Molekyledannelse katalyseret af komisk støv som mulig basis for livets opståen

Liv Hornekær

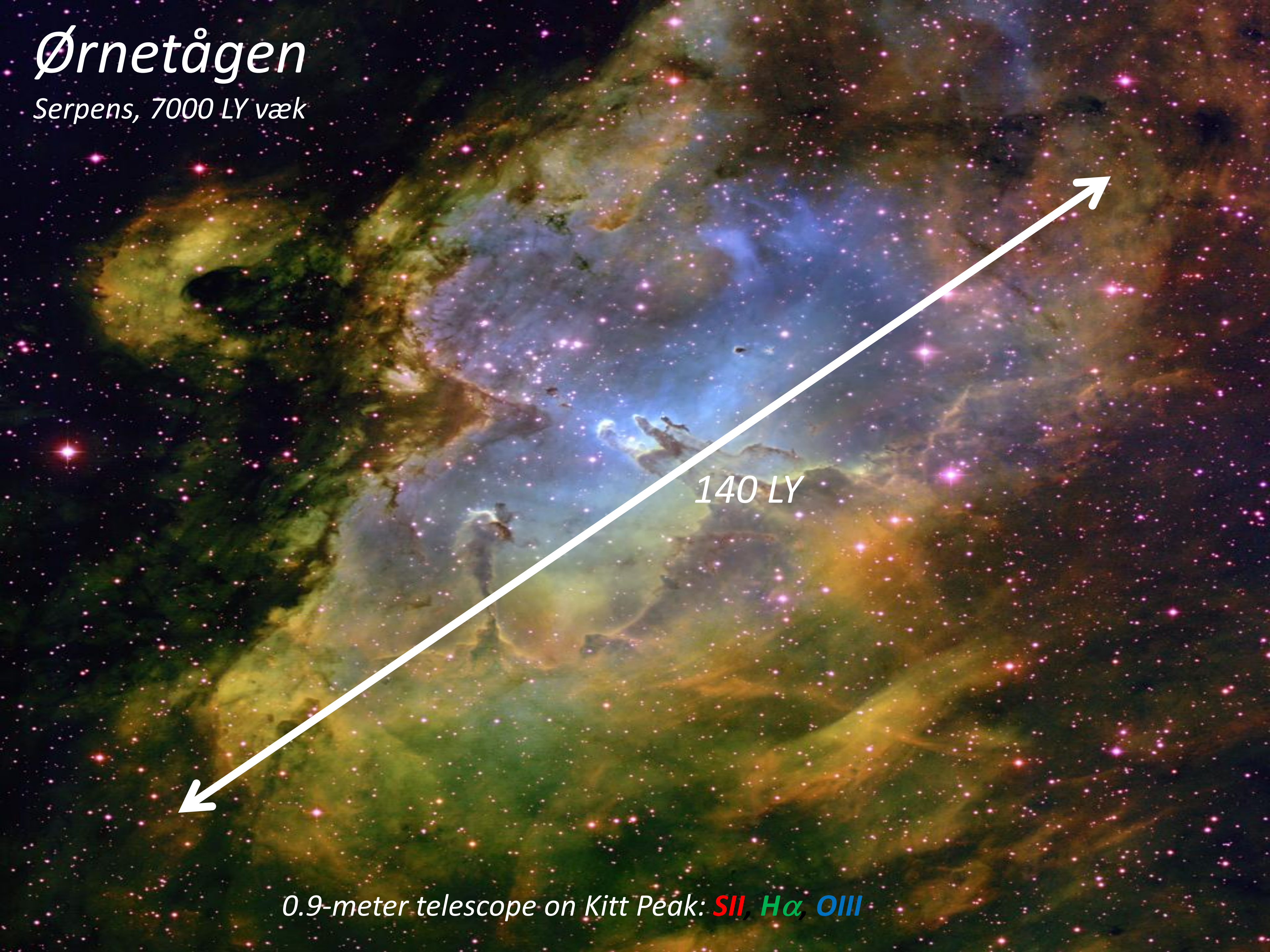
Inst. Fysik & Astronomi, AU

Ørnetågen

0.9-meter telescope on Kitt Peak: SII, Hα, OIII

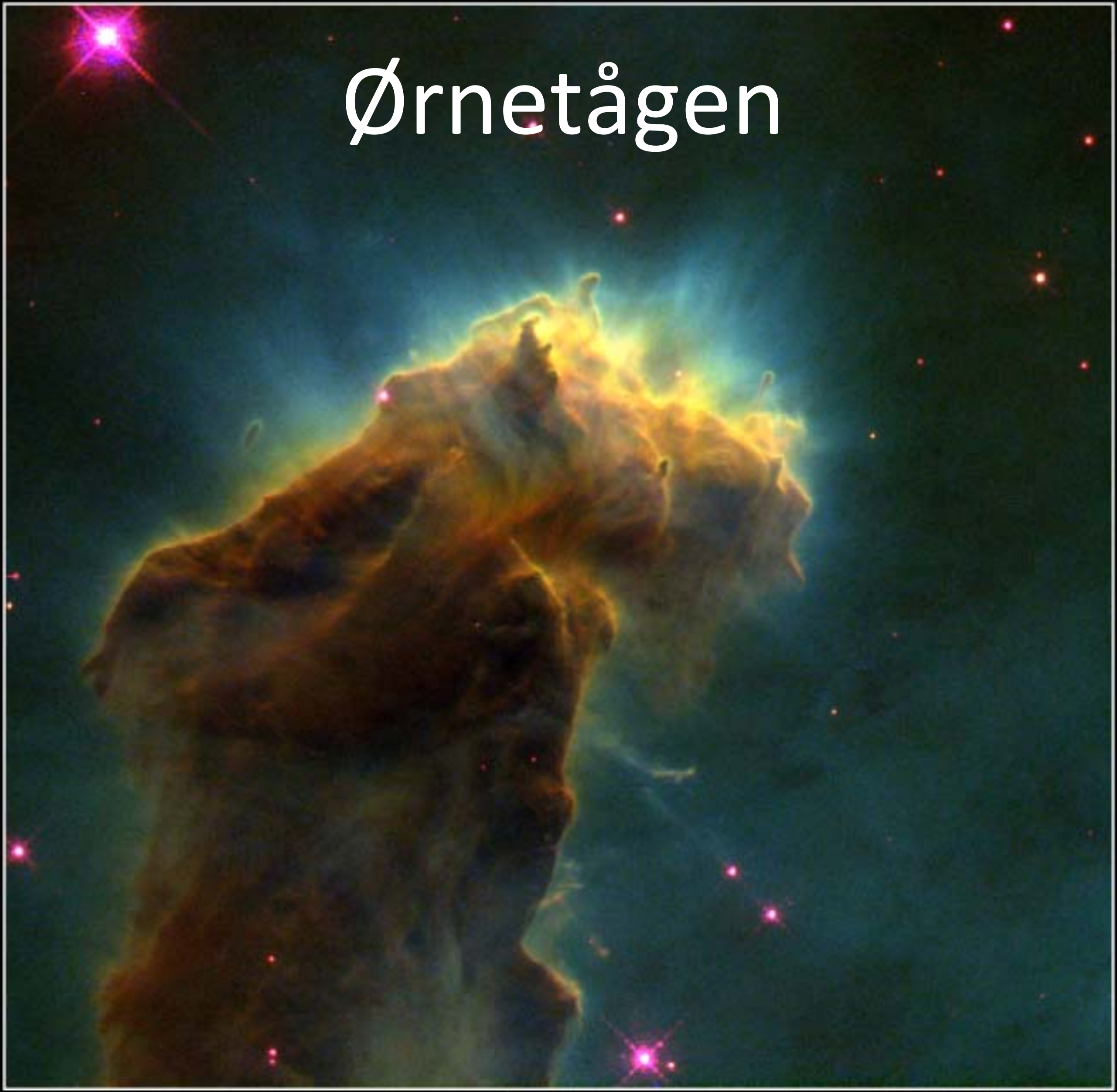
Ørnetågen

Serpens, 7000 LY væk



0.9-meter telescope on Kitt Peak: SII, Hα, OIII

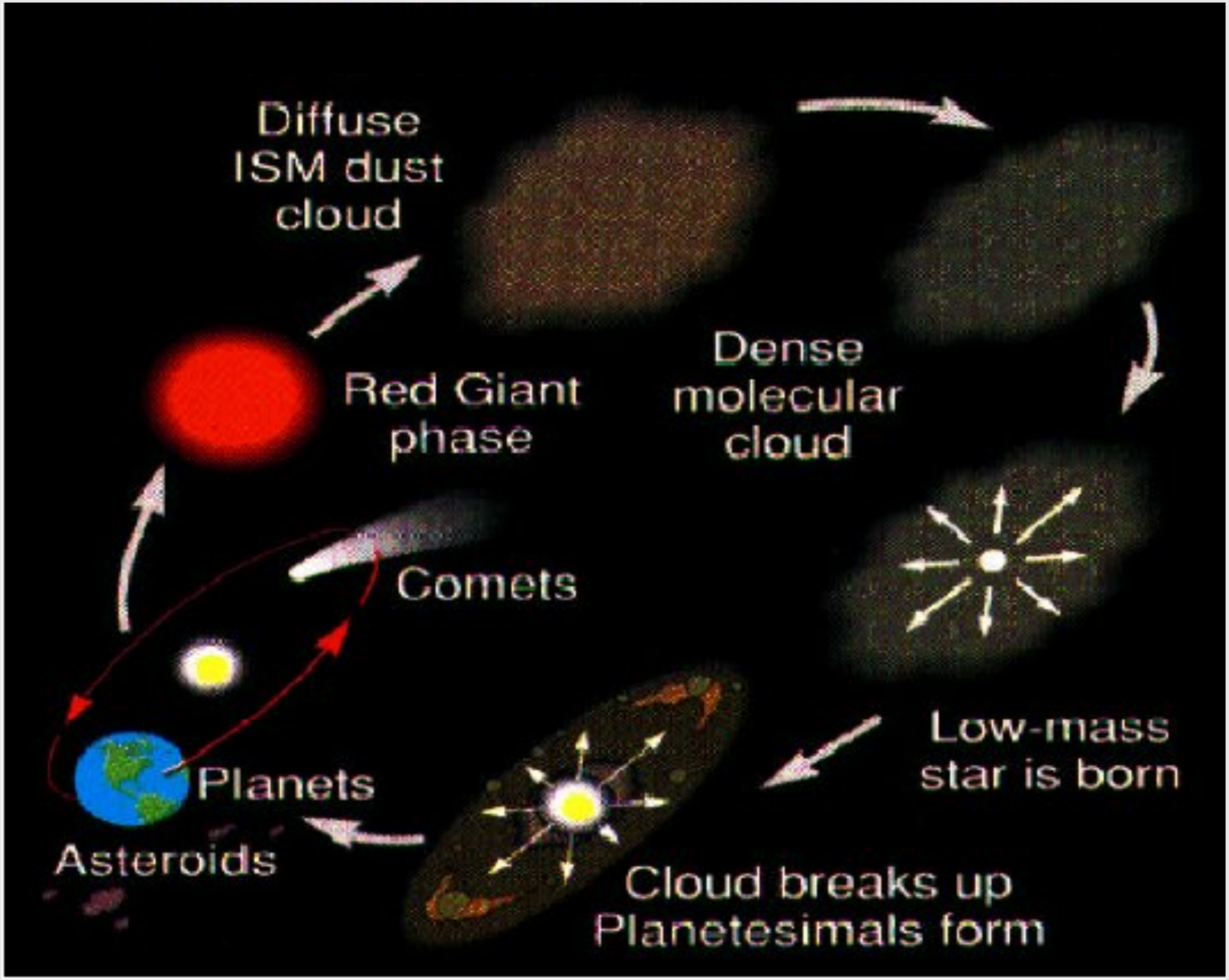
Ørnetågen



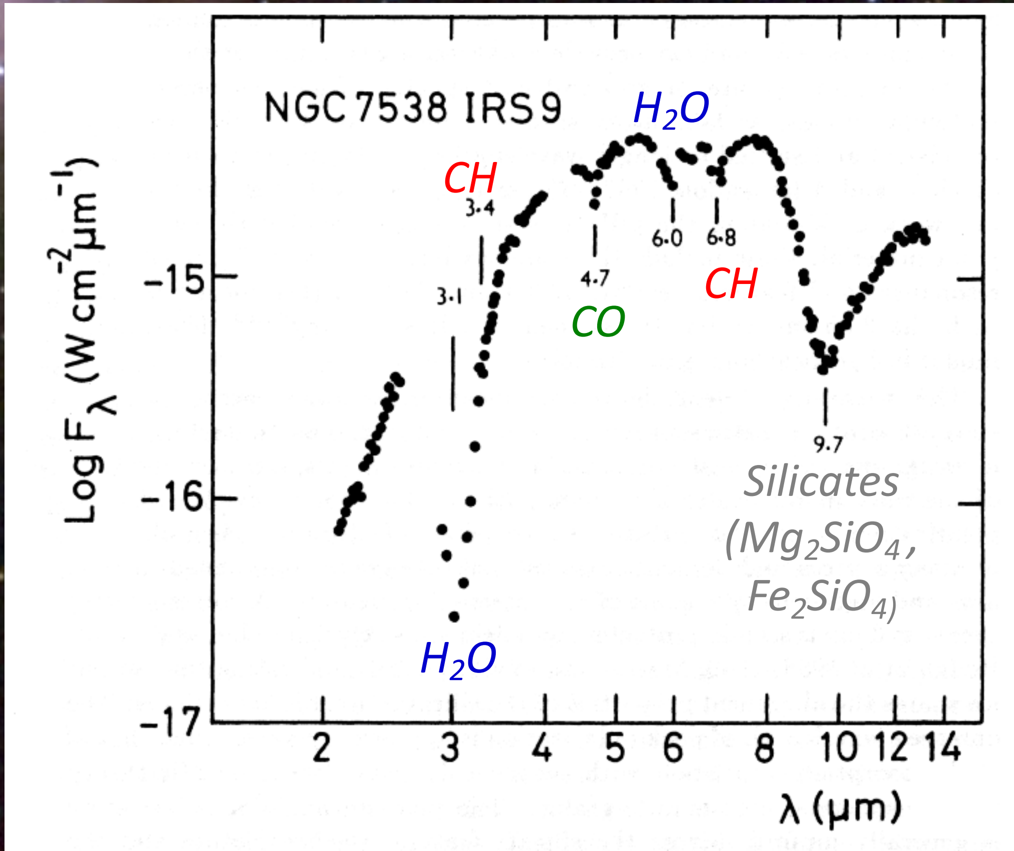
Star-Birth Clouds · M16 HST · WFPC2

PRC95-44b · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

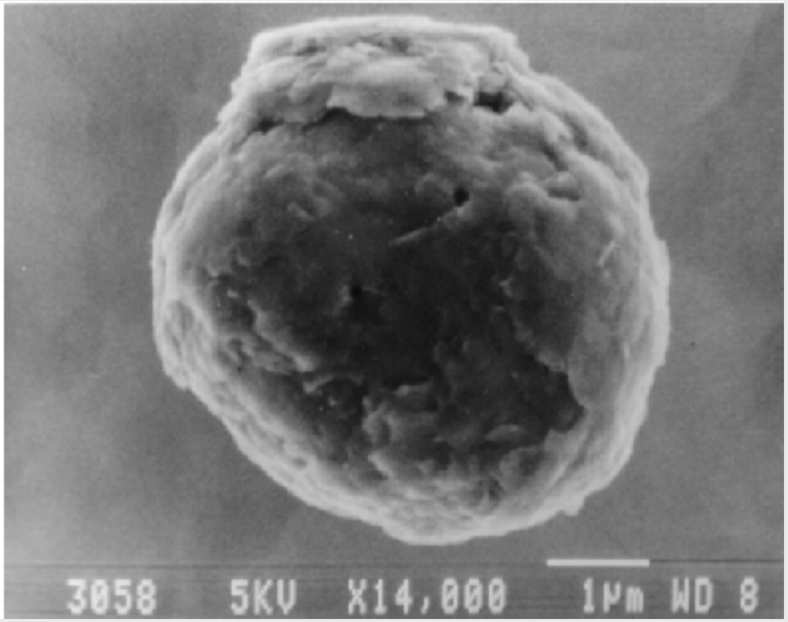
– Stjerners livscyklus

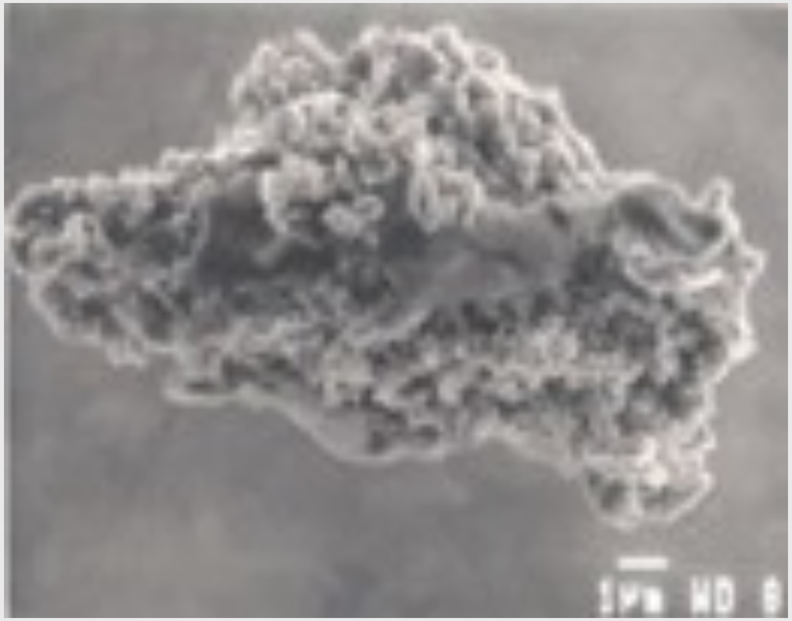


Absorptions spektrum



Støvkorn





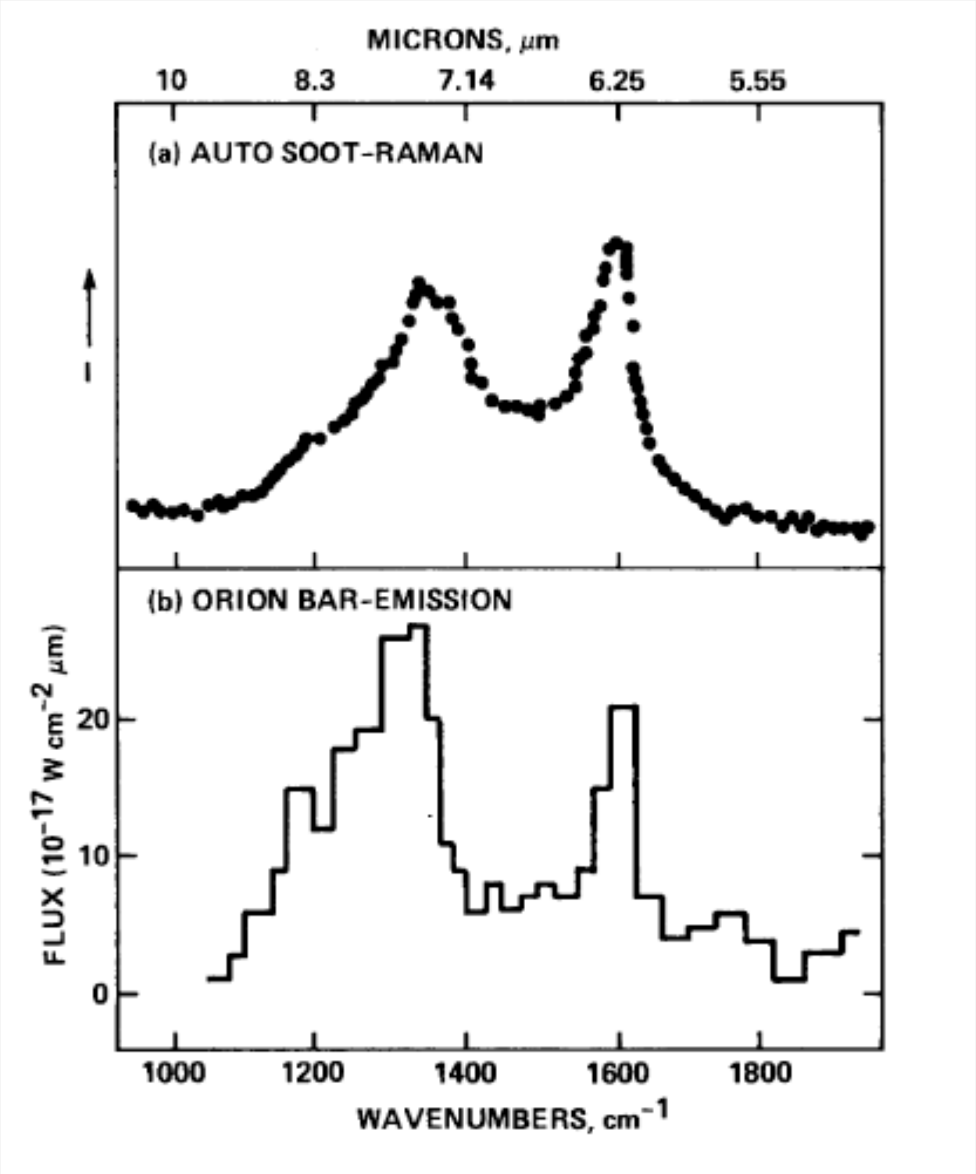
Sod-partikler: Grafit, Amorft Kul, HAC, PAH, Polymerisk Carbon, Diamant

