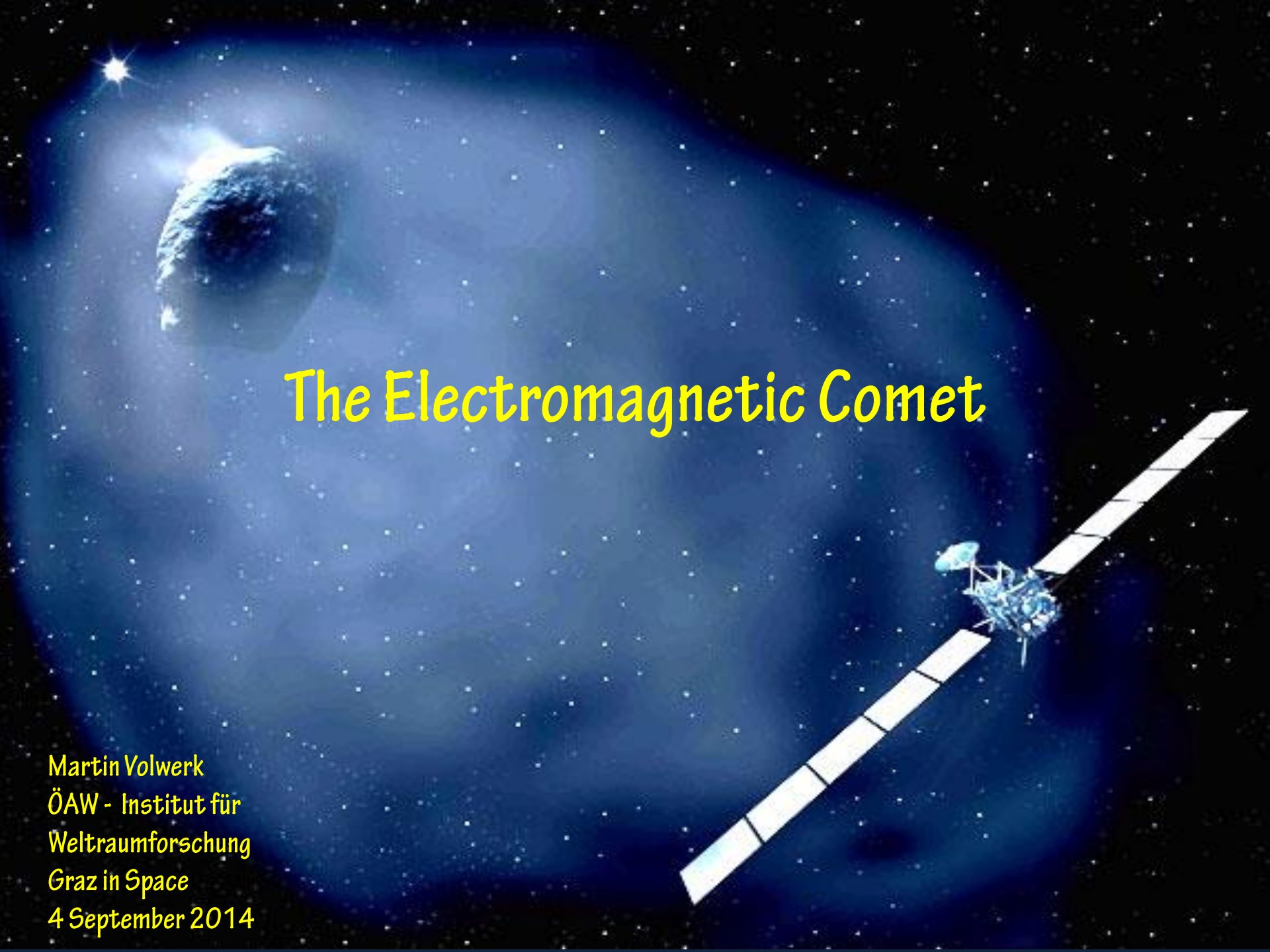


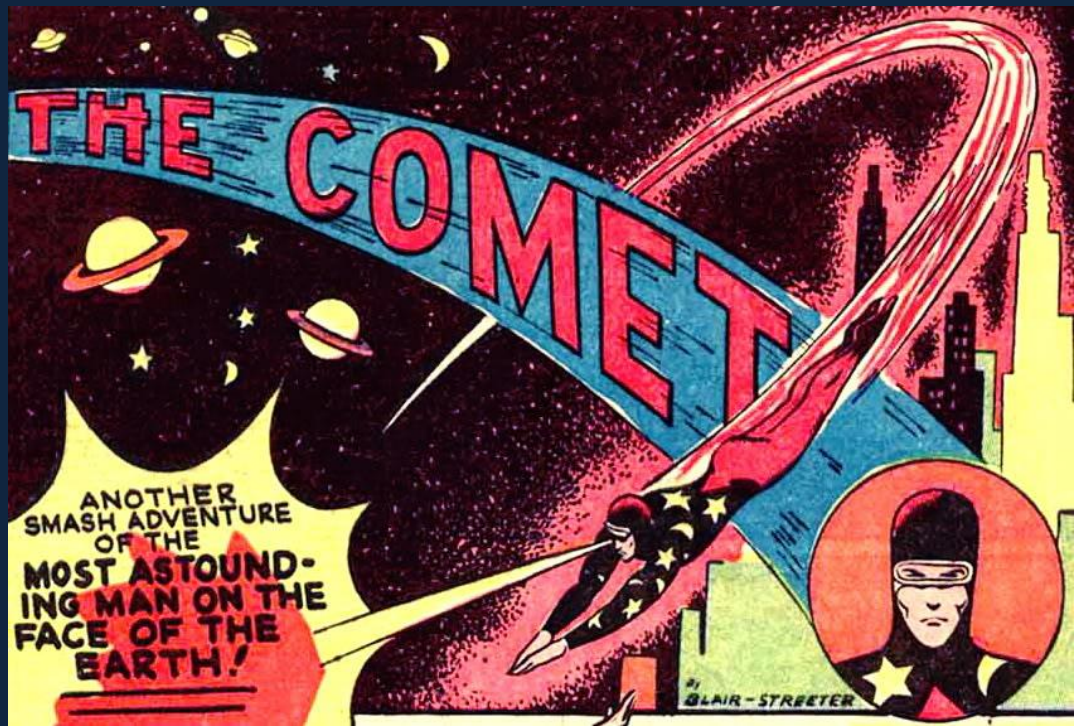
Martin Volwerk
ÖAW - Institut für Weltraumforschung
Graz in Space
4 September 2014

Komet ISON

360 km/s!

