Faszination Nano-Staubteilchen im Kosmos

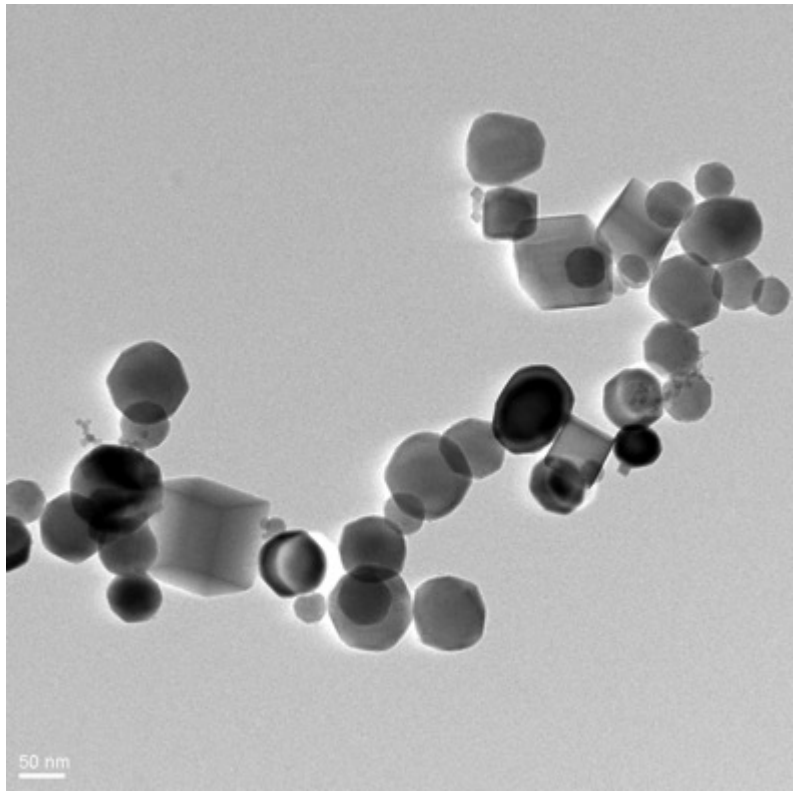
.... Astronomie als Puzzle

Ingrid Mann

UiT Norwegens Arktische Universitaet in Tromsø

Norwegen

Nanoteilchen haben in wenigstens einer Dimension Groessen von wenigen Nanometer



Nanoteilchen kondensiert in Gas

(Y. Kimura in “Nanodust in the Solar System, Springer, 2012)

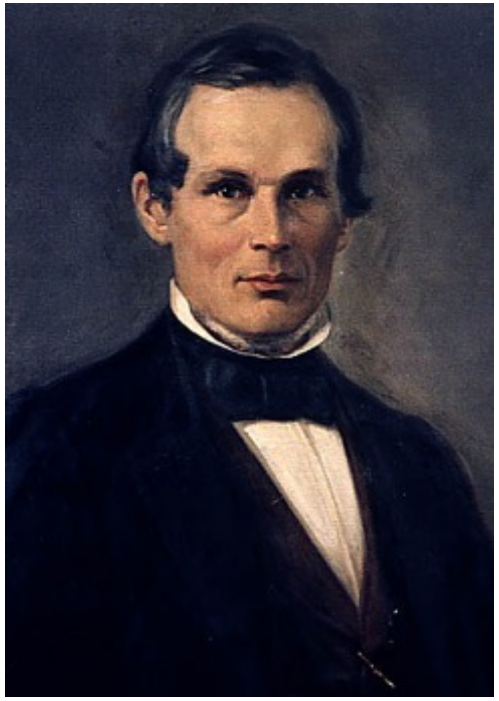
$$1\ \text{nm} = 1\ \text{nanometer} = \frac{1}{1\,000\,000\,000}\ \text{meter}$$

A nano-object is a material with one, two or three external dimensions in the nanoscale, ~ 1 - 100 nm

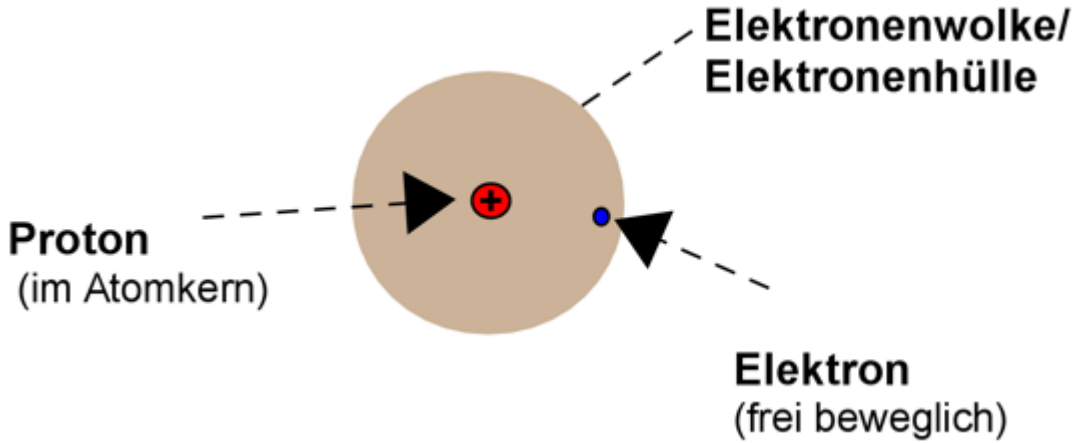
(ISO* TS 27687 CCA)

*International Organization for Standardization: ISO

- 0.1 nm = 1 Å (Ångstrøm): **Durchmesser des Wasserstoffatoms**
- Wellenlaenge von hochenergetischem Licht



Anders Jonas Ångström
1814 – 1874
Astronom & Physiker



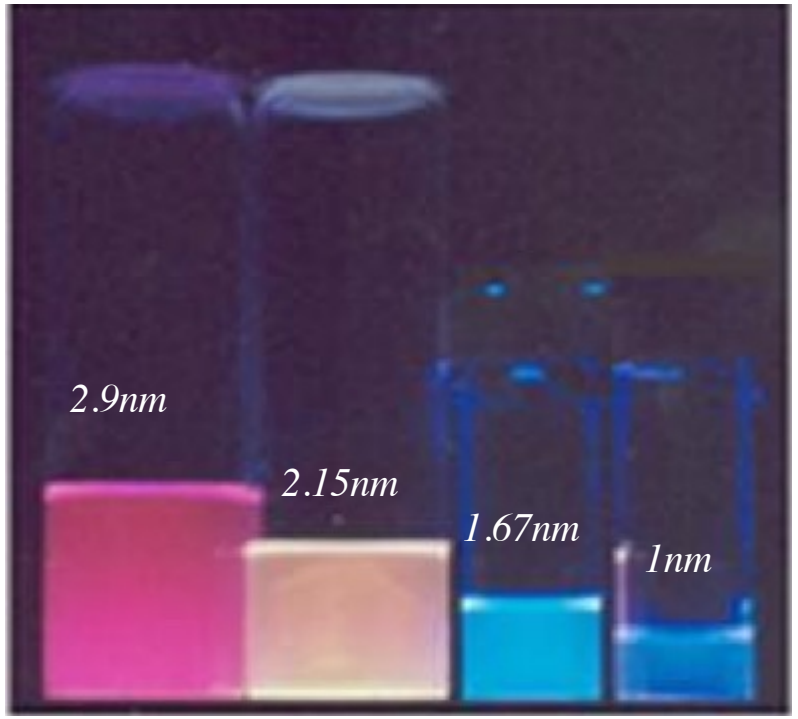
Ångstroem Laboratorium der Univ. Uppsala

Photos: Universitaet Uppsala

Nano Staubteilchen:

- Groesse bestimmt Eigenschaften
- Teilchen ist Oberflaeche
- nicht immer Festkoerperstruktur

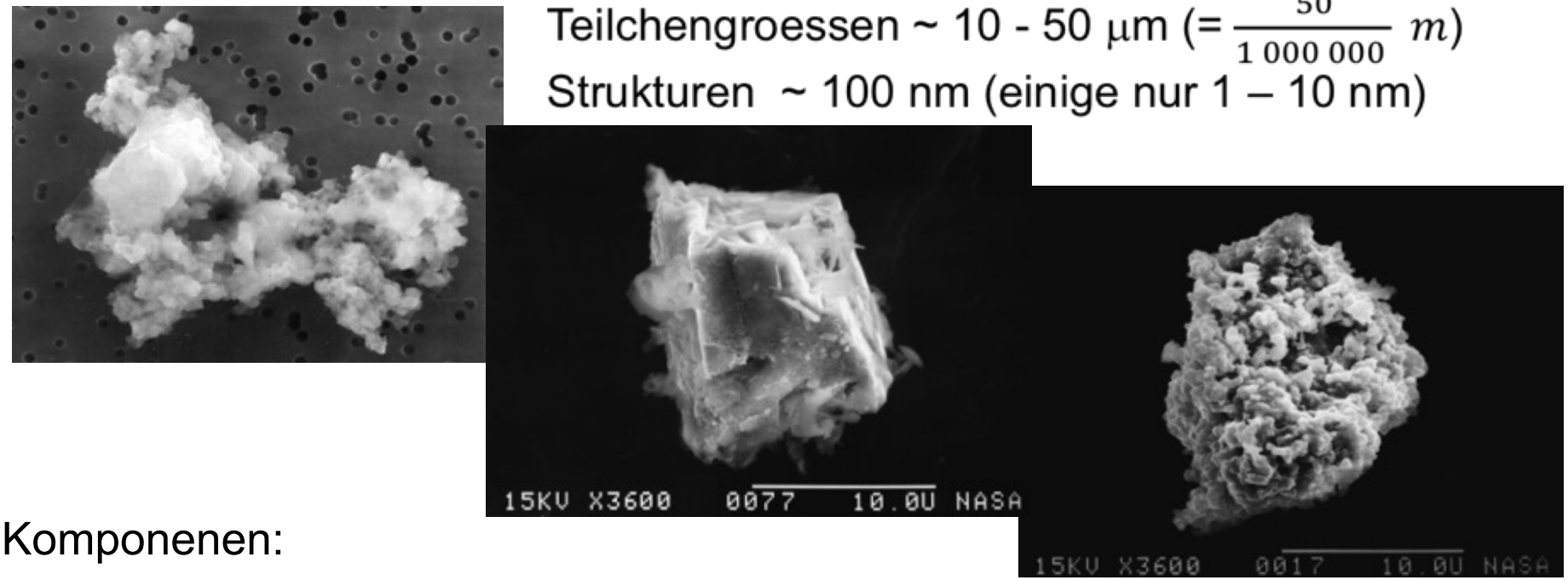
1 nm Forsterite Teilchen
≅ 4 Molekuele !



Silizium Nanoteilchen in Loesung bei Bestrahlung mit ultraviolettem Licht (365 nm)

(von S. Habbal Univ. of Hawaii)

Was ist kosmischer Staub ?



Teilchengroessen ~ 10 - 50 μm (= $\frac{50}{1\,000\,000}\ m$)

Strukturen ~ 100 nm (einige nur 1 – 10 nm)

Einige Komponenen:

Silikate: Enstatit ($MgSiO_3$) & Forsterit (Mg_2SiO_4)

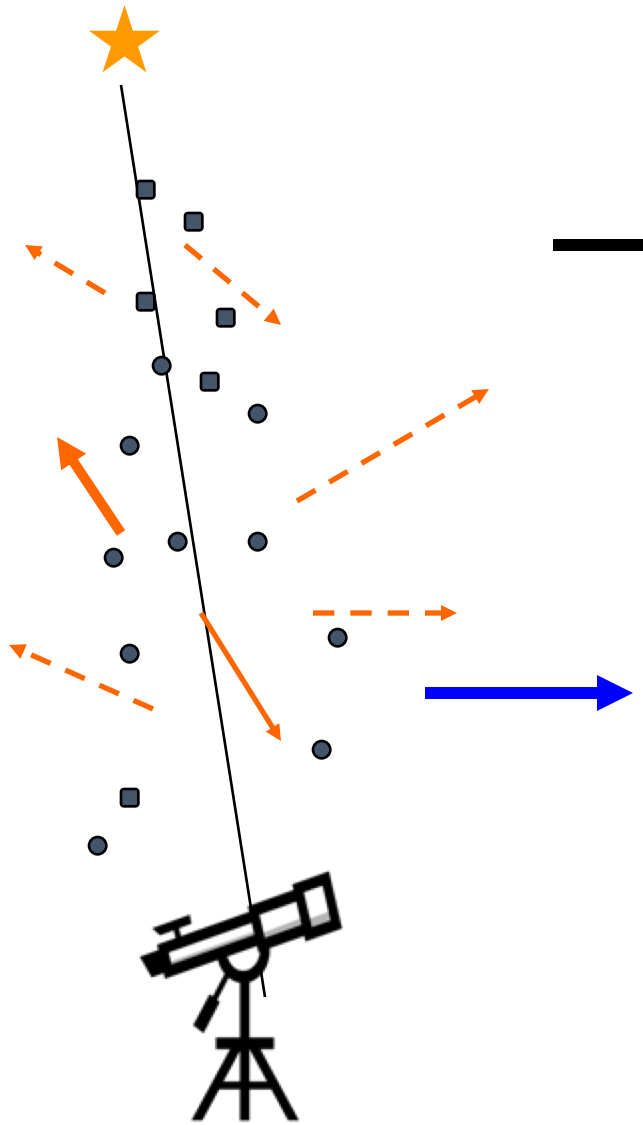
Troilit (FeS), Kamacit (FeNi), Korundum (Al_2O_3)