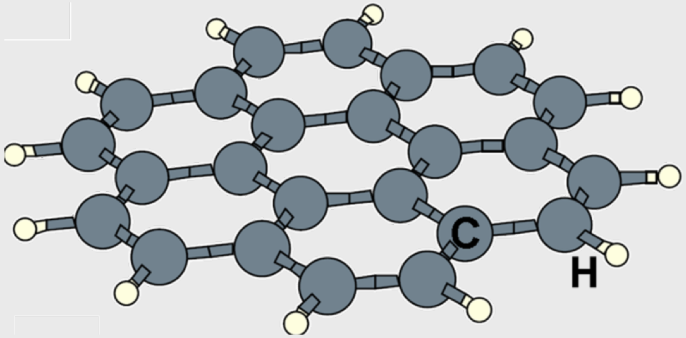
Sand-korn(silikater):

Olivines (Mg_2SiO_4, Fe_2SiO_4)

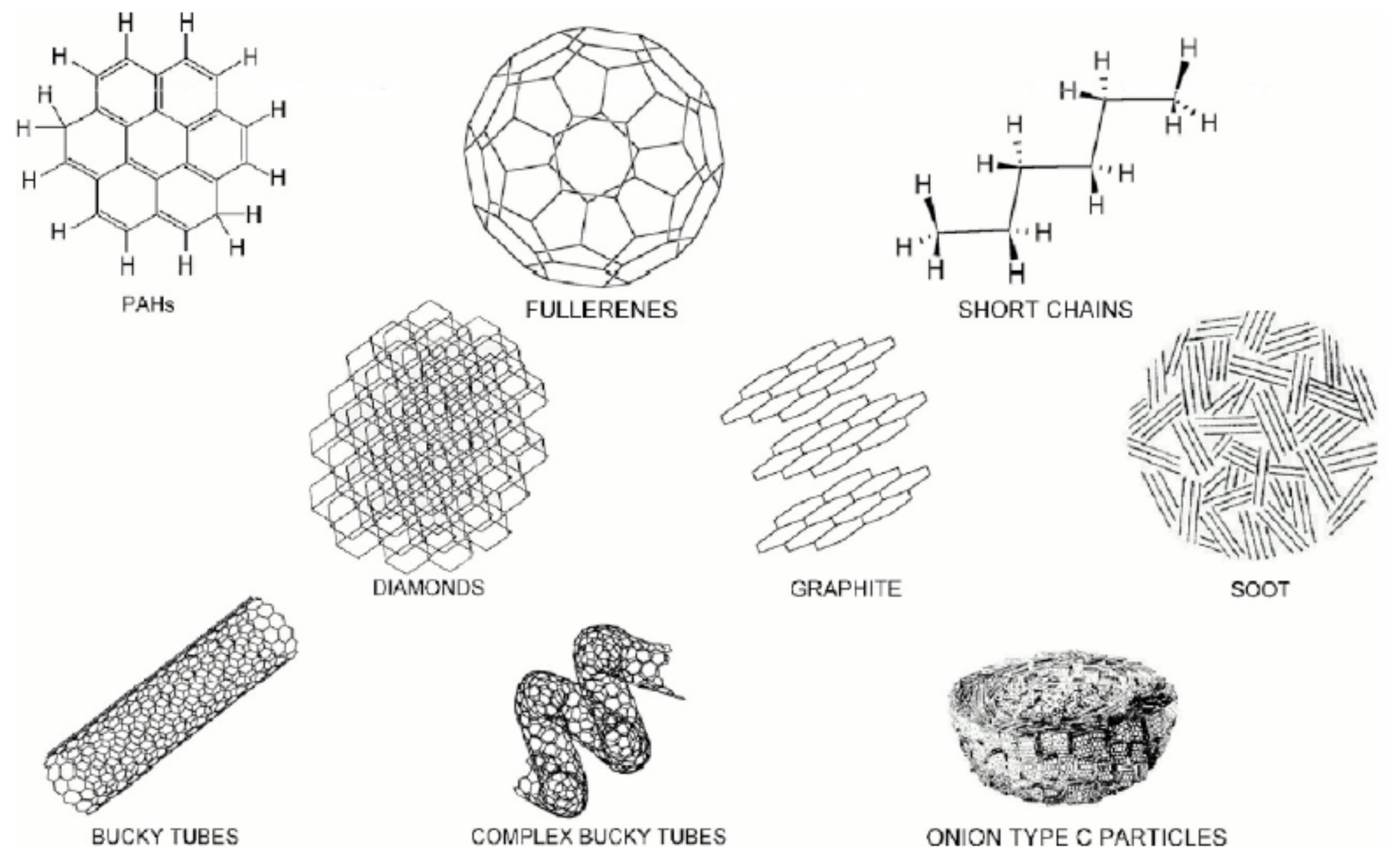
Is: H_2O, CO, CO_2, CH_3OH, CH_4, H_2CO ...

Polycykliske aromatiske kulbrinter (PAH'er)

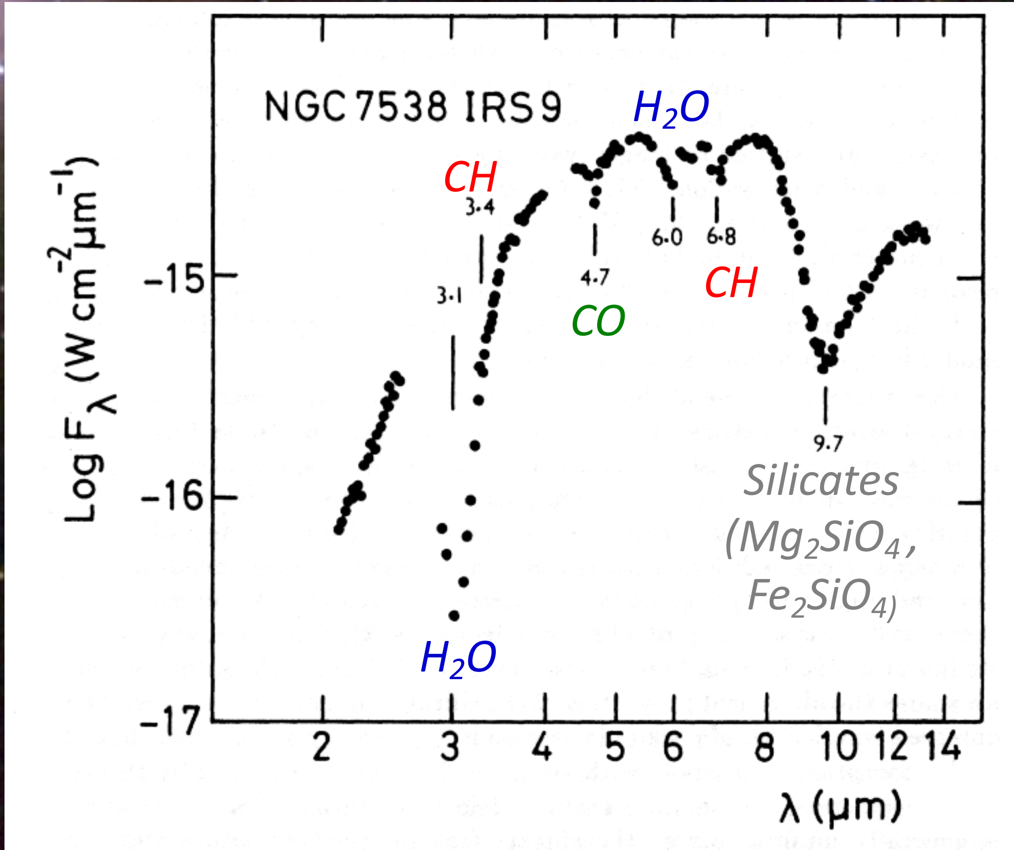




Kul


H
PAHs
FULLERENES
SHORT CHAINS
DIAMONDS
GRAPHITE
SOOT
BUCKY TUBES
COMPLEX BUCKY TUBES
ONION TYPE C PARTICLES

Absorptions spektrum



Sky sammensætning

Atomer:

H, He, O, C, N, Ne, Si, Mg, S, Fe ...

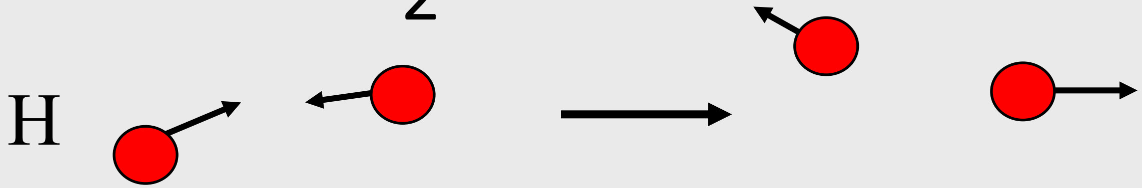
>200 Molekyler:

H_2 , CO, CO_2 , O_2 , H_2O, NH_3 , CH_3OH ...

Sukker: glycolaldehyde (CH_2OHCHO)

Støvkorn

H_2 dannelse



Ingen Dipol Tilladte Overgange

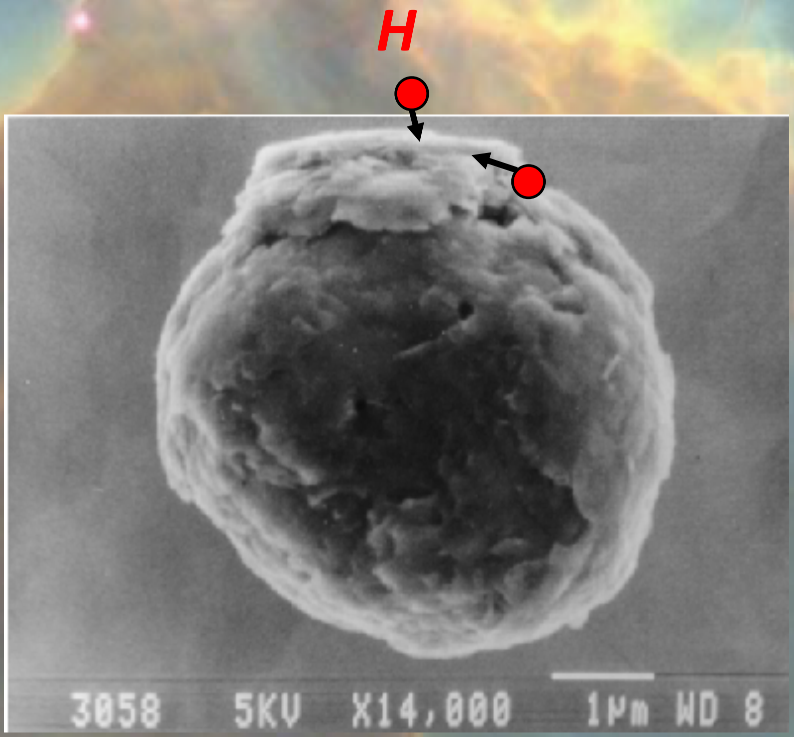
↓

Ingen strålingsstabilisering

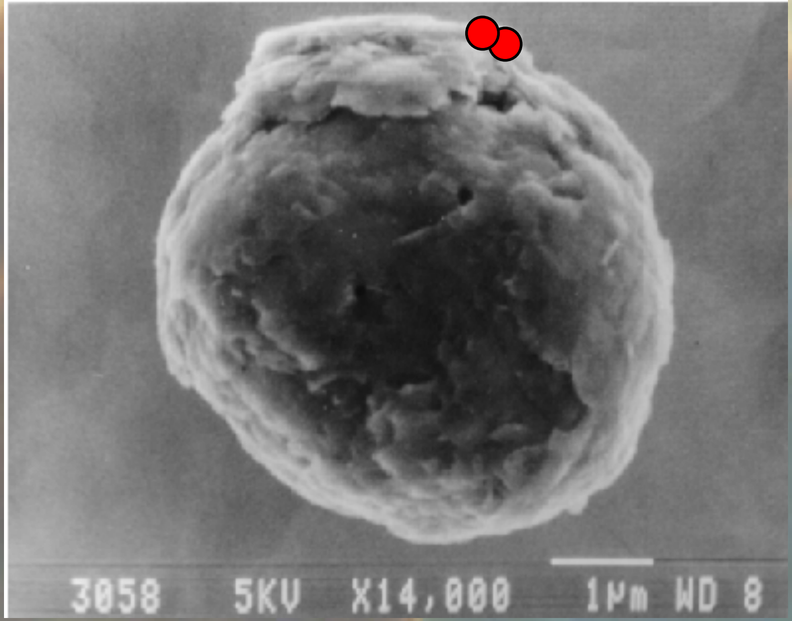
3-legene kollisioner – ok ved høj tæthed

Diffuse/Tætte stjerne tåge tætheder => ~Ingen 3-legeme kollisioner

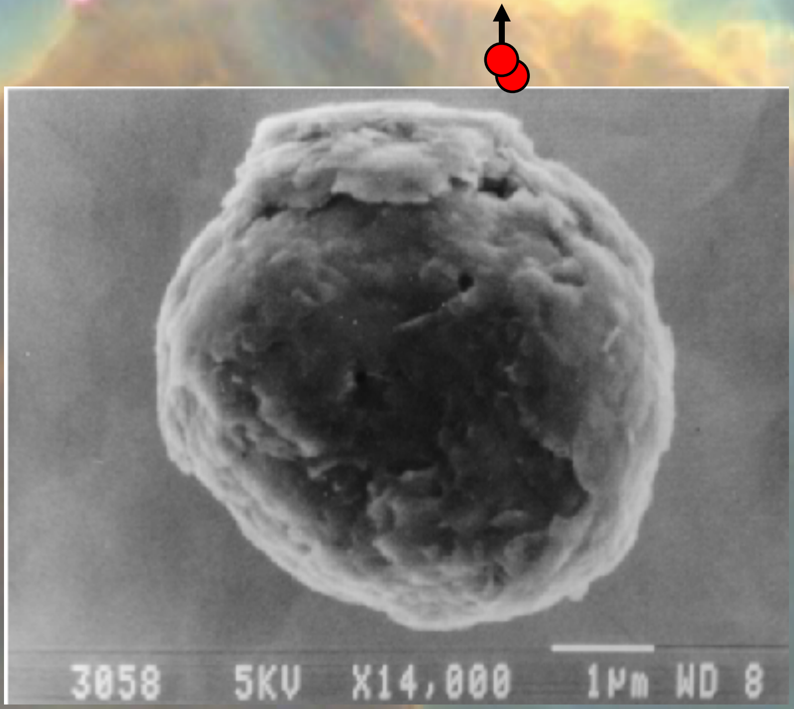
Overflade Reaktioner



Overflade Reaktioner

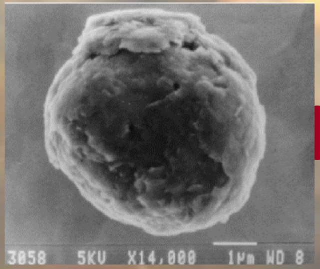


Overflade Reaktioner



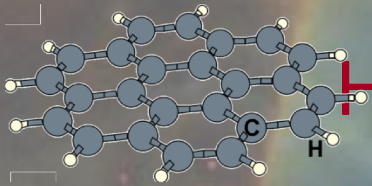
Brint-molekyle dannelse ?

$H + H +$



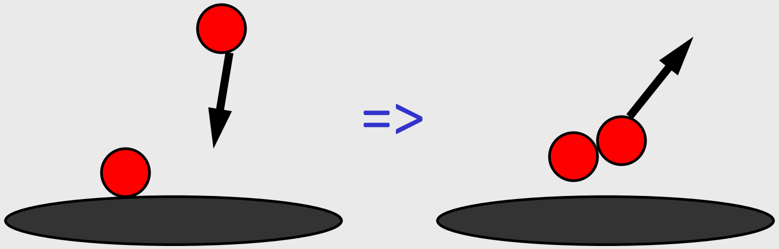
$\rightarrow H_2$

$H + H +$



$\rightarrow H_2$

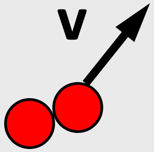
Energi fordeling ved H_2 dannelse ?



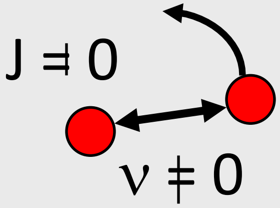
$E_{frigivet} \sim 4.5$ eV

50.000 K

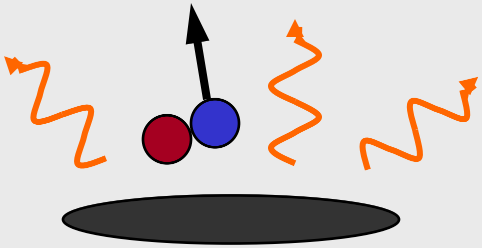
Til:



Kinetisk energi ?