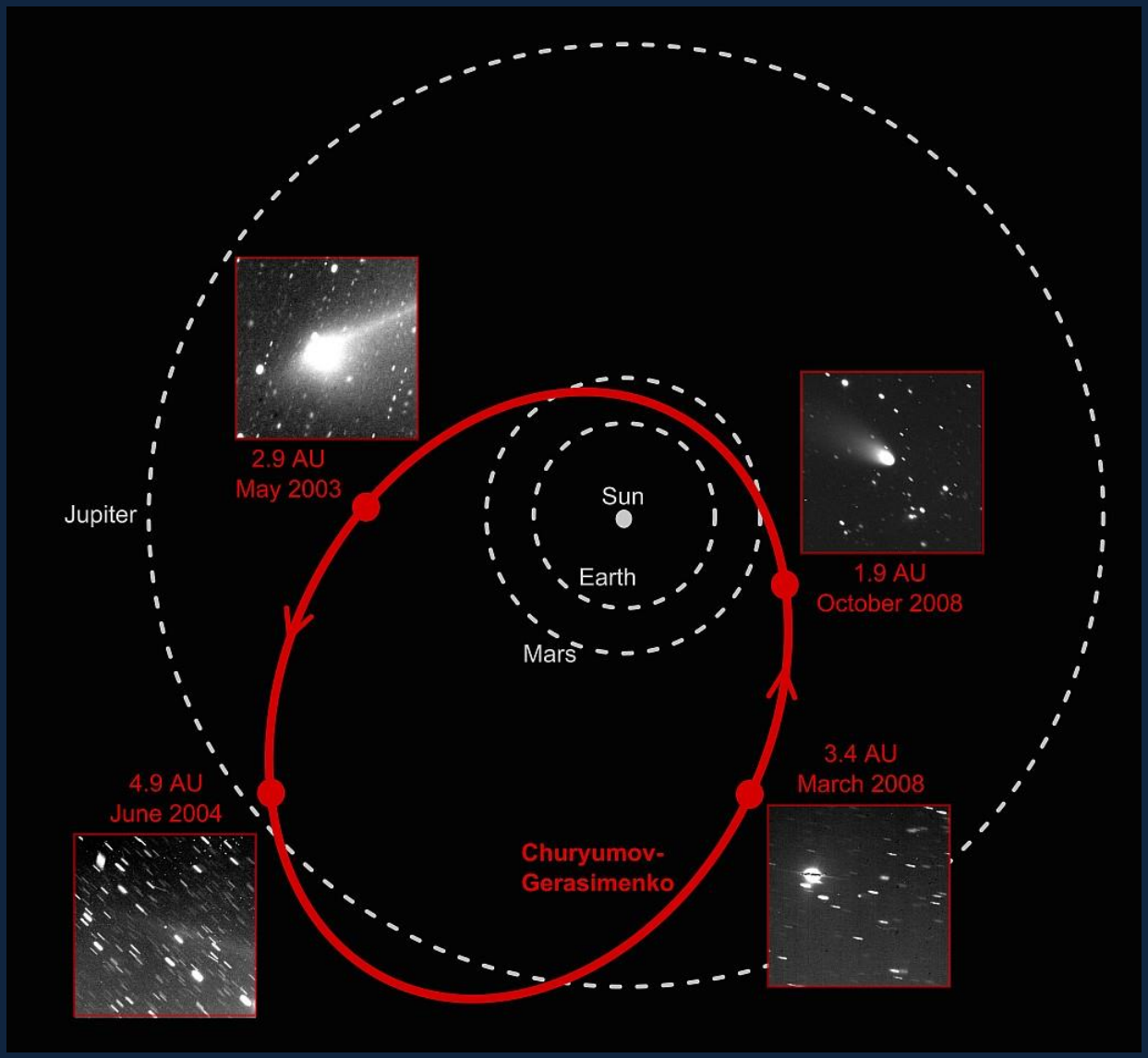
Overview

- Generation of a cometary tail
- Plasma regions around a comet
- Ion species determination from magnetometer data
- X-ray emission from cometary comas
- Rosetta Mission



Changing Activity of a Comet

- Heating of the comet after entering Jupiter's orbit
- Volatiles start to be emitted



Emission of Volatiles

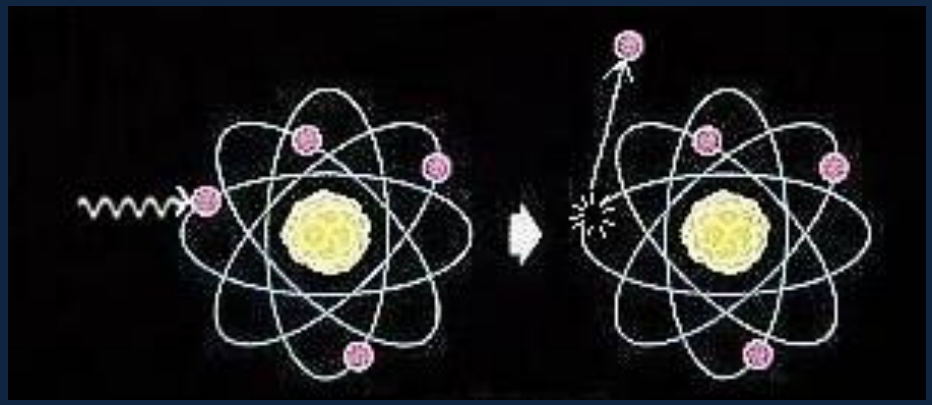
- Sufficient solar heating of cometary surface
- Sublimation of volatiles on surface
- Pressure build-up below the surface
- Geysirs of gas

Comet 67P/Churyumov-Gerasimenko
Outgassing observed by Rosetta (OSIRIS)

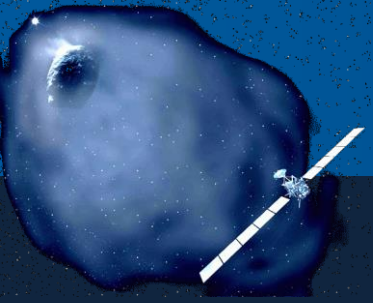
Dangerous Situation

Ionization and Dissociation

- Interaction between solar radiation and molecules
- Ionization of volatiles
  - Creation of free ions and electrons

