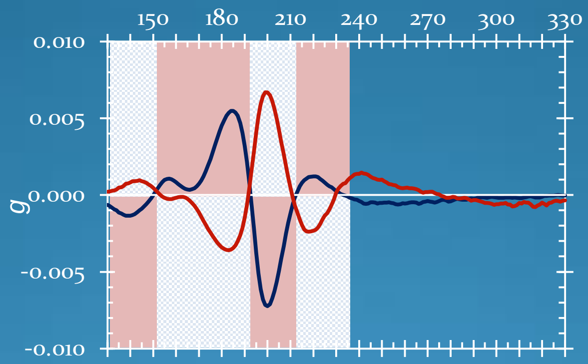
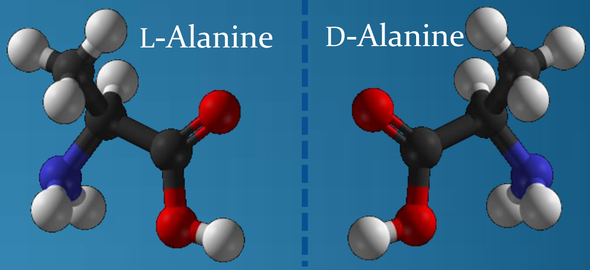
Chirality in life





Søren Vrønning Hoffmann

IFA, Januar 2017

vronning@phys.au.dk

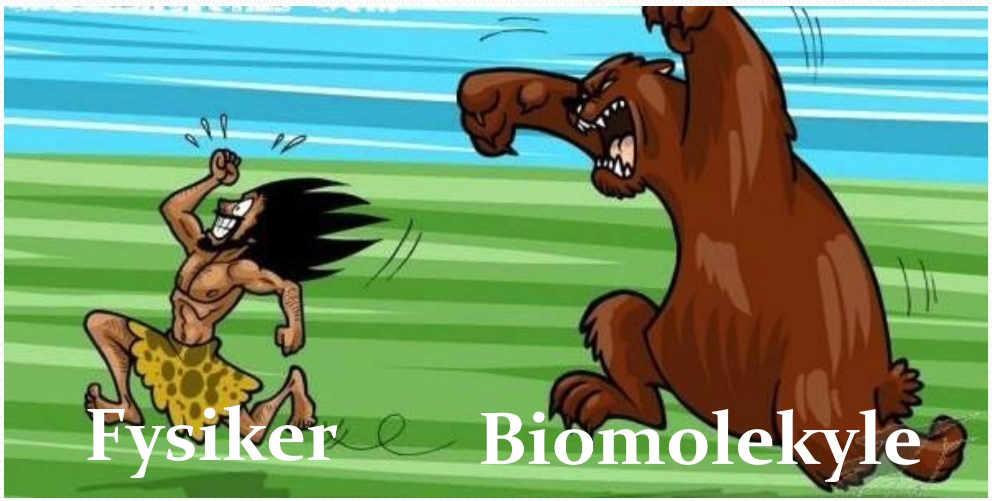
ISA

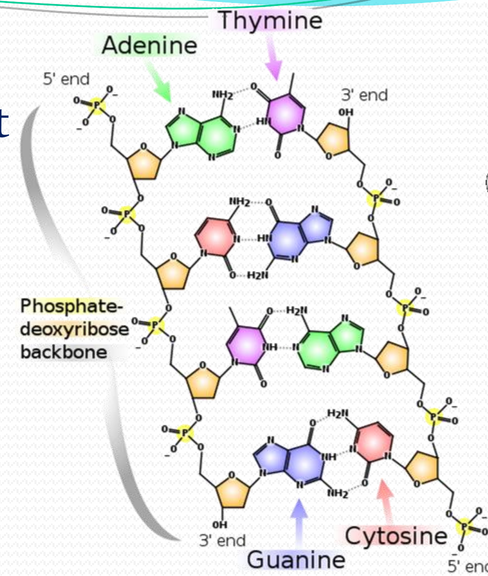
AARHUS UNIVERSITY

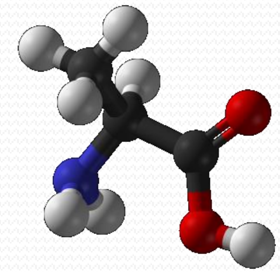
Université Nice Sophia Antipolis

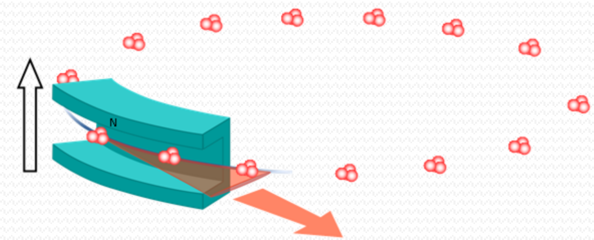
Introduktion

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

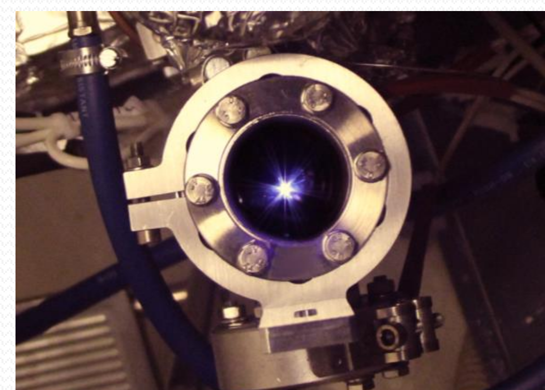




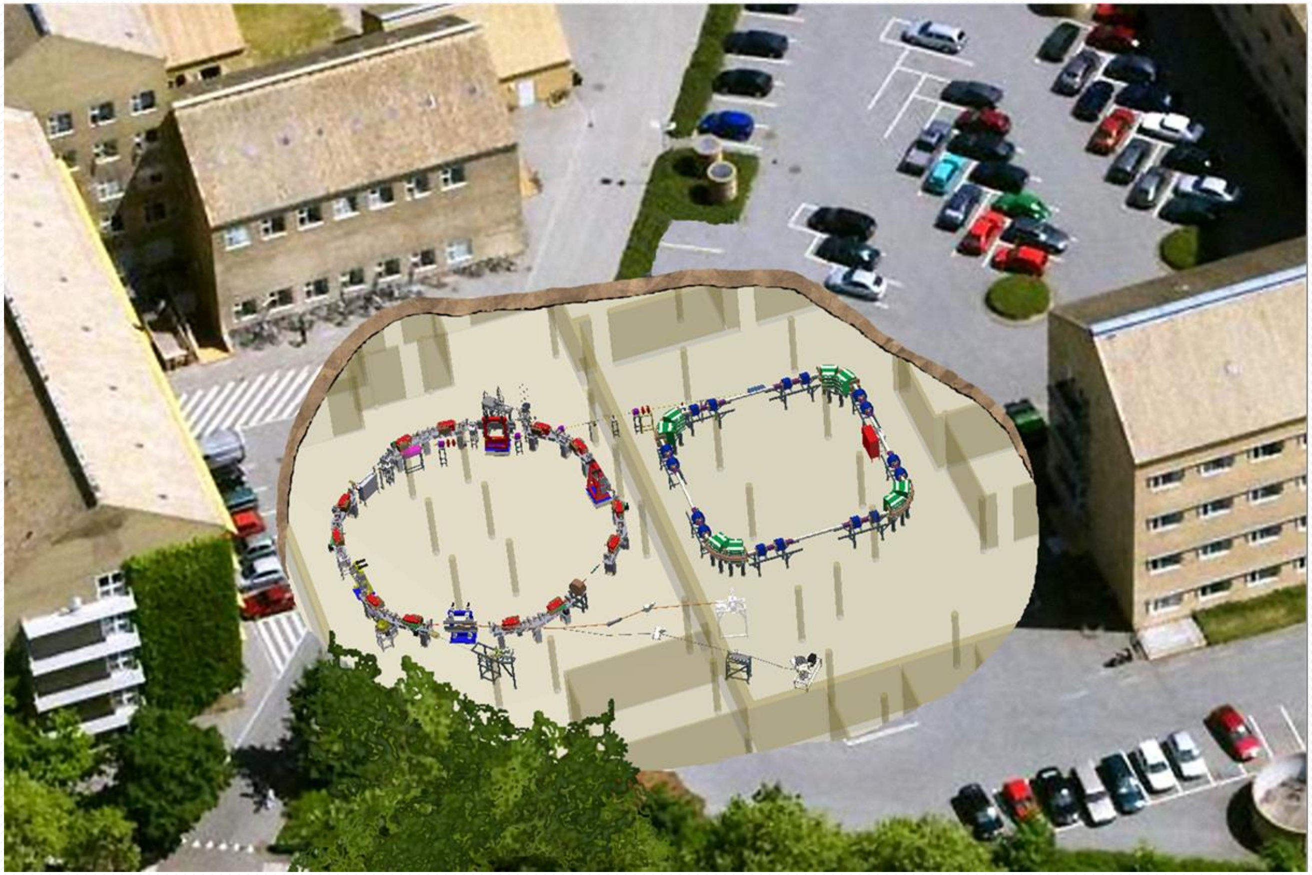




- Amino syrer og sukre absorberer først i det dybe UV område (~200 nm).
- Vi bruger for en kraftig og tunebar UV kilde: Synkrotron stråling.