C, H, O, N in organischen Verbindungen

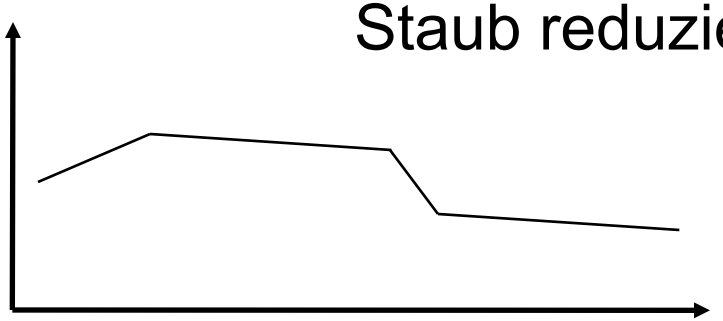
(cf. Mann Ann. Rev. Astron. Astrophys. 2010)

Figures: Electron microscopy of dust collected in upper atmosphere (NASA)

Nachweis von Staub im Interstellaren Medium (ISM):



Extinction



Staub reduziert Sternenlicht

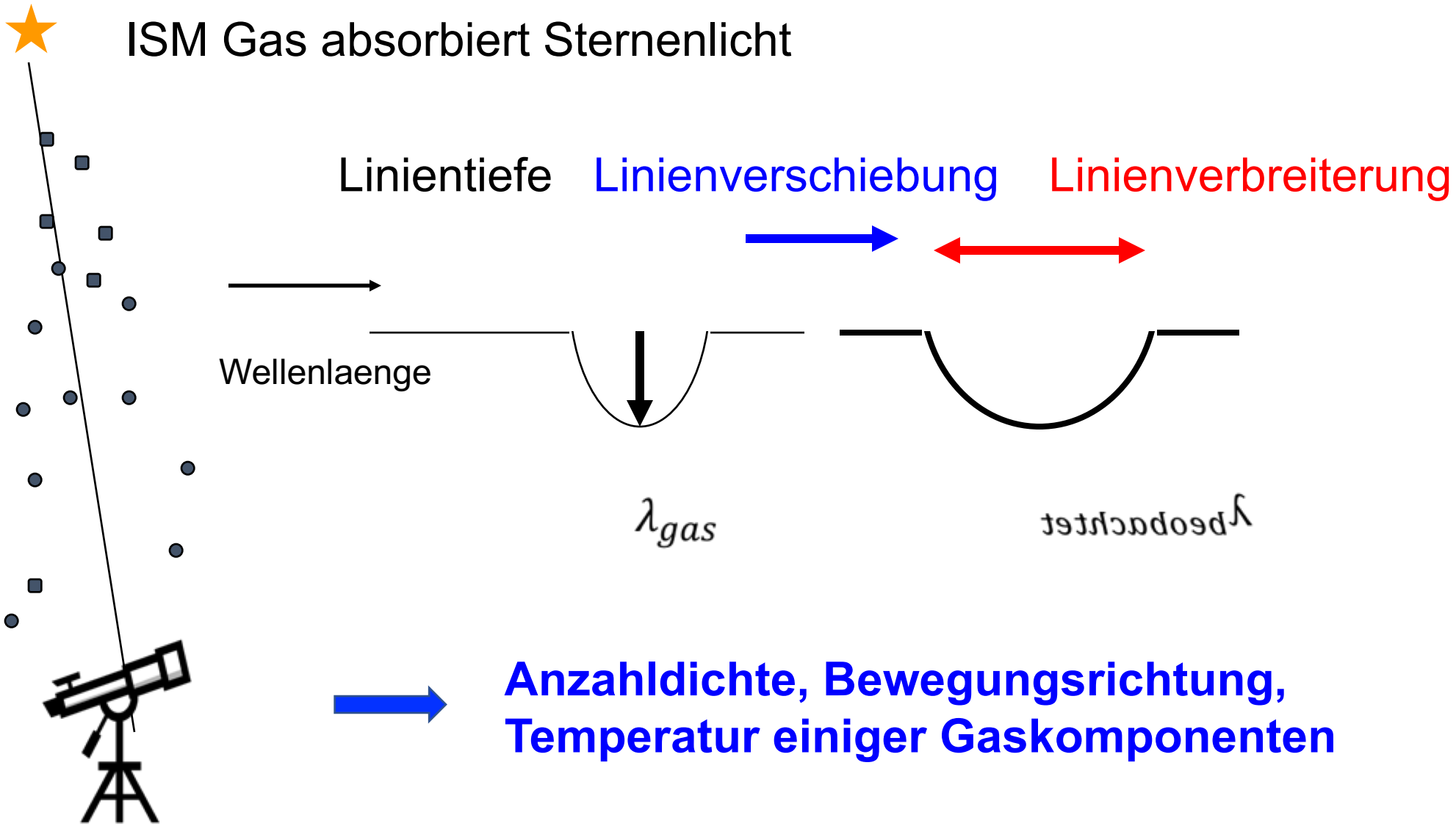
Wellenlaenge

Anzahldichte

Groesse

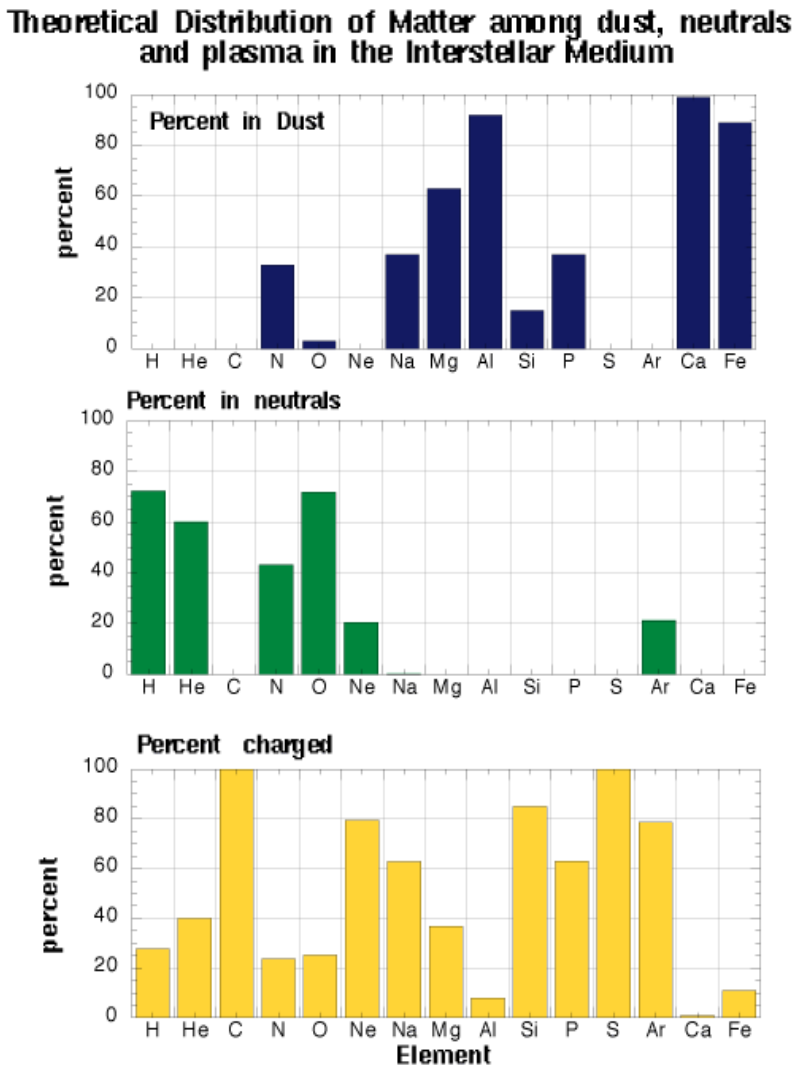
Zusammensetzung

Nachweis der Gaskomponente im interstellaren Medium:



Anzahldichte, Bewegungsrichtung,
Temperatur einiger Gaskomponenten

Verteilung der chemischen Elemente im interstellaren Medium



Staub

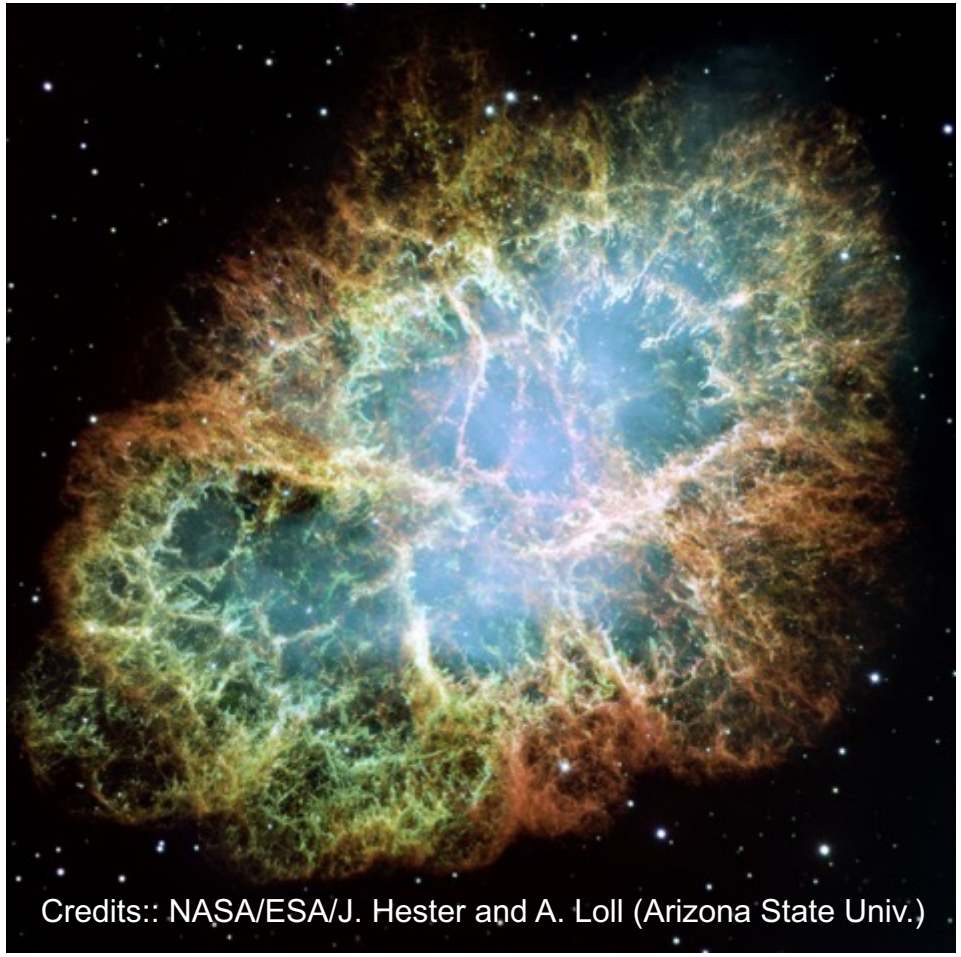
Neutral Gas

Ionen

From NASA - Interstellar Probe Webpage

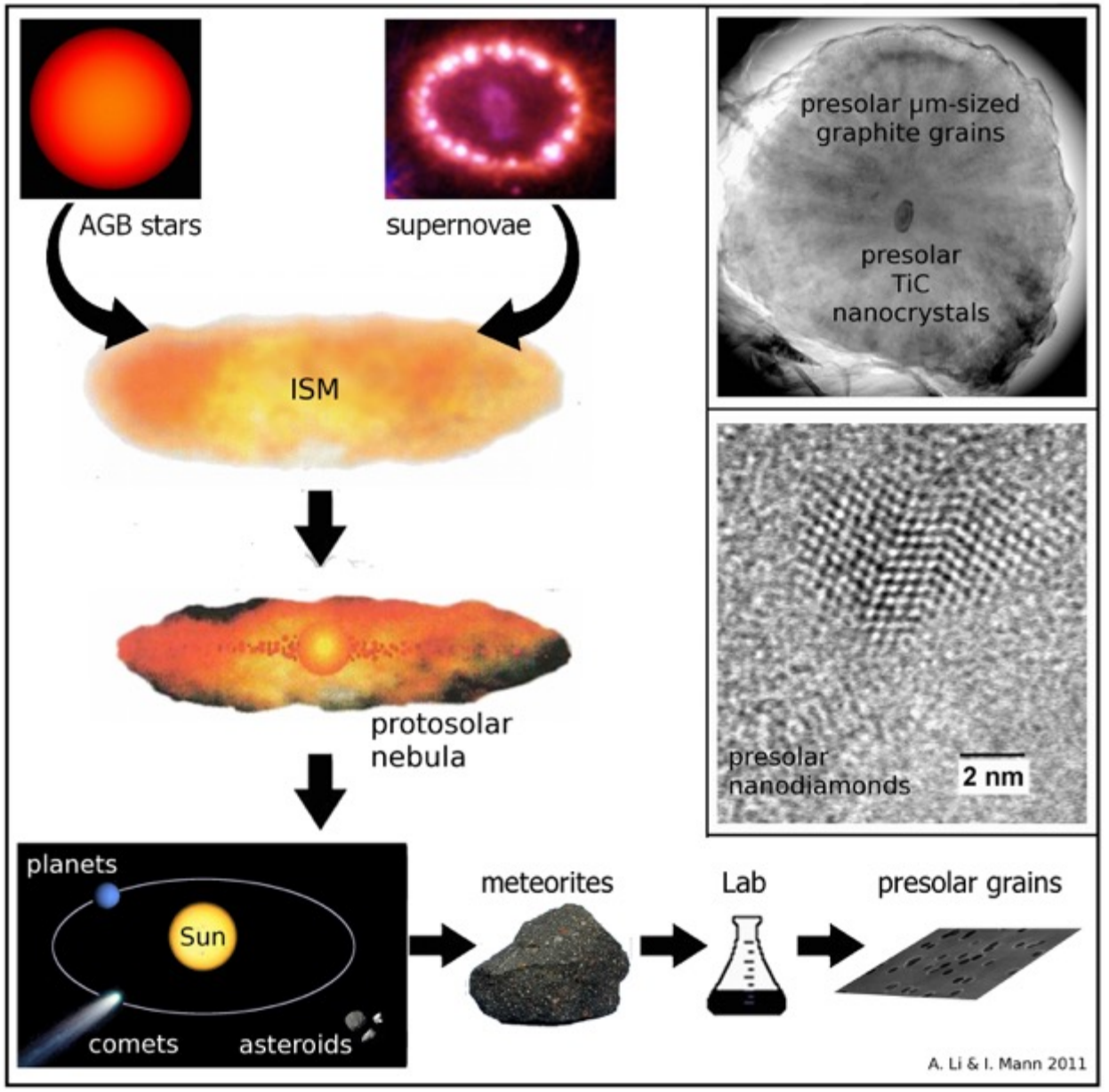
Supernovae formen schwere Elemente

Der Krebsnebel im Sternbild Stier enthaelt Ueberreste einer Supernova. Er ist ca. 2000 pc von uns entfernt.



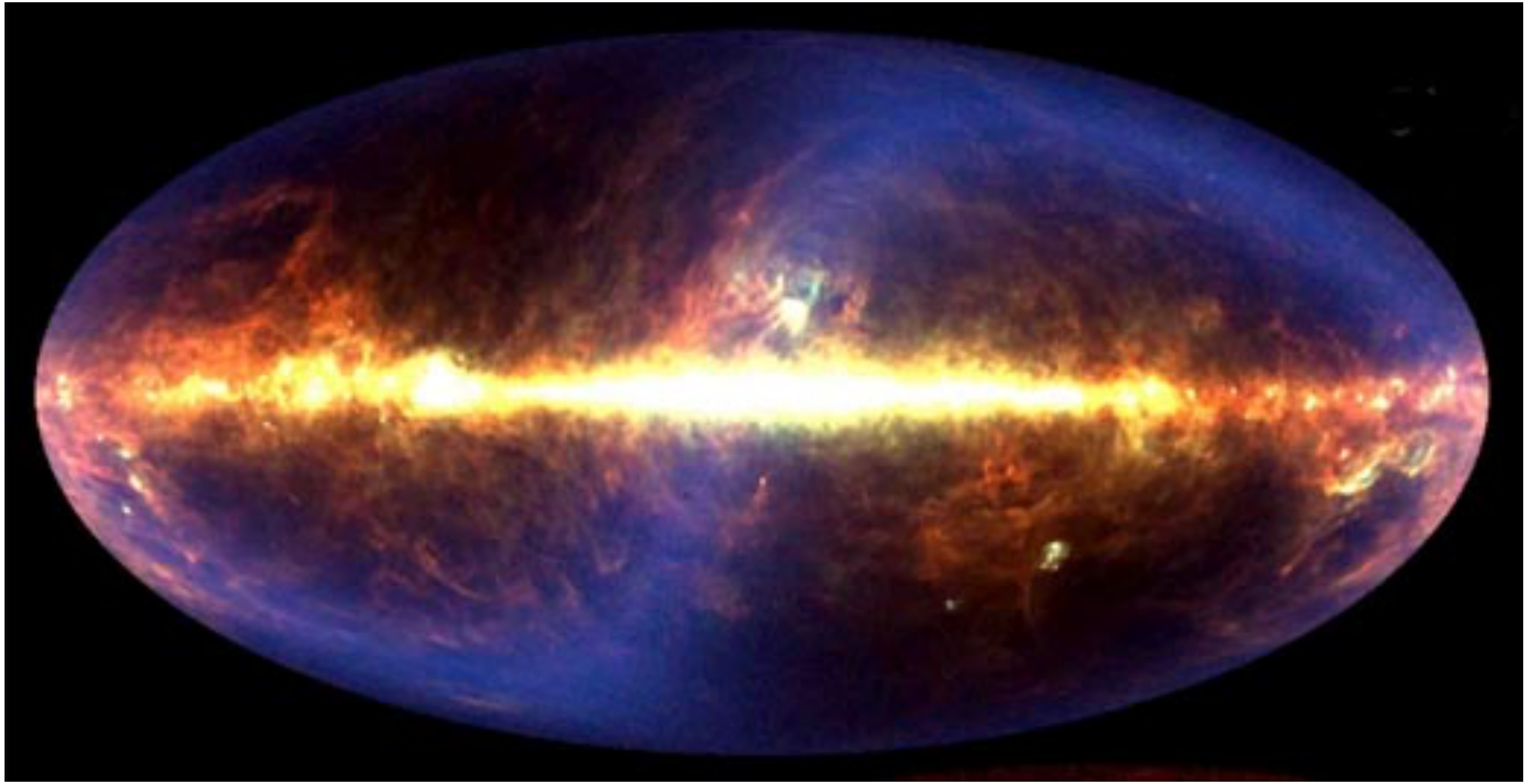
Kosmischer Staubkreislauf:

Entstehung & Vernichtung



Himmelskarte im fernen Infrarot (DIRBE Team, COBE, NASA):

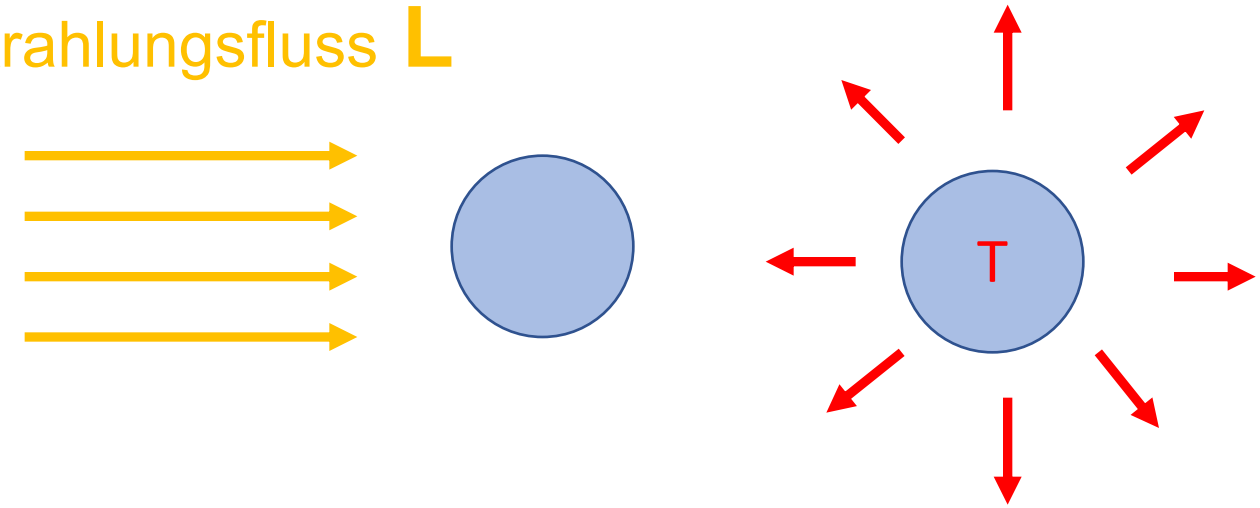
Zodiakkalicht, Milchstrasse & Hintergrundstrahlung

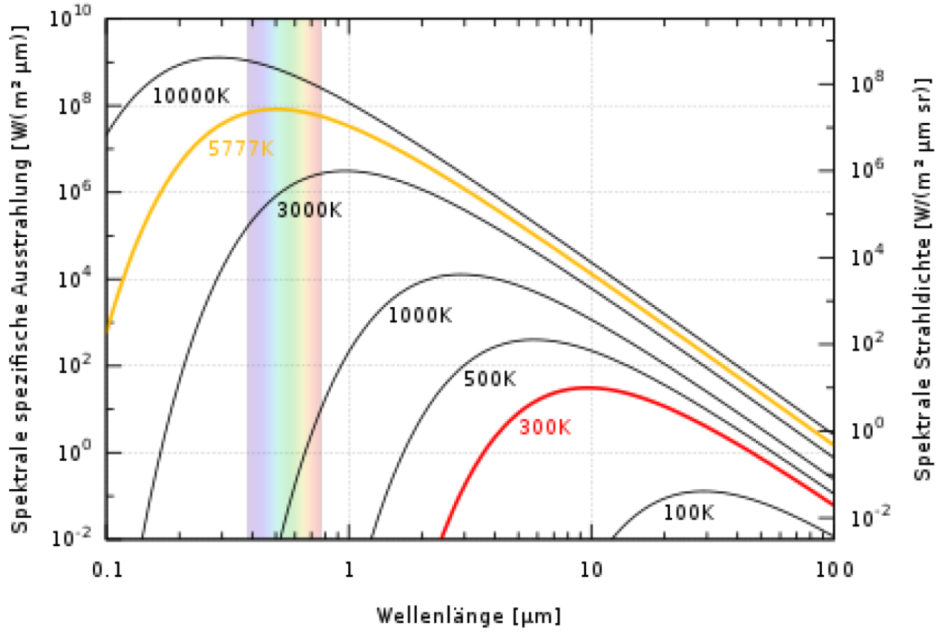


Temperatur im Strahlungsgleichgewicht:

Thermische Emission

Strahlungsfluss **L**





$$E_{in} = E_{out}$$

$$\Leftrightarrow (1\text{-}A)\ \pi\ r^2\ L = 4\ \pi\ r^2\ \sigma\ T_e^4$$

$$\Leftrightarrow \frac{(1\text{-}A)}{4}\ L = \sigma\ T_e^4$$

0° C entspricht 273,15 K

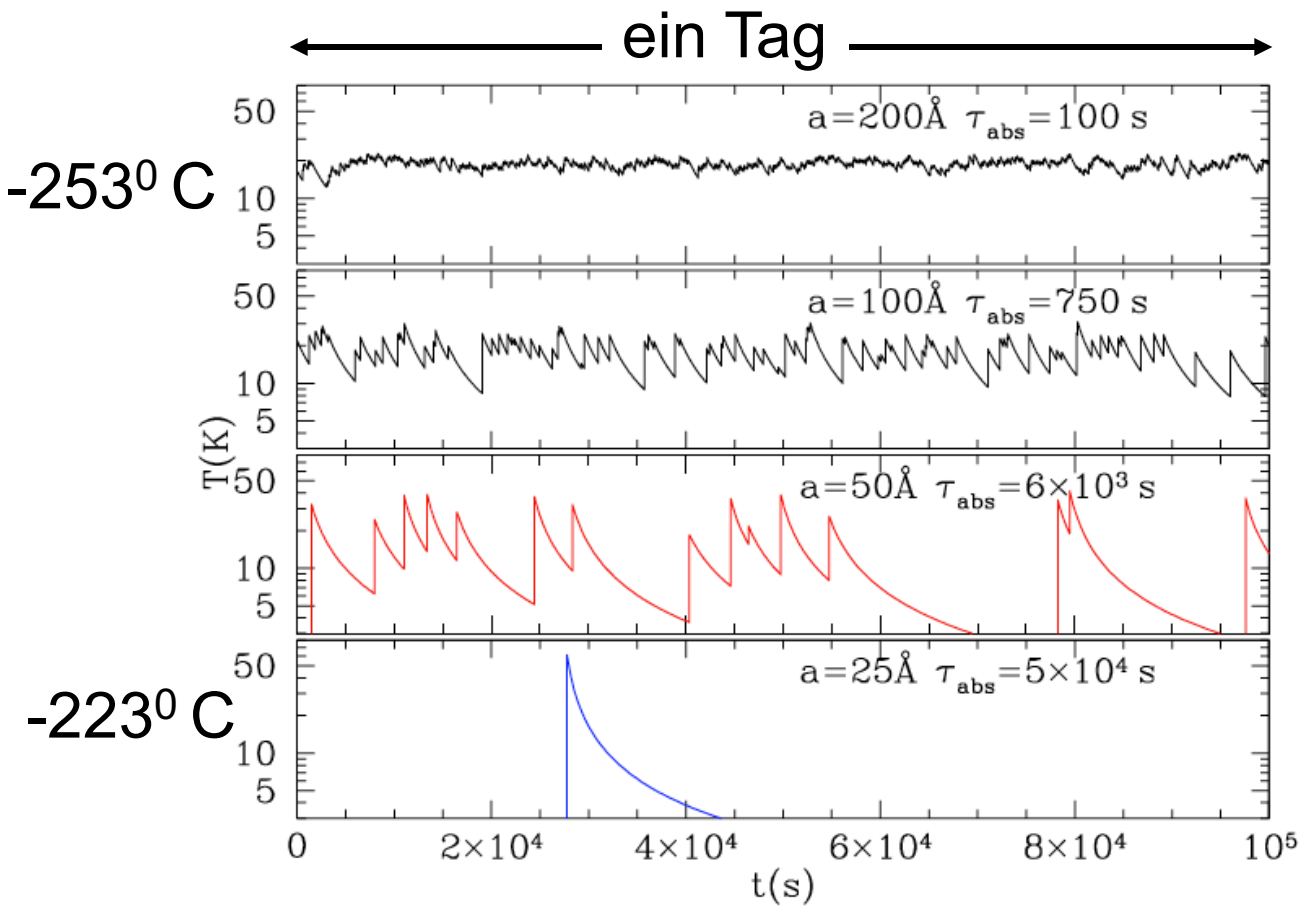
Strahlungsfluss nahe Erdbhahn:

1.3608 ± 0.0005 kW/m²

3.5 10^{21} photonen / m^2 s

fuer nm-Teilchen
ca. 2000 Photonen pro Sekunde

Thermische emission im interstellaren Medium



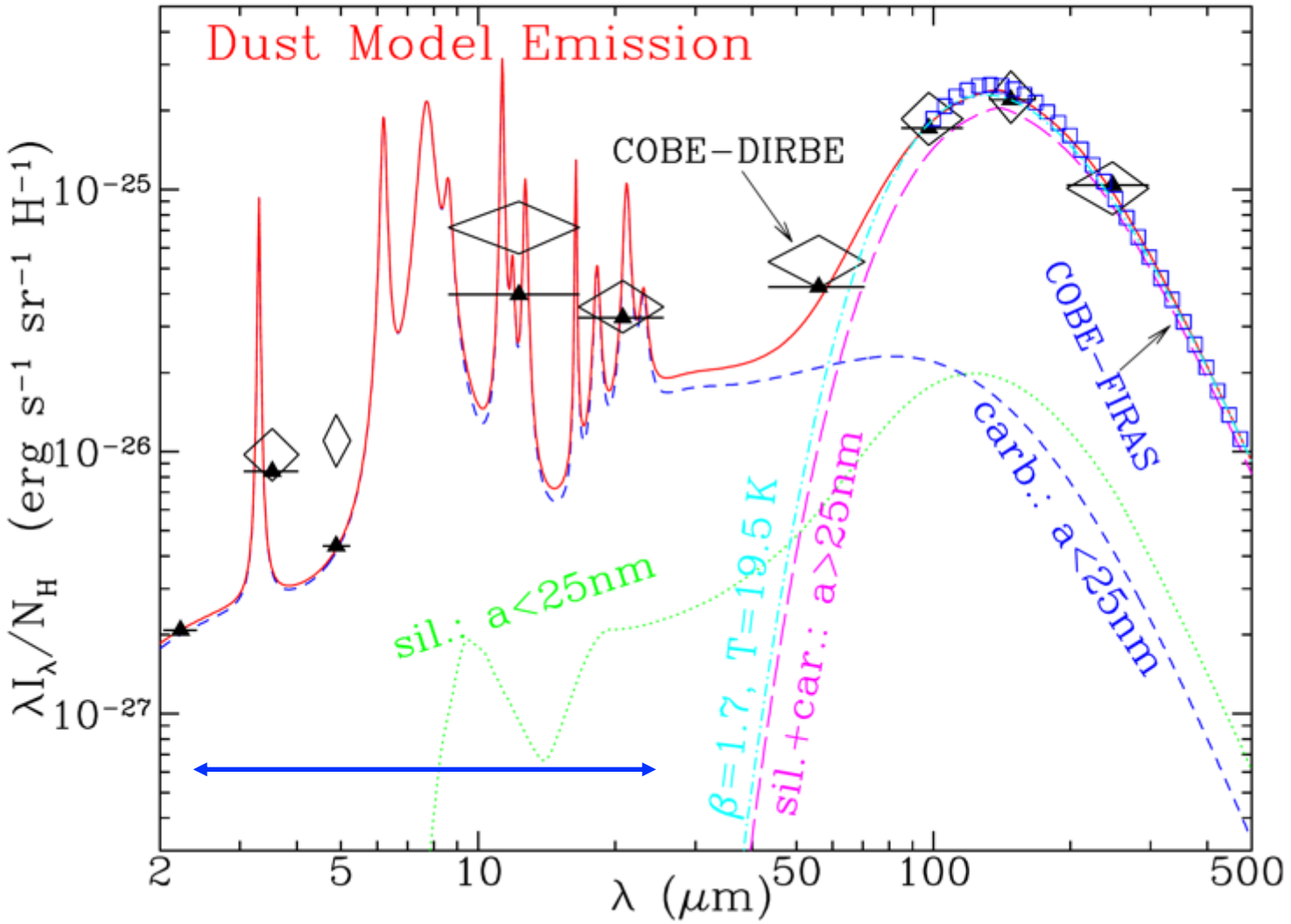
20 nm Teilchen hat Gleichgewichtstemperatur

2.5 nm Teilchen macht nur einen Temperaturhuepfer pro Tag

Nano Staubteilchen sind aus dem Gleichgewicht

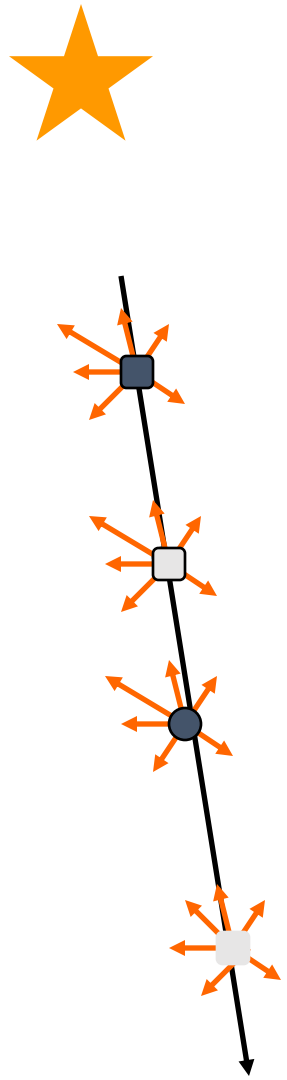
(Fig: Draine and Li 2003)

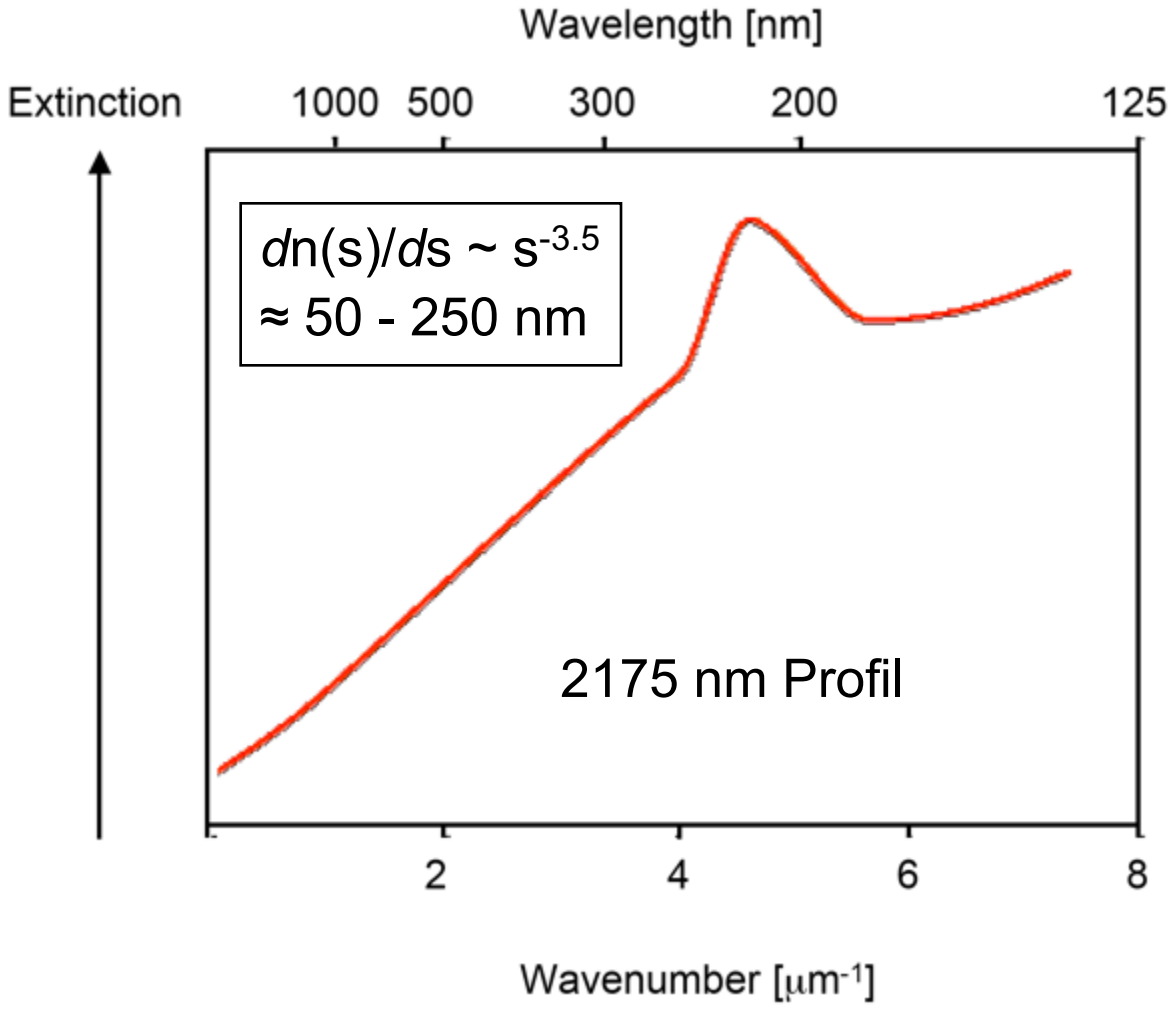
Diffuse Waermestrahlung im Interstellaren Medium



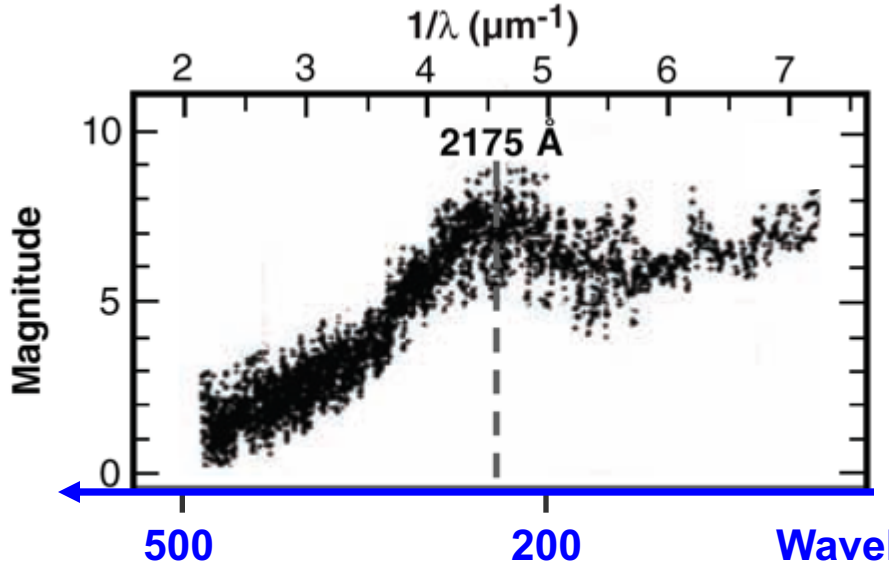
Nano Staubteilchen sind aus dem Gleichgewicht