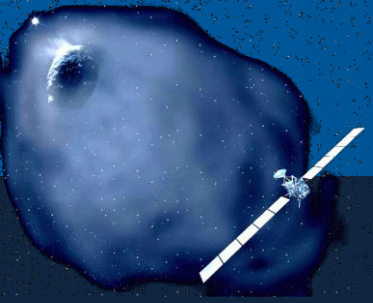


$$h\nu + H_2O \rightarrow H_2O^+ + e^-$$




DC COMICS PRESENTS
SUPERMAN &
CAPTAIN COMET
100,000 YEARS OF EVOLUTION MAKES CAPTAIN COMET MENTALLY & PHYSICALLY SUPERIOR TO THE MAN OF STEEL...
1935 50 DC 1985
BUT WHAT TURNS HIM EVIL?!

Ionization and Dissociation



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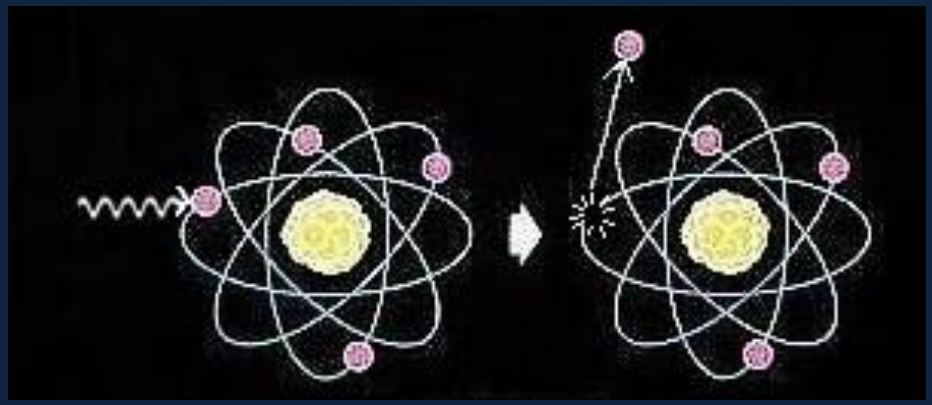

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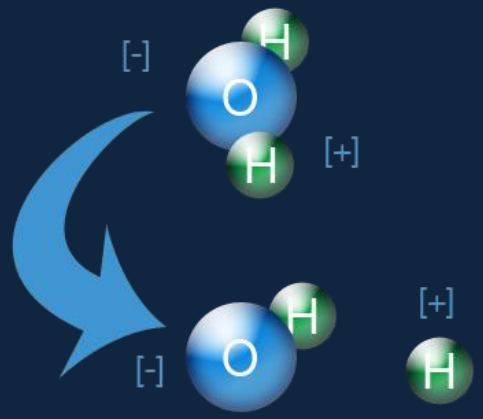
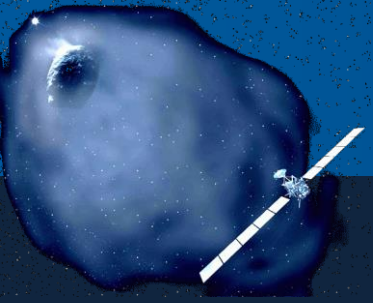
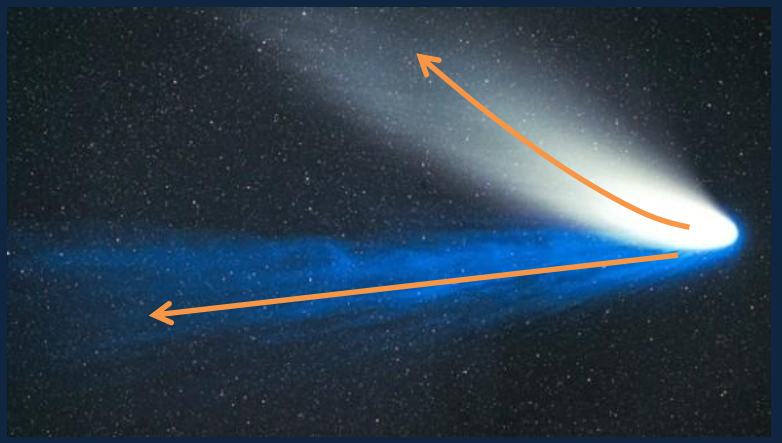