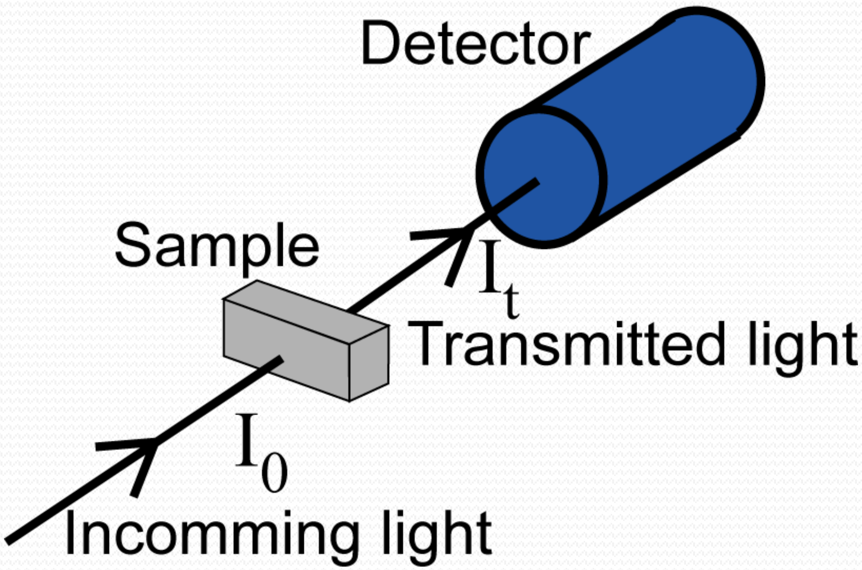


The ASTRID accelerator complex



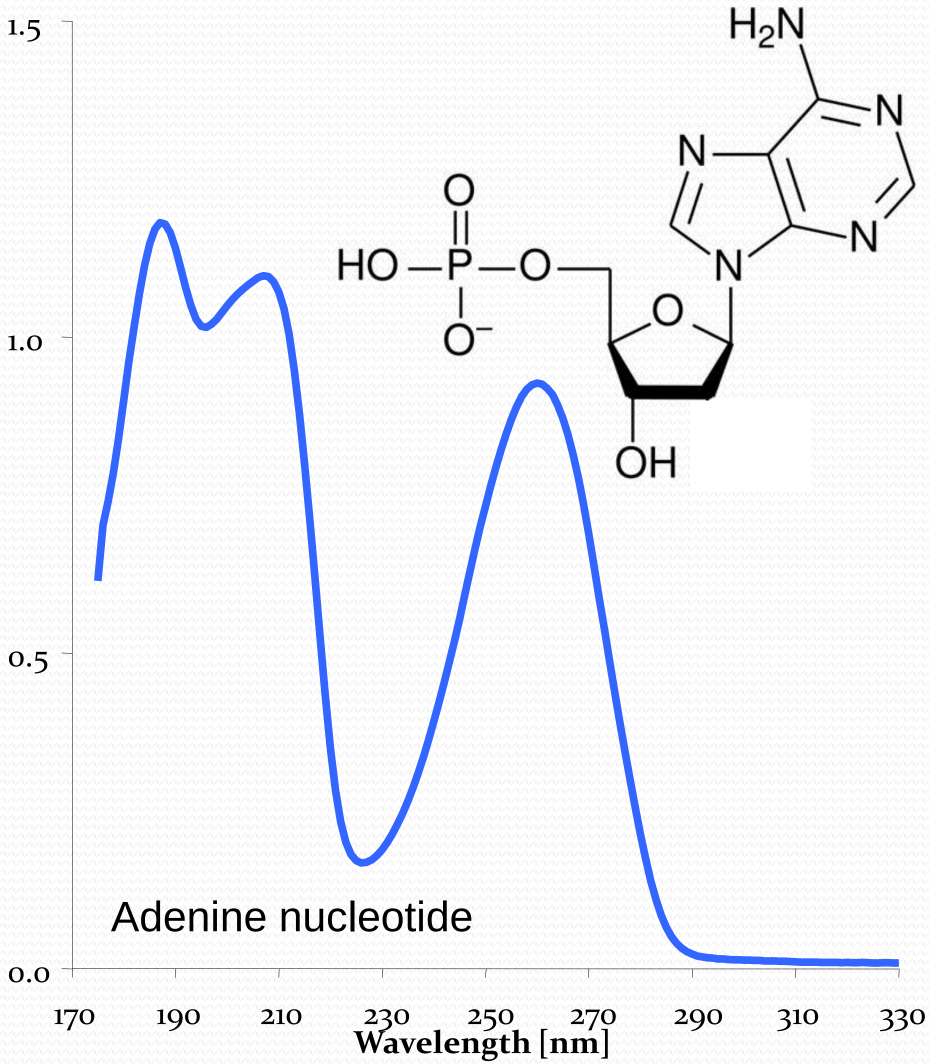
The ASTRID and ASTRID2 complex is situated under the parking lot between physics and chemistry

Spectroscopy: UV-Absorption



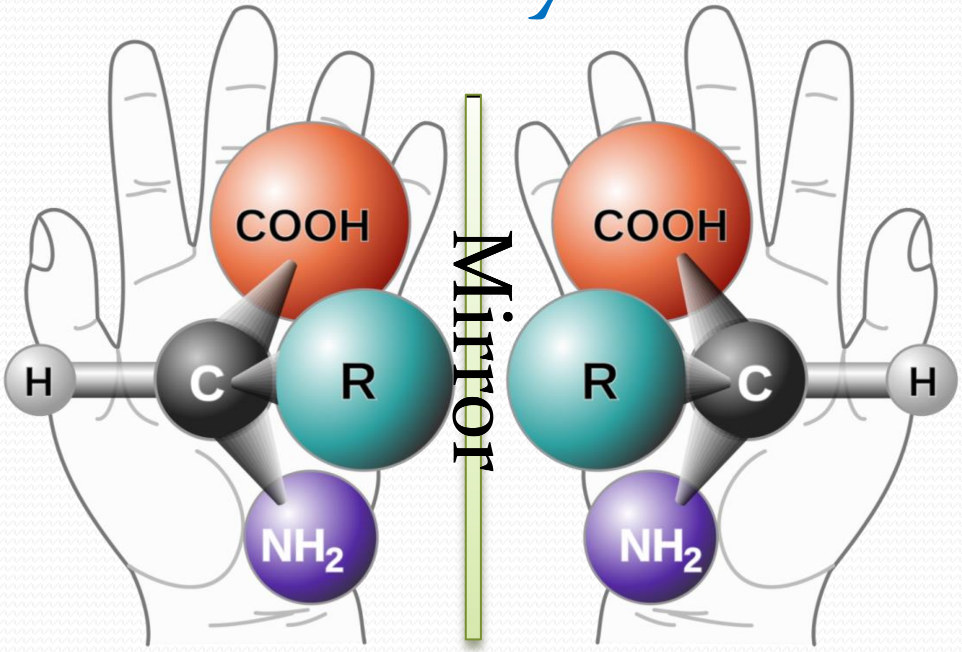
Absorbance:

