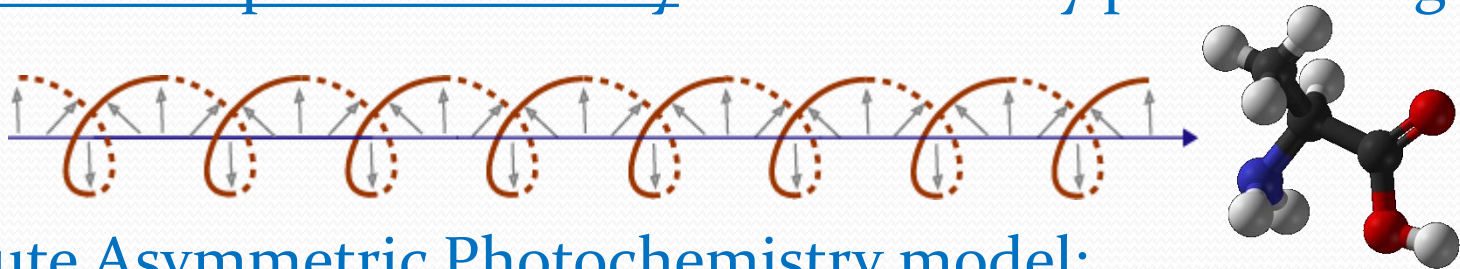


-Beta decay:

Parity violation in weak nuclear force



-Asymmetric photochemistry with circularly polarized light.



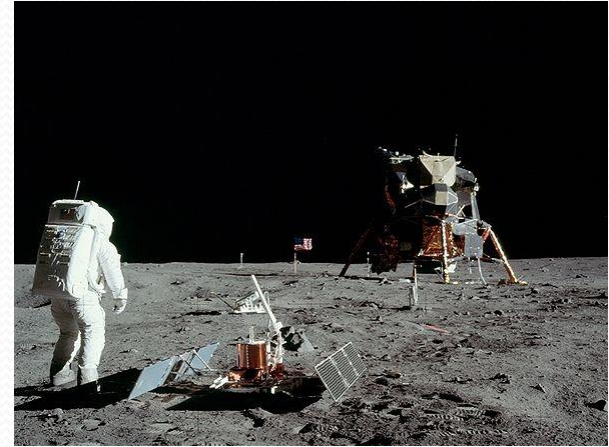
- Absolute Asymmetric Photochemistry model:
Possible *extra-terrestrial* origin of homochirality

Man's exploration of space: 1969

July 1969: The lunar landing.

First man to land on the moon

Possible to actively bring 'home'
extra-terrestrial material



September 1969: Murchison meteorite

This *carbonaceous chondrite* Meteorite
fell near Murchison, Victoria, Australia.

Found to contain amino acids

Enantiomeric excess (*ee*):

Up to a few %

Up to 18.5%

L- α -H amino acids

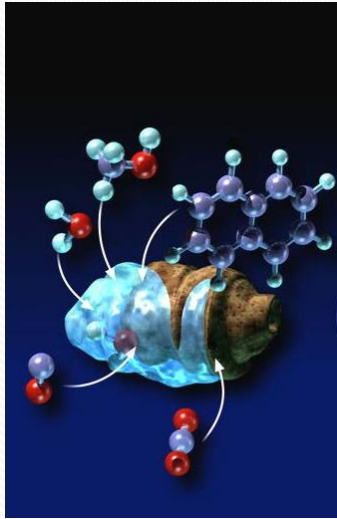
L-Iva (α -Methyl amino acid)



Ice of molecules on particles and comets

Origin of pre-biotic molecules on Interstellar Dust Particles (IDP)

H_2O , CO_2 , CO , NH_3
and CH_3OH on IDP



Irradiated with UV light

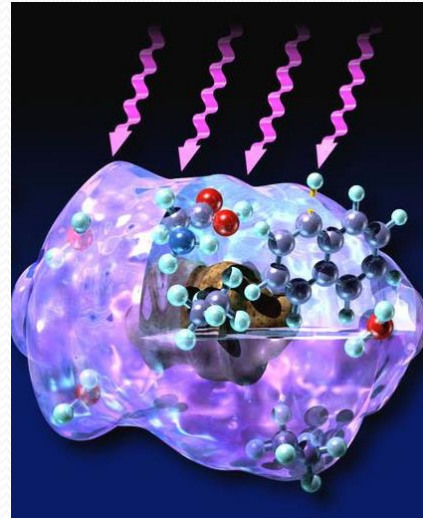
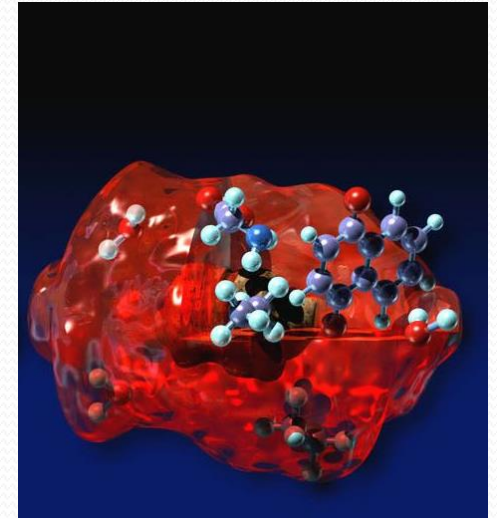


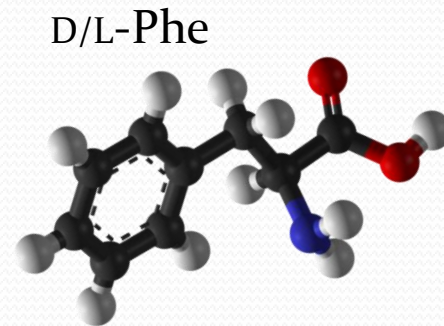
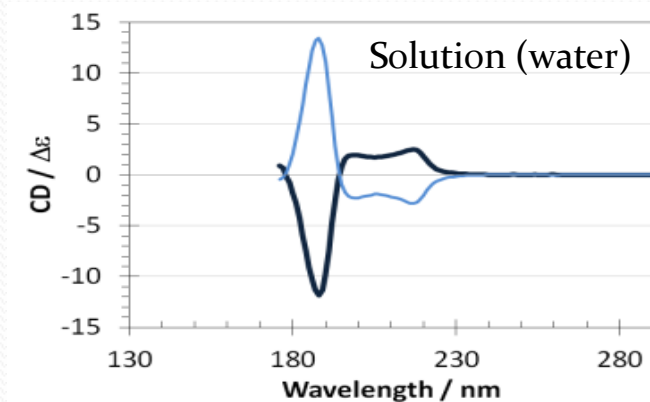
Photo-reactions form
organic molecules



Amino acids has been observed in Simulated, UV irradiated *Interstellar Ice Analouges*

The Absolute Asymmetric Photochemistry model

Photolysis upon absorption by energetic UV light



A chiral molecule with a CD signal would photo-decompose asymmetrically under irradiation with CPL.