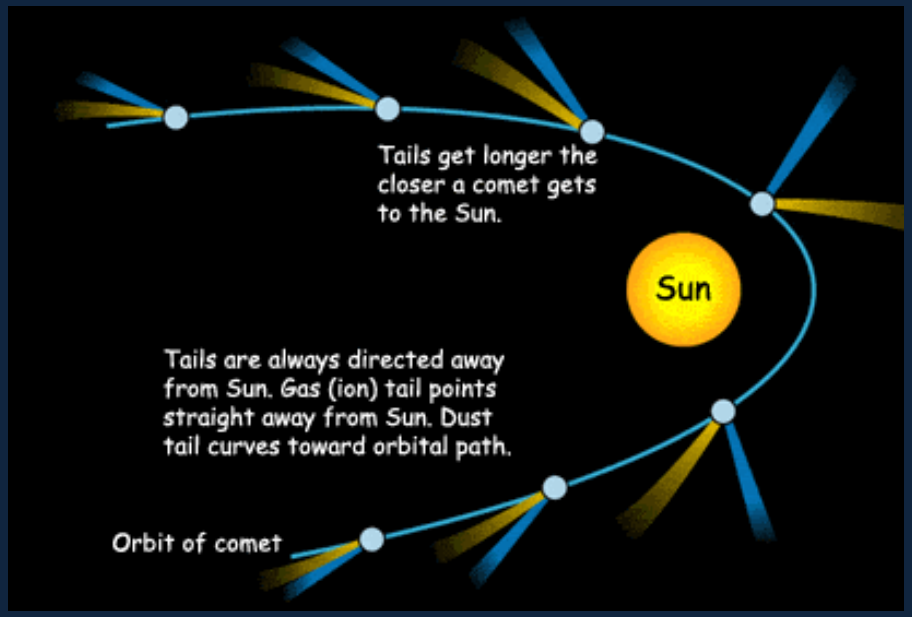
- Dissociation:
  - Change of the molecular structure
  - Two ions: OH^- and H^+

Generation of a Cometary Tail



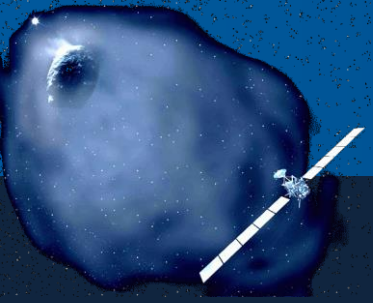
- There are two tails:
  - Dust Tail
  - Gas/Ion Tail





- The escaping dust is blown away by the solar wind and curves around the orbit of the comet
- The ions connect with the solar wind magnetic field and are carried out radially from the Sun direction

Hannes Alfvén's Model (1957)



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By H. ALFVÉN. The Royal Institute of Technology, Stockholm

(Manuscript received June 22, 1956)

Abstract

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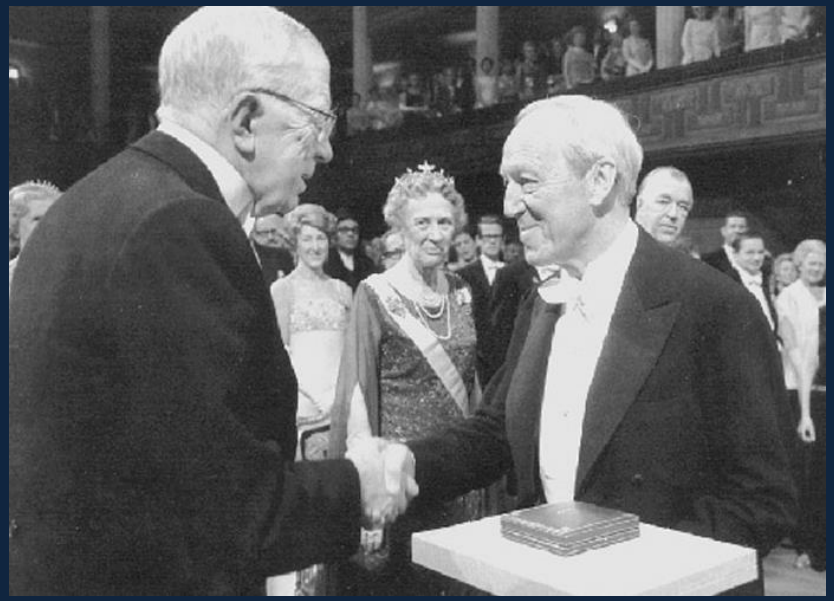
The interaction between such a beam and the head of the comet produces an amplified magnetic field which determines the shape of the tail. The high accelerations, which have been observed in the tails may be due to electromagnetic forces.