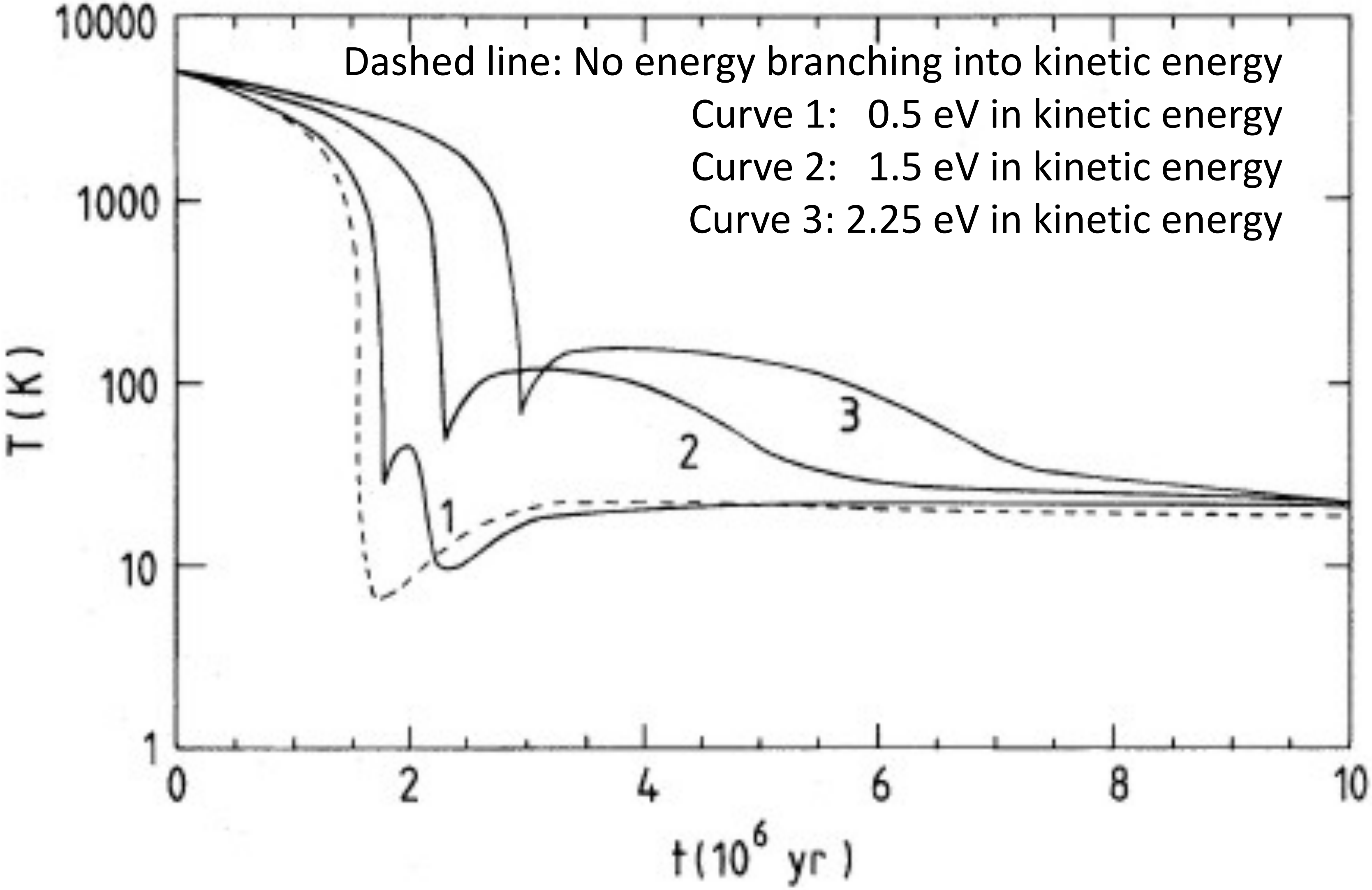


Molekylær eksitation ?



Støvkorns opvarmning ?

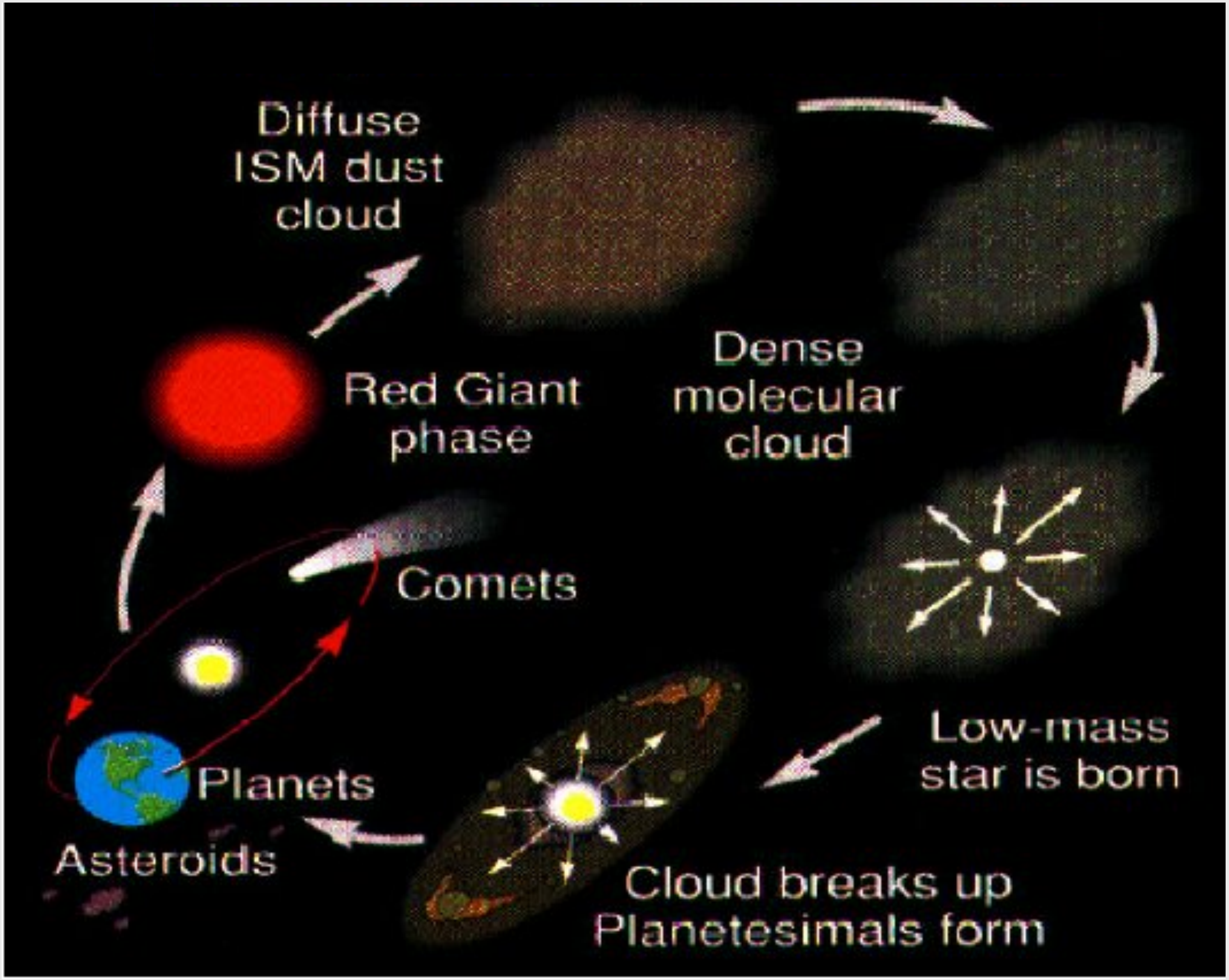
Energi frigivelse af H_2 dannelse og termisk evolution af interstellare skyer



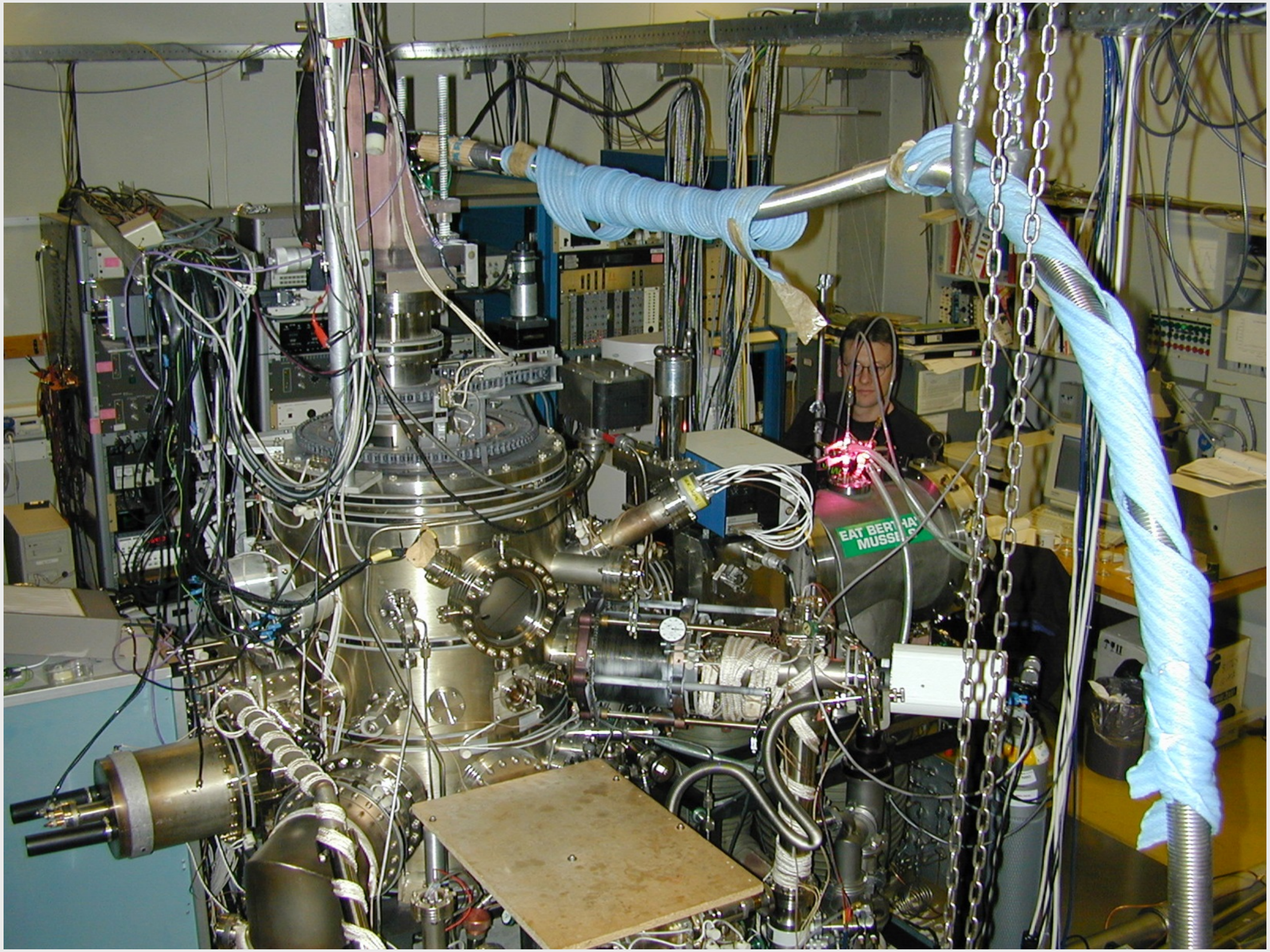
Dashed line: No energy branching into kinetic energy
Curve 1: 0.5 eV in kinetic energy
Curve 2: 1.5 eV in kinetic energy
Curve 3: 2.25 eV in kinetic energy

Flower & des Forêts, MNRAS 247, 500 (1990)

– Stjerners livscyklus



Bringing the Interstellar medium to a laboratory near you



Genskabe interstellare betingelser ?

Interstellart tryk:

$P = 10^{-13}$ atm

Interstellare temperaturer:

$T = 6\text{-}1000$ K

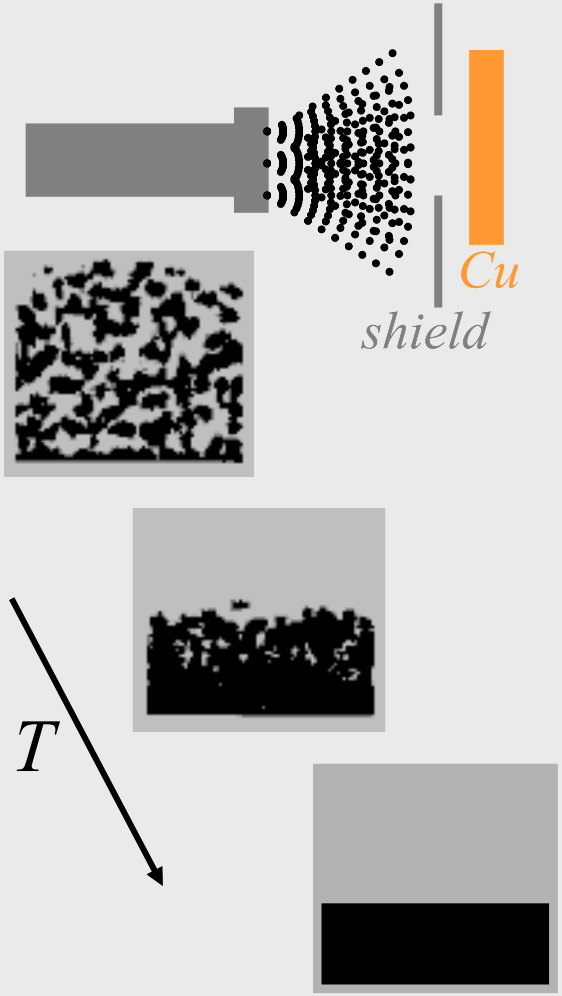
Relevante overflader:

***Is, grafit**, amorft kul, silikater*

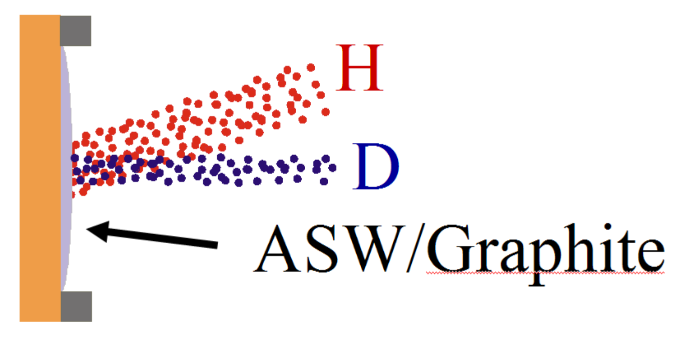
Overflader af interstellar relevans

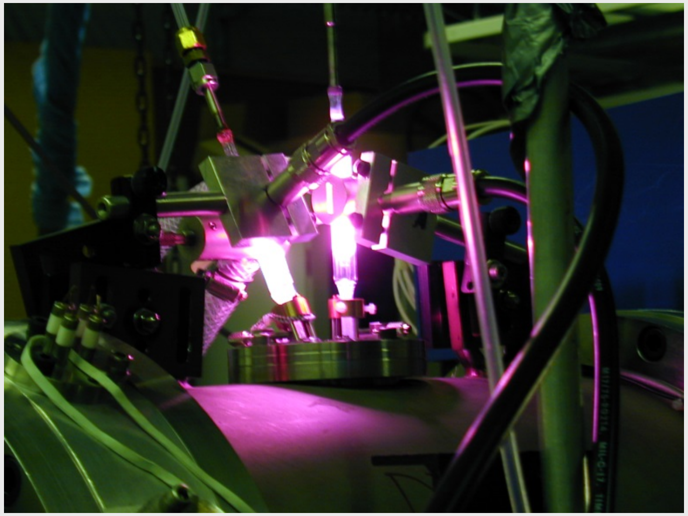
Grafit

Vand is

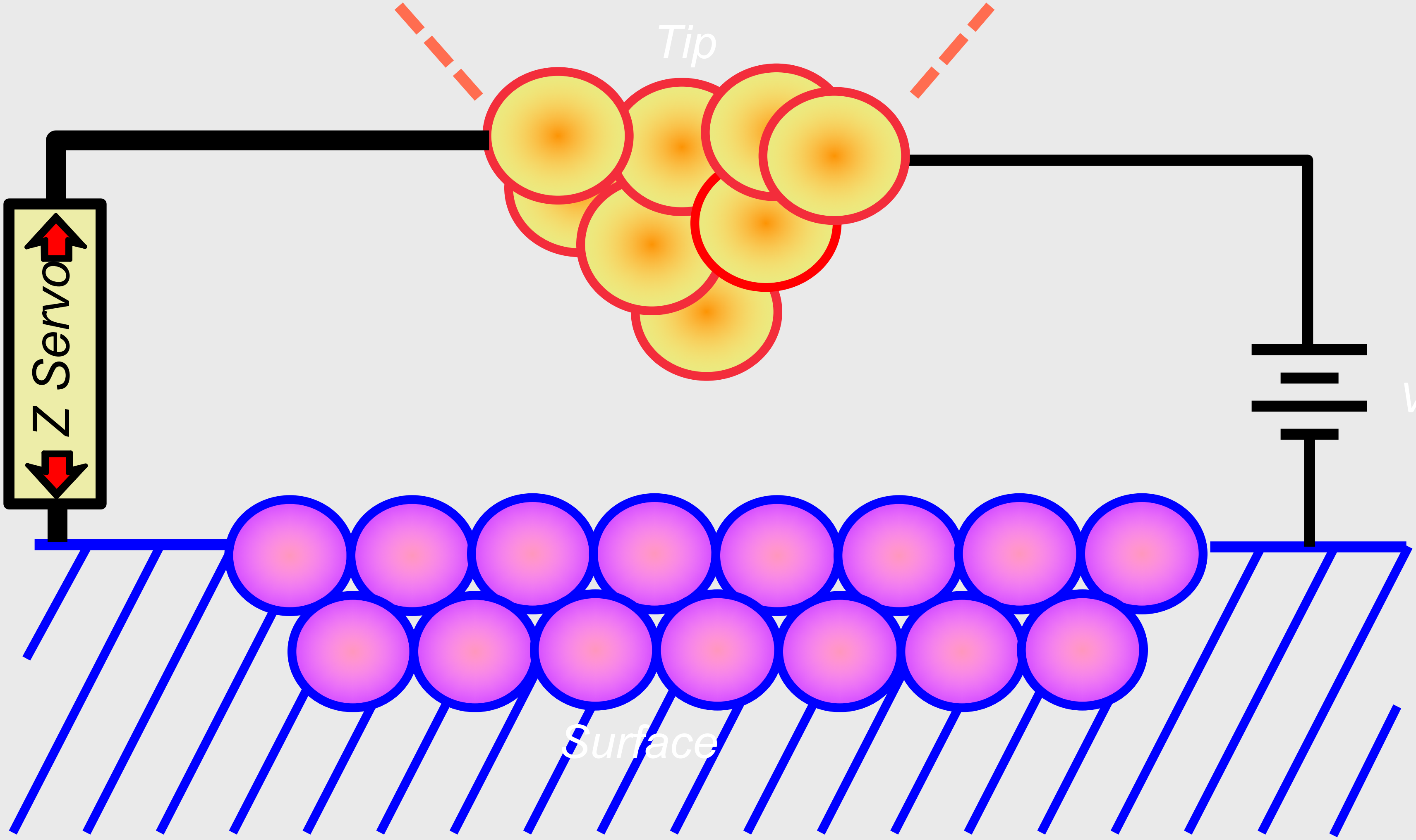


Atomar deponering

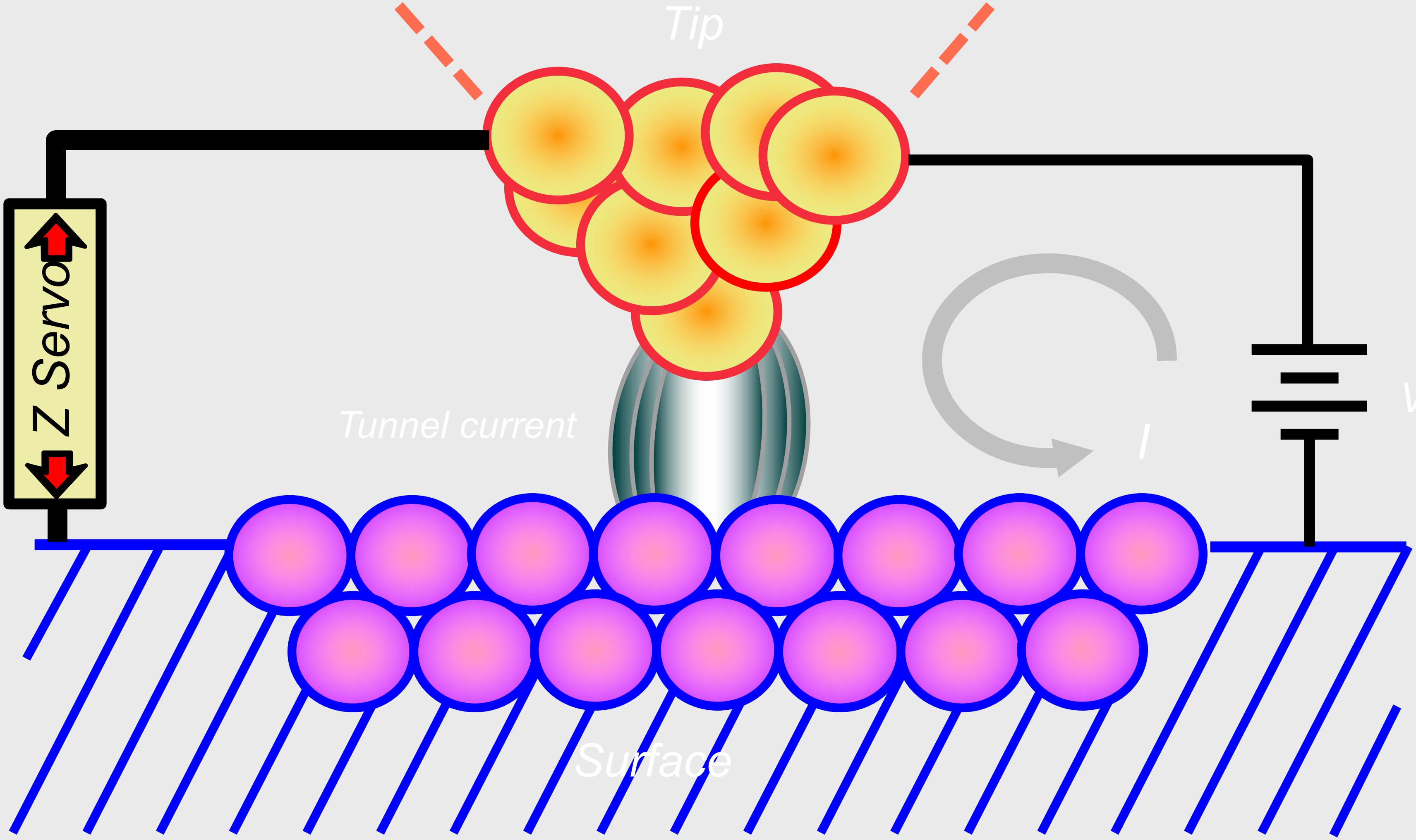




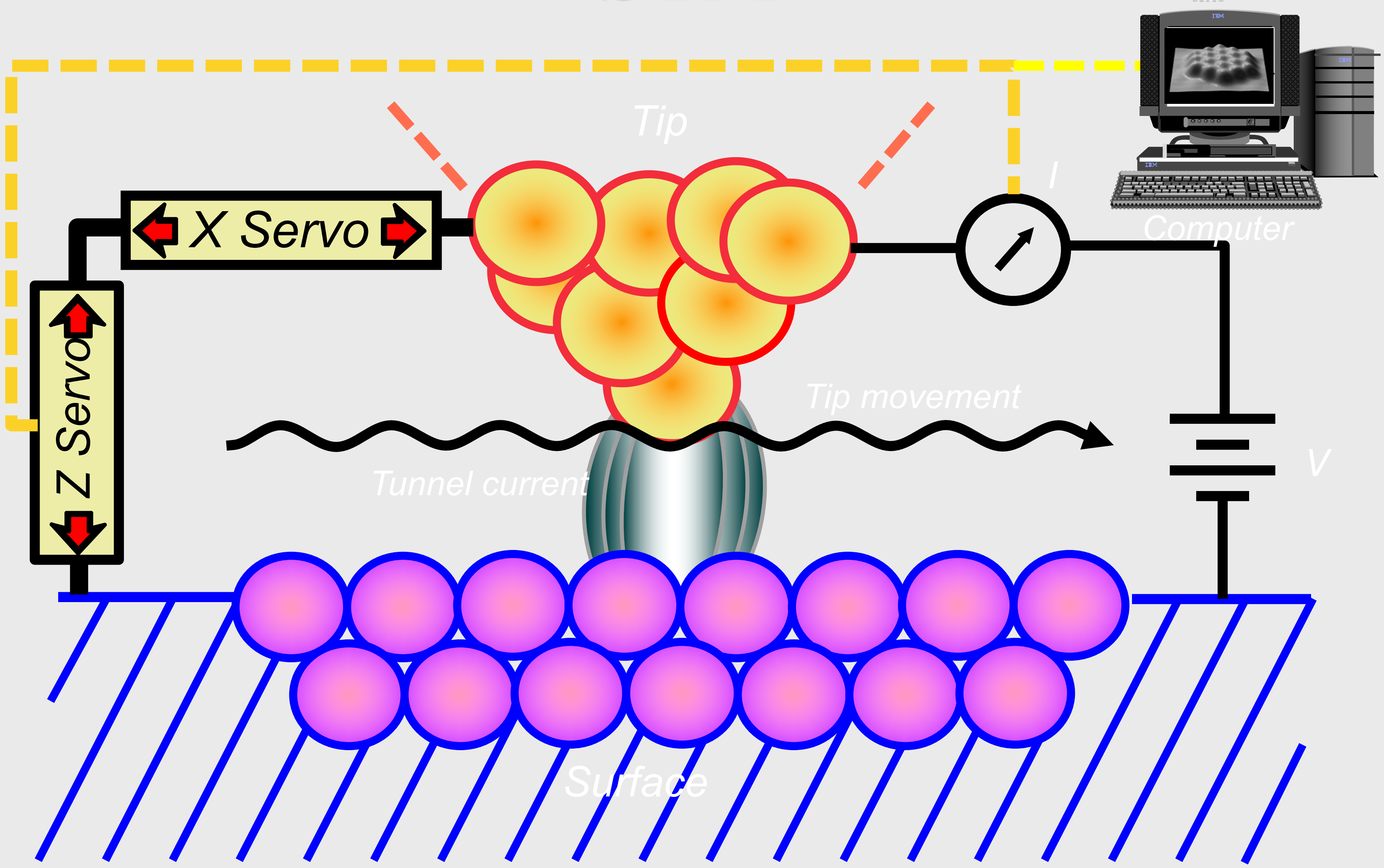
Skanne Tunnel Mikroskopi



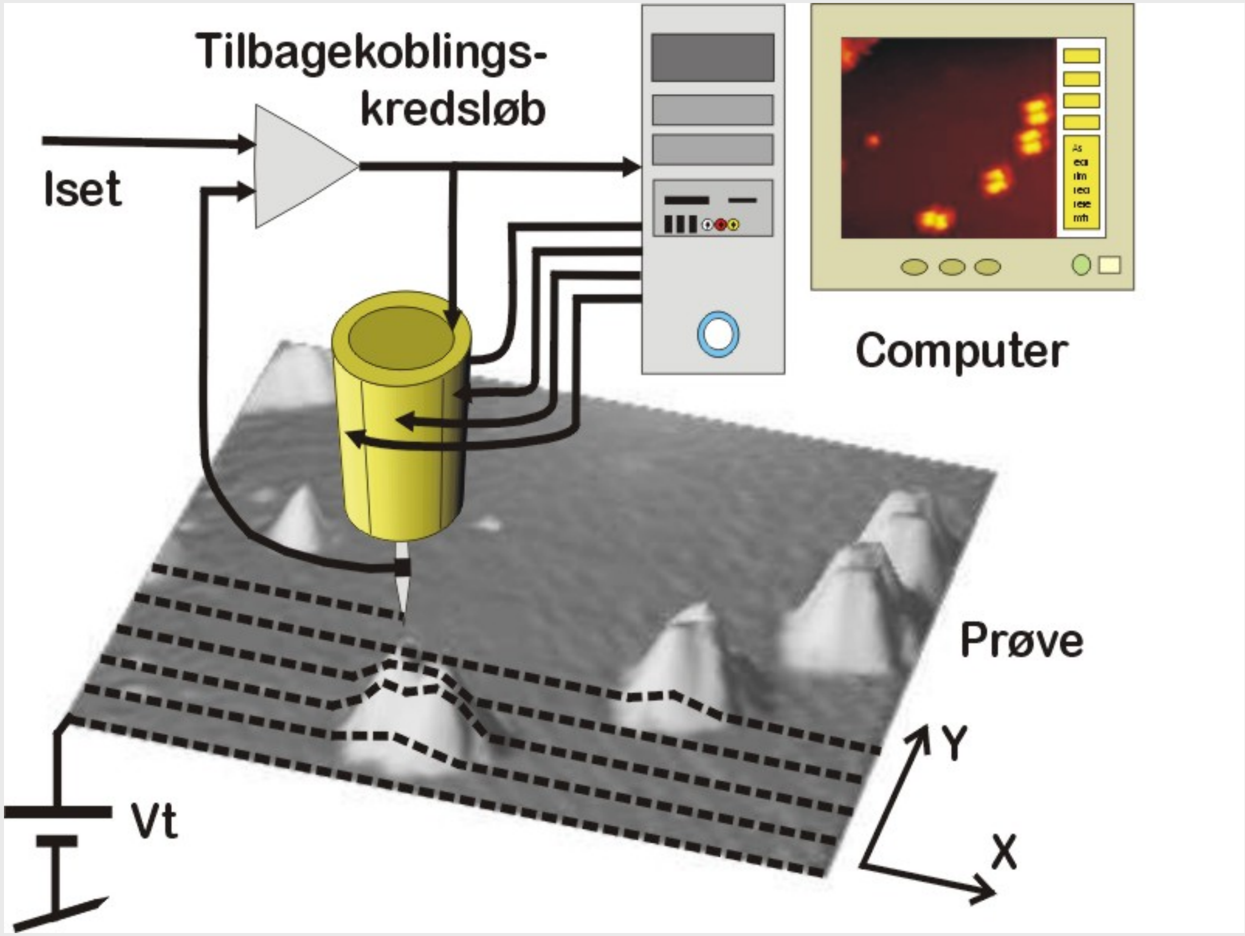
STM



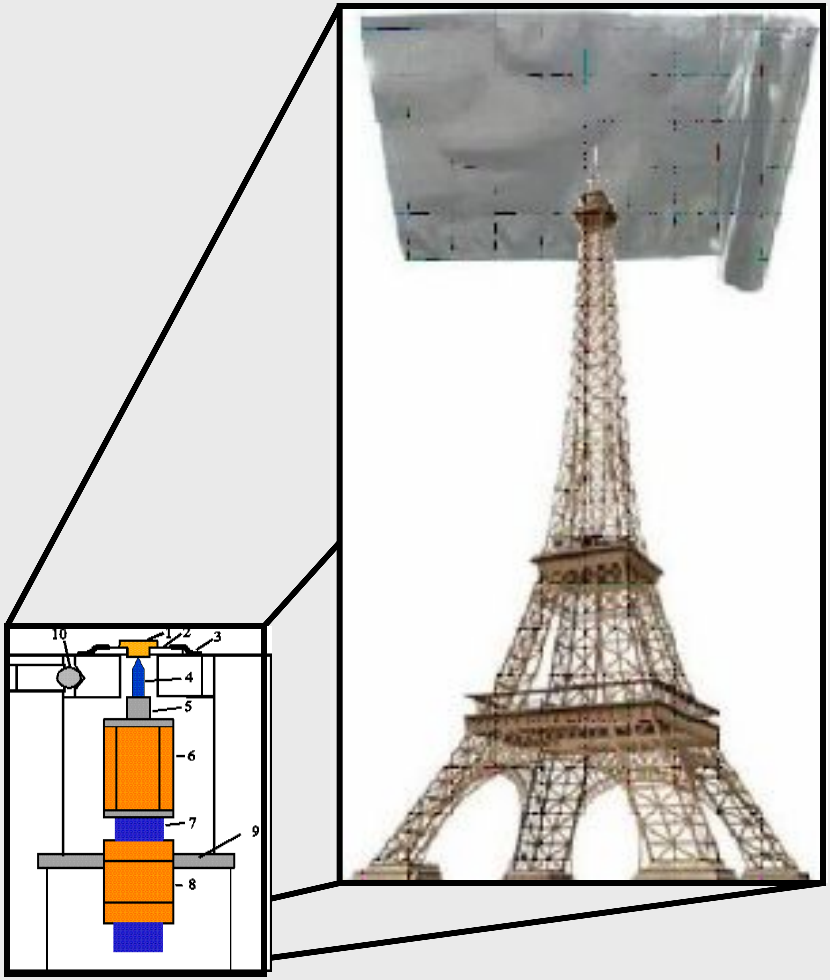
STM


Tip
X Servo
Z Servo
I
Computer
Tip movement
V
Tunnel current
Surface

STM Princip



STM og vibrationer



STM nål: ca. 3 cm

Nål-prøve: 0.1 nm

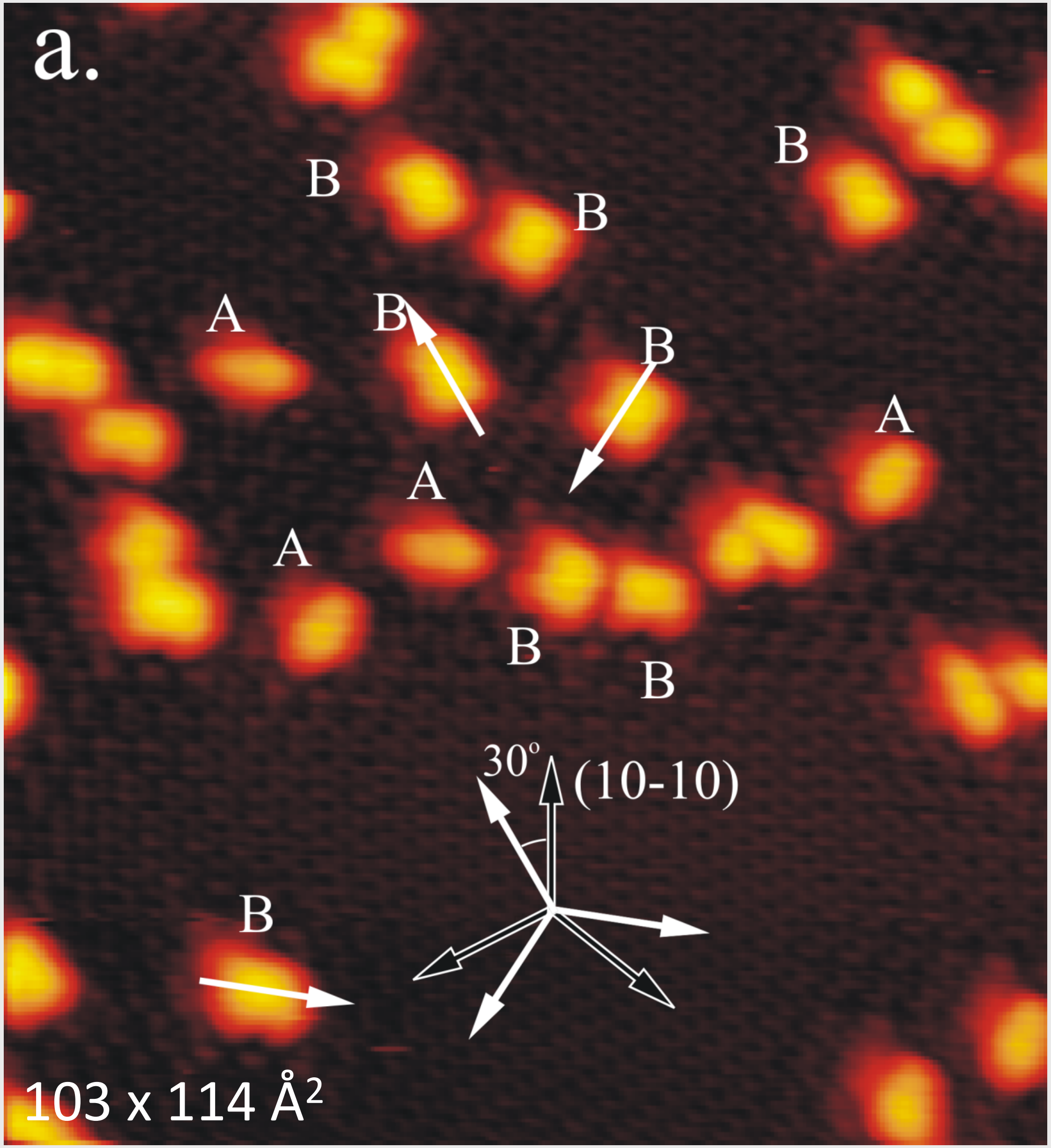
Nål-prøve vibration < 0.01 nm

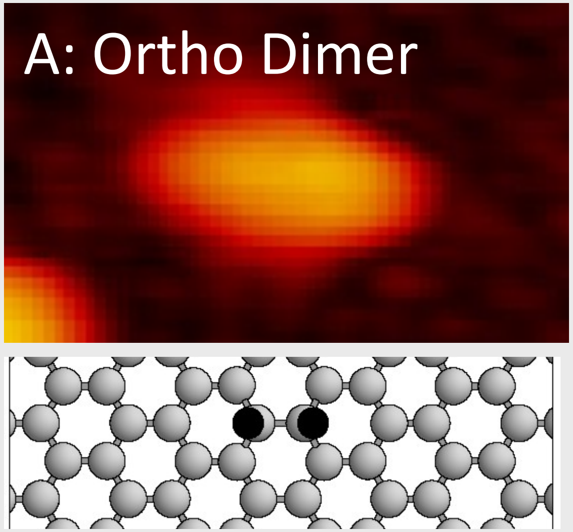
Eiffeltårnet: 320 m

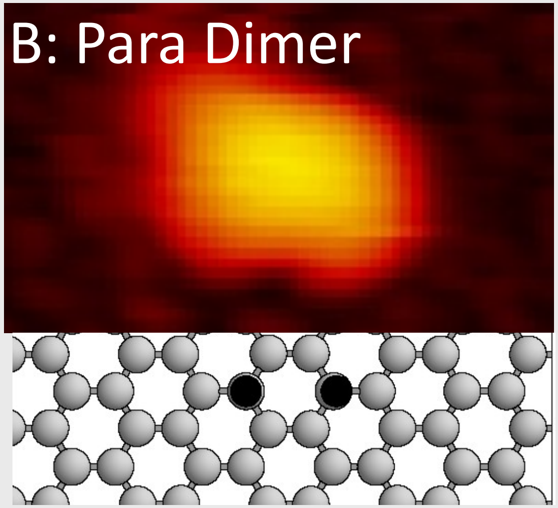
Eiffeltårn – jord: 1 μm

Eiffeltårn – jord vib. < 0.1 μm !!