Interstellare Extinktion im UV

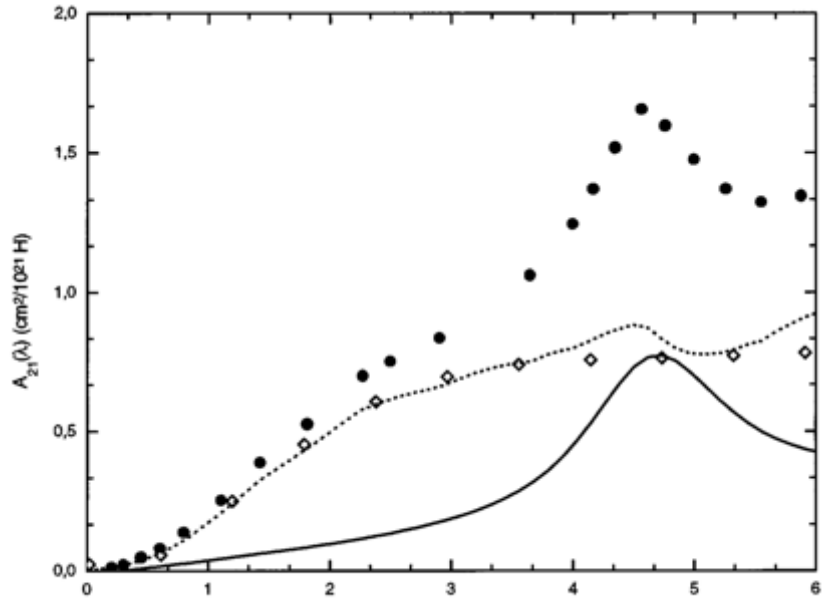




Extinction



Lorentzprofil in der interstellaren Extinktionskurve



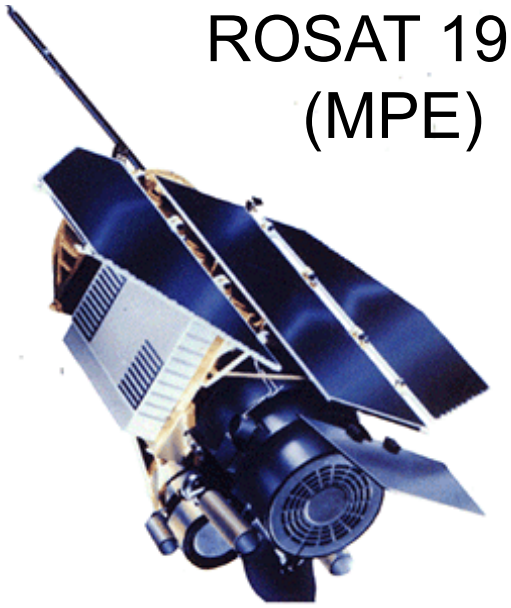
Wellenzahl [μm-1]

IS Extinktion
=
"grosse Staubteilchen"
+
C Nano Staubteilchen

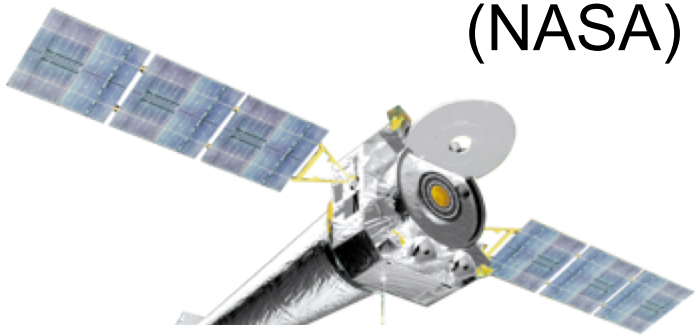
(Schnaiter et al. ApJ 1998)

Roentgenteleskope im Weltraum

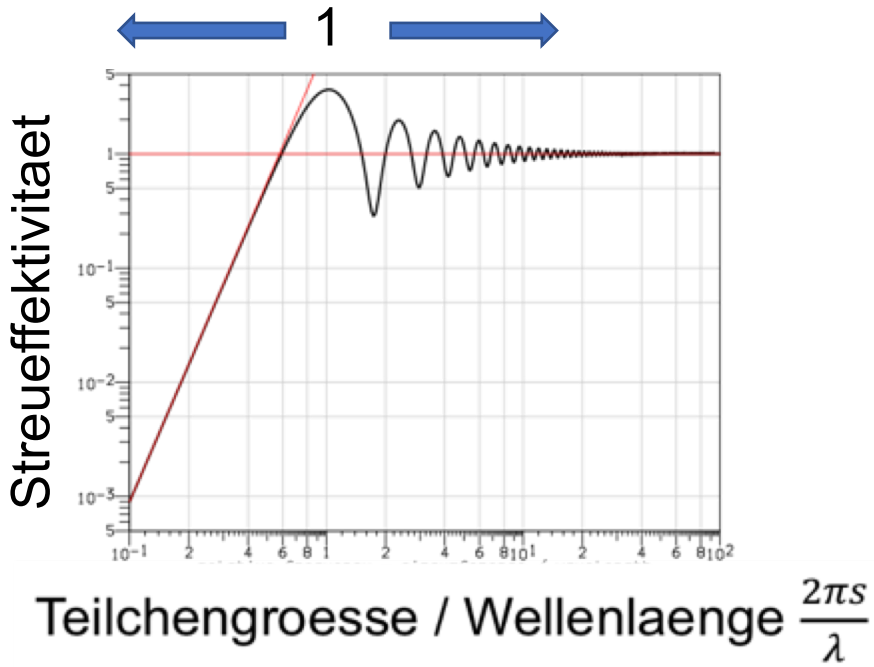
ROSAT 1990
(MPE)



Chandra - 1999
(NASA)

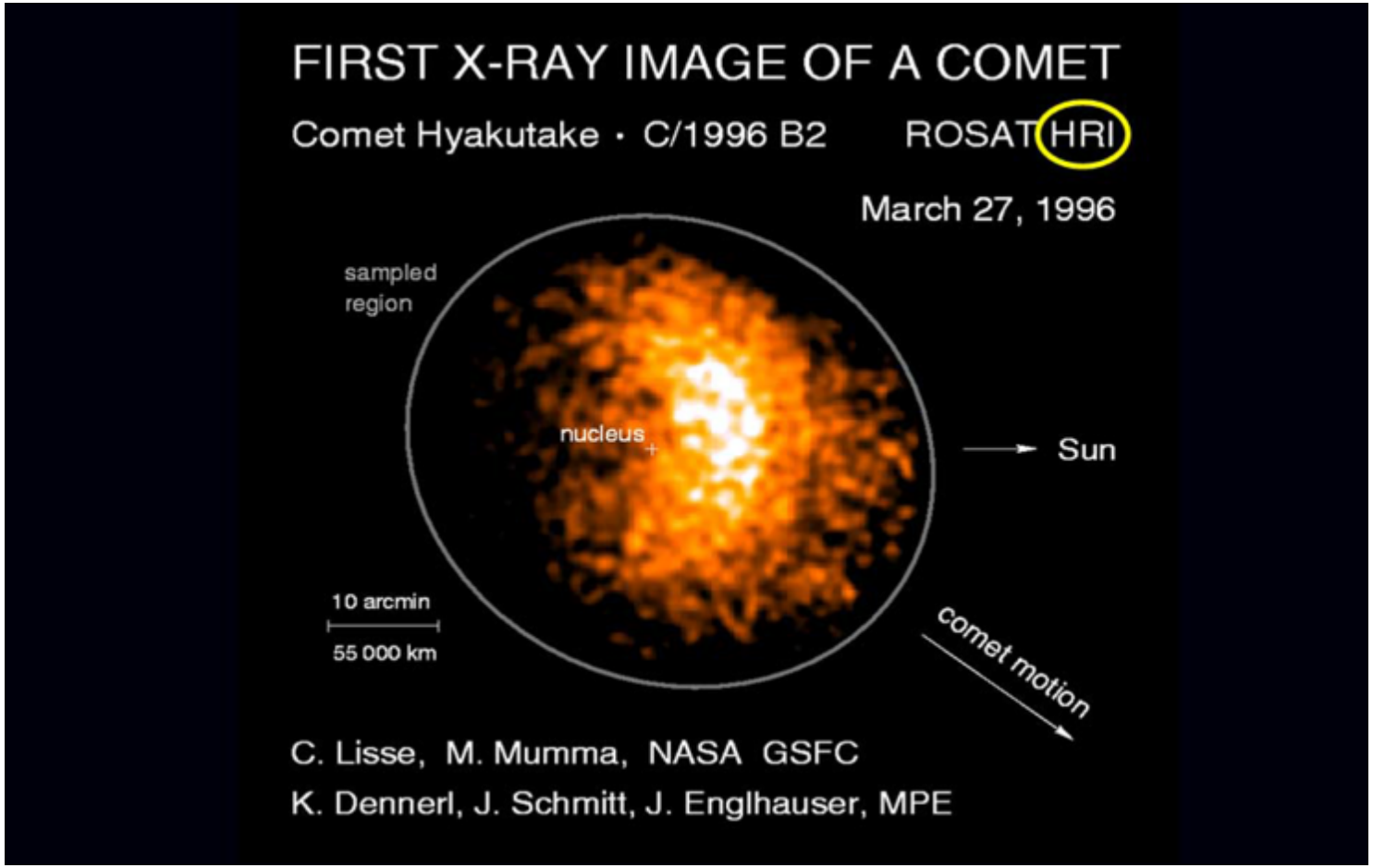


Newton XMM - 1999
(ESA)



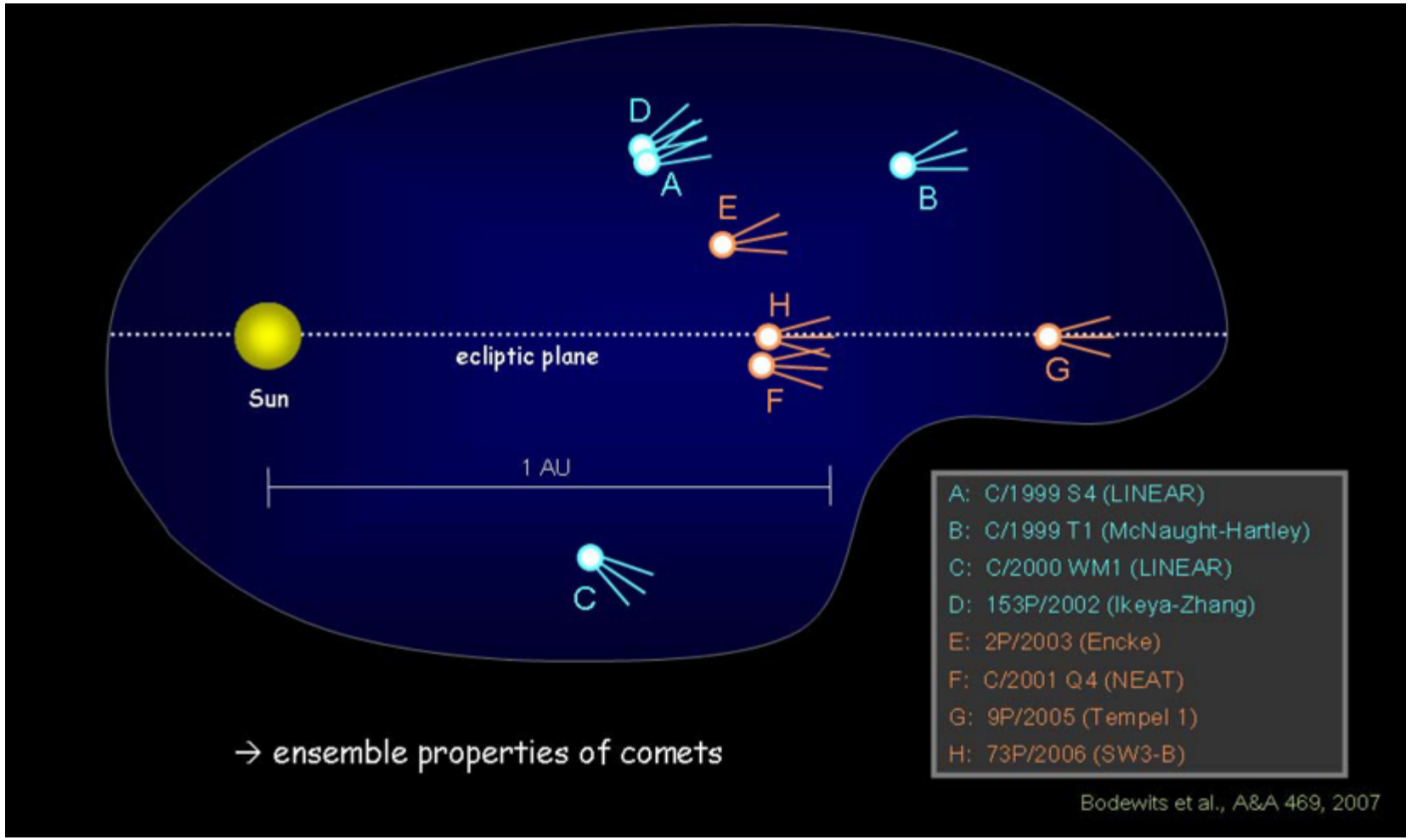
Staubteilchen muessen mindestens so gross wie die Wellenlaenge sein, um Licht effektiv zu streuen