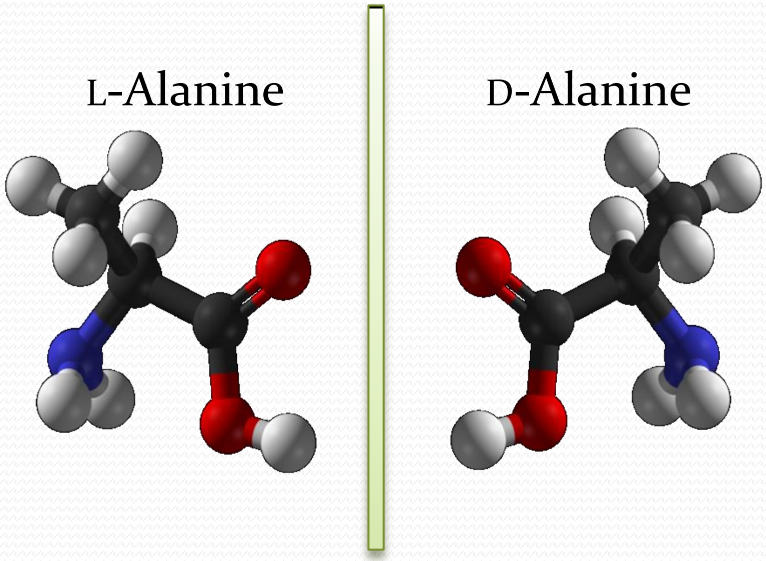
$$A=\log(I_0/I_t)$$

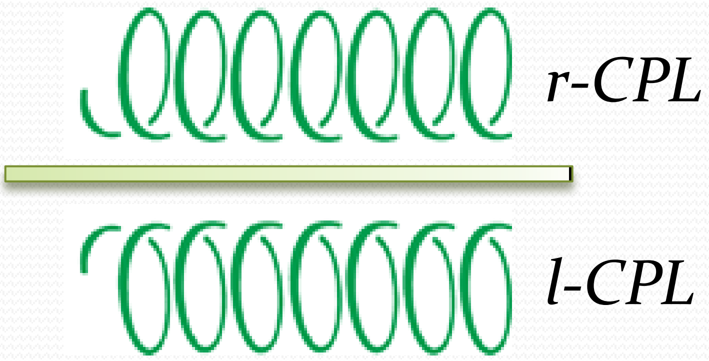


Introduction: Chirality

Many biomolecules are chiral

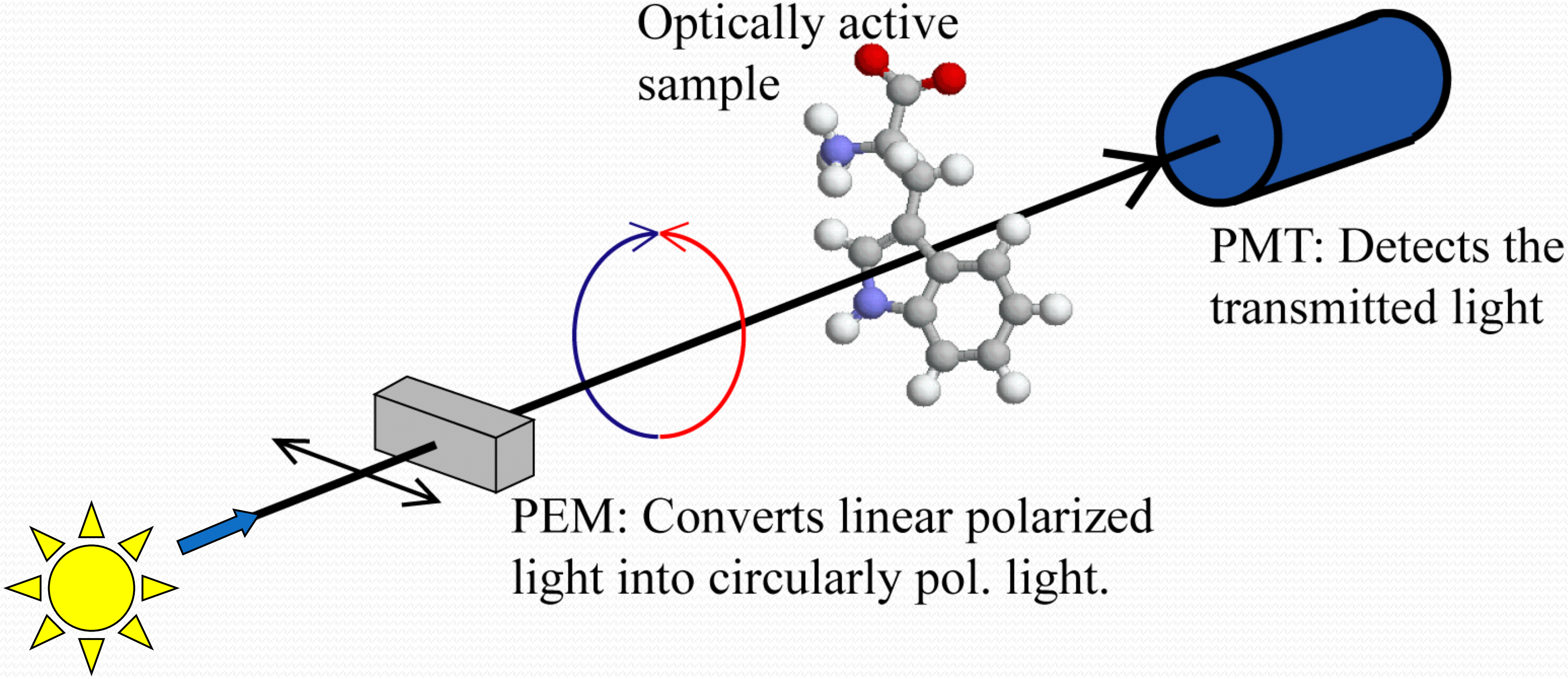






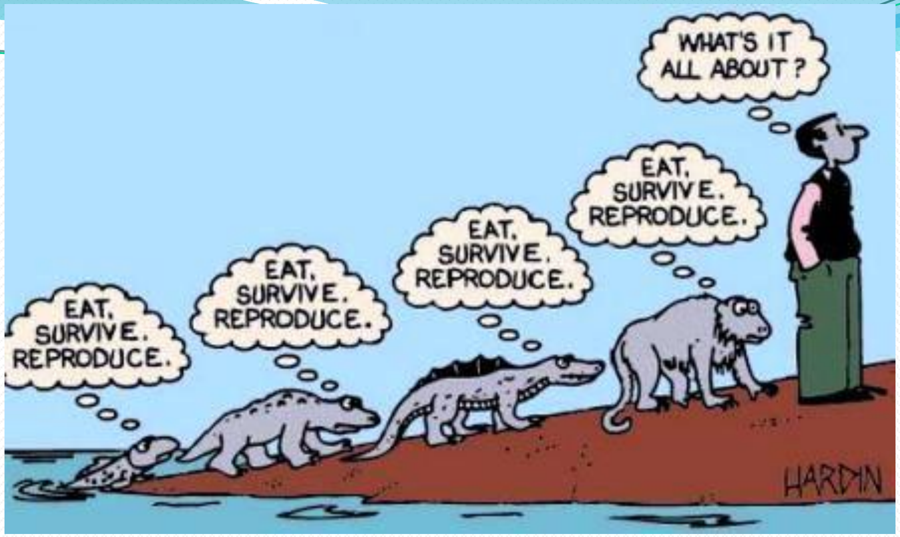
Circularly polarized light is also chiral

Circular Dichroism



The CD signal: CD = A_L-A_R

Introduction

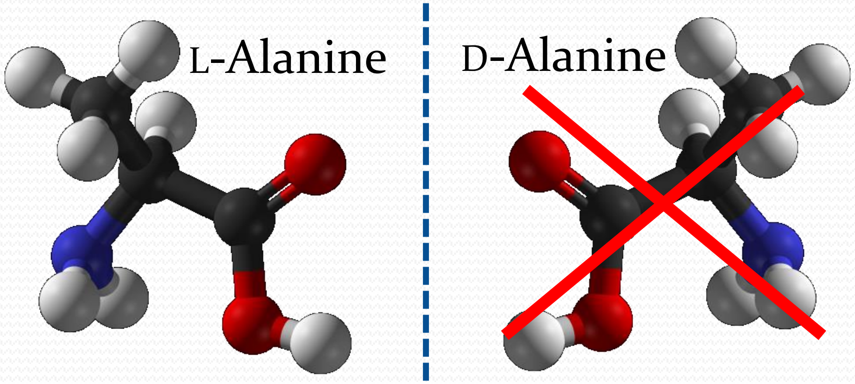


- *The origin of life is a fascinating topic.*

- ***Homochirality*** in life: Almost exclusively single enantiomers:

  L-form of amino acids in proteins

  D-form of sugars in DNA



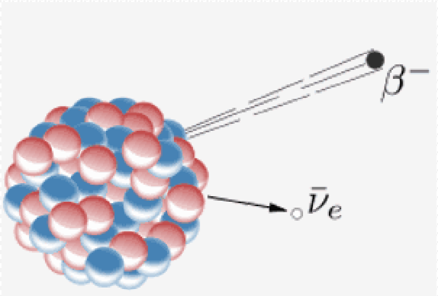
Where, Why, How come....

Introduction

- Many theories for origin of this racemic symmetry breaking.

-<u>By chance:</u>

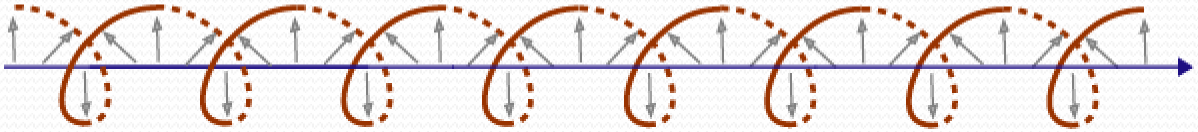
Stochastic fluctuations breaking symmetry

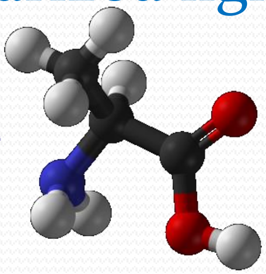


-<u>Beta decay:</u>

Parity violation in weak nuclear force

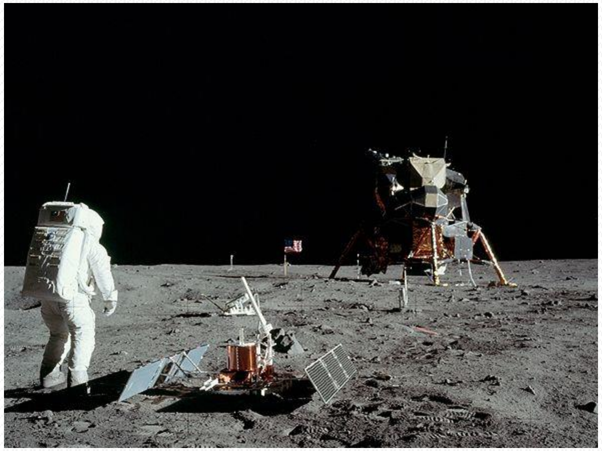
-<u>Asymmetric photochemistry</u> with circularly polarized light.





- <u>Absolute Asymmetric Photochemistry model:</u>
  Possible *extra-terrestrial* origin of homochirality

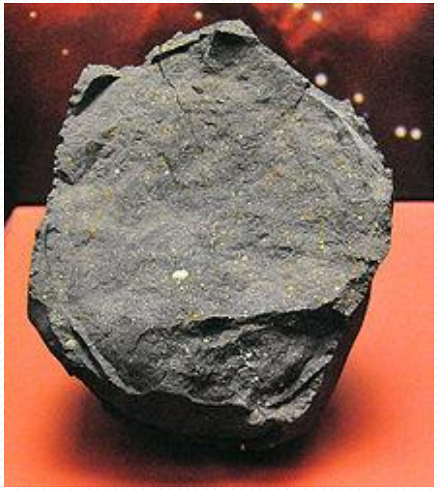
Man's exploration of space: 1969



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

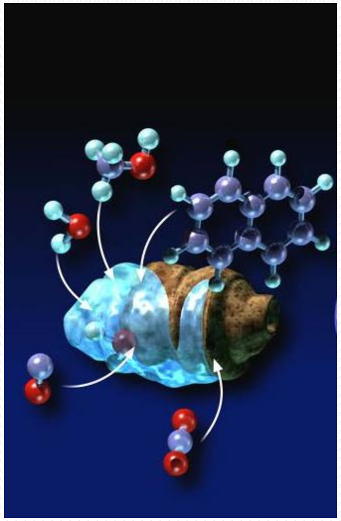
Enantiomeric excess (*ee*):

Up to a few %	L-α-H amino acids
Up to 18.5%	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

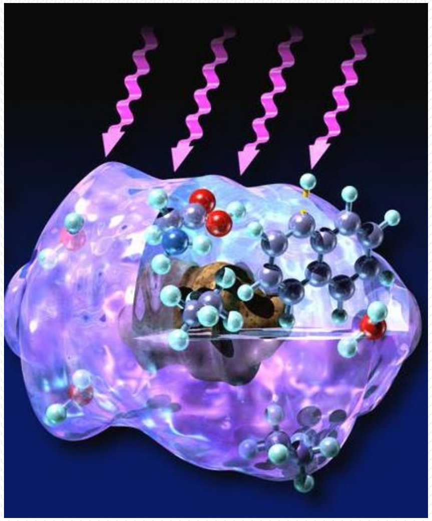
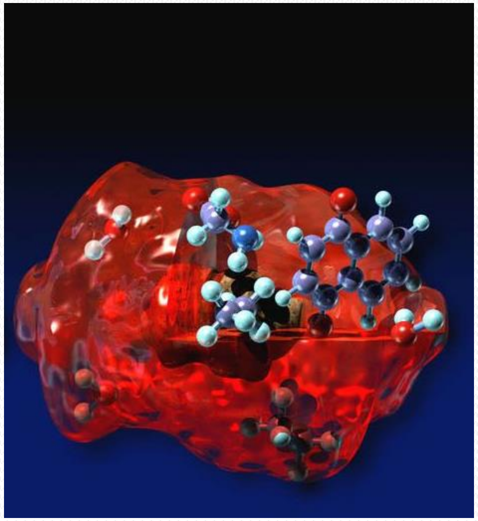


Photo-reactions form organic molecules

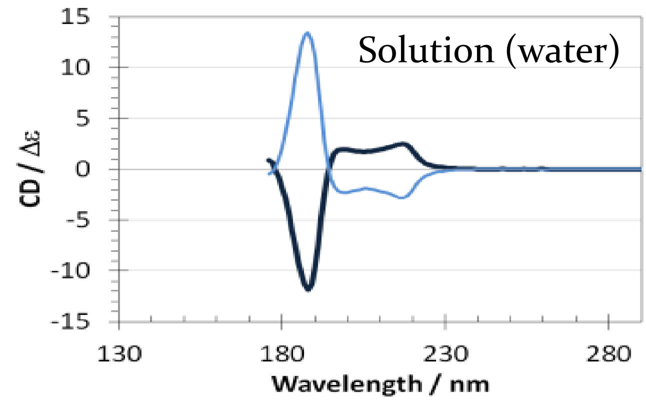


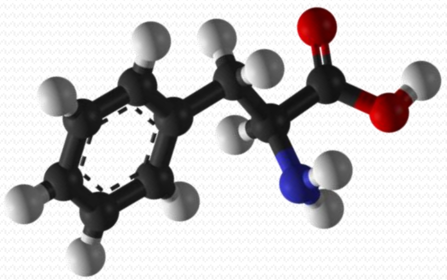
Amino acids has been observed in Simulated, UV irradiated *Interstellar Ice Analouges*