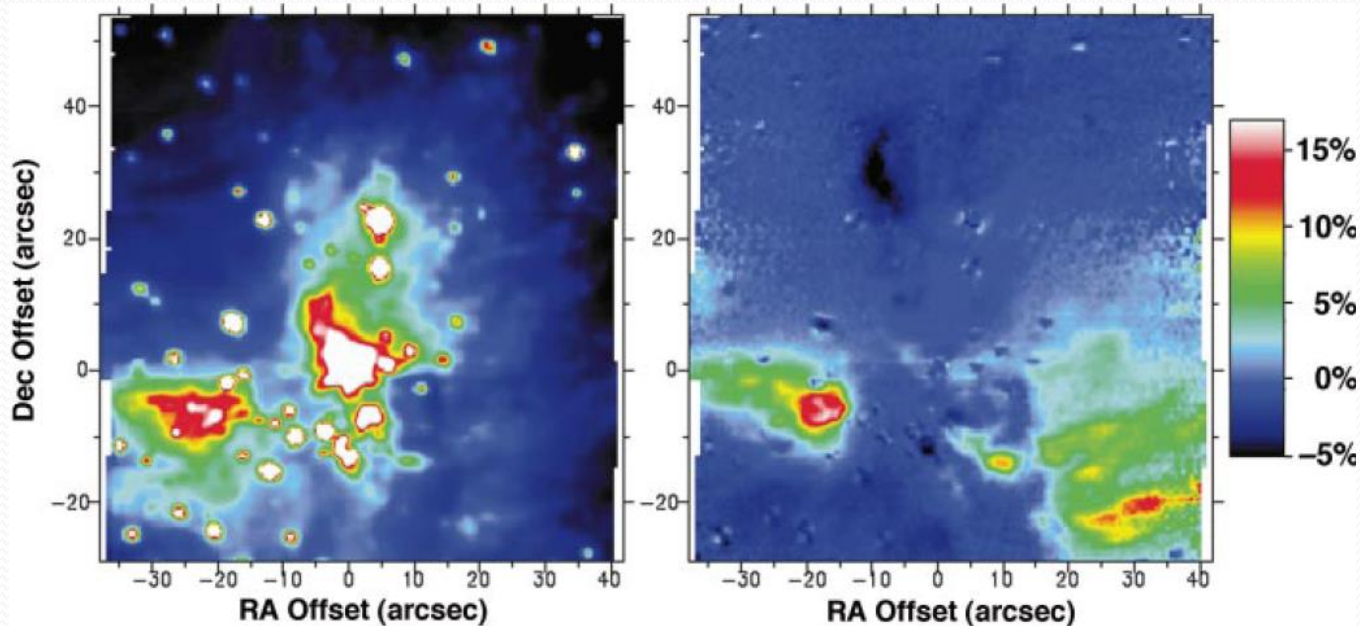
The devils advocate



Is there really Circularly Polarized UV light in interstellar space?

The Absolute Asymmetric Photochemistry model

The OMC-1 star forming region in Orion



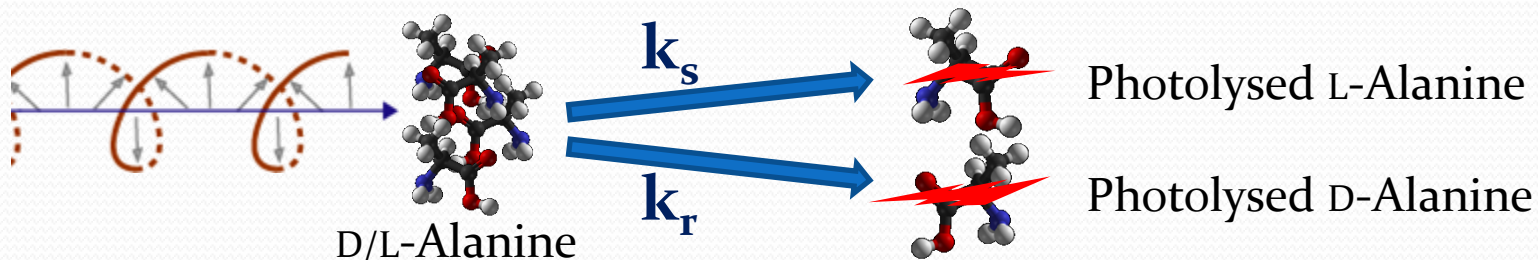
Total IR Intensity (2.2 μm)

Percentage circular polarization

Calculated CPL from Mie scattering of aligned ellipsoidal grains extends into the VUV-UV spectral region...

The Absolute Asymmetric Photochemistry model

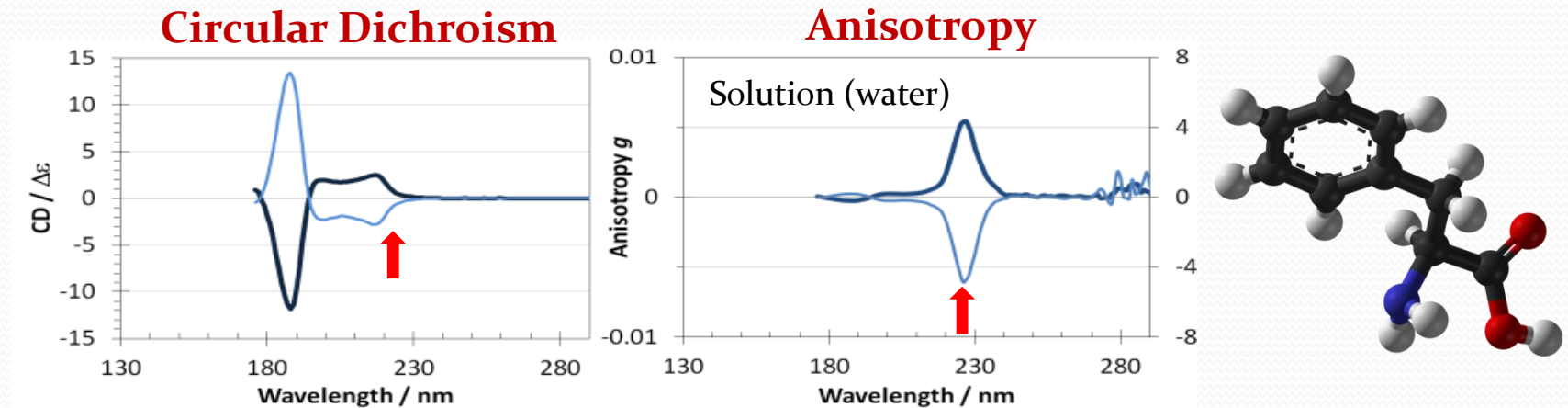
Photo chemical reactions are governed *not by CD* but by **anisotropy, g**



$$g = \frac{CD}{Abs} = \frac{\Delta\varepsilon}{\varepsilon} = \frac{(k_r - k_s)}{\frac{1}{2}(k_r + k_s)}$$