Roentgenstrahlung von Kometen



Konrad Dennerl MPI Garching 2009)

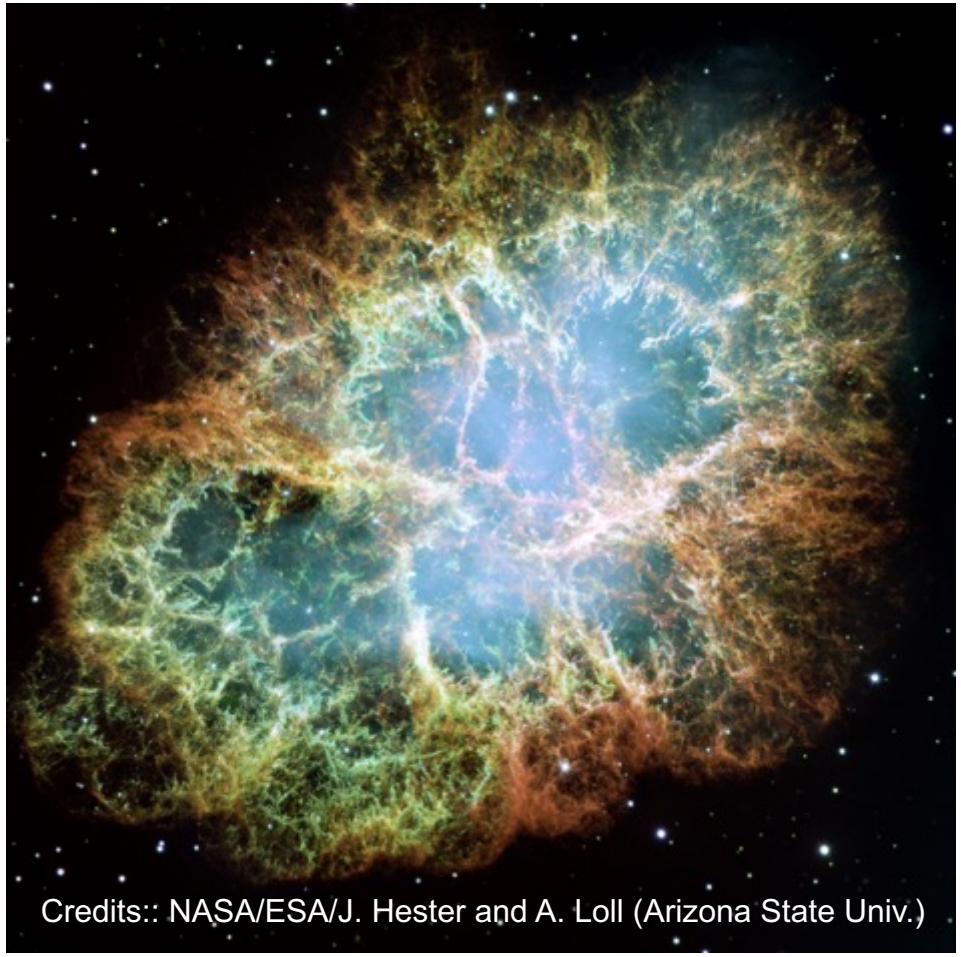
Kometenbeobachtungen mit Chandra



Konrad Dennerl MPI Garching 2009)

Supernovae – Geburtsstaette von Staubteilchen?

Der Krebsnebel im Sternbild Stier enthaelt Ueberreste einer Supernova. Er ist ca. 2000 pc von uns entfernt.

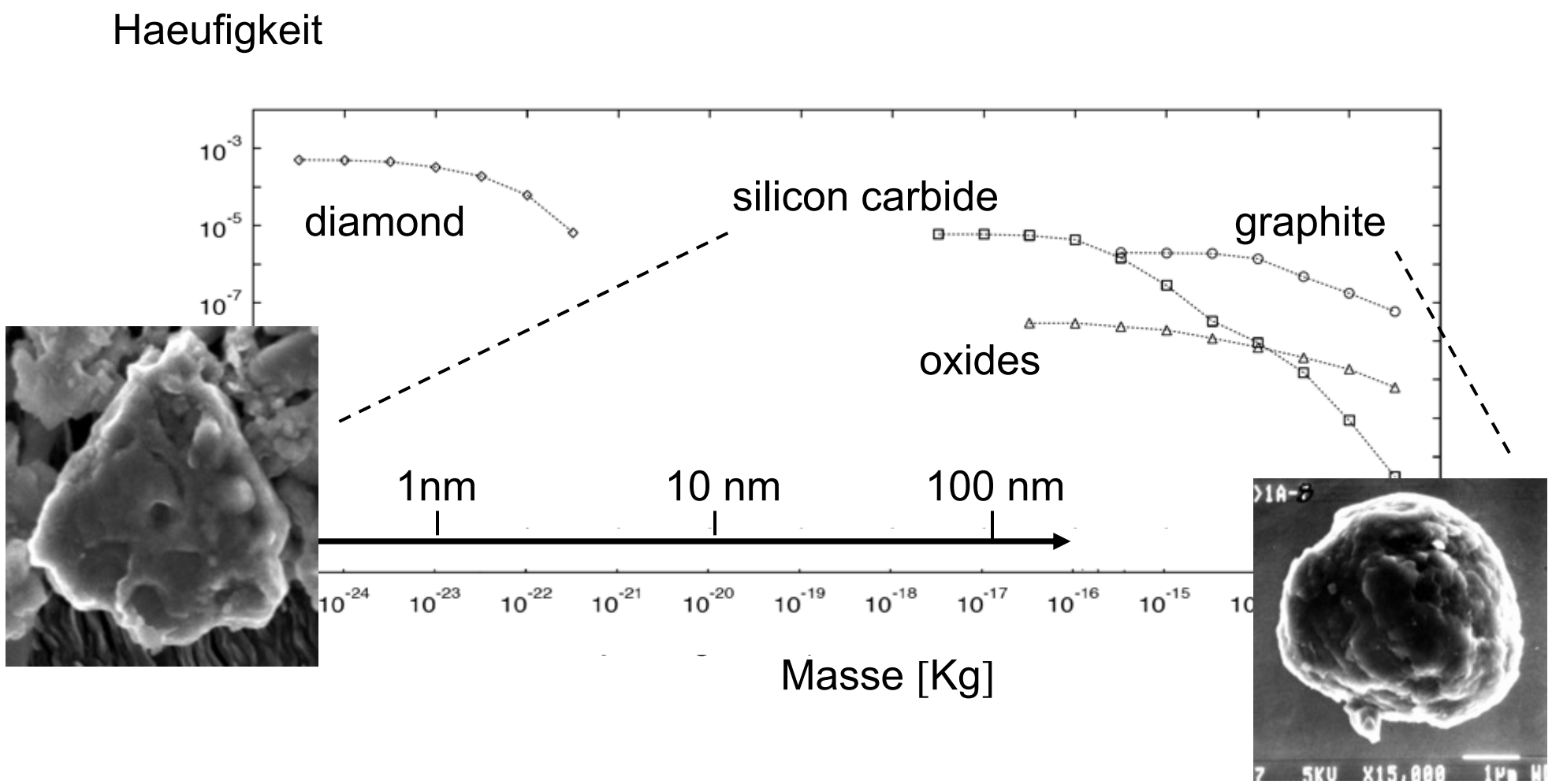


Credits:: NASA/ESA/J. Hester and A. Loll (Arizona State Univ.)

Meteorite werden im Labor analysiert

Image Credit: NASA Johnson Space Center

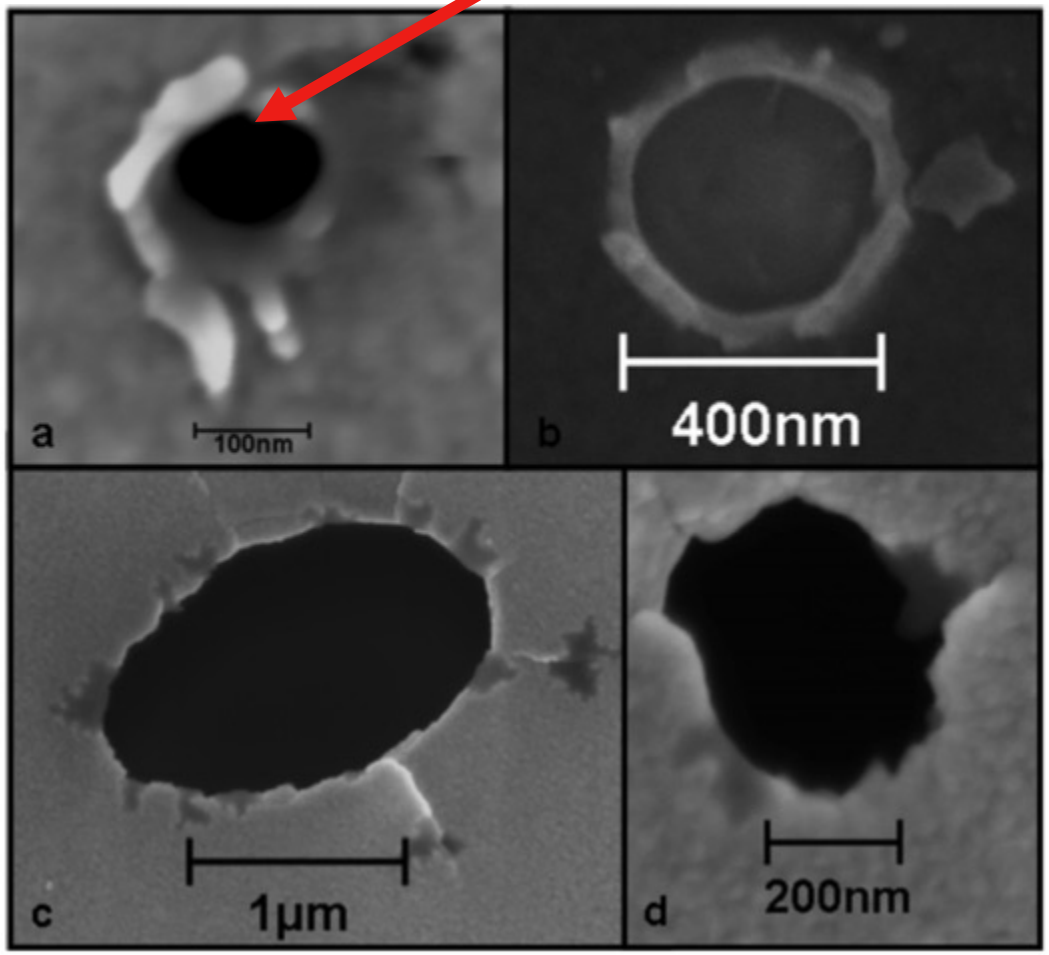
Prae-solarer Staub in Meteoriten:



(images S. Sandford)

Nano Staubteilchen im interplanetaren Raum ?