Meierhenrich U.J. *Amino Acids and the Asymmetry of Life.* Springer-Verlag Berlin Heidelberg 2008

The Absolute Asymmetric Photochemistry model

Photolysis upon absorption by energetic UV light





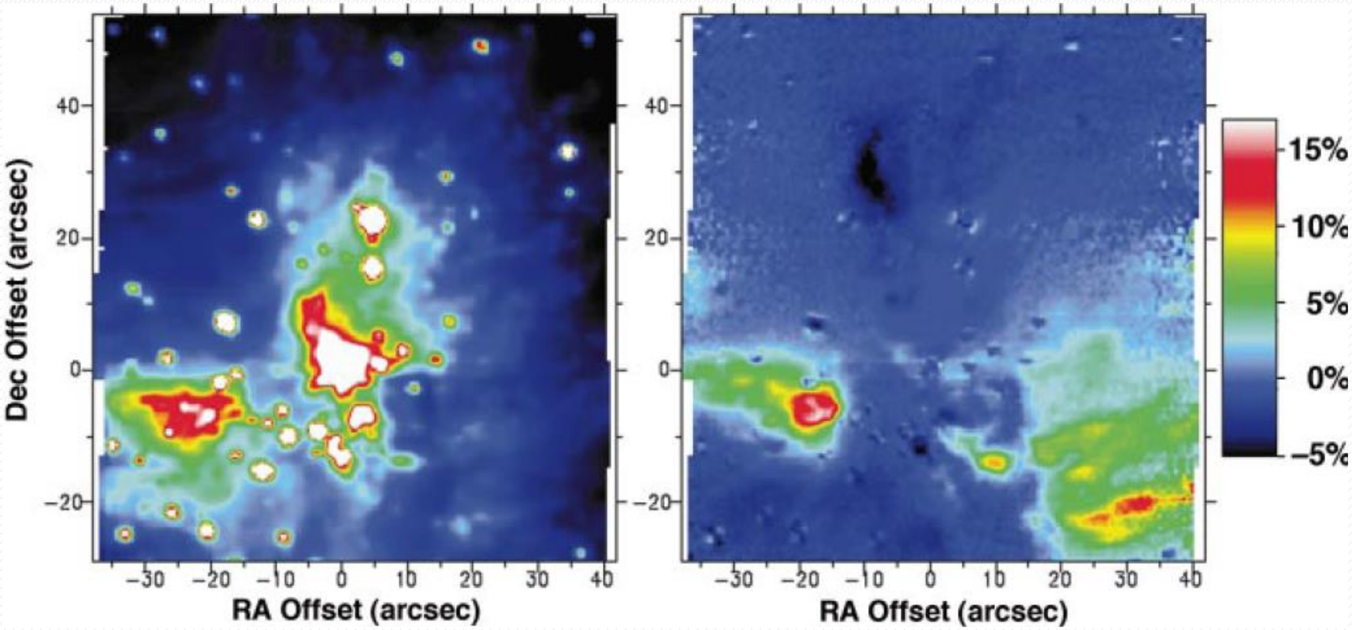
A chiral molecule with a CD signal would photo-decompose asymmetrically under irradiation with CPL.

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



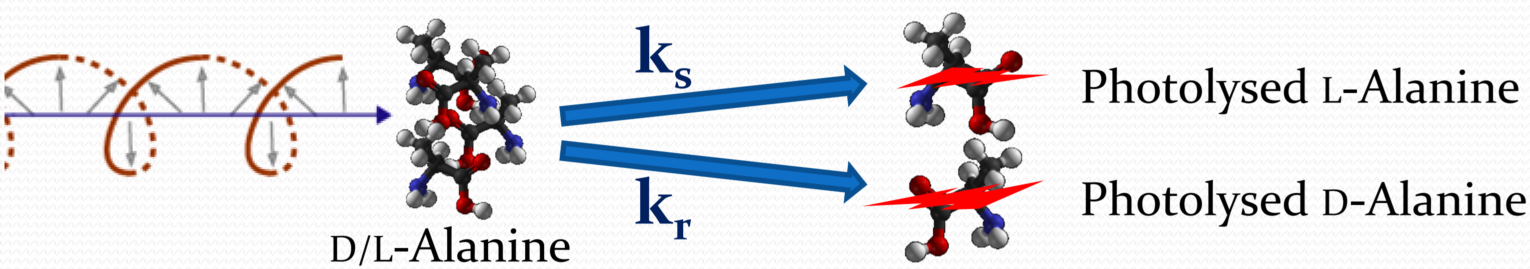
Total IR Intensity (2.2 μm)   Percentage circular polarization

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

Bailey J. Science 281 (1998) 672

The Absolute Asymmetric Ahotochemistry model

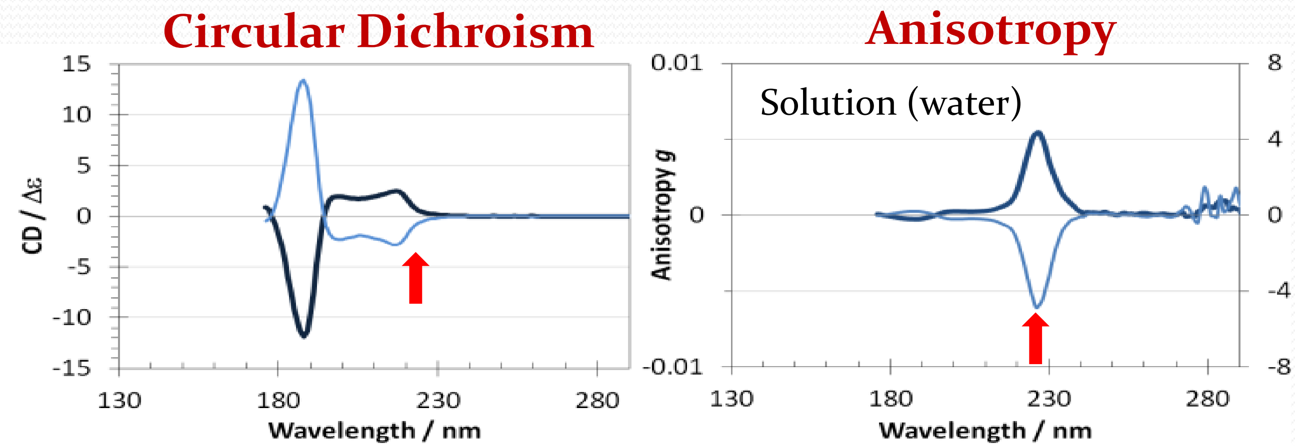
Photo chemical reactions
are governed *not by CD* but by **anisotropy, *g***

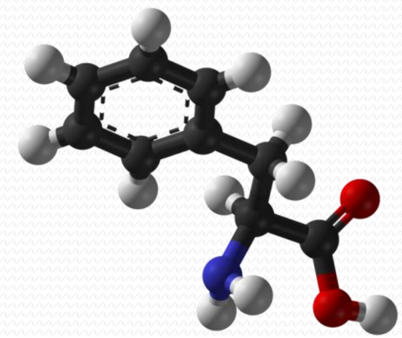


$$g = \frac{CD}{Abs} = \frac{\Delta\varepsilon}{\varepsilon} = \frac{(k_r - k_s)}{\frac{1}{2}(k_r + k_s)}$$

Anisotropy Spectroscopy

Full spectra of anisotropy are recorded: *g(λ)*



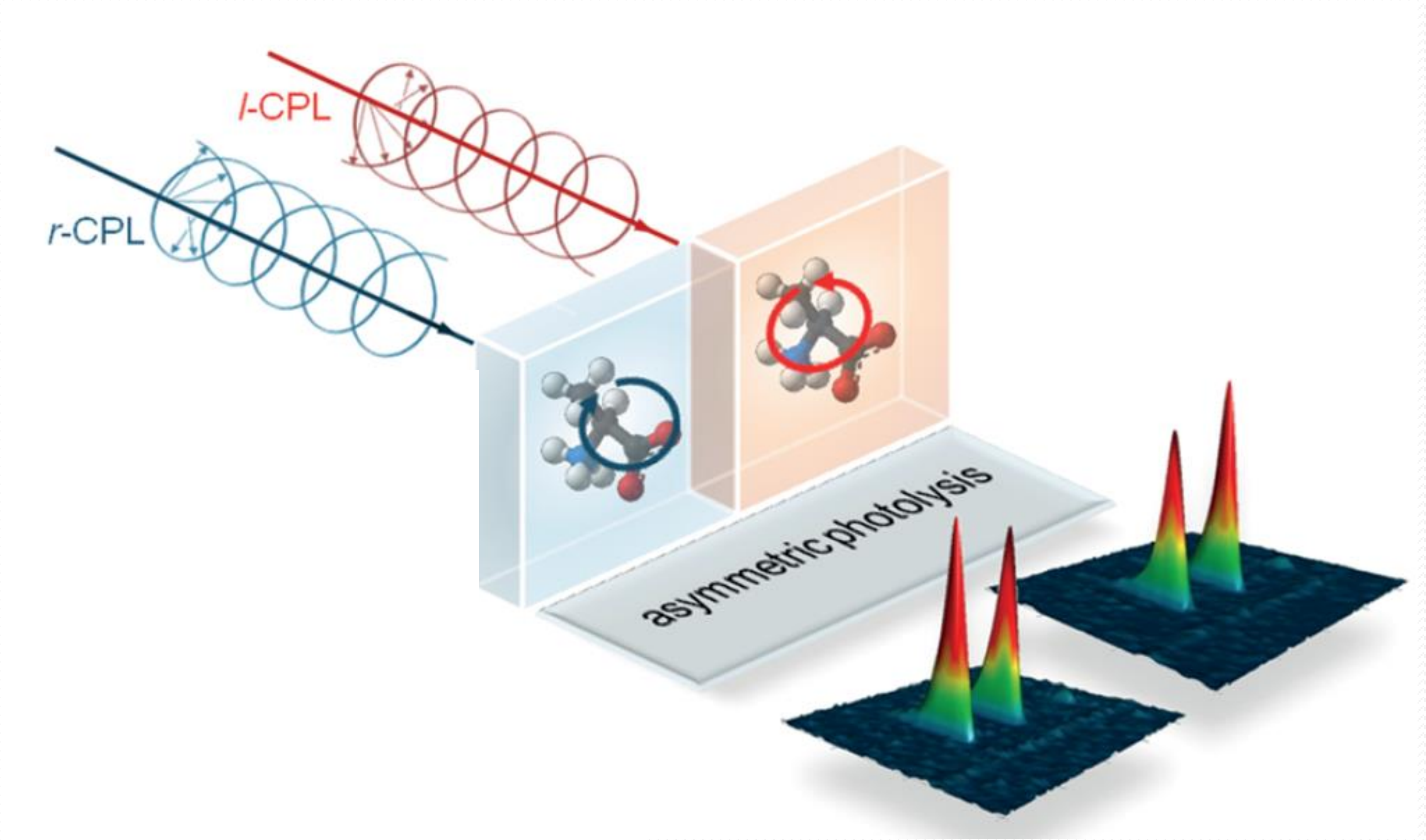


$g = \Delta\varepsilon / \varepsilon = \Delta A / A$ enhances CD bands of low absorption