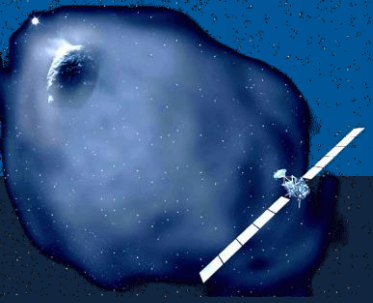


Biermann assumed that the pressure of the solar wind particles „corpuscular radiation" would collimate the escaping ions

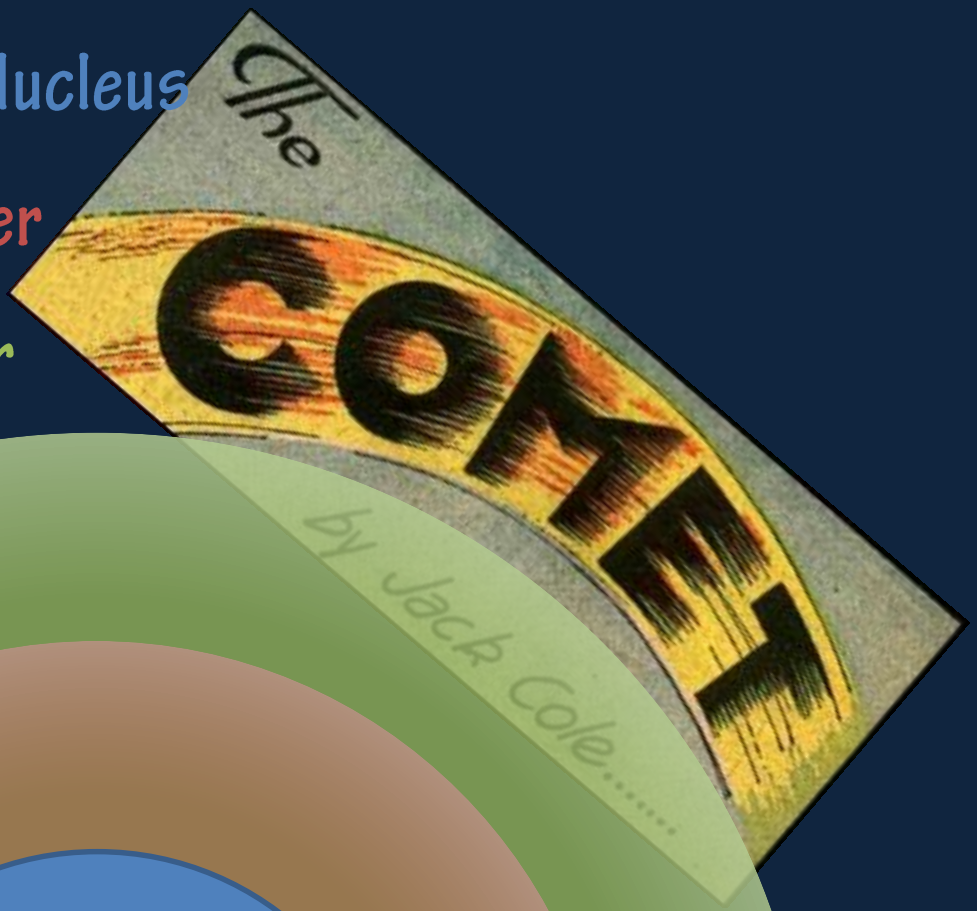
Only after Hannes Alfvén published his plasma theory „MHD" could the creation of the ion tail be explained