Einschlaege von Staub < 10 nm

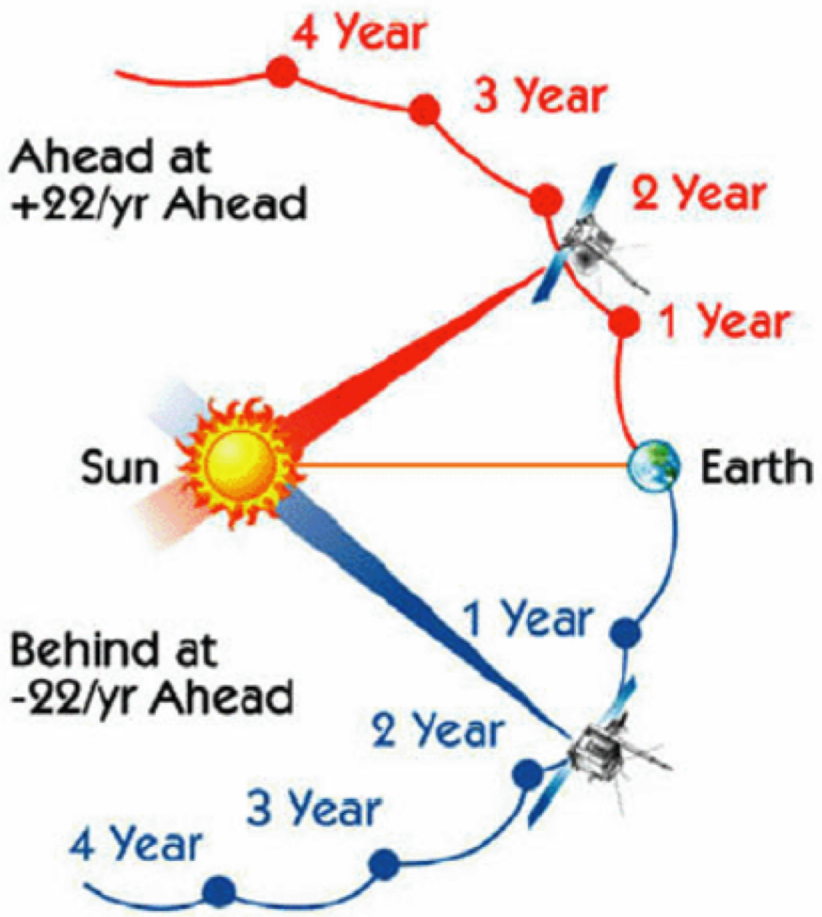


Aluminiumfolien (60 nm Al) auf der International Space Station (~ 400 km Hoehe)

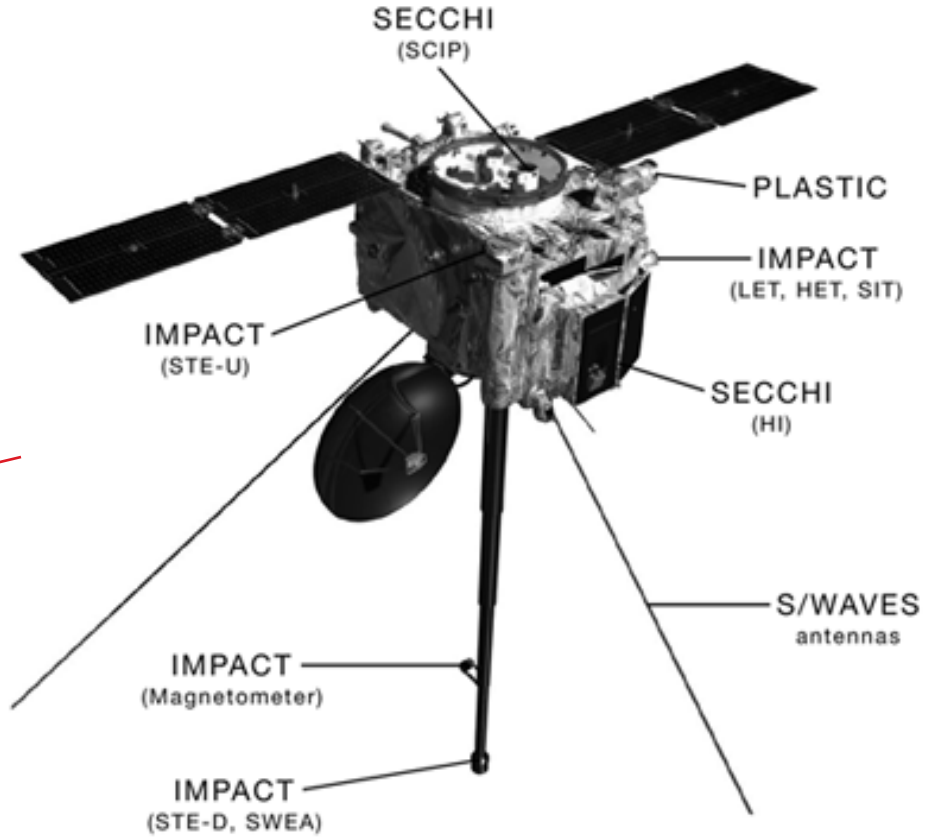
(Carpenter et al. J. Geophys. Res. 2007)

... zufaellige Entdeckung

STEREO Mission



Geocentric Solar Ecliptic Coordinates
Fixed Earth-Sun Line
(Ecliptic Plane Projection)



Sonnenbeobachtungen

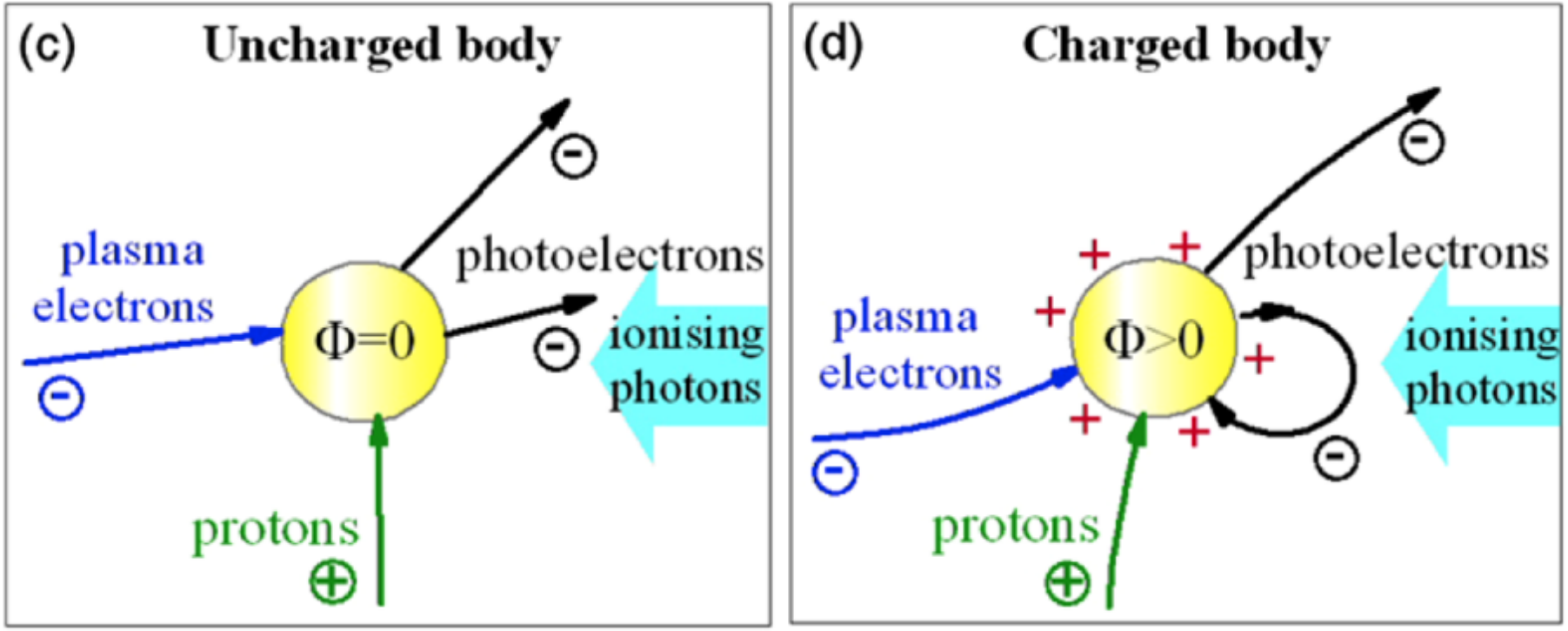
Sonenwindmessungen

Mission: Oct. 2006 -

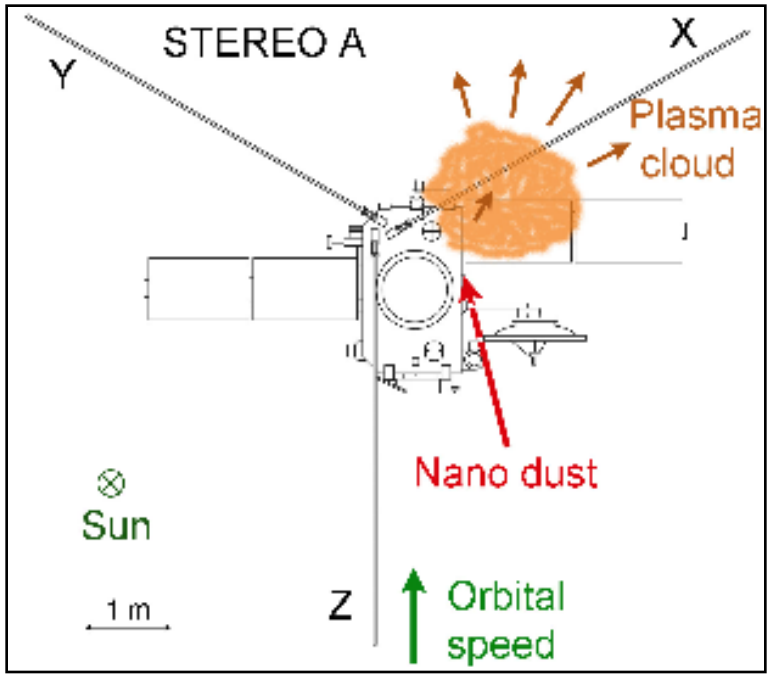
Objekte im Weltraum sind elektrisch geladen

... und haben elektrisches Potential $\Phi > 0$ relativ zu ihrer Umgebung, sie

- stossen gleiche (positive) Ladungen ab und
- ziehen entgegengesetzte (negative Ladungen an)



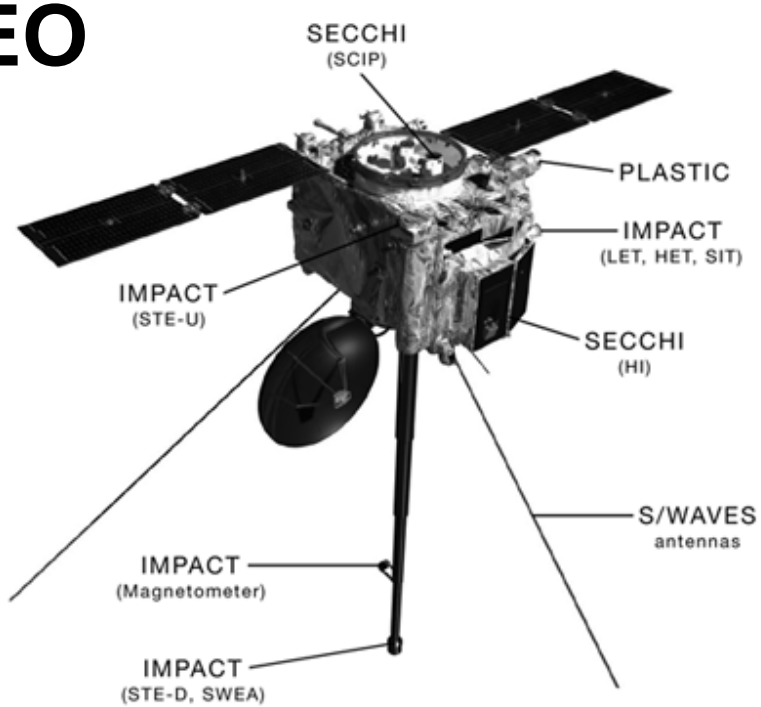
(Figure from N. Meyer-Vernet, Basics of the Solar Wind, 2007)



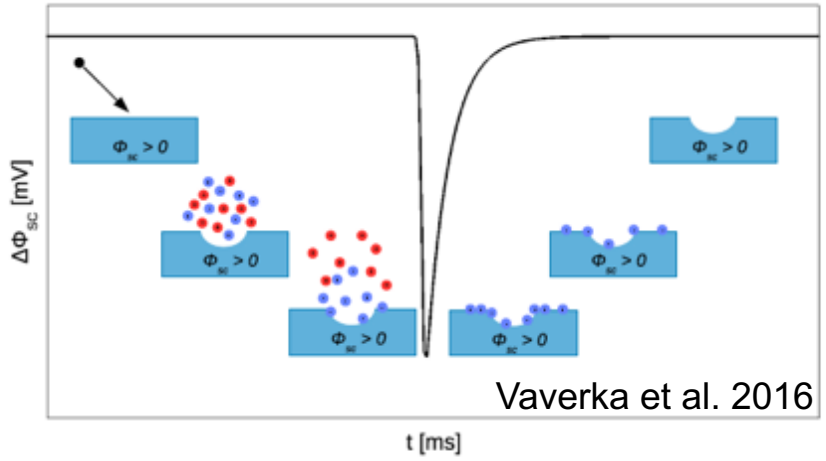
Meyer – Vernet et al. 2009

Einschlag erzeugt freie Ladungen...