The *g(λ)* 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

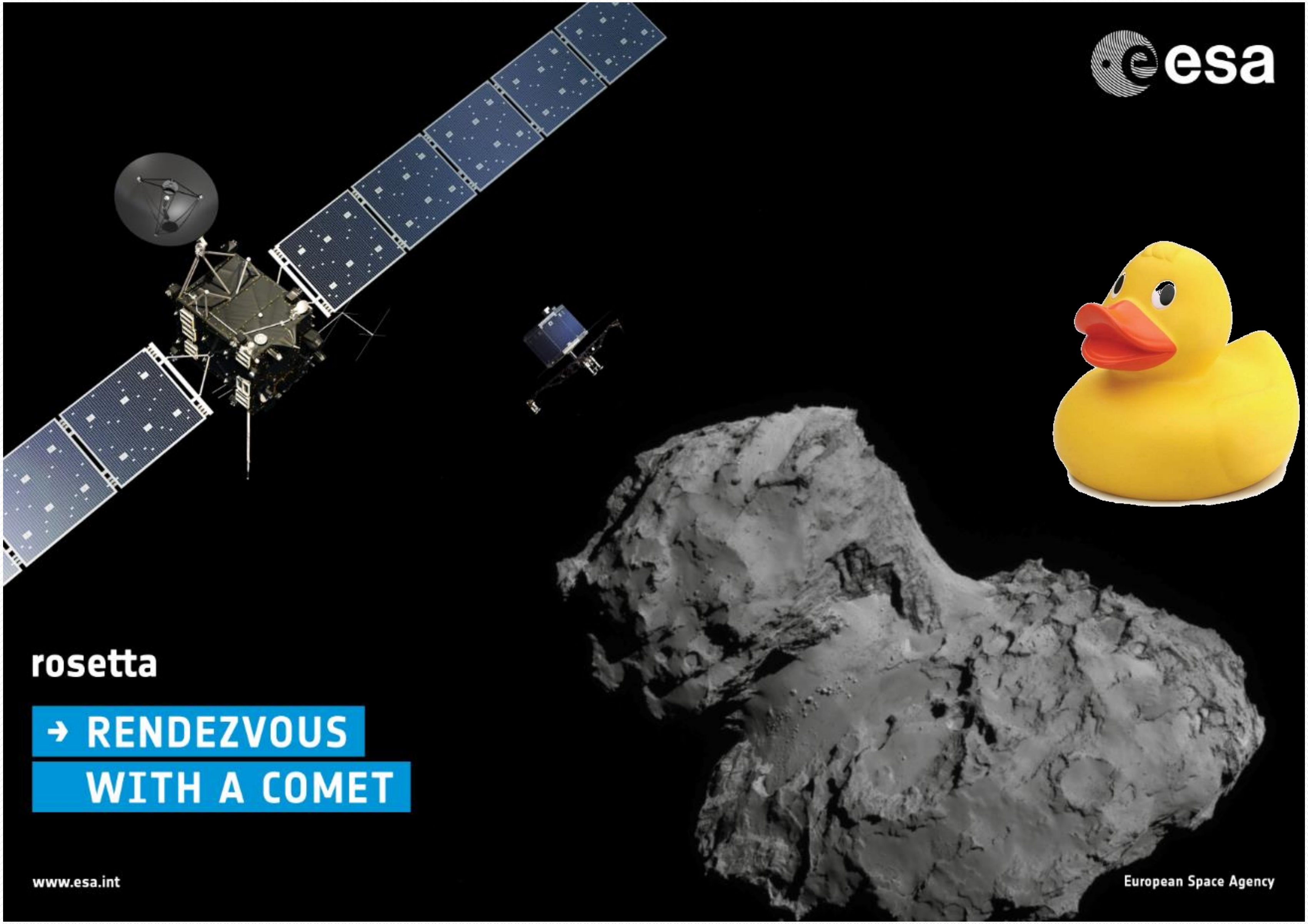
The Fascinating Comets

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

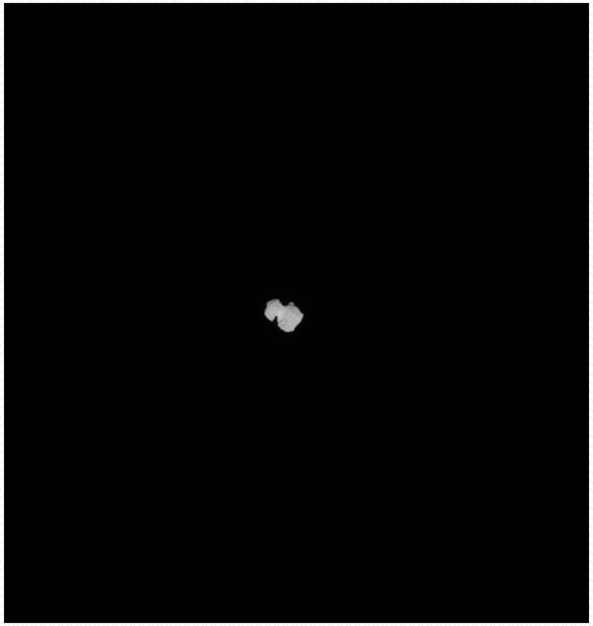


Man's exploration of space: 2014-16

<u>November 2014: Exploration of a comet.</u>

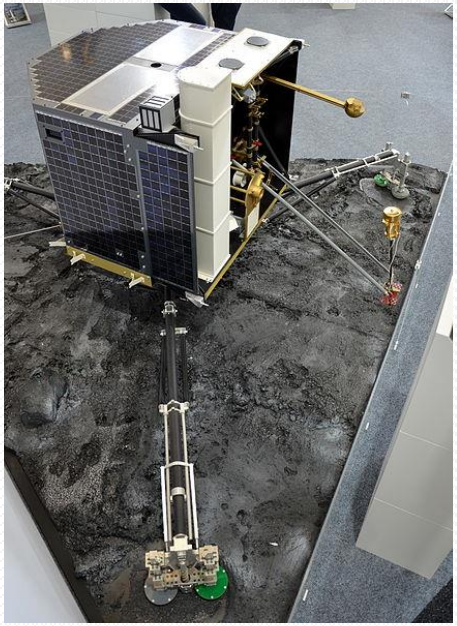
The European Space Agency's (ESA) *Rosetta mission* will study the *comet 67P*/Churyumov–Gerasimenko

The Philae lander: Experiments on the comets surface



Navcam Animaion
6 August 2014

Artist impression of the Philae lander

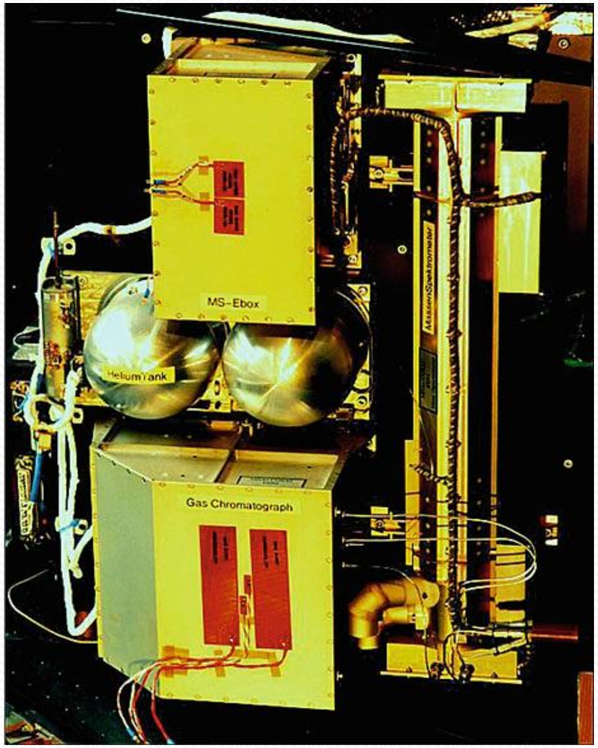


Model of the Philae lander

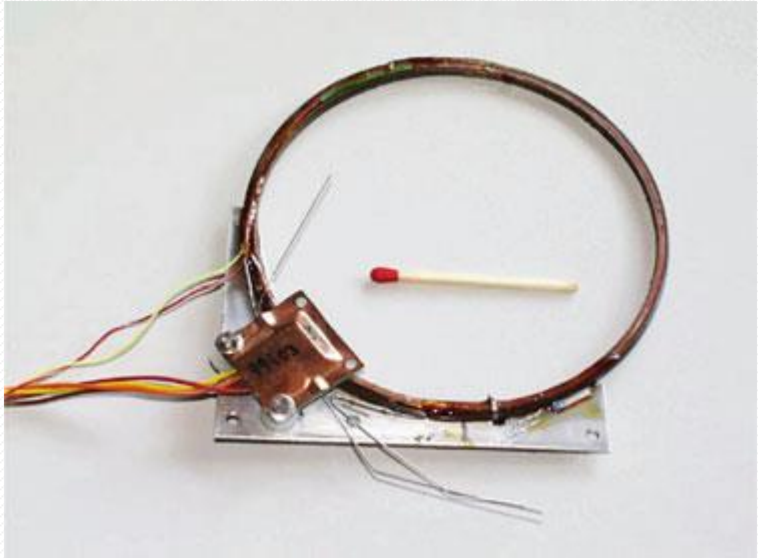
The Rosetta mission

November 2014: Exploration of a comet.