Anisotropy Spectroscopy

Full spectra of anisotropy are recorded: $g(\lambda)$

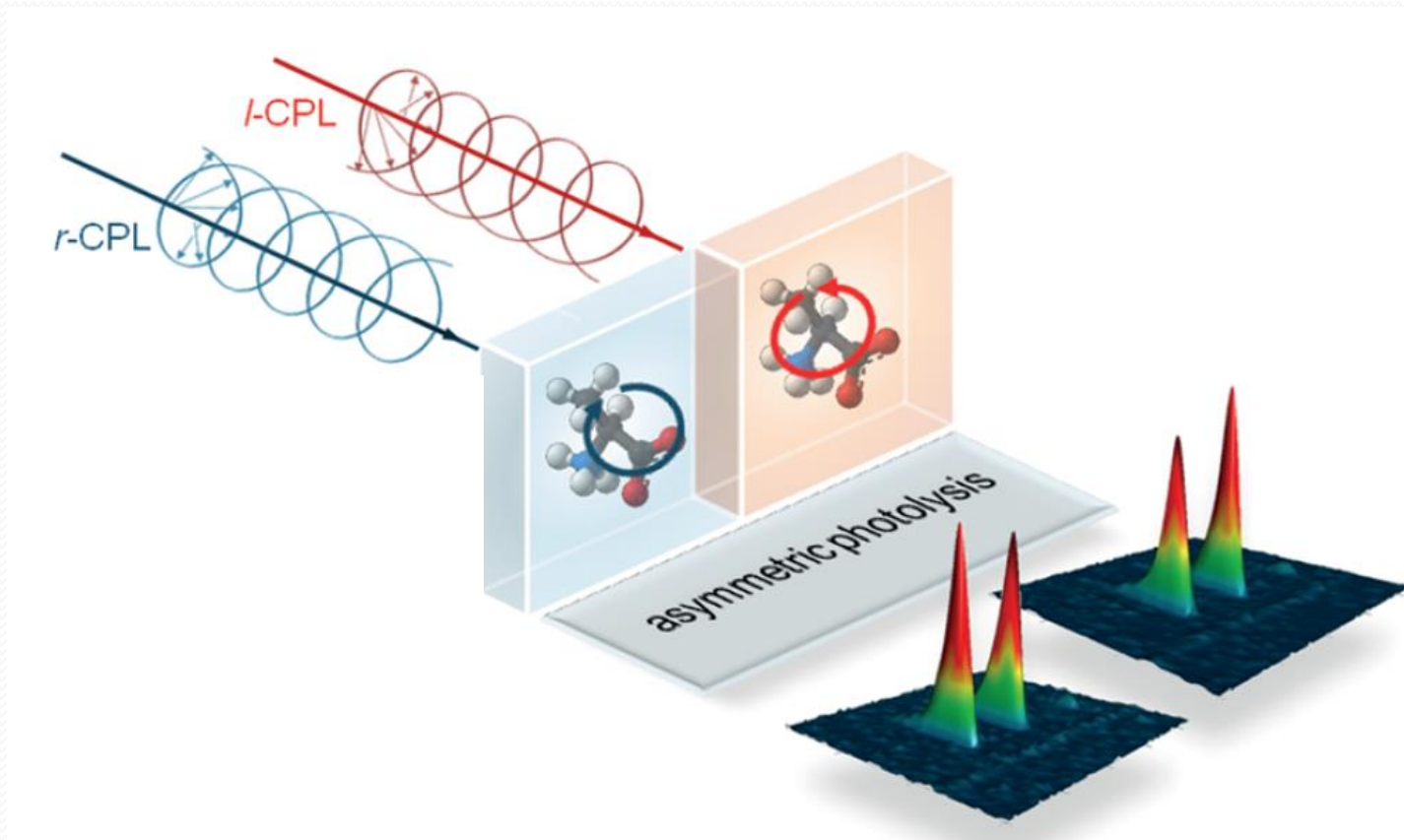


$g = \Delta\epsilon/\epsilon = \Delta A/A$ enhances CD bands of low absorption

The $g(\lambda)$ spectrum shows that even a *broad band uniform UV source* can **induce an e.e. in Phenylalanine** in solution.

CPL induced *ee* in Amino Acids

UV irradiation of Alanine



Meinert, **Hoffmann**, Cassam-Chena, Evans, Giri, Nahon, Meierhenrich
Angew. Chem. Int. Ed. 2014, 53, 210 –214

The Fascinating Comets

Do they shape course of history?

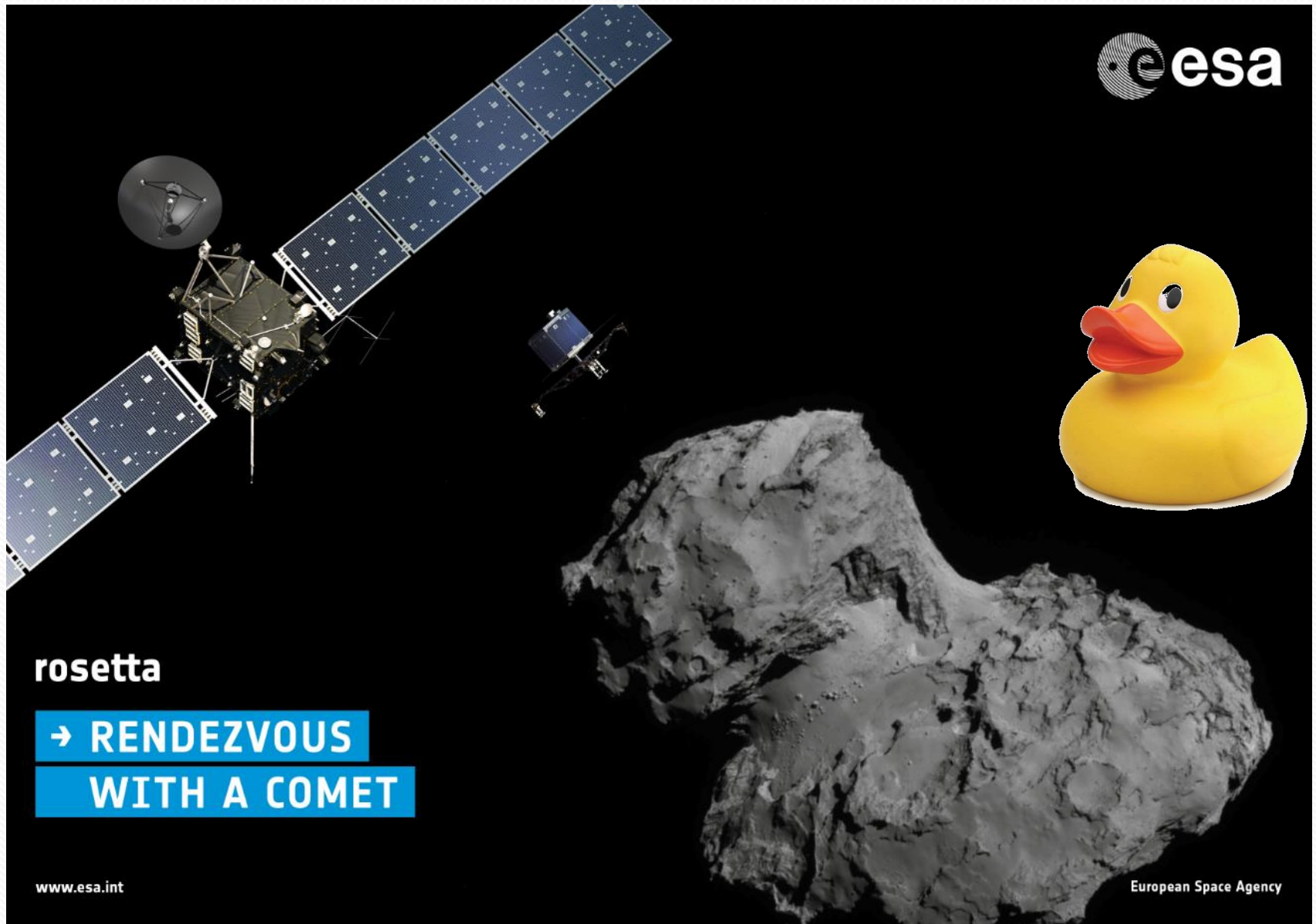


Halley's comet in 1066 as recorded on the Bayeux Tapestry



Halley's comet in 1986. Explored by the Giotto spacecraft

Man's exploration of space: 2014-16



The image is a promotional poster for the ESA Rosetta mission. It features a large, detailed illustration of the Rosetta spacecraft on the left, with its long solar panel array extending towards the top right. In the center, a smaller satellite is shown orbiting a large, grey, rocky comet nucleus. On the right side, a bright yellow rubber duck is superimposed on the black background. The ESA logo is in the top right corner. Text at the bottom left identifies the mission as 'rosetta' and '→ RENDEZVOUS WITH A COMET'. The website 'www.esa.int' and the text 'European Space Agency' are at the bottom.

esa

rosetta

→ RENDEZVOUS
WITH A COMET

www.esa.int

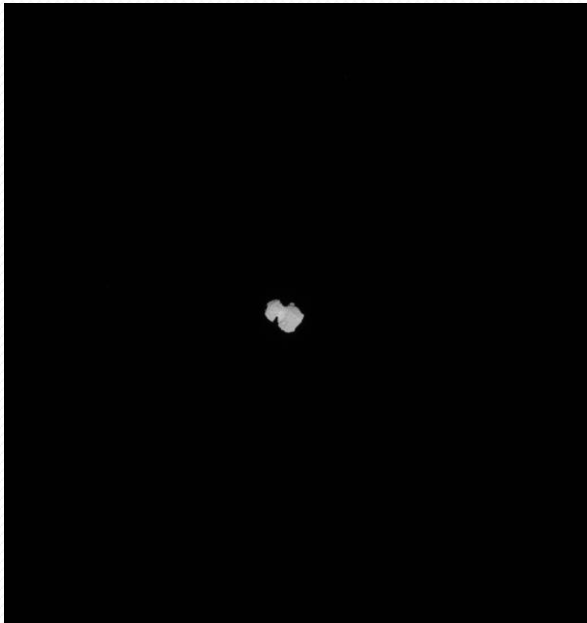
European Space Agency

Man's exploration of space: 2014-16

November 2014: Exploration of a comet.