Brint atomer på grafit

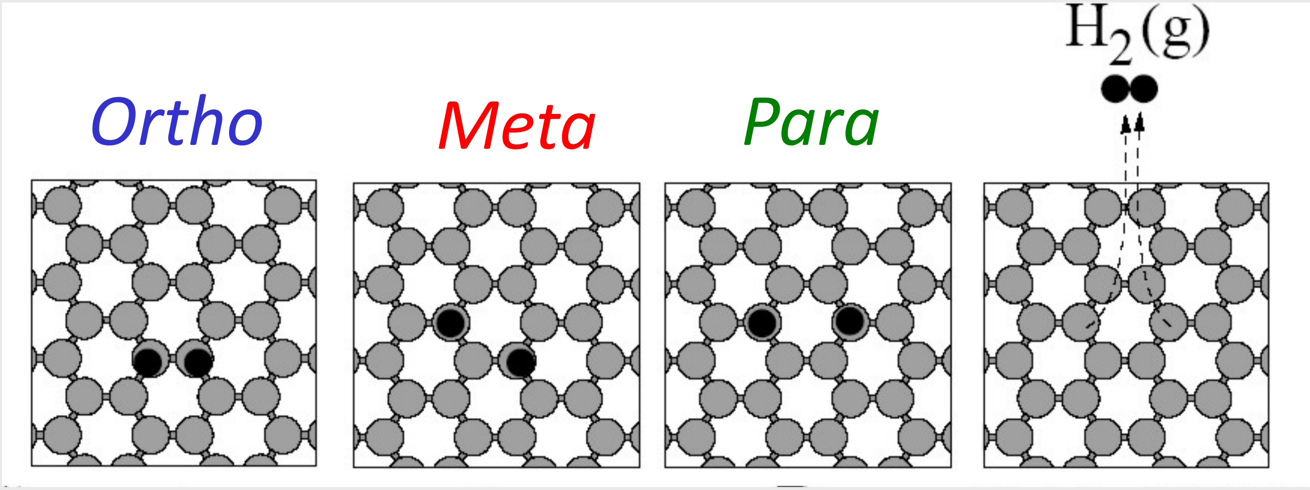


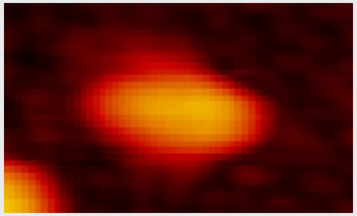


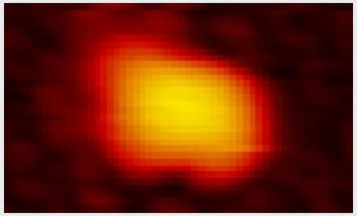


*Hornekær et al. PRL **96**, 156104 (2006)*

H_2 dannelse

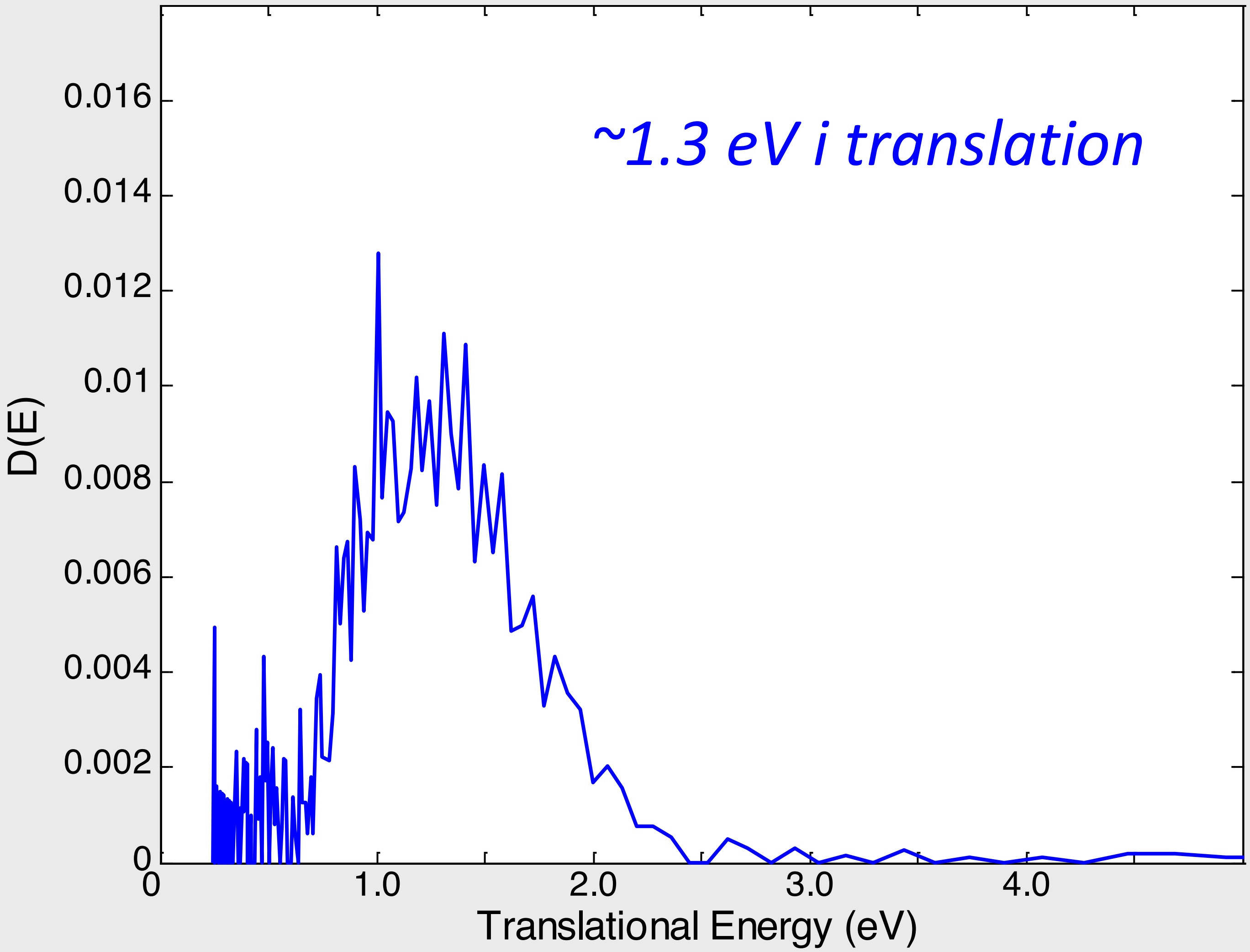






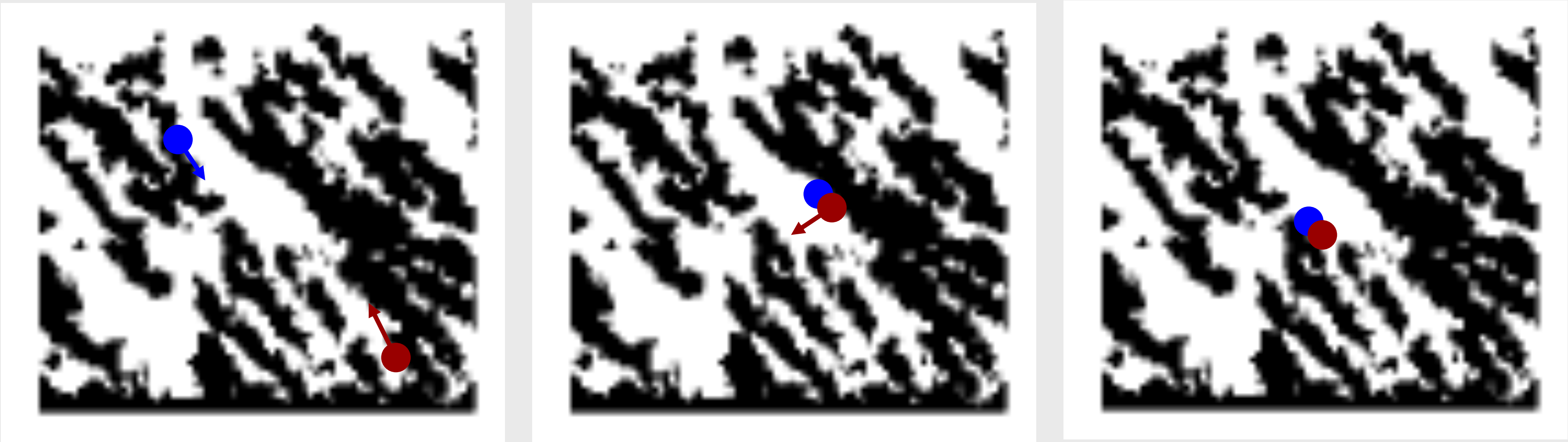
Opvarmning

Kinetisk energi af D_2 dannet på grafit



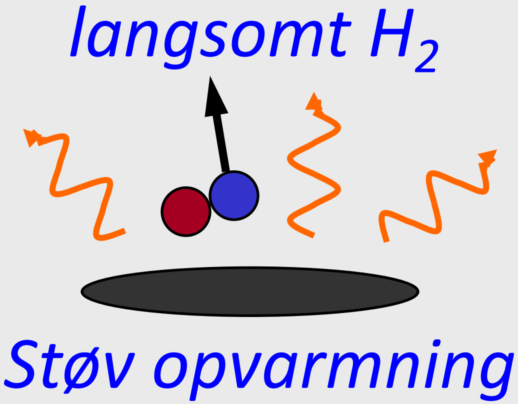
S. Baouche et al, J. Chem. Phys. 2006

H_2 dannet på porøs vand is



Overfladestruktur bestemmer energifordeling

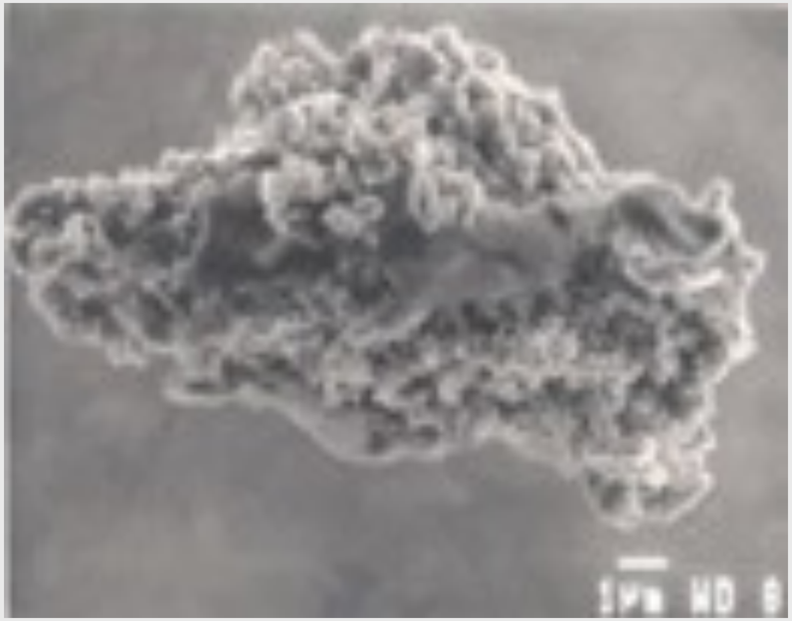
Porøs overflade:

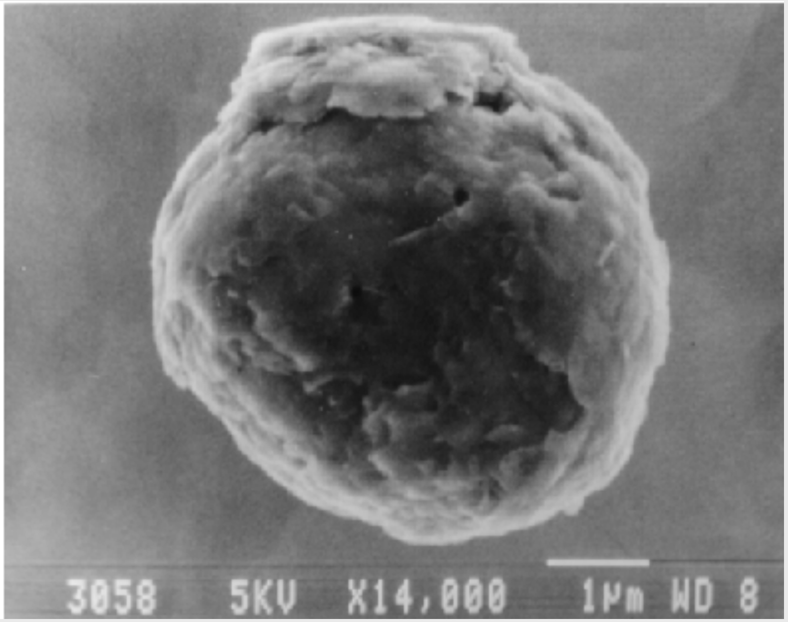


Resultat

Overfladestruktur bestemmer energi-fordeling

Støvkorns morfologi

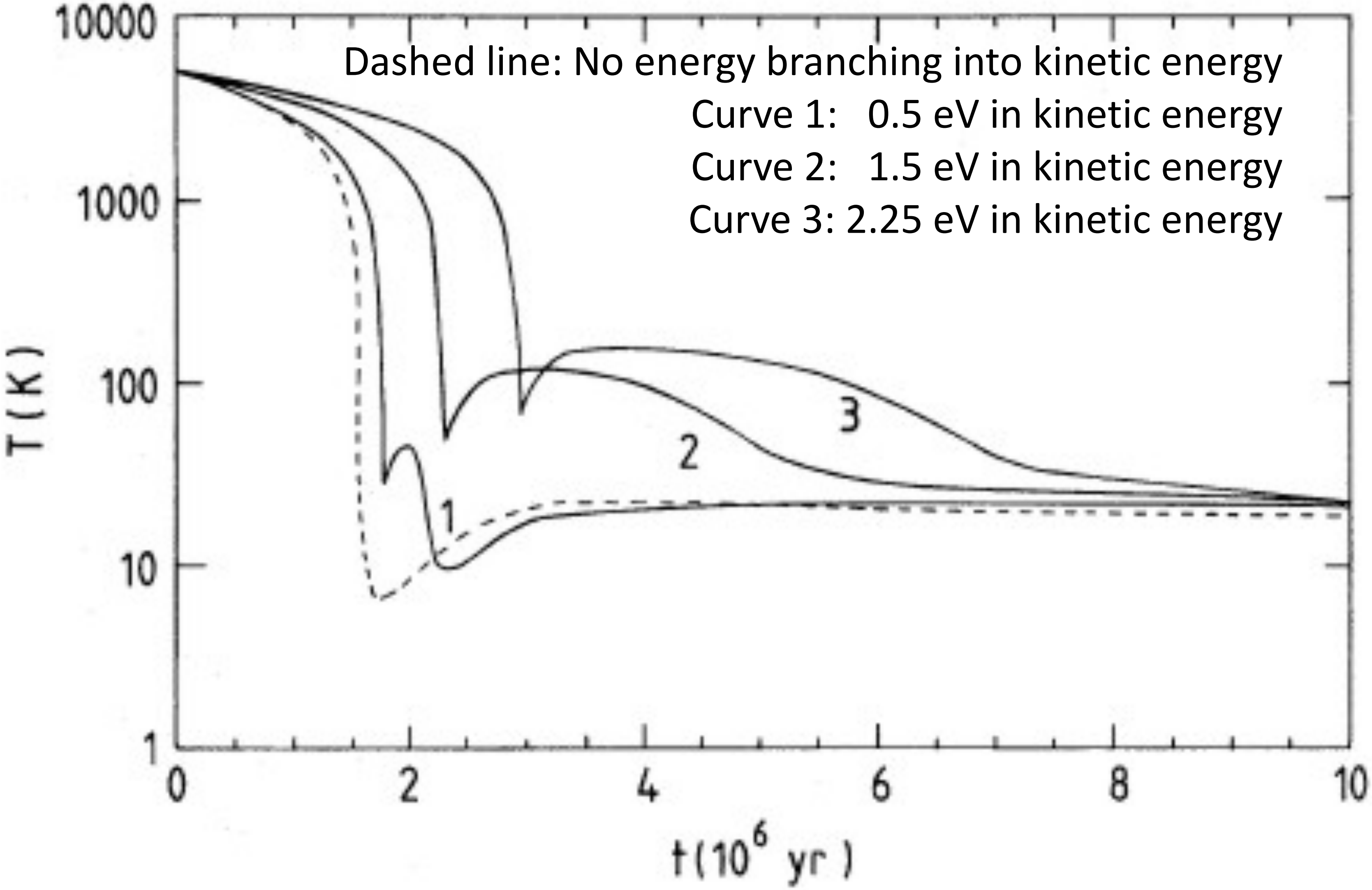




Bare korn – porøse og ikke-porøse

Is dækkede korn

Energi frigivelse af H_2 dannelse og termisk evolution af interstellare skyer



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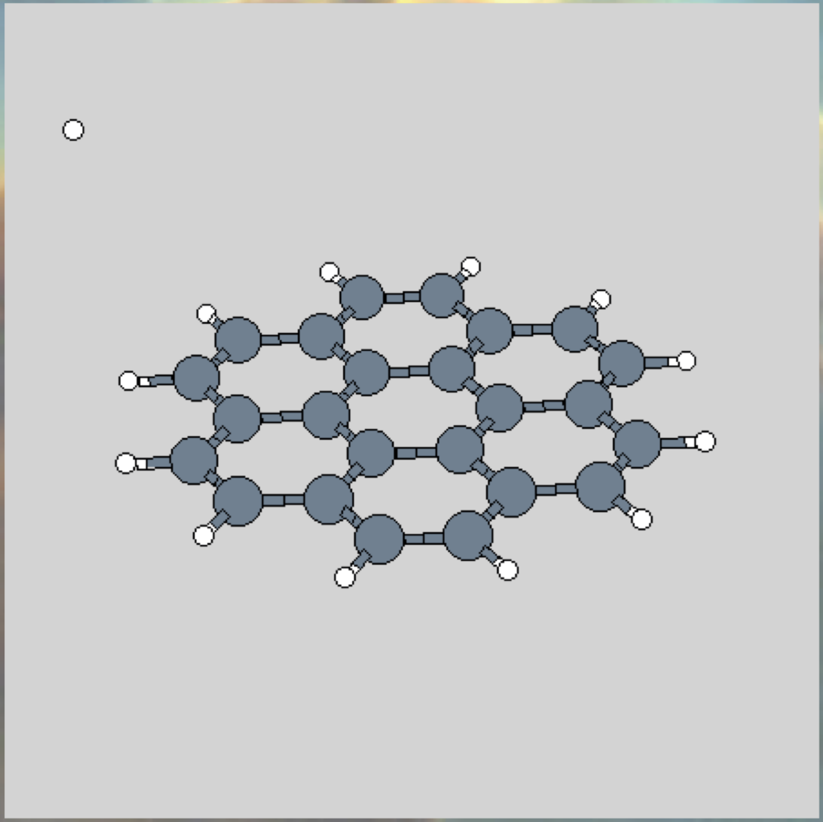
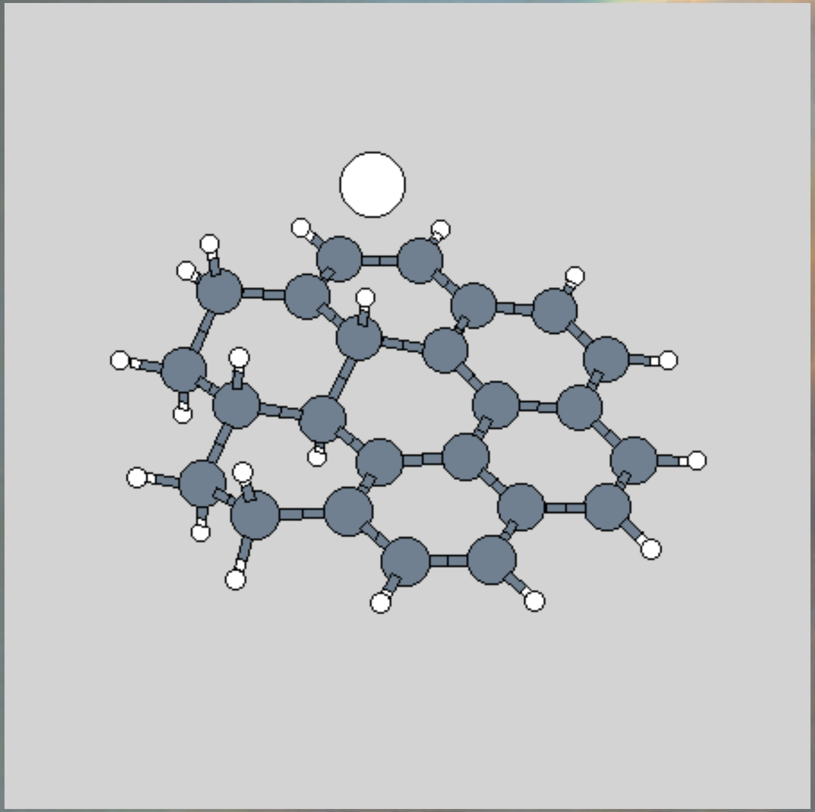
Flower & des Forêts, MNRAS 247, 500 (1990)