COSAC: Cometary Sampling and Composition Experiment



Gas Chromatograph coupled to a TOF Mass Spectrometer



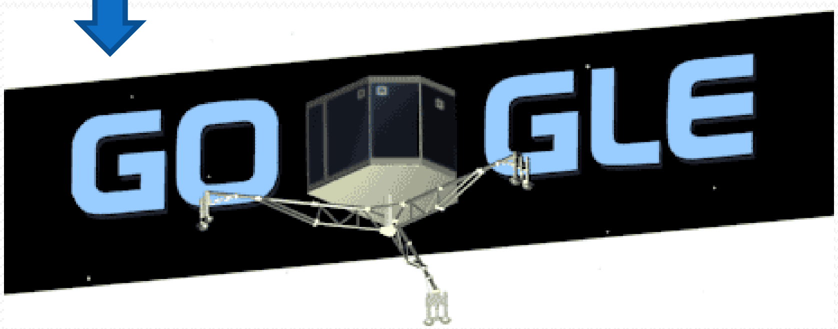
Chiral Capillary column in the COSAC experiment can separate enantiomers

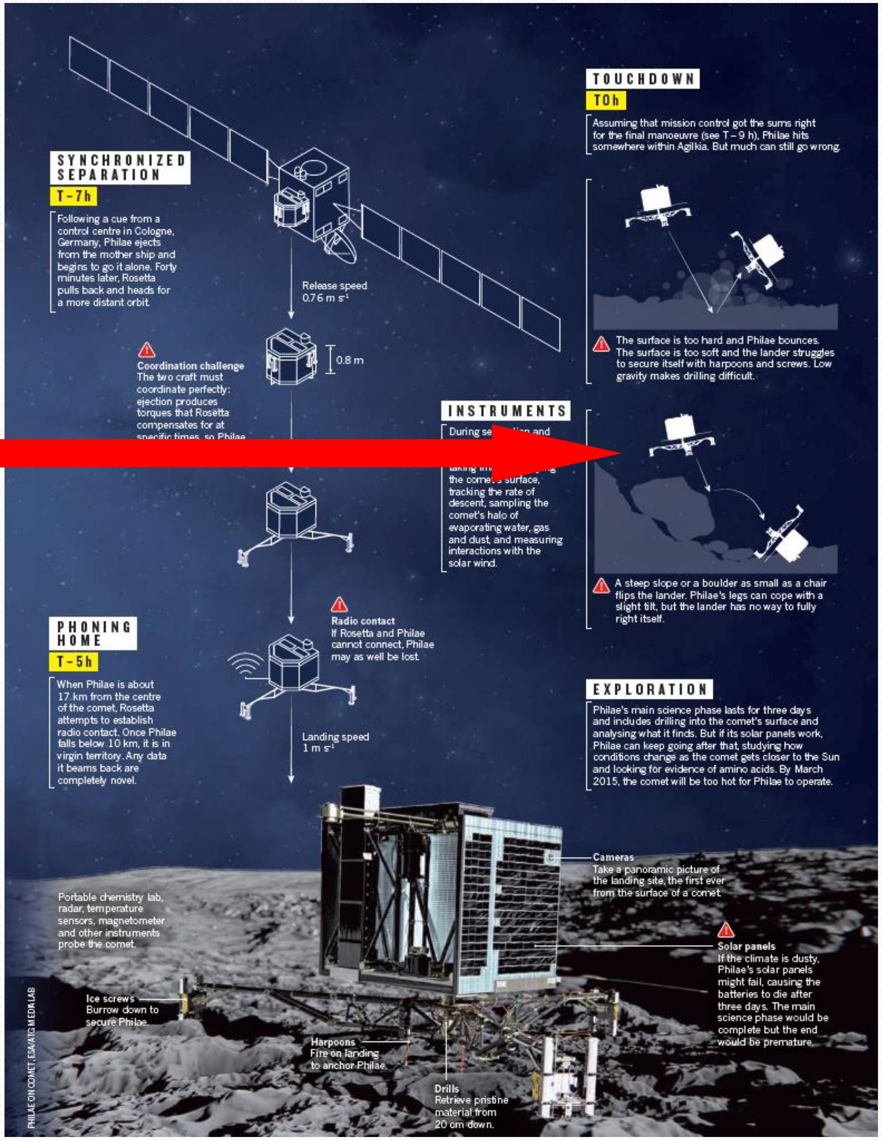
The Rosetta mission

Philae landing on November 12th 2014

Excitement

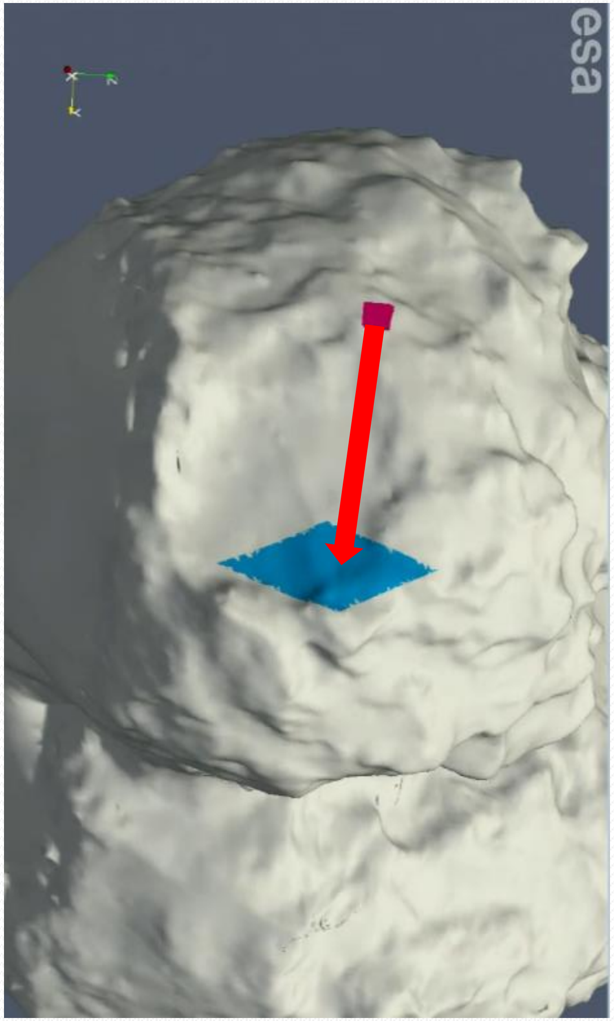
and worries

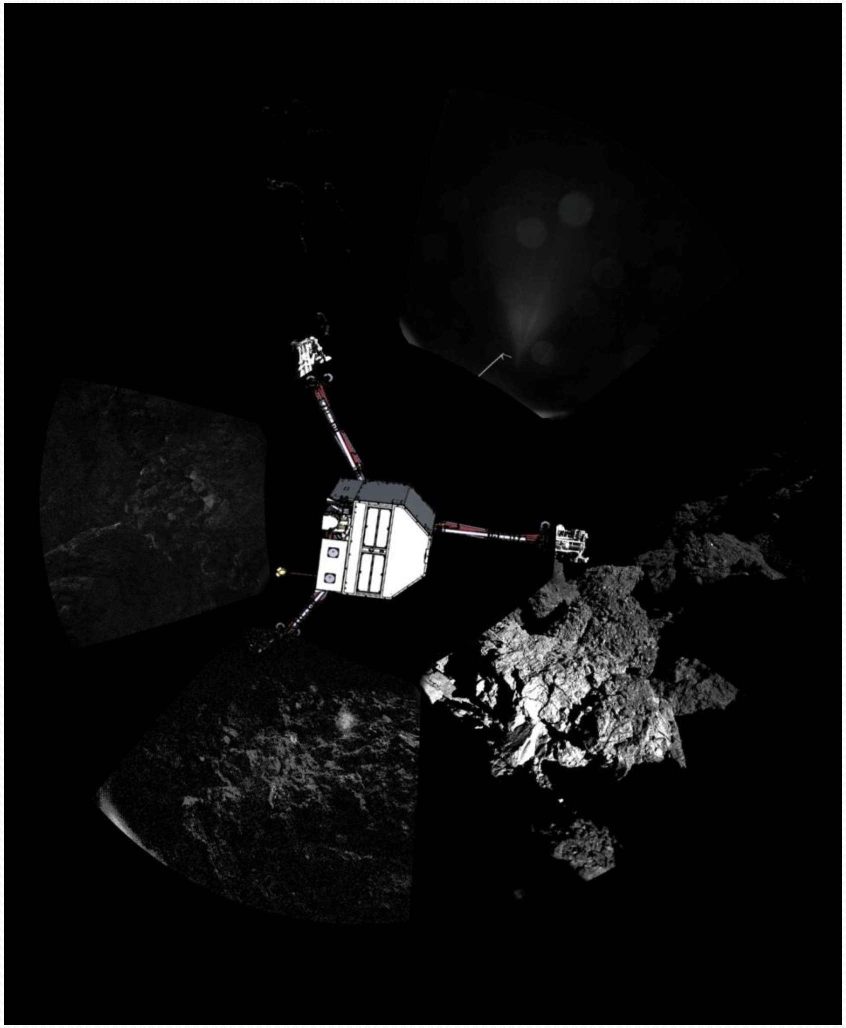




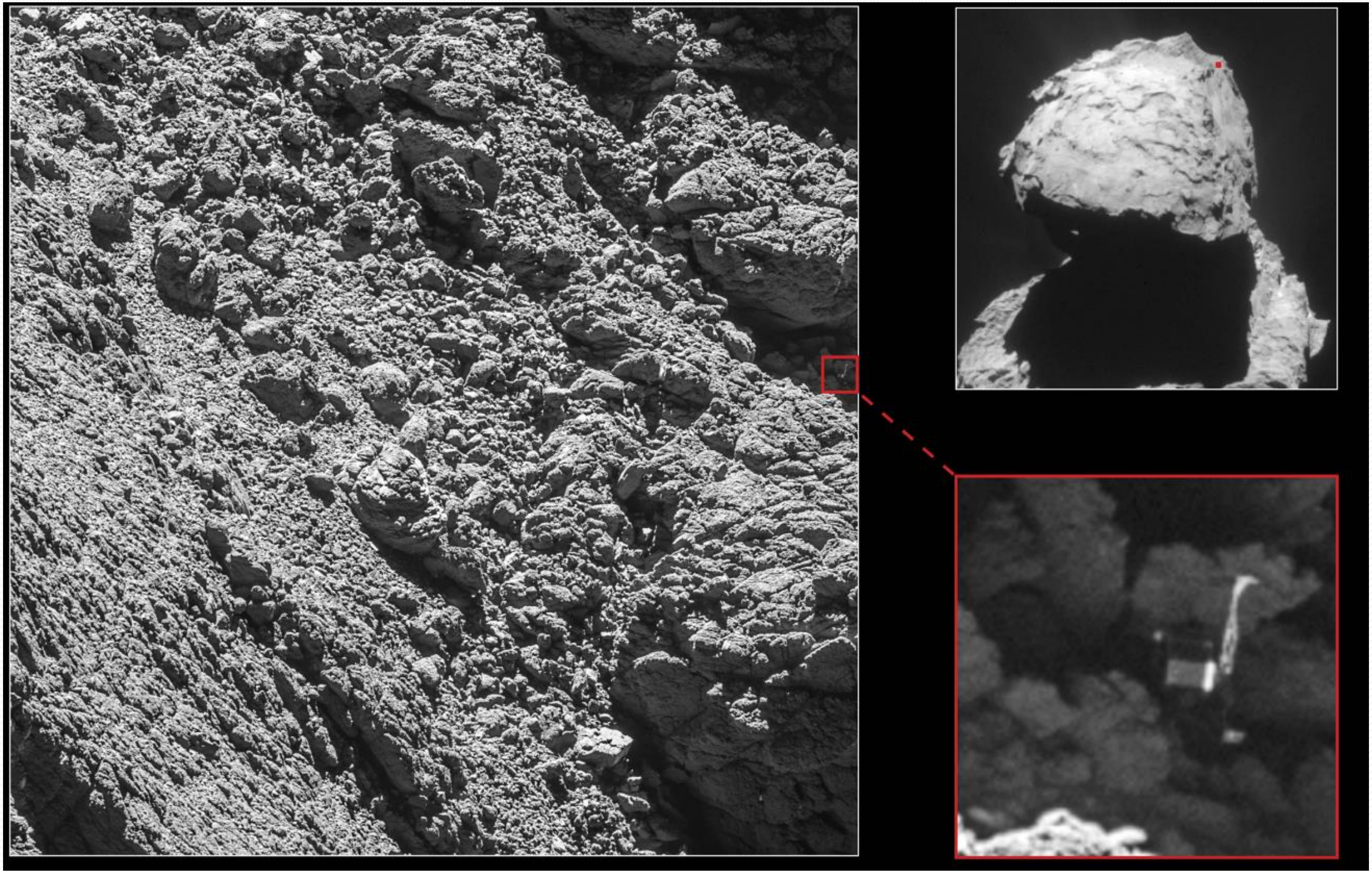
The Rosetta mission

Bounced of the surface, but it stayed at the comet



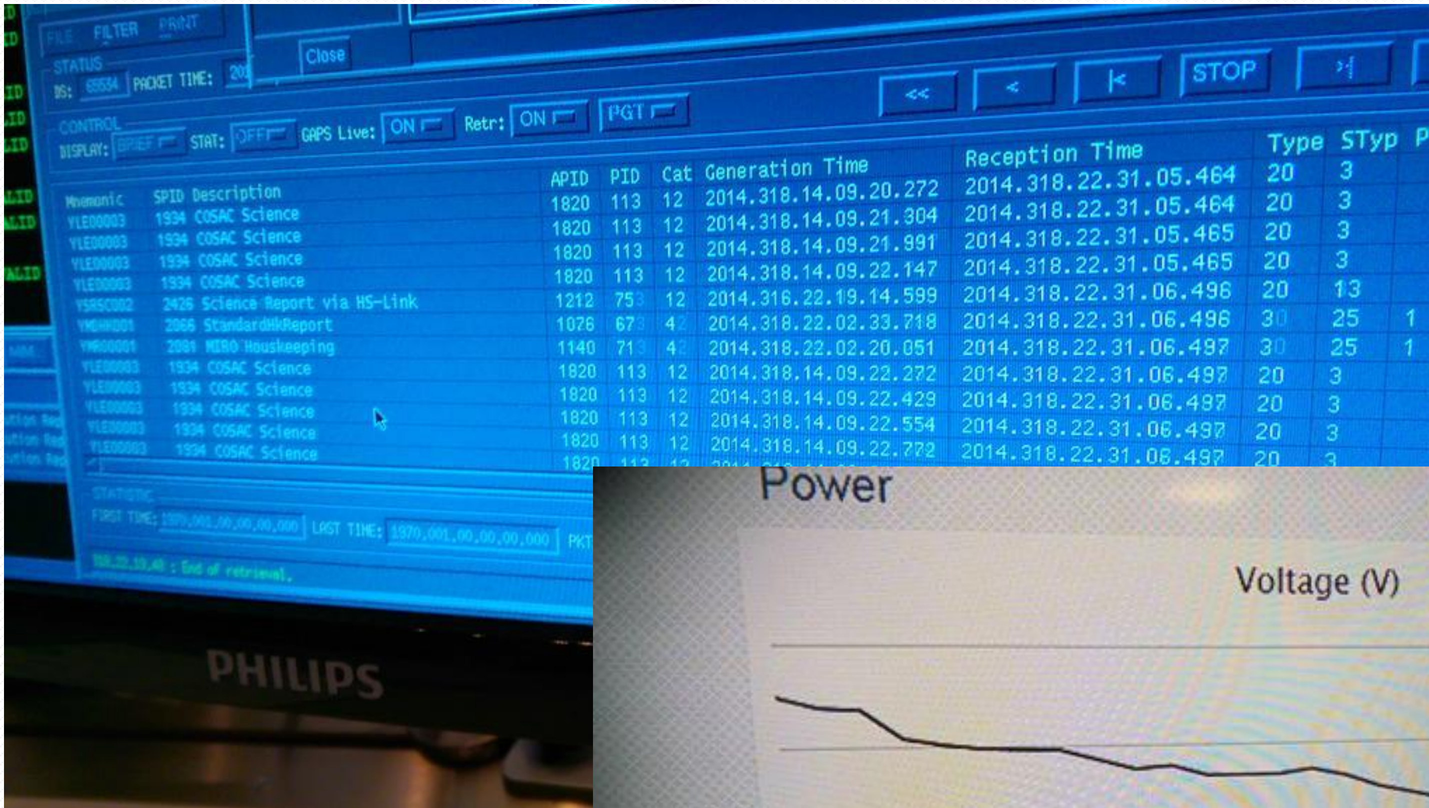


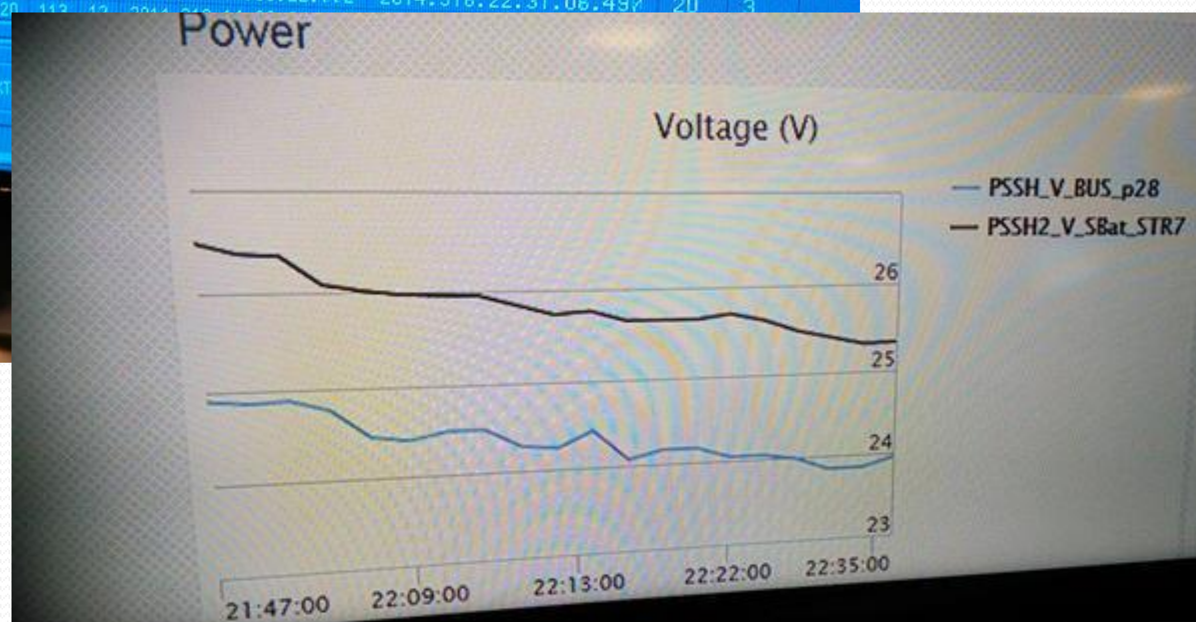
The Rosetta mission



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 | Teknol

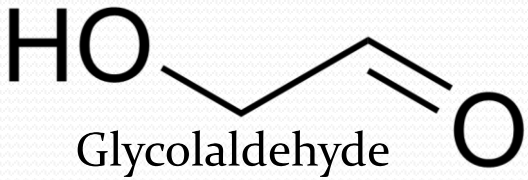