Staubmessungen mit STEREO



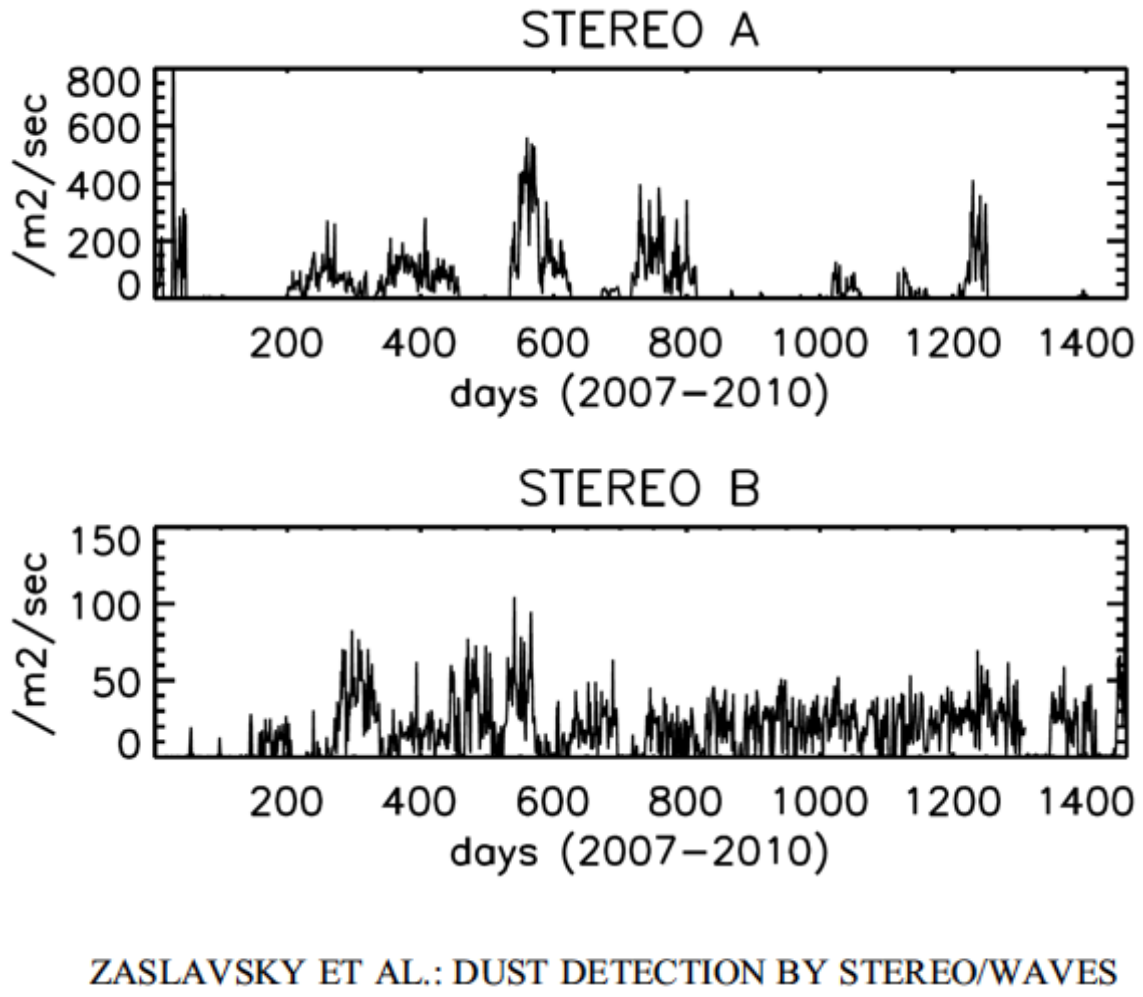
... aendert elektrische Potential



Vaverka et al. 2016

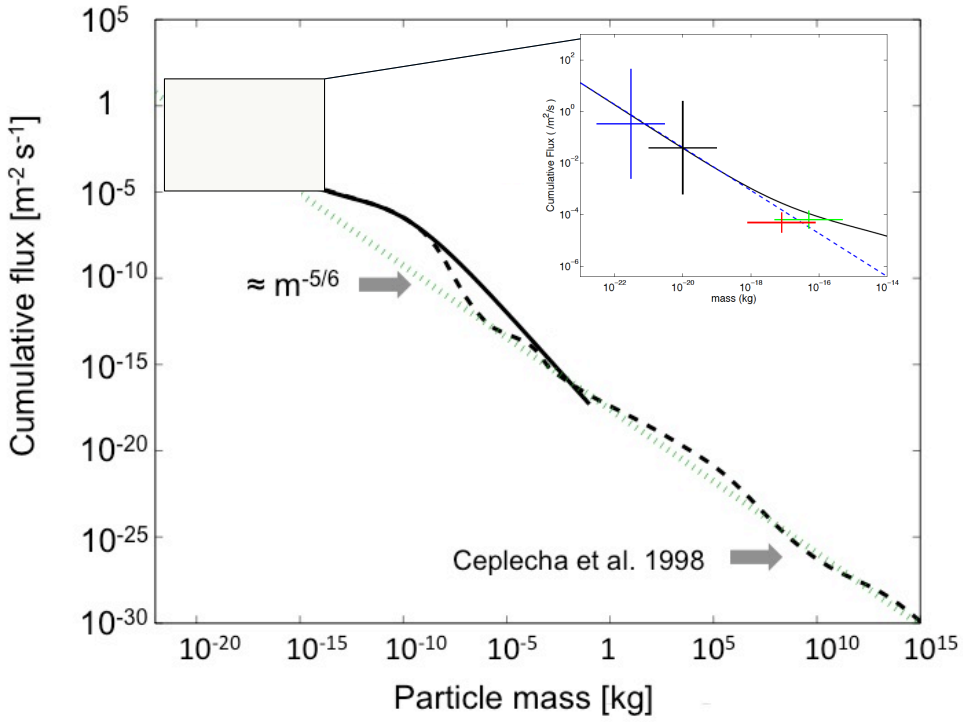
Figure 1. A simplifying sketch of the impact cloud (red ions and blue electrons) generation by a hypervelocity dust impact and the following electron recollection by a positively charged spacecraft body. The black line represents a dip in the temporal evolution of the spacecraft potential, Φ_{SC}, caused by the impact.

Staubmessungen mit STEREO

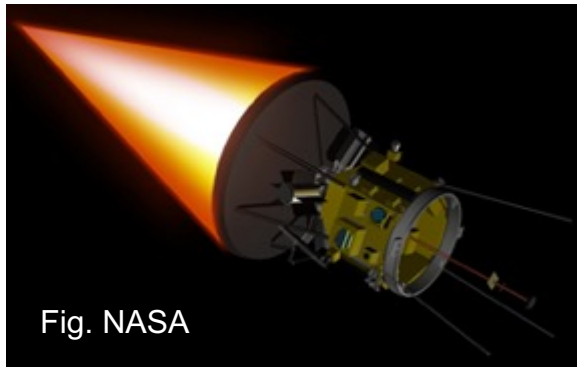


ZASLAVSKY ET AL.: DUST DETECTION BY STEREO/WAVES

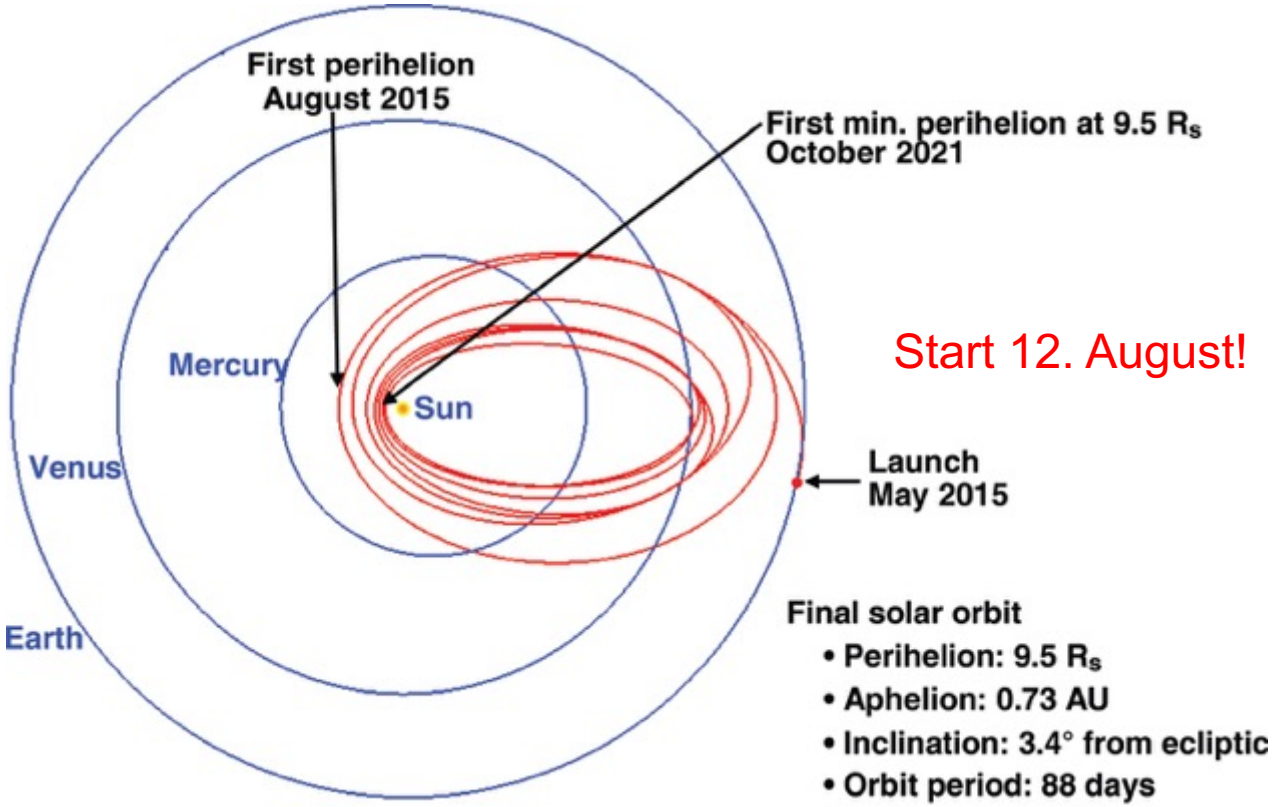
Groessenverteilung von Staub



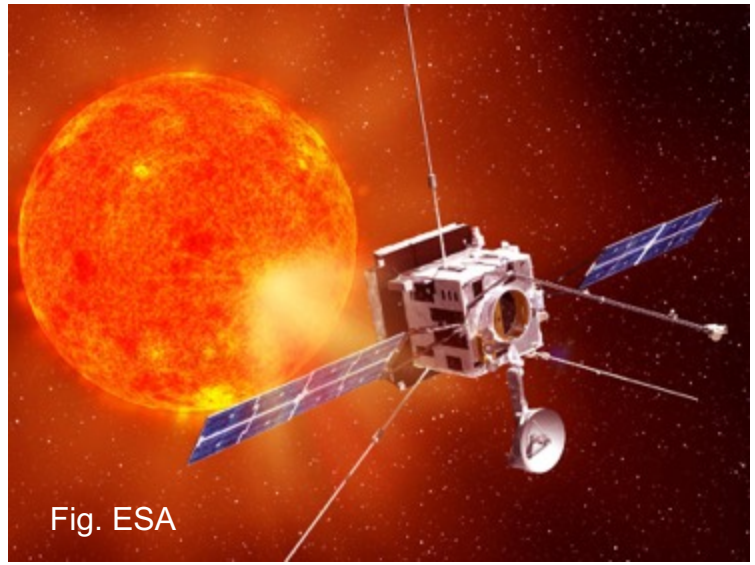
Solar Orbiter (ESA) & Parker Solar Probe (NASA)



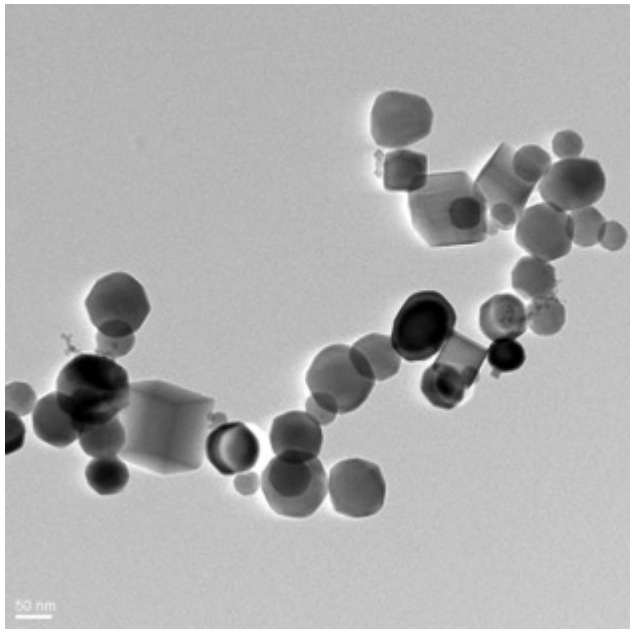
Parker Solar Probe Bahn (NASA)

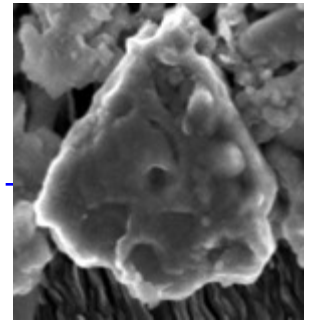


Start 12. August!



Nano Staubteilchen:





Wir wissen, dass es sie gibt.

Wir kennen einige Eigenschaften,….

… und setzen das Puzzle zusammen.