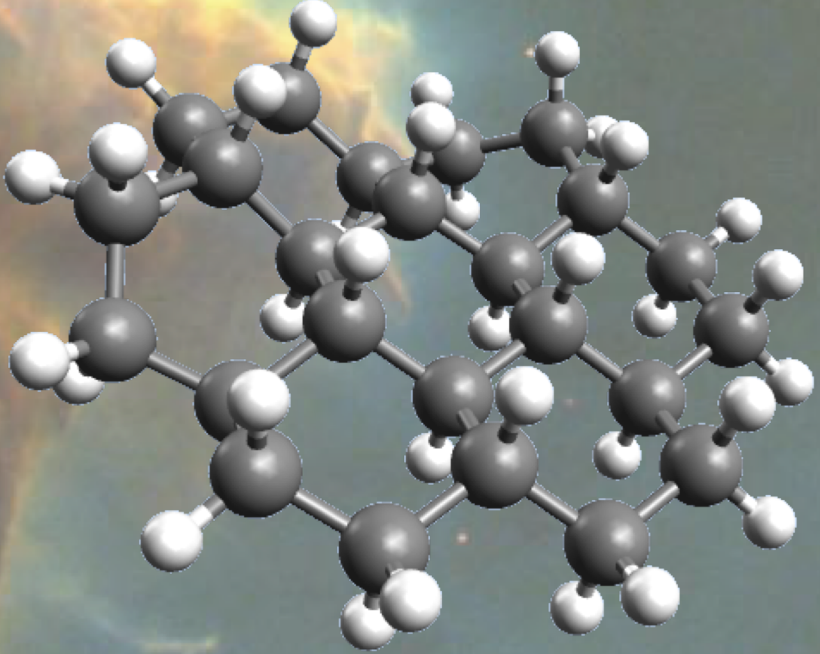
PAH’er som H_2 katalysator



Rauls and Hornekær, Astrophys. J. 679, 531 (2008)

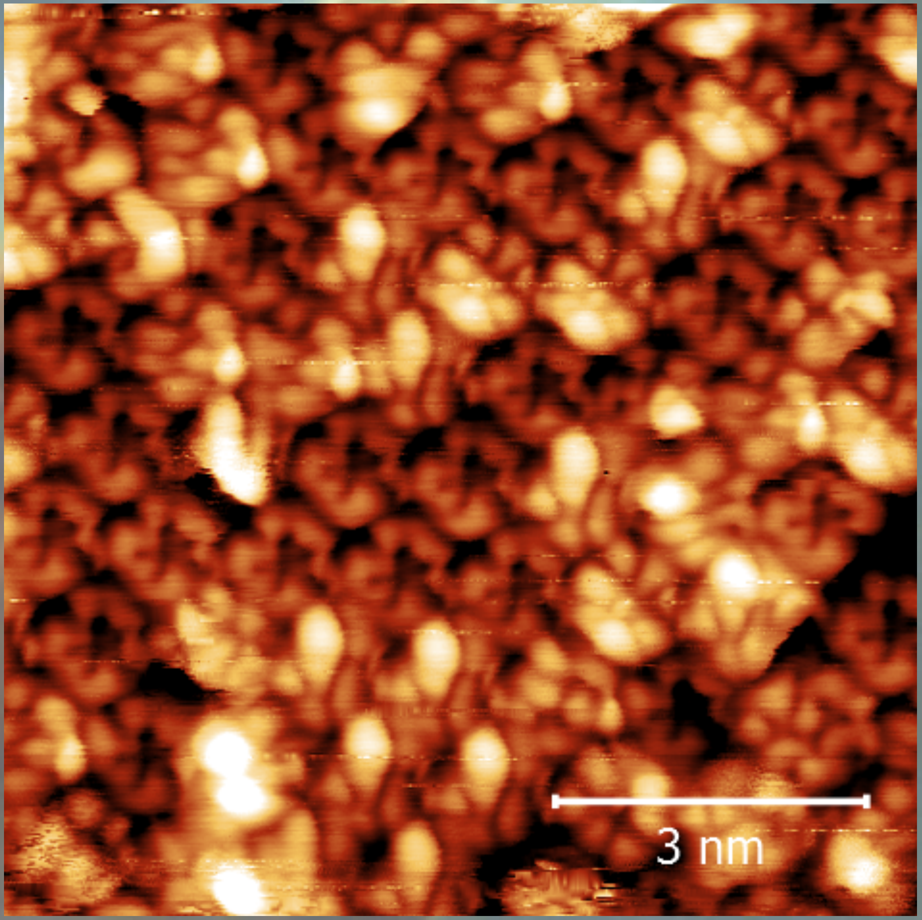
PAH'er som H_2 katalysator



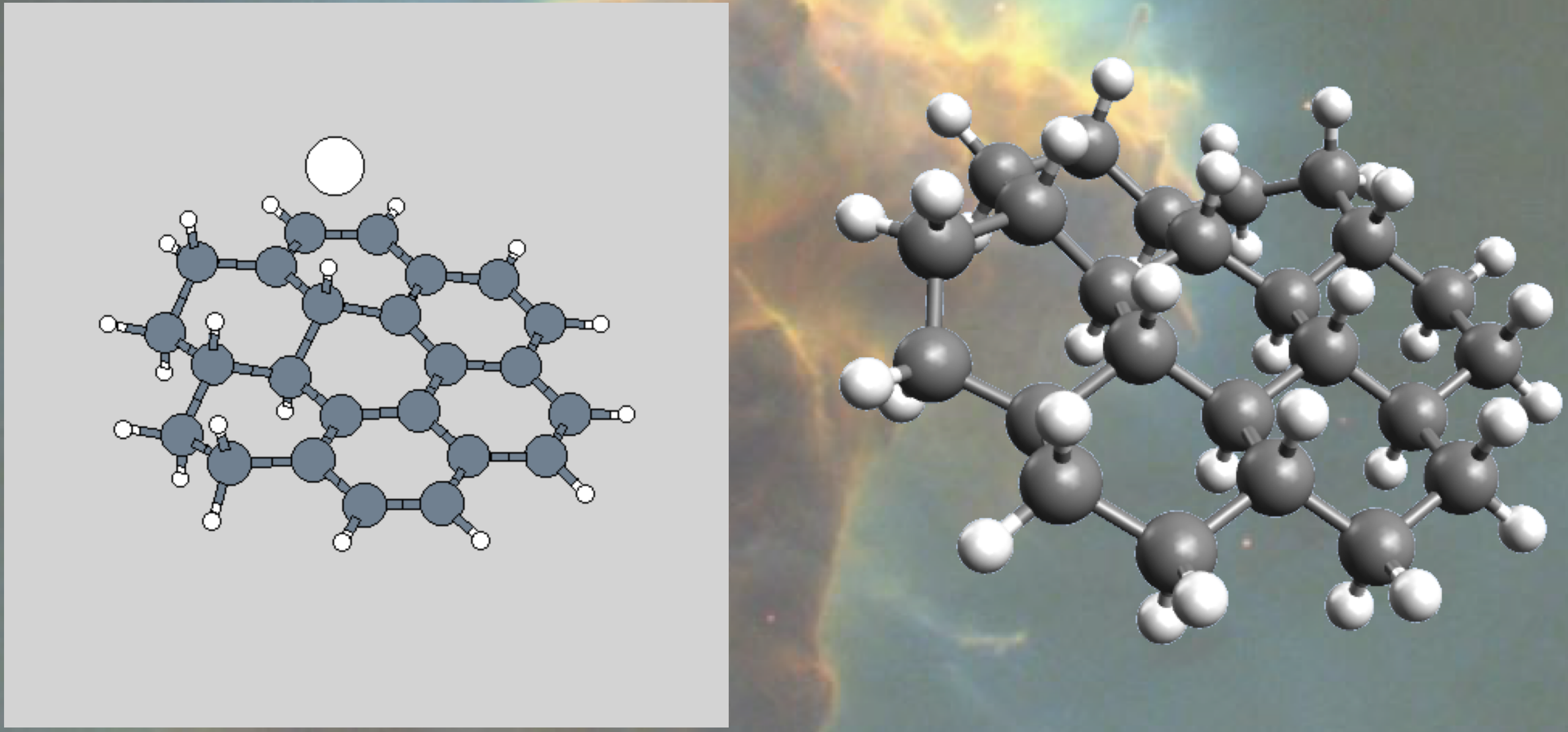


Rauls and Hornekær, Astrophys. J. 679, 531 (2008)

Brint atomer på PAH molekyler

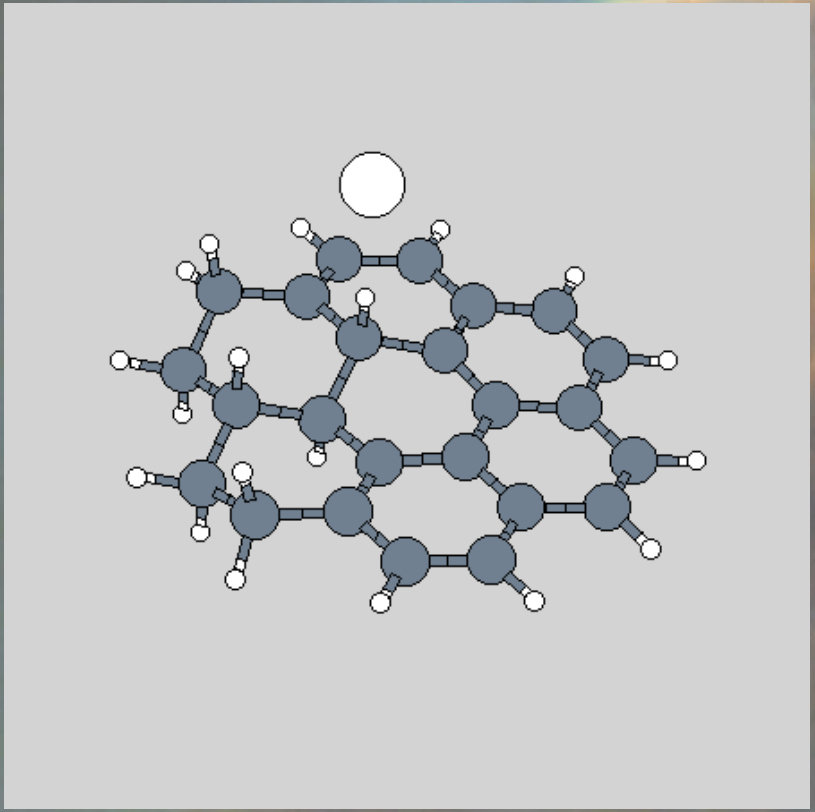


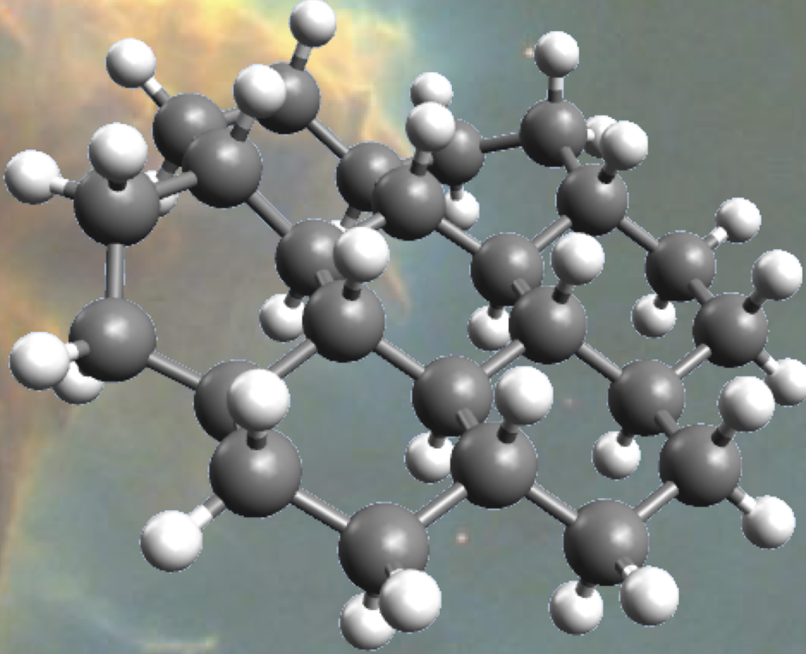
PAH’er som H_2 katalysator



Rauls and Hornekær, Astrophys. J. 679, 531 (2008)

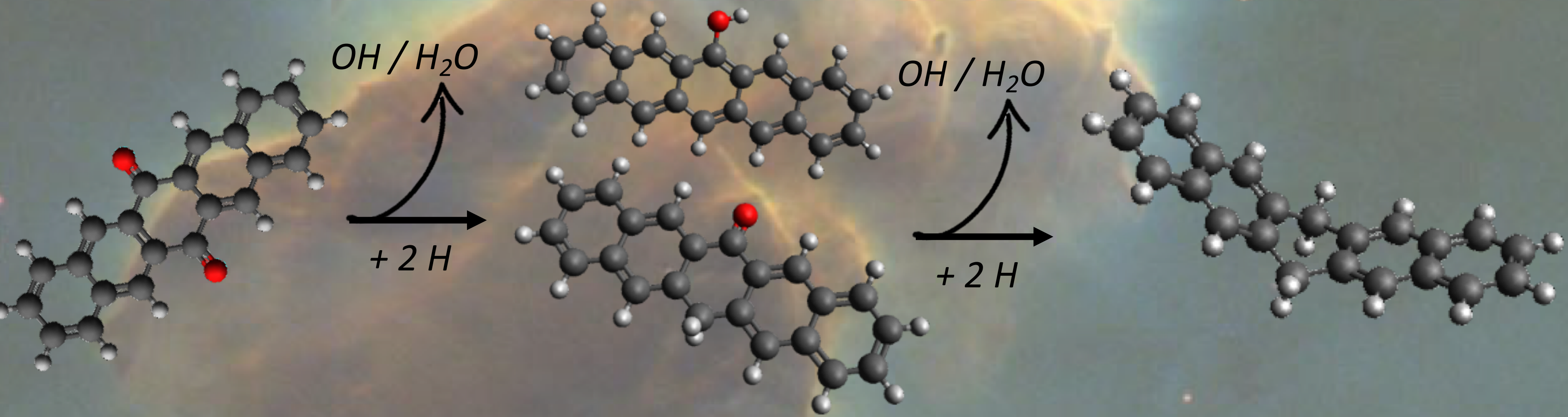
PAH'er som H_2 katalysator



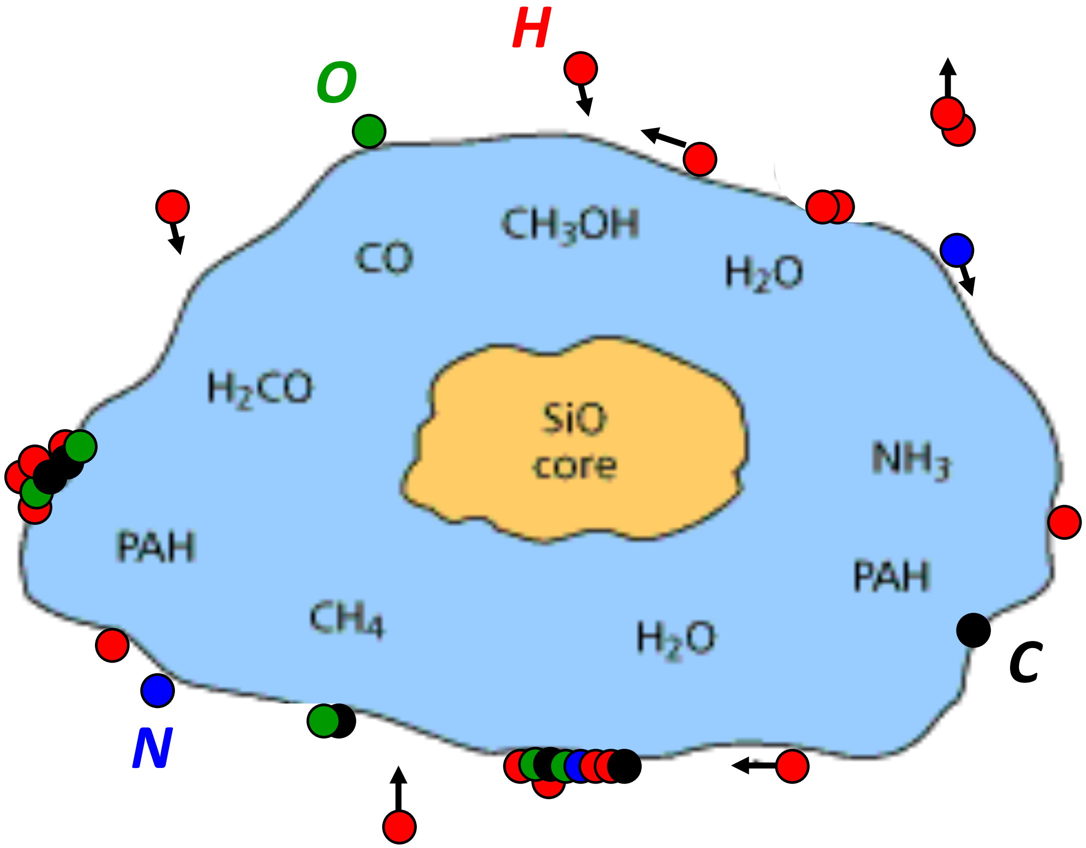


Rauls and Hornekær, Astrophys. J. 679, 531 (2008)