Nye analyser: Philae sniffede acetone på kometen

Name	Formula
Water	H_2O
Methane	CH_4
Methanenitrile (hydrogen cyanide)	HCN
Carbon monoxide	CO
Methylamine	CH_3NH_2
Ethanenitrile (acetonitrile)	CH_3CN
Isocyanic acid	$HNCO$
Ethanal (acetaldehyde)	CH_3CHO
Methanamide (formamide)	$HCONH_2$
Ethylamine	$C_2H_5NH_2$
Isocyanomethane (methyl isocyanate)	CH_3NCO
Propanone (acetone)	CH_3COCH_3
Propanal (propionaldehyde)	C_2H_5CHO
Ethanamide (acetamide)	CH_3CONH_2
2-Hydroxyethanal (glycolaldehyde)	CH_2OHCHO
1,2-Ethanediol (ethylene glycol)	$CH_2(OH)CH_2(OH)$

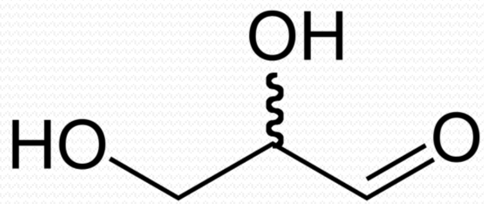
The Rosetta mission

…. dust from the landing(s) was analysed

Formose reaction

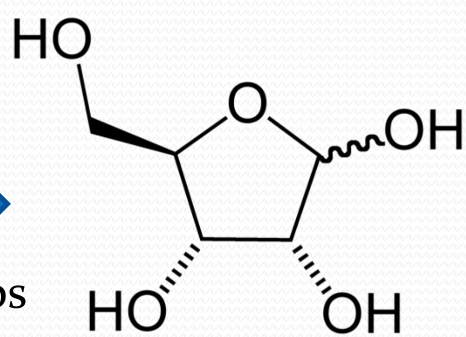


Glycolaldehyde



Glyceraldehyde (chiral)

several steps



Ribose

The chiral unit of RNA!