The European Space Agency's (ESA) *Rosetta mission* will study the comet *67P/Churyumov-Gerasimenko*

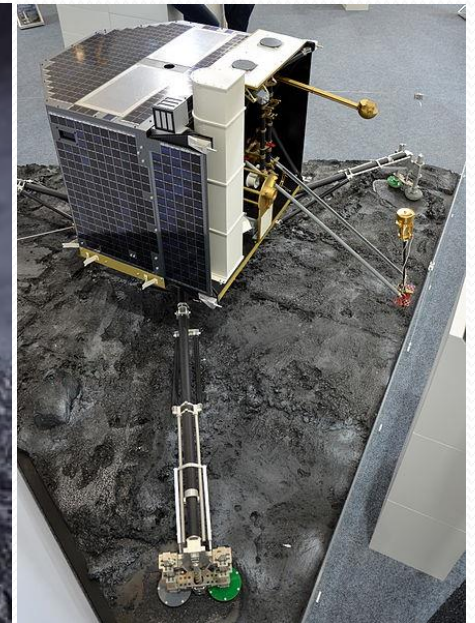
The Philae lander: Experiments on the comets surface



Navcam Animation
6 August 2014



Artist impression of
the Philae lander

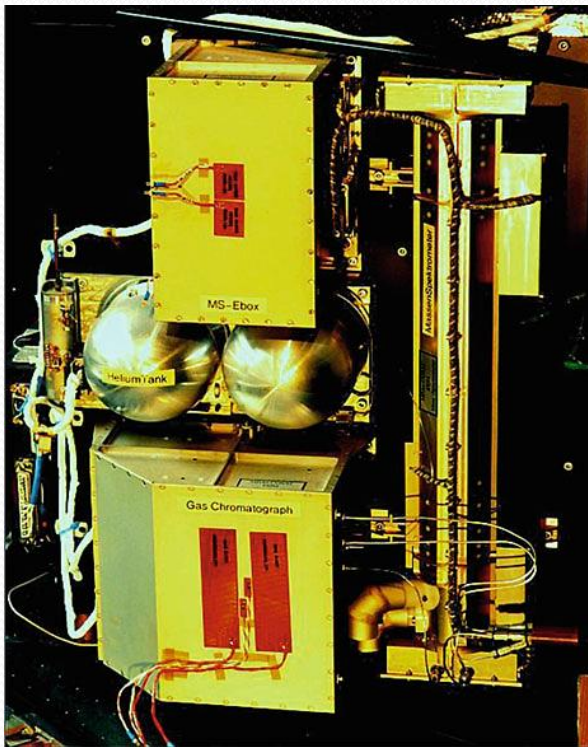


Model of the
Philae lander

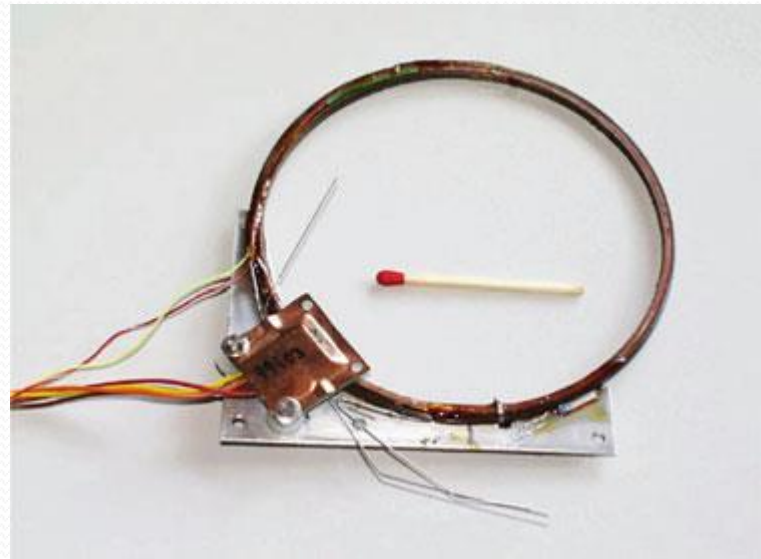
The Rosetta mission

November 2014: Exploration of a comet.

COSAC: Cometary Sampling and Composition Experiment



Gas Chromatograph coupled to a TOF Mass Spectrometer



Chiral Capillary column in the COSAC experiment can separate enantiomers

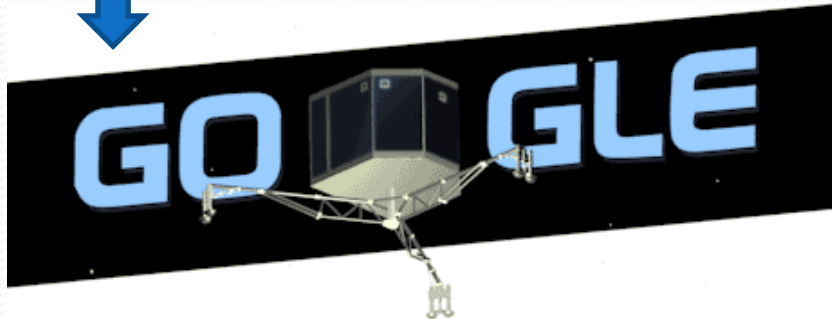
The Rosetta mission

Philae landing on
November 12th 2014

Excitement



and worries



SYNCHRONIZED SEPARATION
T-7h
Following a cue from a control centre in Cologne, Germany, Philae ejects from the mother ship and begins to go it alone. Forty minutes later, Rosetta pulls back and heads for a more distant orbit.

Coordination challenge
The two craft must coordinate perfectly: ejection produces torques that Rosetta compensates for at exactly the same time, so Philae

Release speed
0.76 m s⁻¹

0.8 m

INSTRUMENTS
During separation and descent, the lander tracks the comet's surface, tracking the rate of descent, sampling the comet's halo of evaporating water, gas and dust, and measuring interactions with the solar wind.

TOUCHDOWN
T-0h
Assuming that mission control got the sums right for the final manoeuvre (see T-9 h), Philae hits somewhere within Agilkia. But much can still go wrong.

The surface is too hard and Philae bounces.
The surface is too soft and the lander struggles to secure itself with harpoons and screws. Low gravity makes drilling difficult.

A steep slope or a boulder as small as a chair flips the lander.
Philae's legs can cope with a slight tilt, but the lander has no way to fully right itself.

PHONING HOME
T-5h
When Philae is about 17 km from the centre of the comet, Rosetta attempts to establish radio contact. Once Philae falls below 10 km, it is in virgin territory. Any data it beams back are completely novel.

Radio contact
If Rosetta and Philae cannot connect, Philae may as well be lost.

Landing speed
1 m s⁻¹

Exploration
Philae's main science phase lasts for three days and includes drilling into the comet's surface and analysing what it finds. But if its solar panels work, Philae can keep going after that, studying how conditions change as the comet gets closer to the Sun and looking for evidence of amino acids. By March 2015, the comet will be too hot for Philae to operate.