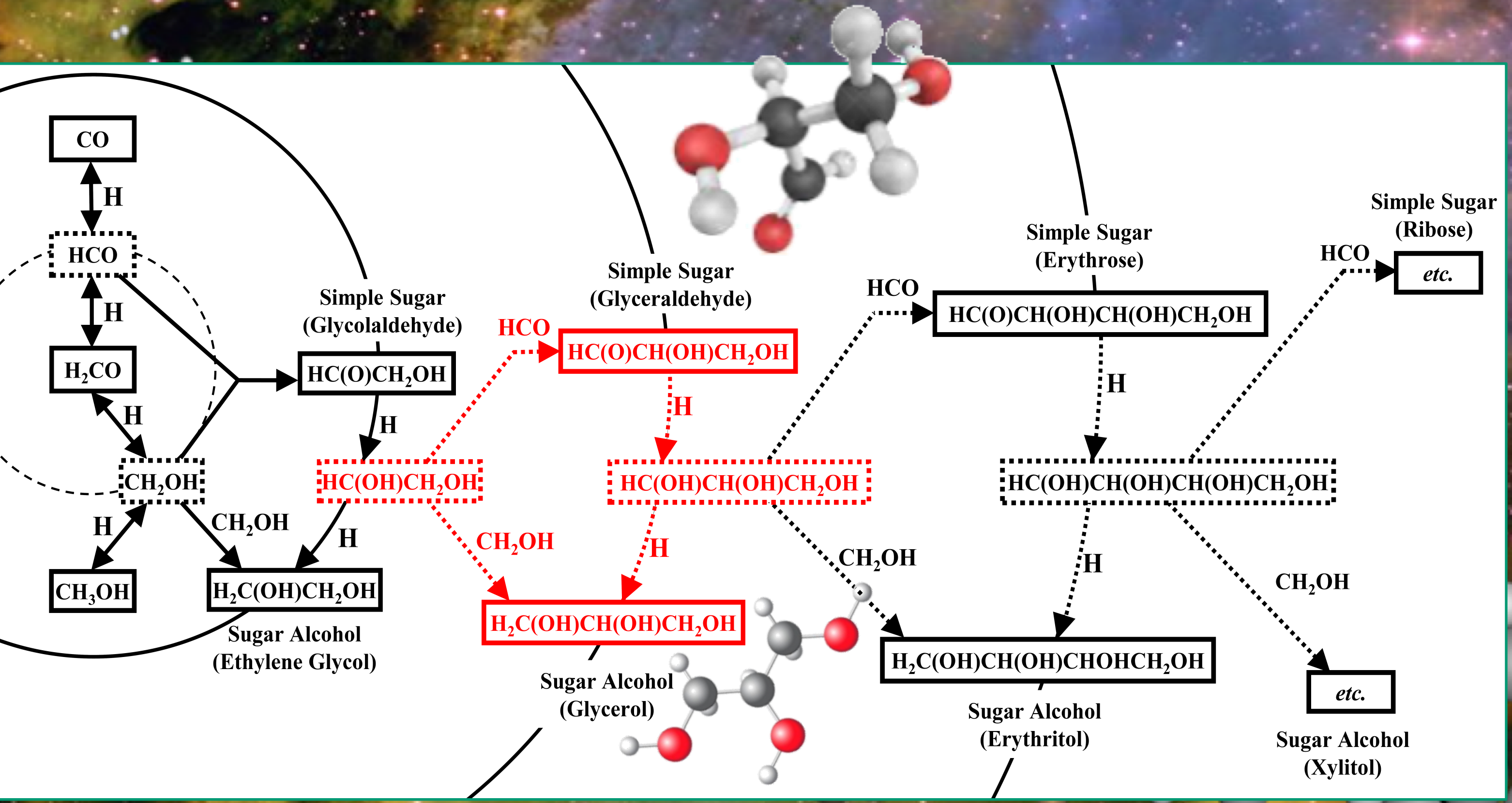
PAH’er som katalysator



Overflade Reaktioner



Grænserne for lav-temperatur kemisk kompleksitet?



CO

H

HCO

H

H_2CO

H

CH_2OH

H

CH_3OH

CH_2OH

$H_2C(OH)CH_2OH$

Sugar Alcohol
(Ethylene Glycol)

Simple Sugar
(Glycolaldehyde)

$HC(O)CH_2OH$

H

$HC(OH)CH_2OH$

H

HCO

CH_2OH

Simple Sugar
(Glyceraldehyde)

$HC(O)CH(OH)CH_2OH$

H

$HC(OH)CH(OH)CH_2OH$

H

$H_2C(OH)CH(OH)CH_2OH$

Sugar Alcohol
(Glycerol)

HCO

CH_2OH

Simple Sugar
(Erythrose)

$HC(O)CH(OH)CH(OH)CH_2OH$

H

$HC(OH)CH(OH)CH(OH)CH_2OH$

H

$H_2C(OH)CH(OH)CHOHCH_2OH$

Sugar Alcohol
(Erythritol)

HCO

Simple Sugar
(Ribose)

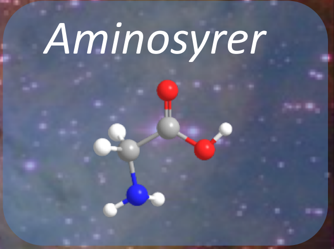
etc.

CH_2OH

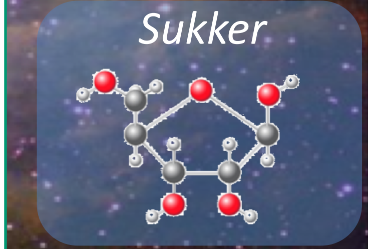
etc.

Sugar Alcohol
(Xylitol)

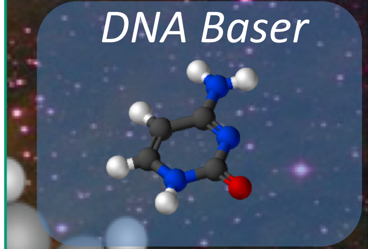
Aminosyrer



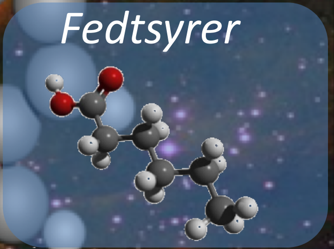
Sukker



DNA Baser



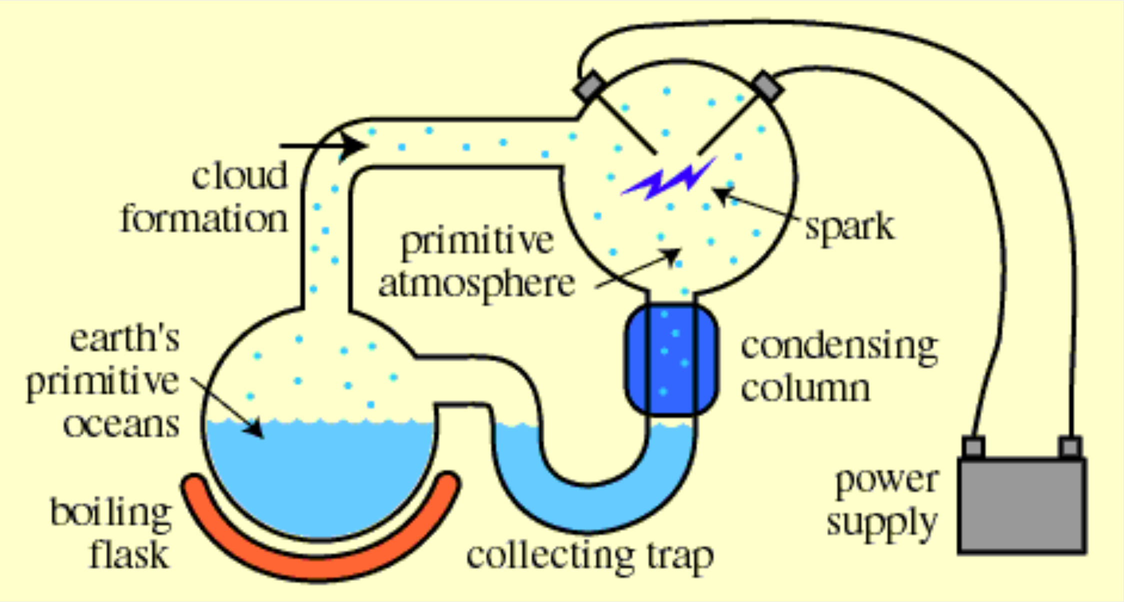
Fedtsyrer



Hvordan opstod livet?

I atmosfæren?

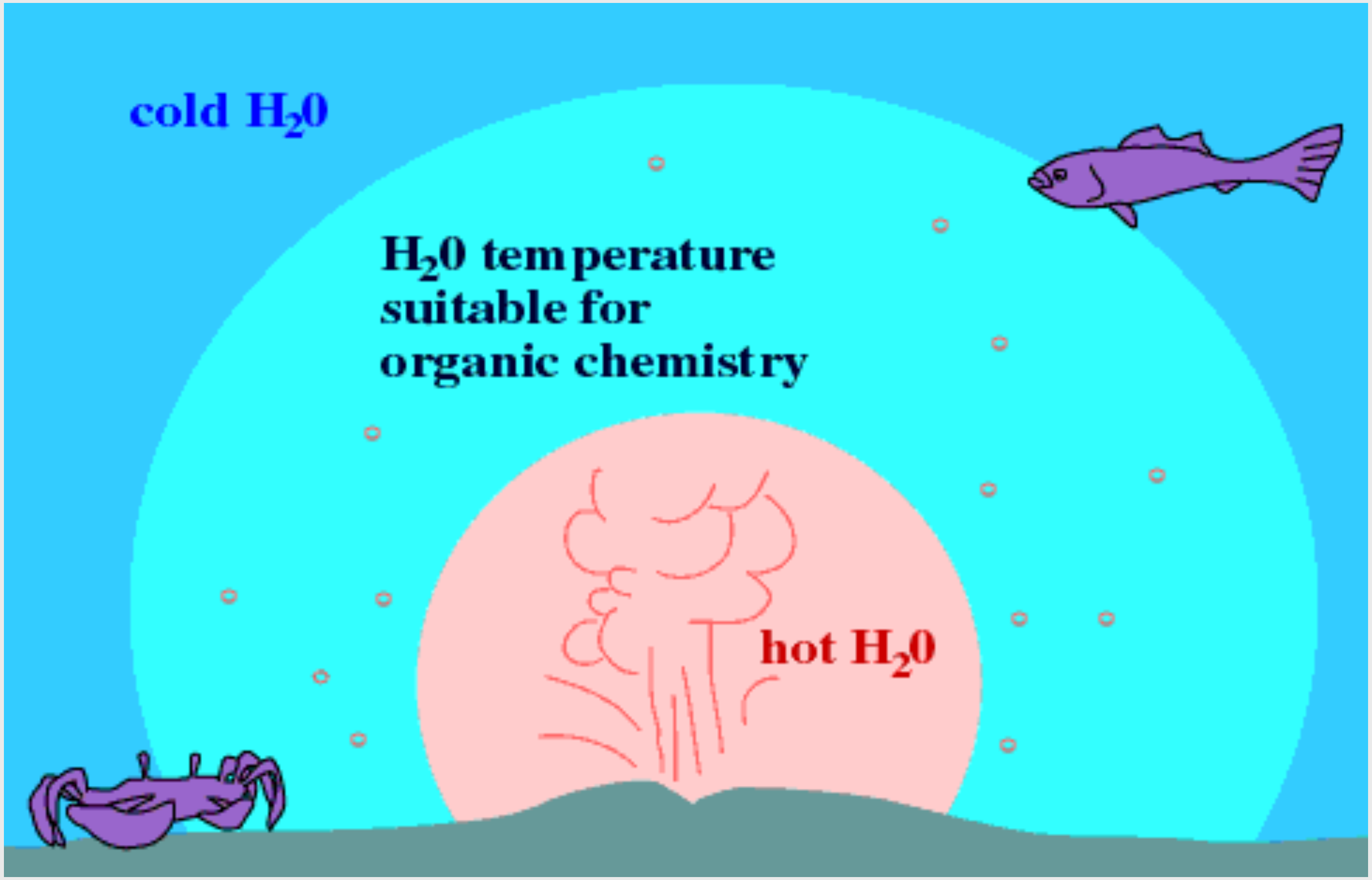
Stanley Miller, 1953



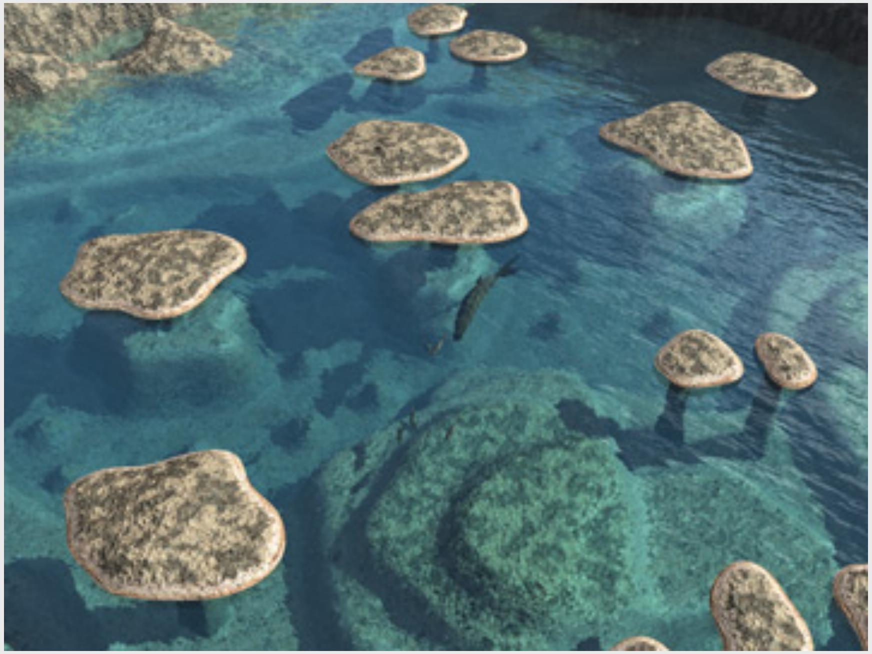
Miller-Urey eksperimentet

Brint	*Kvælstof*	*Kuldioxid*	*Vand*	*ammoniak*	*Methan*
(H_2)	(N_2)	(CO_2)	(H_2O)	(NH_3)	(CH_4)

Hydrotermiske Huller

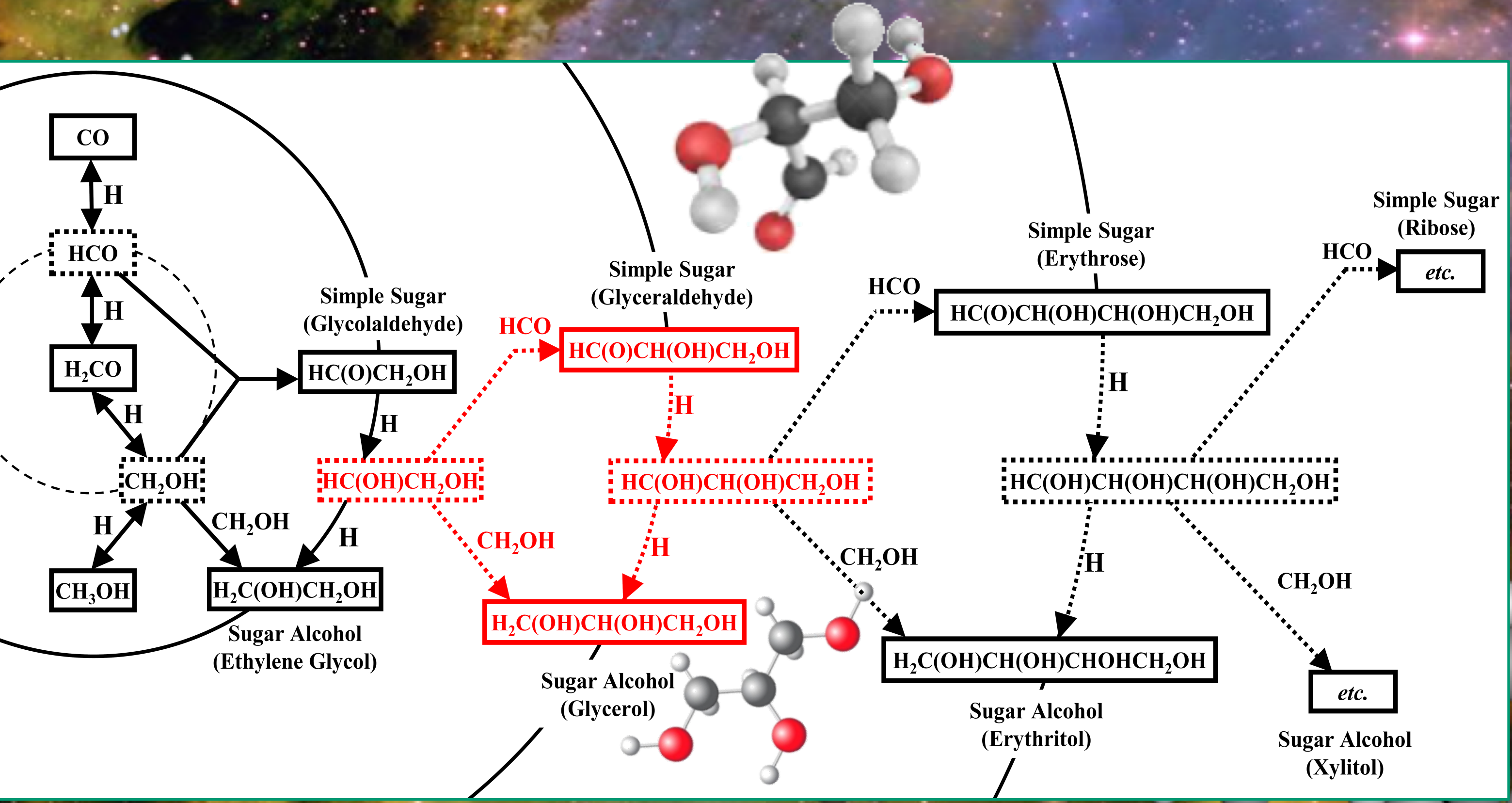


Tidevands-pytter



Fra rummet?

Grænserne for lav-temperatur kemisk kompleksitet?