Name	Formula
Water	H_2O
Methane	CH_4
Methanenitrile (hydrogen cyanide)	HCN
Carbon monoxide	CO
Methylamine	CH_3NH_2
Ethanenitrile (acetonitrile)	CH_3CN
Isocyanic acid	HNCO
Ethanal (acetaldehyde)	CH_3CHO
Methanamide (formamide)	$HCONH_2$
Ethylamine	$C_2H_5NH_2$
Isocyanomethane (methyl isocyanate)	CH_3NCO
Propanone (acetone)	CH_3COCH_3
Propanal (propionaldehyde)	C_2H_5CHO
Ethanamide (acetamide)	CH_3CONH_2
2-Hydroxyethanal (glycolaldehyde)	CH_2OHCHO
1,2-Ethanediol (ethylene glycol)	$CH_2(OH)CH_2(OH)$

UV induced formation of sugars

Science AAAS

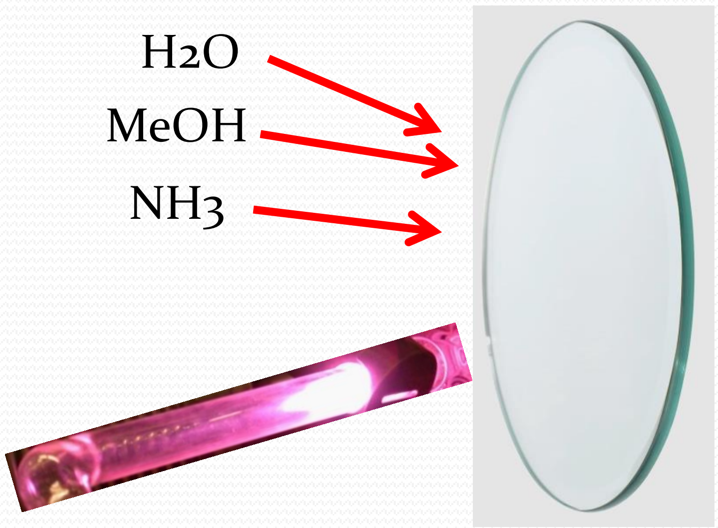
UV induced formation of

Glycolaldehyde

Glyceraldehyde

and *RIBOSE*

… *and many others…*



H2 UV lamp

Liquid nitrogen cooled plate

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..

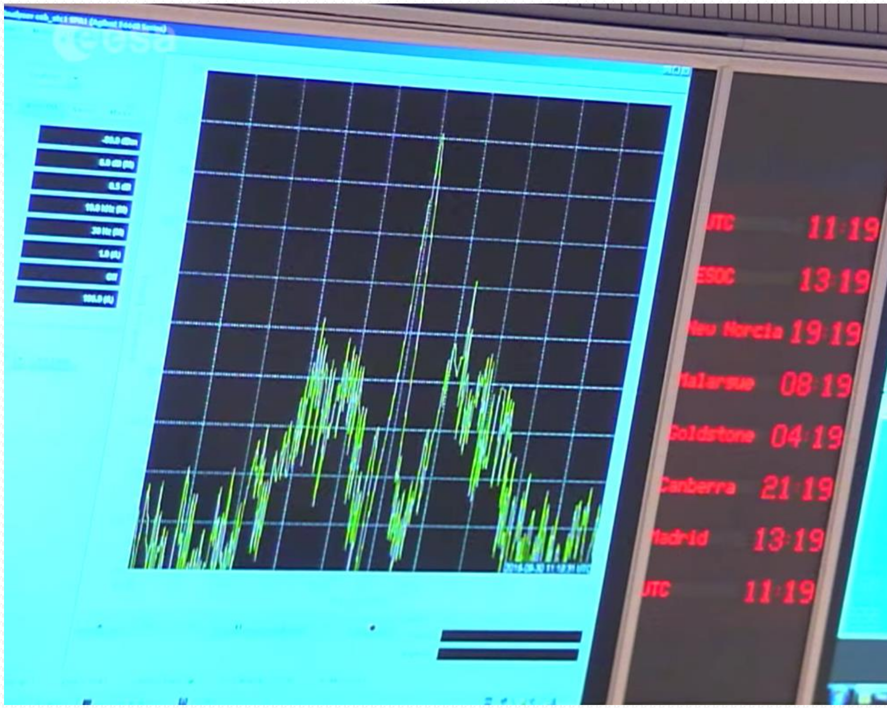
What comes next…

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

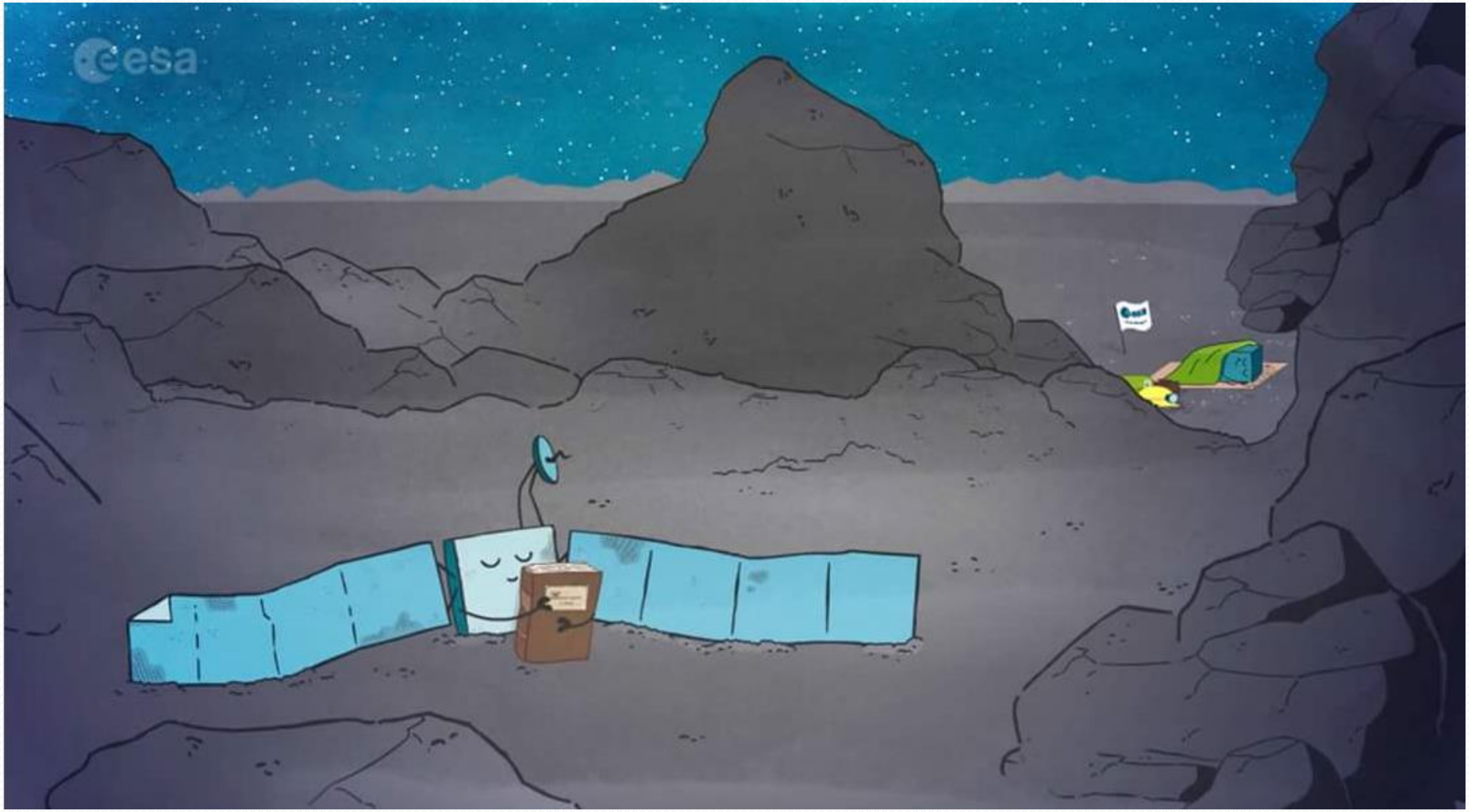


ROSETTA signal just before….

…and after the CRASH

The Rosetta mission

Mission ended 30th September 2016

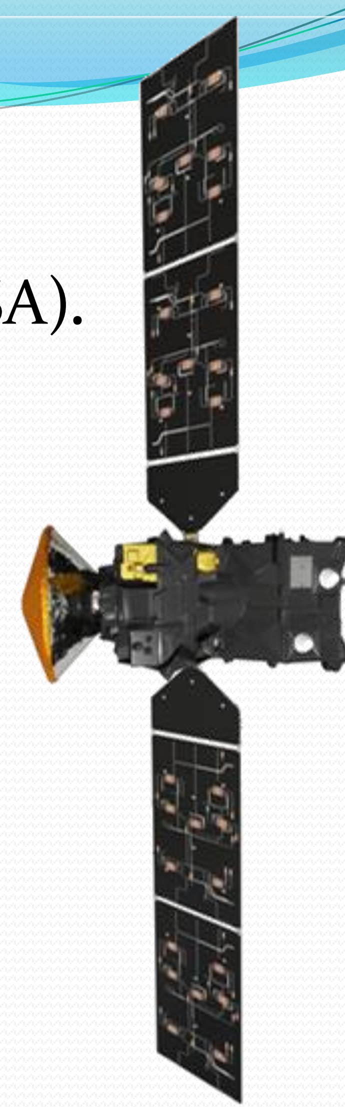


The ExoMars mission

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, Univeristy of Nice
Prof. Uwe J. Meierhenrich, Univeristy 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