Cameras
Take a panoramic picture of the landing site, the first ever from the surface of a comet.

Solar panels
If the climate is dusty, Philae's solar panels might fail, causing the batteries to die after three days. The main science phase would be complete but the end would be premature.

Portable chemistry lab, radar, temperature sensors, magnetometer and other instruments probe the comet.

Ice screws
Borrow down to secure Philae.

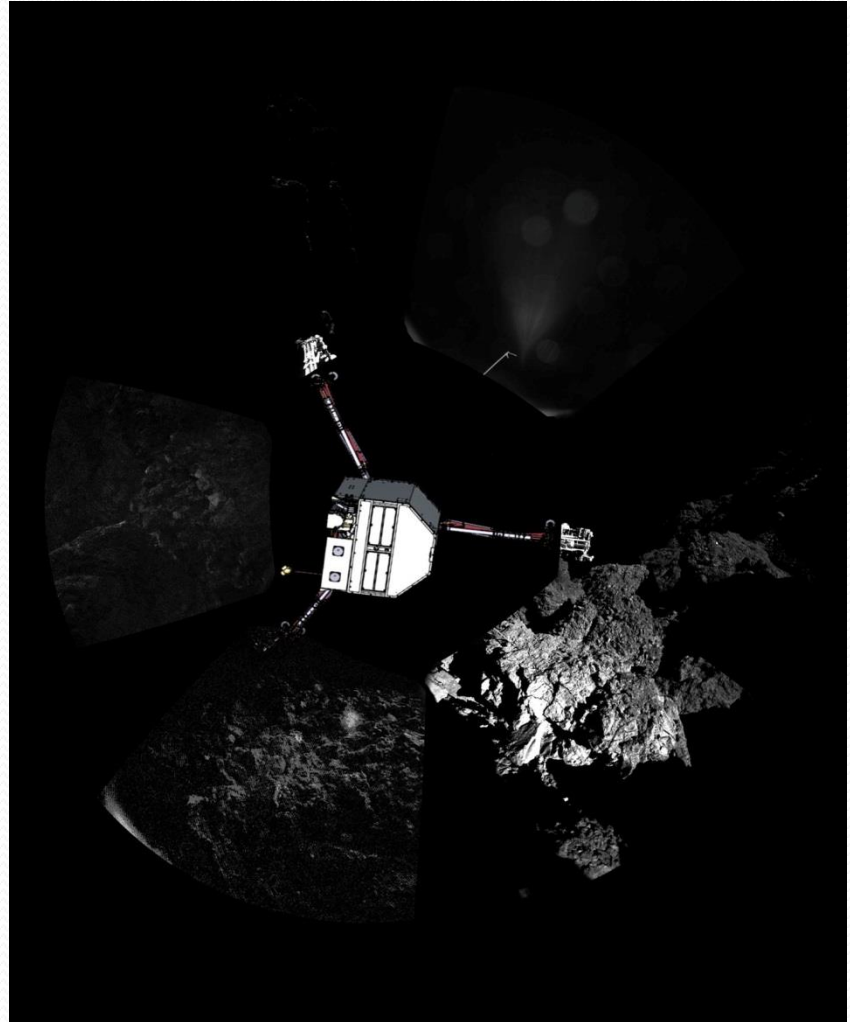
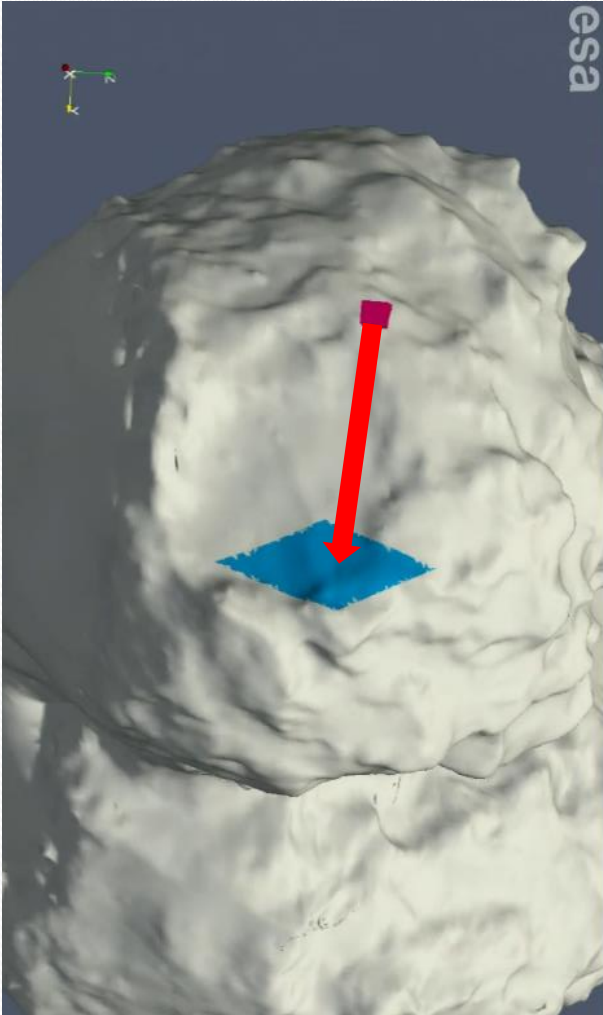
Harpoons
Fire on landing to anchor Philae.

Drills
Retrieve pristine material from 20 cm down.