CO

H

HCO

H

H_2CO

H

CH_2OH

H

CH_3OH

CH_2OH

H

Simple Sugar
(Glycolaldehyde)

$HC(O)CH_2OH$

H

$HC(OH)CH_2OH$

$H_2C(OH)CH_2OH$

Sugar Alcohol
(Ethylene Glycol)

HCO

CH_2OH

Simple Sugar
(Glyceraldehyde)

$HC(O)CH(OH)CH_2OH$

H

$HC(OH)CH(OH)CH_2OH$

H

$H_2C(OH)CH(OH)CH_2OH$

Sugar Alcohol
(Glycerol)

HCO

CH_2OH

Simple Sugar
(Erythrose)

$HC(O)CH(OH)CH(OH)CH_2OH$

H

$HC(OH)CH(OH)CH(OH)CH_2OH$

H

$H_2C(OH)CH(OH)CHOHCH_2OH$

Sugar Alcohol
(Erythritol)

HCO

Simple Sugar
(Ribose)

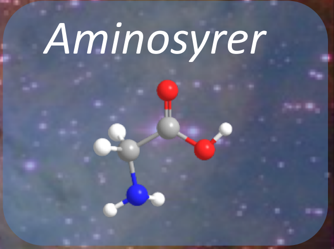
etc.

CH_2OH

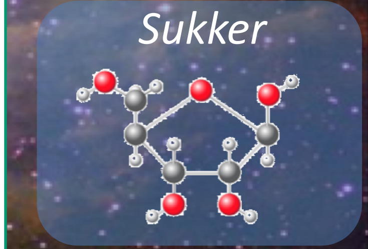
etc.

Sugar Alcohol
(Xylitol)

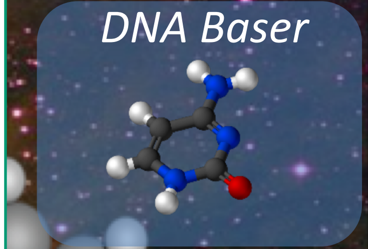
Aminosyrer



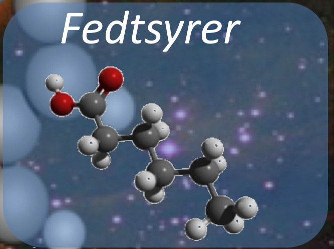
Sukker



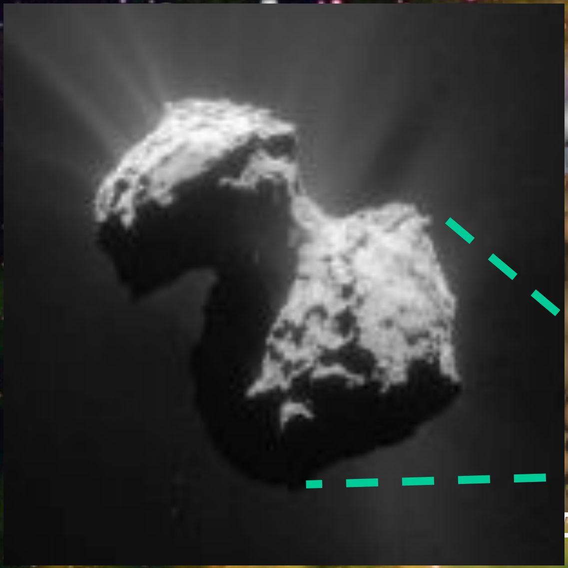
DNA Baser

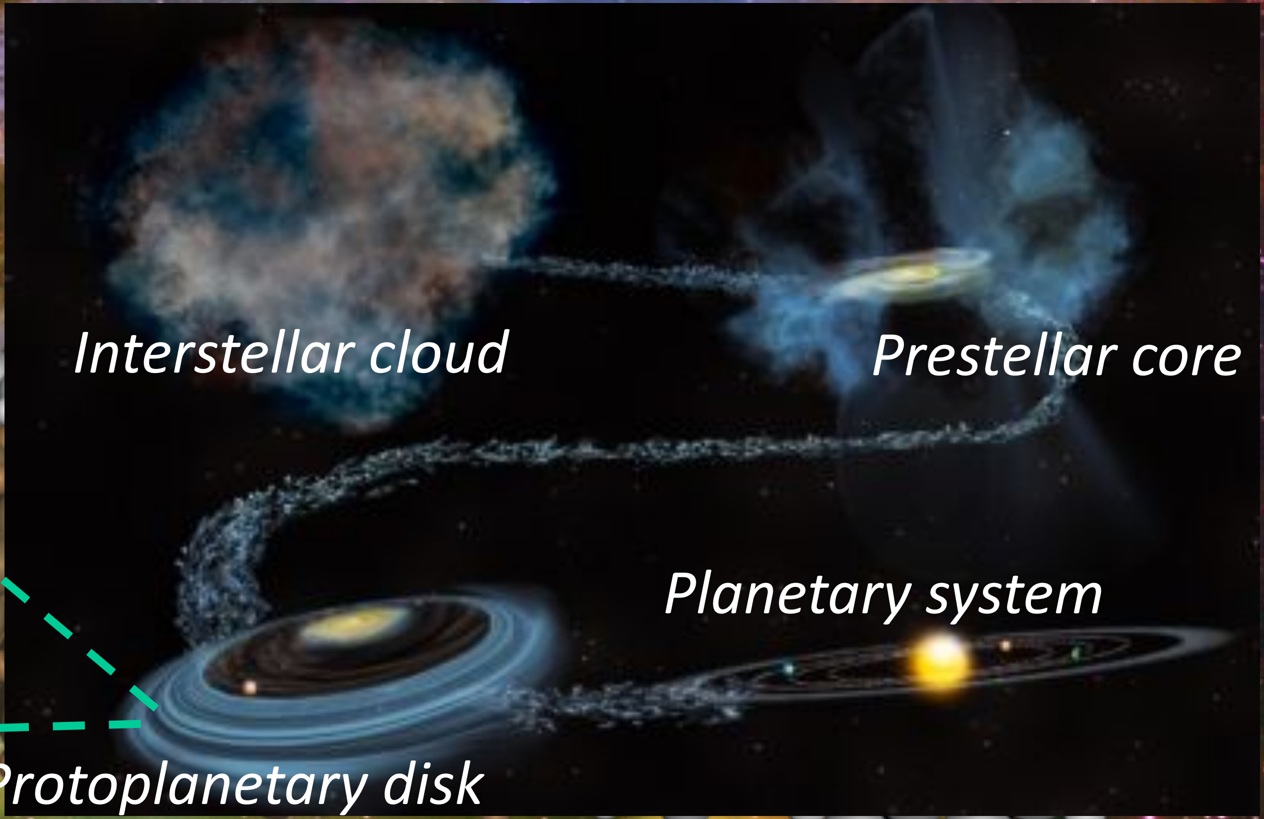


Fedtsyrer



Interstellar chemistry and origen of Life





Exogeneous vs. Endogeneous origin of life?

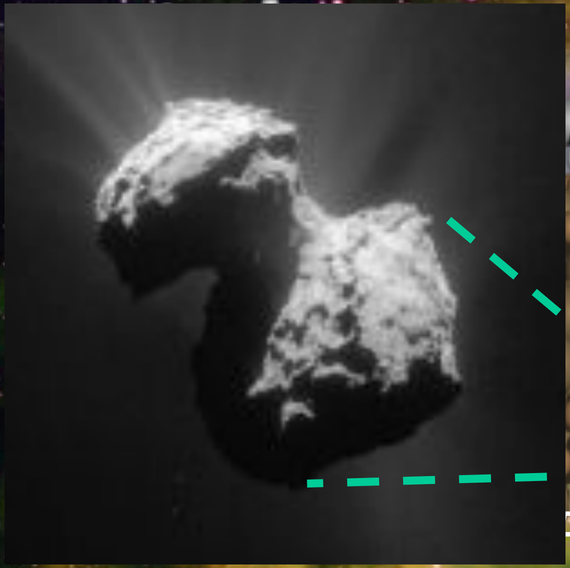
Murchison meteoritten

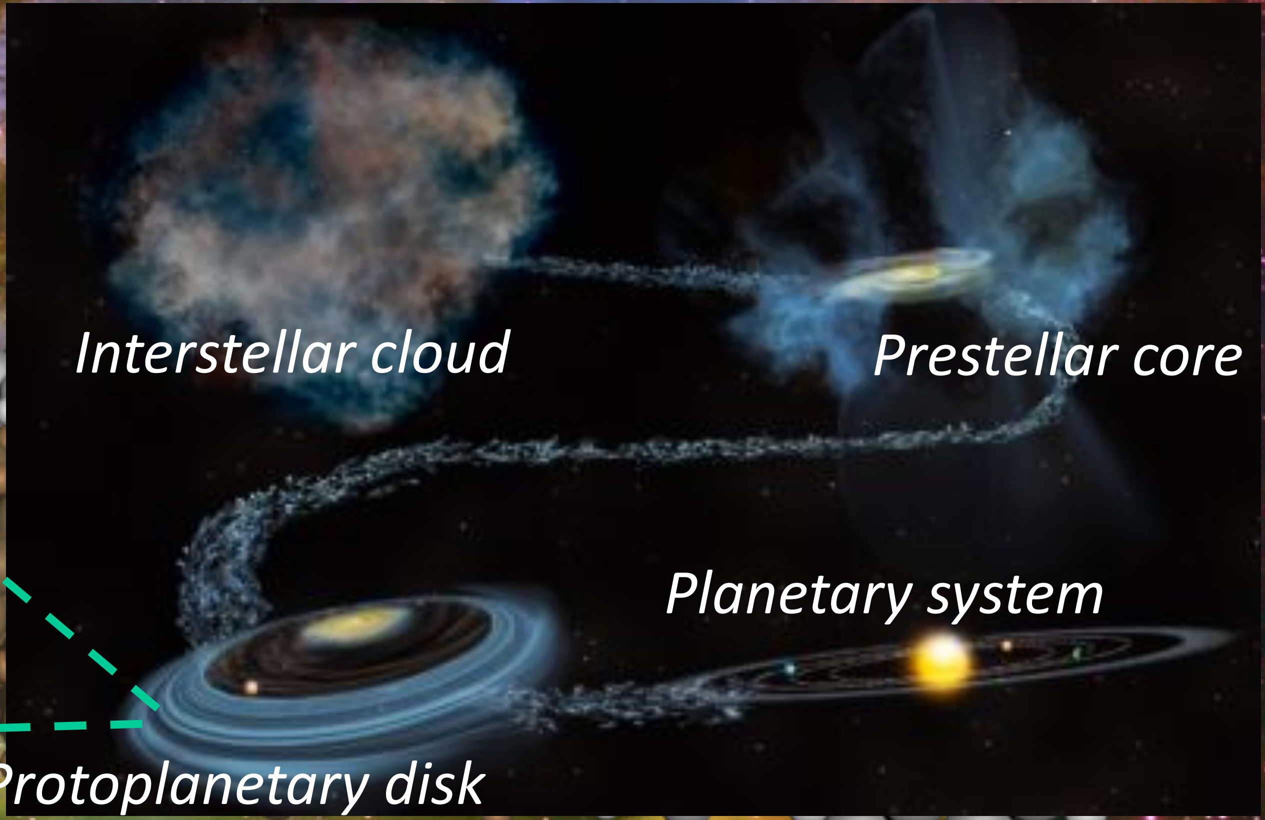
Australien 1969, 100 kg

~92 aminosyrer
19 jordiske
8 vigtige for liv

~20 forskellige sukkergrupper

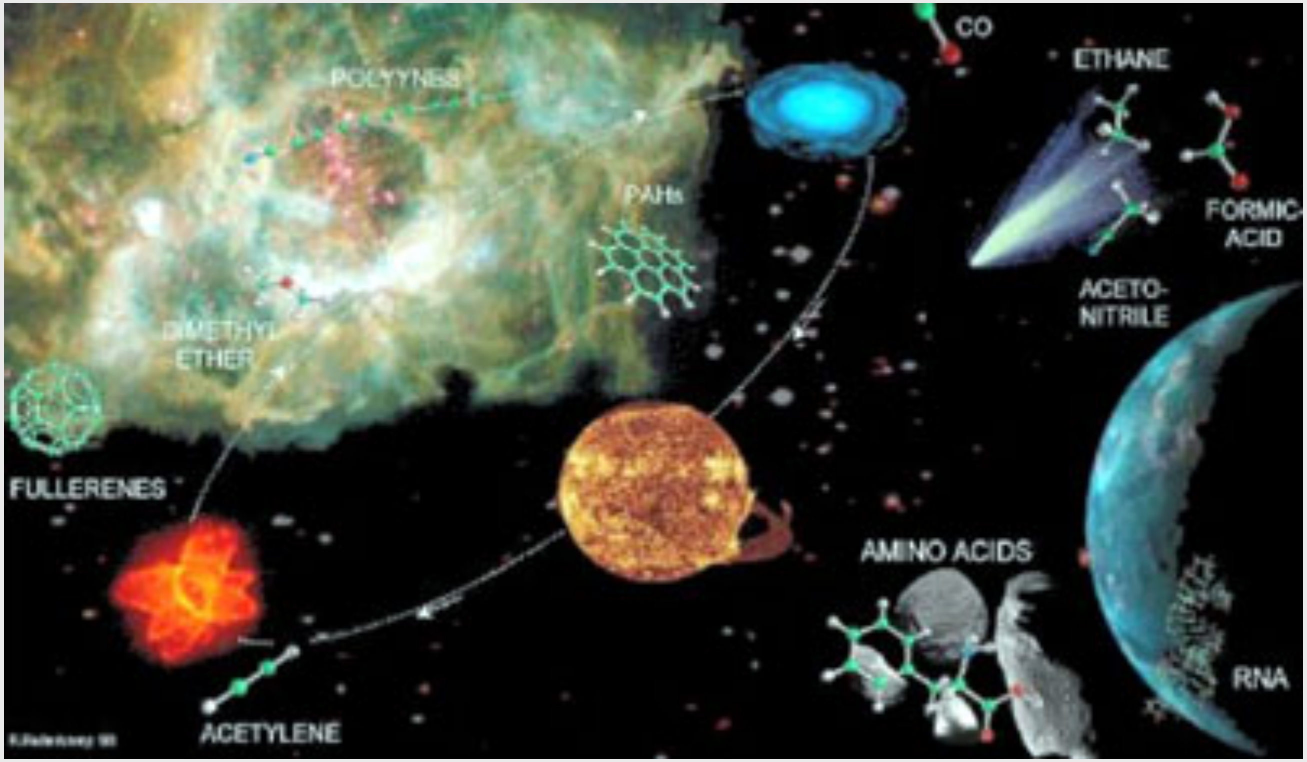
Interstellar Chemistry and origen of Life





Exogeneous vs. Endogeneous origin of life?

Blev livets molekylære byggesten – aminosyrer, DNA baser, sukkergrupper, fedtsyrer - dannet i det interstellare rum før solsystemet blev skabt?



The Habitable Zone

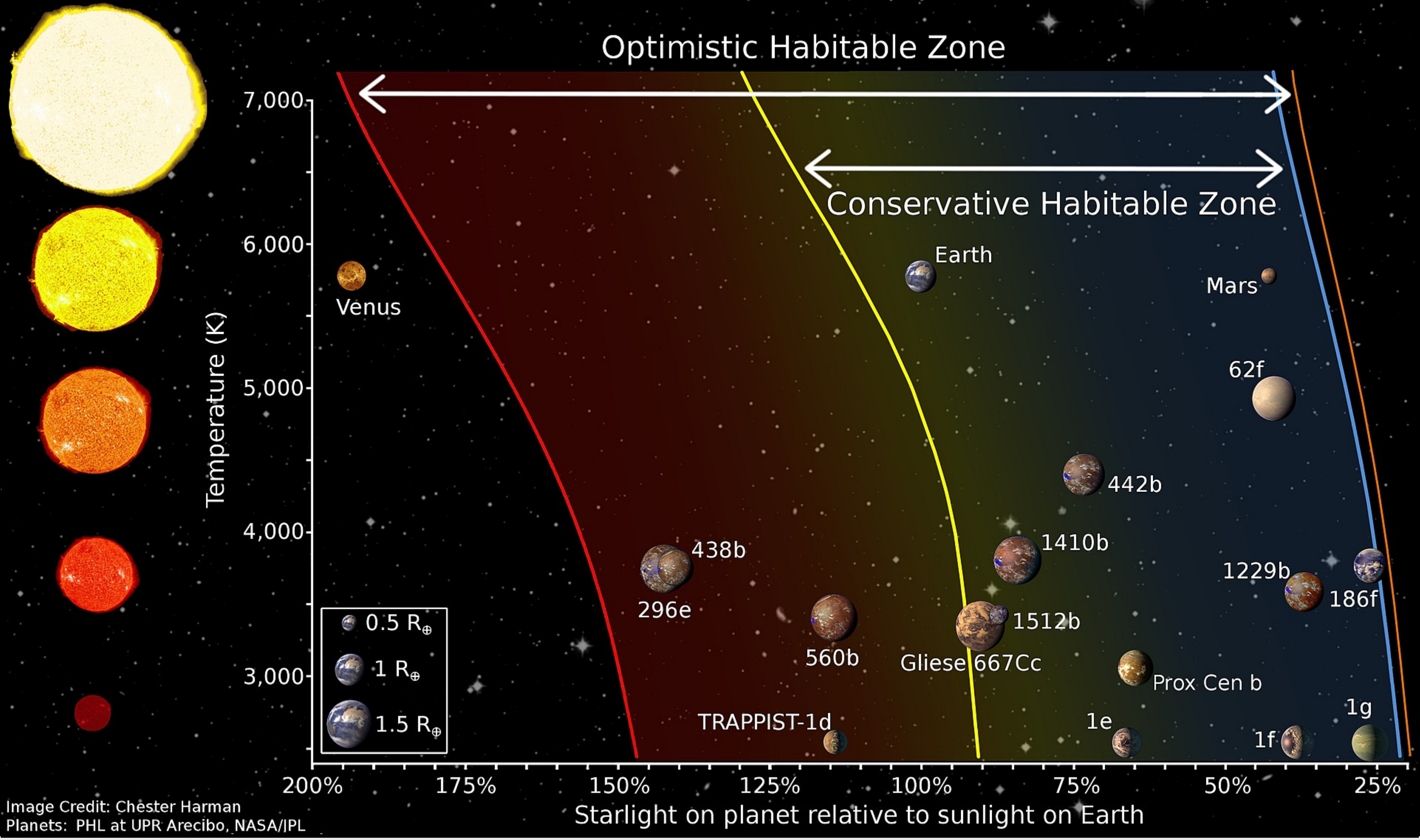


Image Credit: Chester Harman
Planets: PHL at UPR Arecibo, NASA/JPL

April 2014

InterCat
Center for Interstellar Katalyse

Liv Hornekær, Bjørk Hammer, Ewine van Dishoeck and Harold Linnartz

Mål: At bestemme om livets molekylære byggesten – Aminosyrer, DNA baser, sukker, fedtsyrer – dannes i rummet

InterCat vil bestemme startbetingelserne for livets oprindelse i universet

Surface Dynamics Group

LASSIE

erc

The Danish National
Advanced Technology Foundation

Forsknings- og
Innovationsstyrelsen
Ministeriet for Videnskab
Teknologi og Udvikling

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