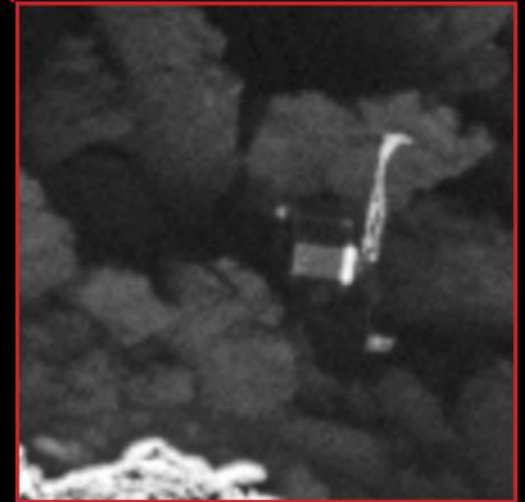
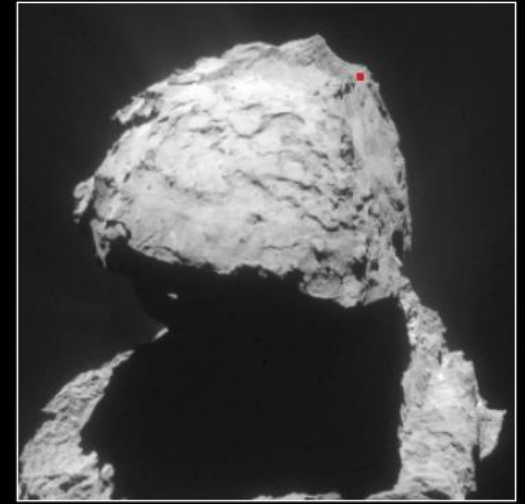
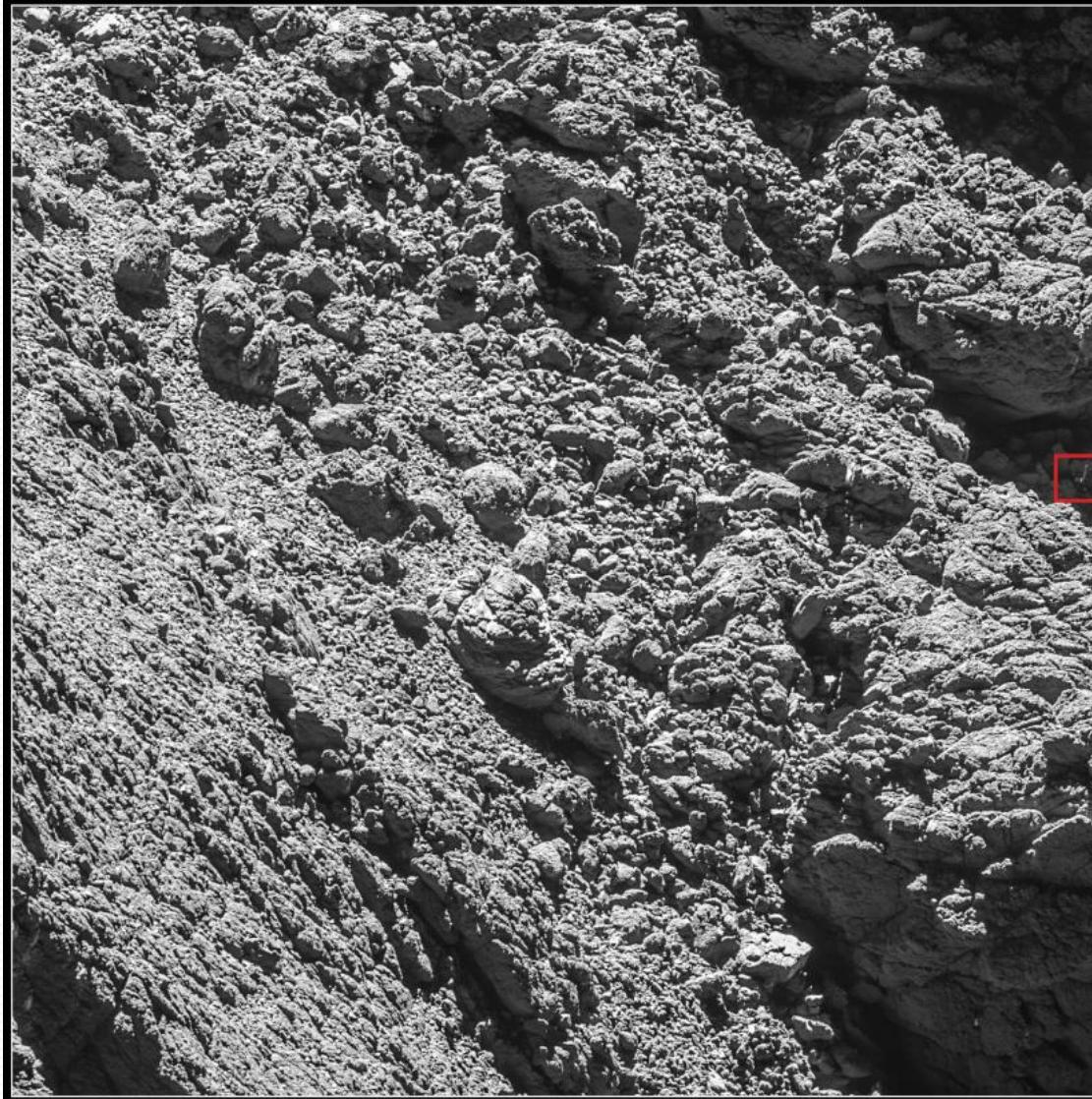
PHILAE ON COMET / ESA/ATG MEDIALAB

The Rosetta mission

Bounced off the surface, but it stayed at the comet

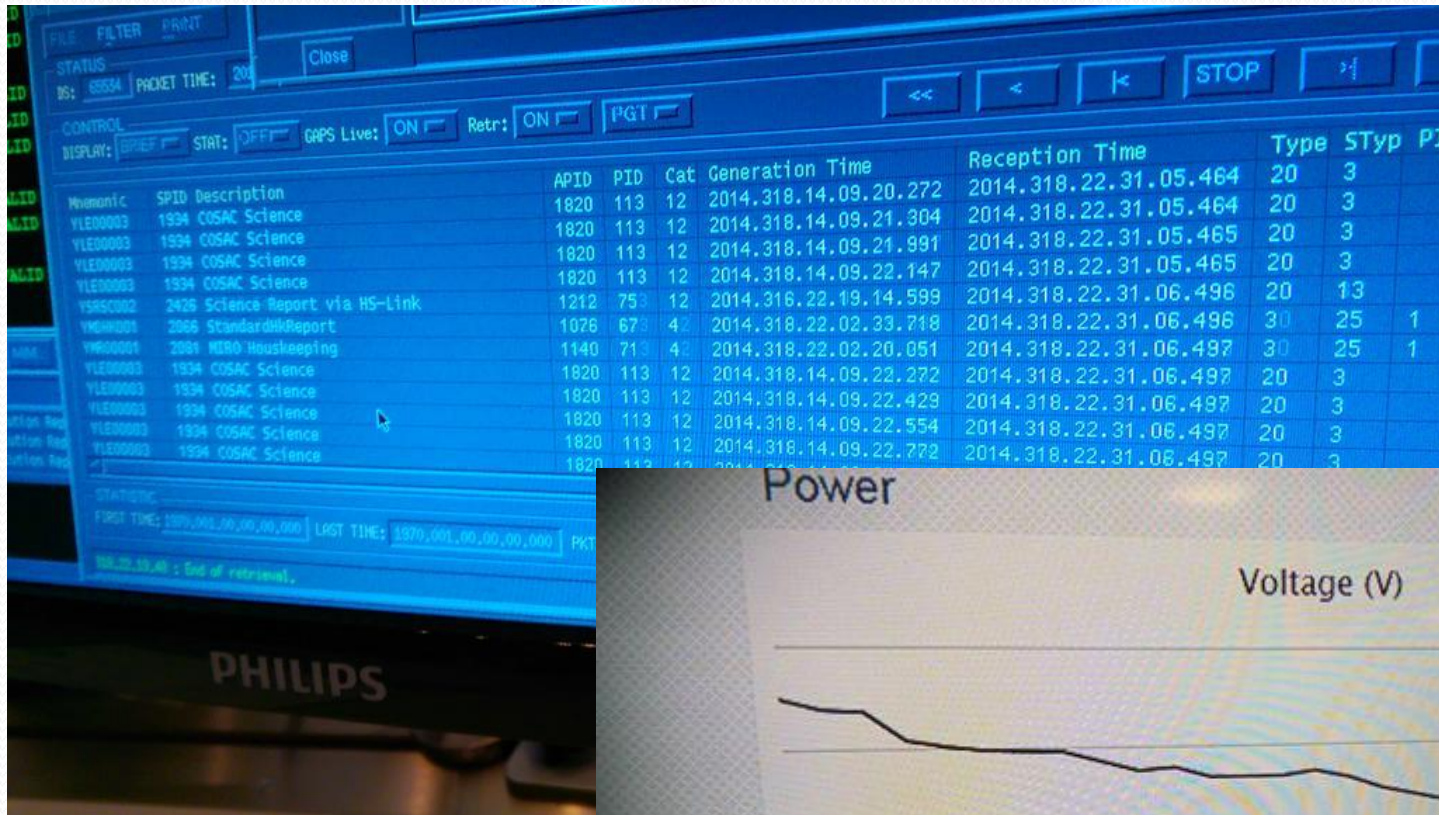


The Rosetta mission

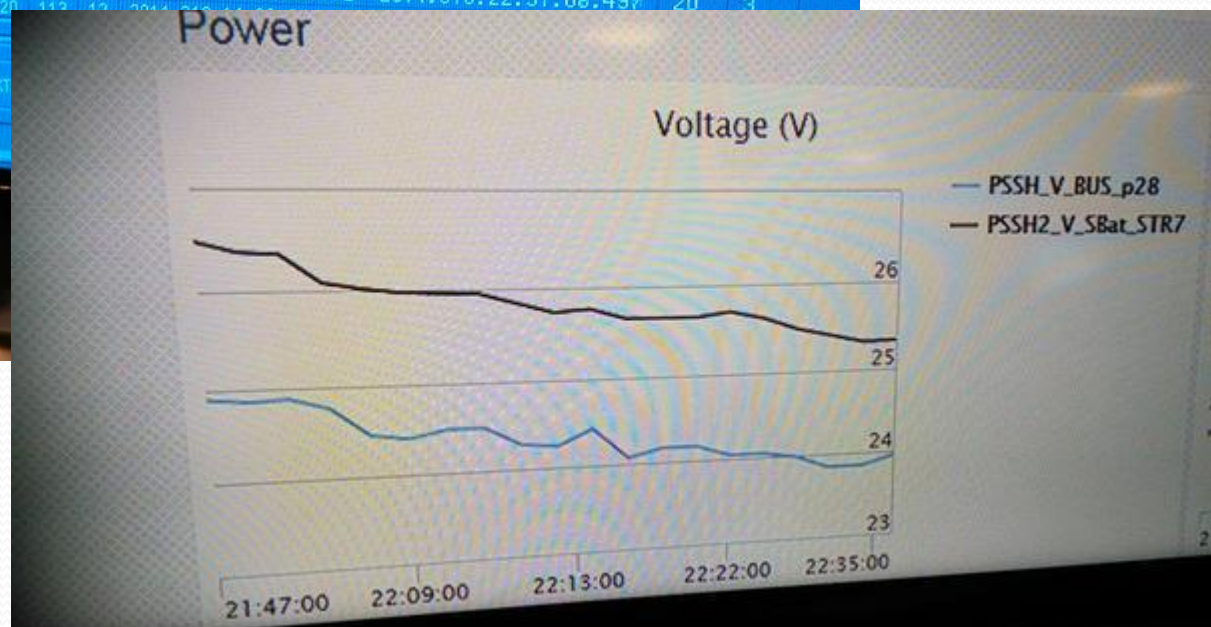


The Rosetta mission

Data from COSAC relayed back to earth....



...while battery was dying



The Rosetta mission

No samples was collected with the drill

But dust from the landing(s) was analysed

Videnskab dk

Forside | Krop & Sundhed | Kultur & Samfund | Miljø & Naturvidenskab | Teknologier

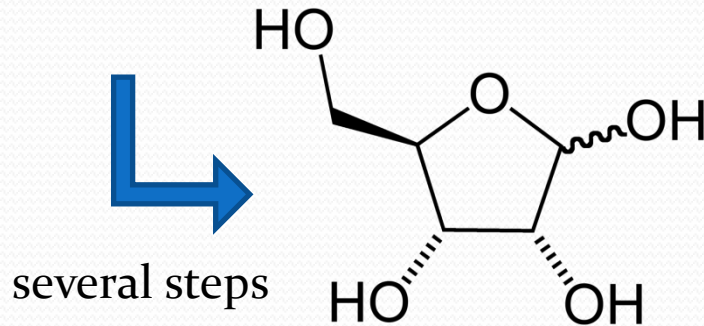
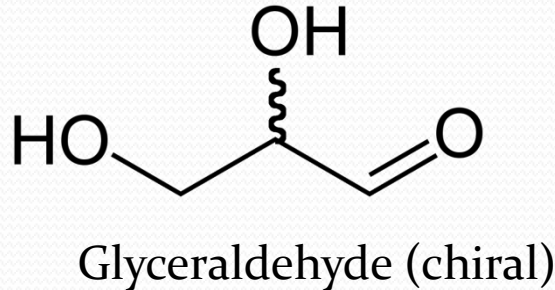
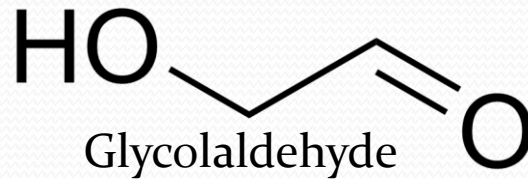
Nye analyser: Philae sniffede acetone på kometen



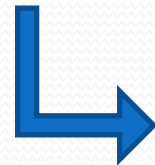
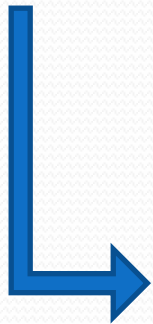
Name	Formula
Water	H ₂ O
Methane	CH ₄
Methanenitrile (hydrogen cyanide)	HCN
Carbon monoxide	CO
Methylamine	CH ₃ NH ₂
Ethanenitrile (acetonitrile)	CH ₃ CN
Isocyanic acid	HNCO
Ethanal (acetaldehyde)	CH ₃ CHO
Methanamide (formamide)	HCONH ₂
Ethylamine	C ₂ H ₅ NH ₂
Isocyanomethane (methyl isocyanate)	CH ₃ NCO
Propanone (acetone)	CH ₃ COCH ₃
Propanal (propionaldehyde)	C ₂ H ₅ CHO
Ethanamide (acetamide)	CH ₃ CONH ₂
2-Hydroxyethanal (glycolaldehyde)	CH ₂ OHCHO
1,2-Ethanediol (ethylene glycol)	CH ₂ (OH)CH ₂ (OH)

The Rosetta mission

... dust from the landing(s) was analysed



Formose reaction



Name	Formula
Water	H ₂ O
Methane	CH ₄
Methanenitrile (hydrogen cyanide)	HCN
Carbon monoxide	CO
Methylamine	CH ₃ NH ₂
Ethanenitrile (acetonitrile)	CH ₃ CN
Isocyanic acid	HNCO
Ethanal (acetaldehyde)	CH ₃ CHO
Methanamide (formamide)	HCONH ₂
Ethylamine	C ₂ H ₅ NH ₂
Isocyanomethane (methyl isocyanate)	CH ₃ NCO
Propanone (acetone)	CH ₃ COCH ₃
Propanal (propionaldehyde)	C ₂ H ₅ CHO
Ethylamide (acetamide)	CH ₃ CONH ₂
2-Hydroxyethanal (glycolaldehyde)	CH ₂ OHCHO
1,2-Ethanediol (ethylene glycol)	CH ₂ (OH)CH ₂ (OH)

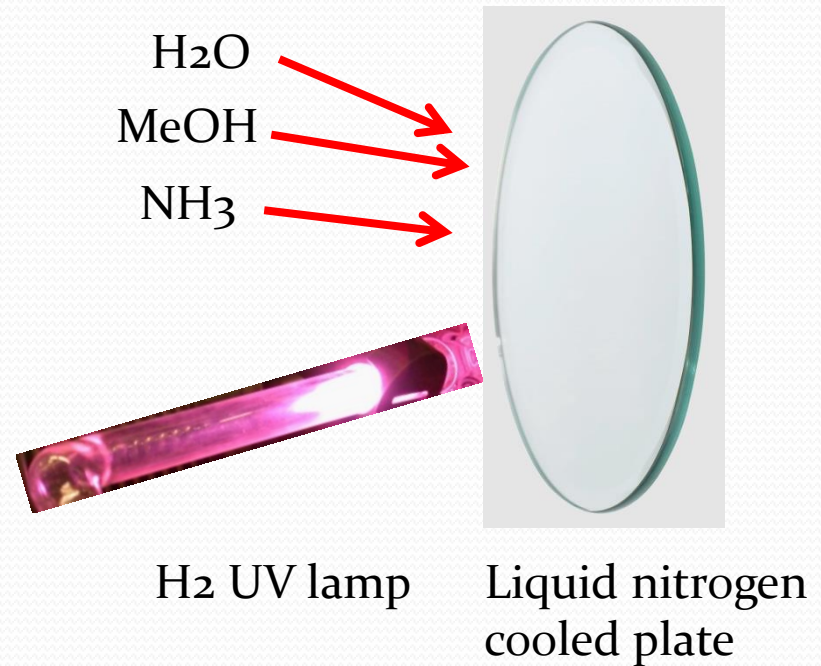
UV induced formation of sugars

Science AAAS

UV induced formation of
Glycolaldehyde
Glyceraldehyde
and *RIBOSE*

... and many others...

3.5% of the sample is sugars



Meinert C., Myrgorodska I., de Marcellus P., Buhse T., Nahon L., Hoffmann S.V., d'Hendecourt L., Meierhenrich U.J. *Science* **352**, 2016, 208-212..

What comes next...

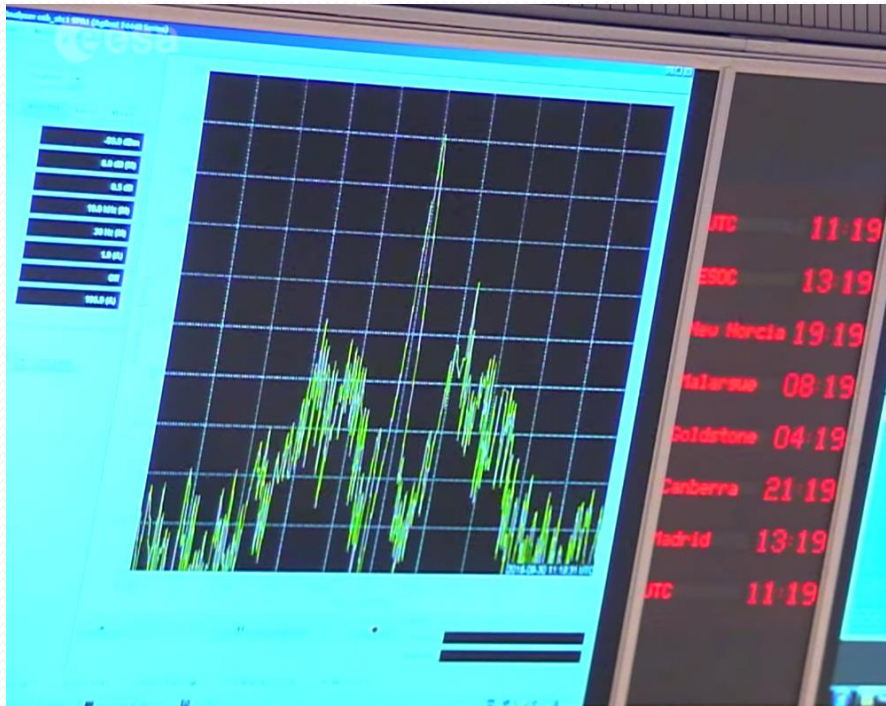
Spectroscopy on aldehydes and
aldopentoses (sugar)



Why is the D-form of DNA/RNA exclusively used in life on earth?

The Rosetta mission

Mission ended 30th September 2016



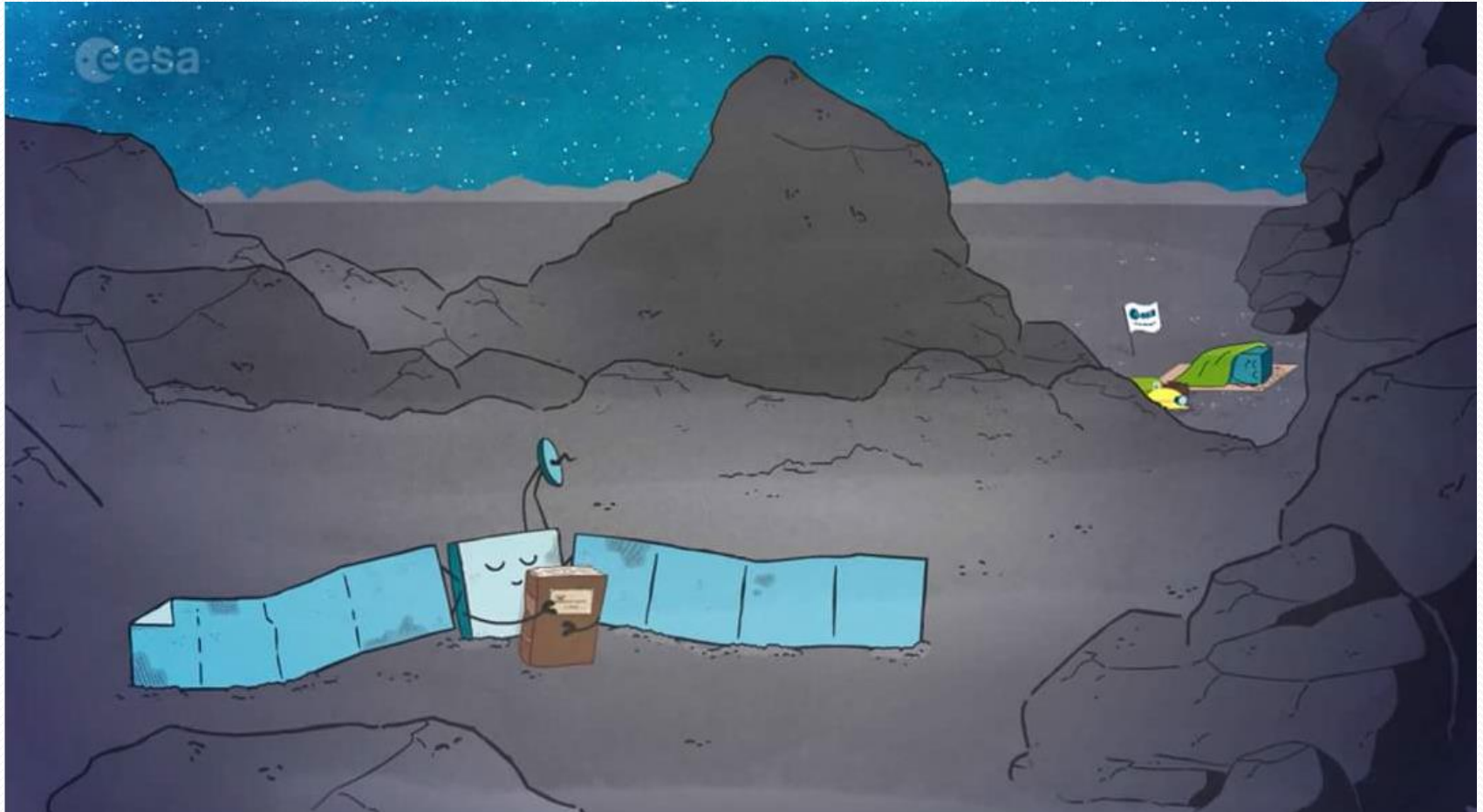
ROSETTA signal just before....

...and after the CRASH



The Rosetta mission

Mission ended 30th September 2016



The ExoMars mission

A new and ongoing mission to Mars
by the European Space Agency (ESA).

“Landing” of Schiaparelli : 19th October 2016

Look for life, past or present



*ExoMars rover
in 2020*



Outlook



Why is the D-form of DNA/RNA exclusively used in life on earth?



Dr. C. Meinert, University of Nice
Prof. Uwe J. Meierhenrich, University of Nice



Dr. Laurent Nahon, Synchrotron SOLEIL

Dr. Nykola C. Jones, ISA, Aarhus University

Links til læsning....

Scienceblog.dk

<http://www.scienceblog.dk/2016/04/25/det-soede-liv-livets-kirale-sukker/>

Politiken

<http://politiken.dk/viden/article5618042.ece>

Dr.dk

<http://www.dr.dk/nyheder/viden/kometfund-livets-byggeklodser-findes-i-rummet>

Ingeniøren

<https://ing.dk/artikel/aarhus-forsker-vi-har-genskabt-universets-livgivende-byggeklodser-i-laboratoriet-183290>

Carlsbergfondet

<http://www.carlsbergfondet.dk/da/Nyheder/Nyt-fra-fondet/Nyheder/Livets-sukker>