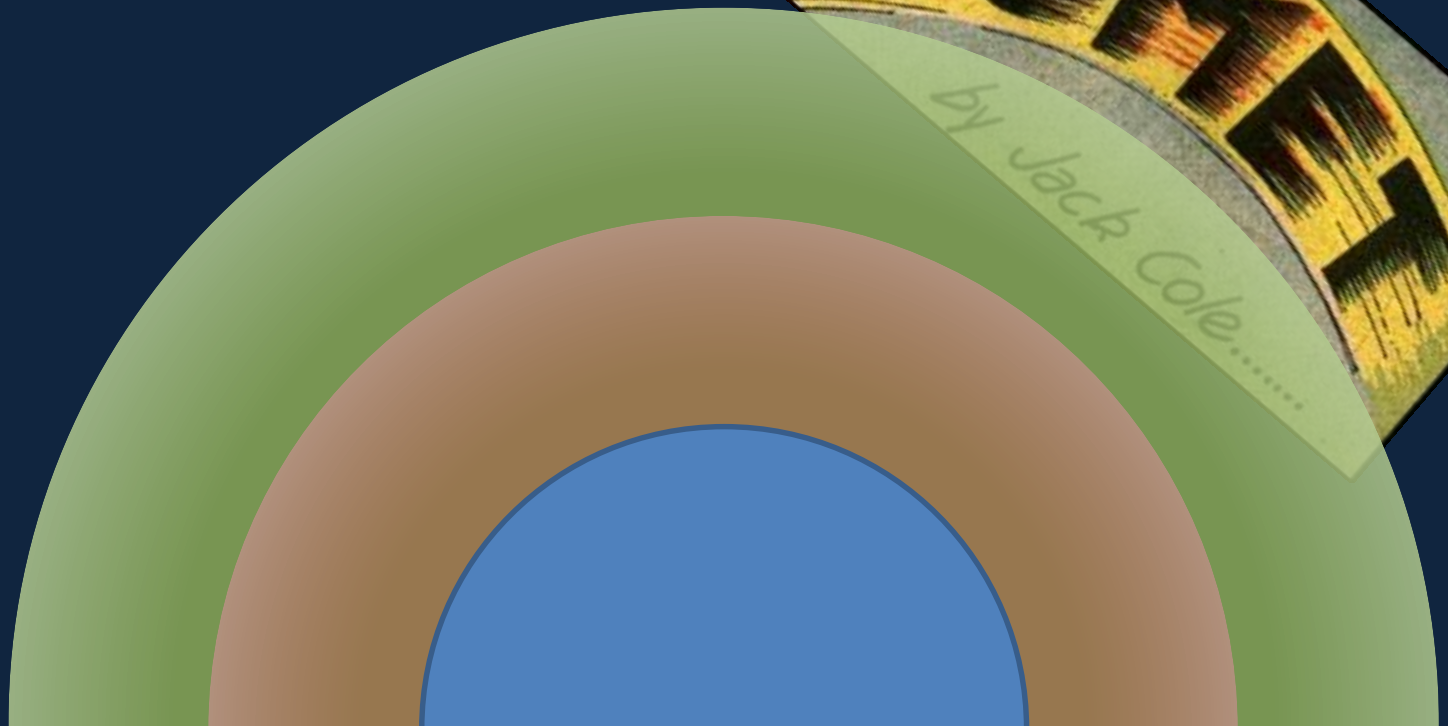
Alfvén in his own words

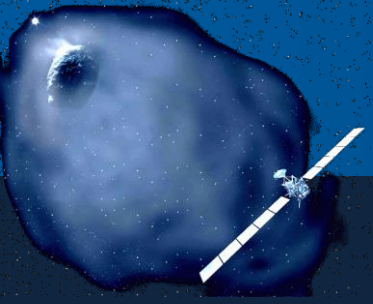
Gas/Ion Layers around a Comet



- Outgassing Cometary Nucleus
  - Rarifying Gas Layer
    - Ionized Layer



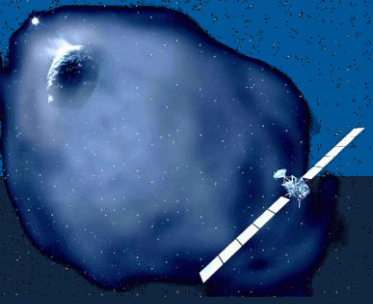




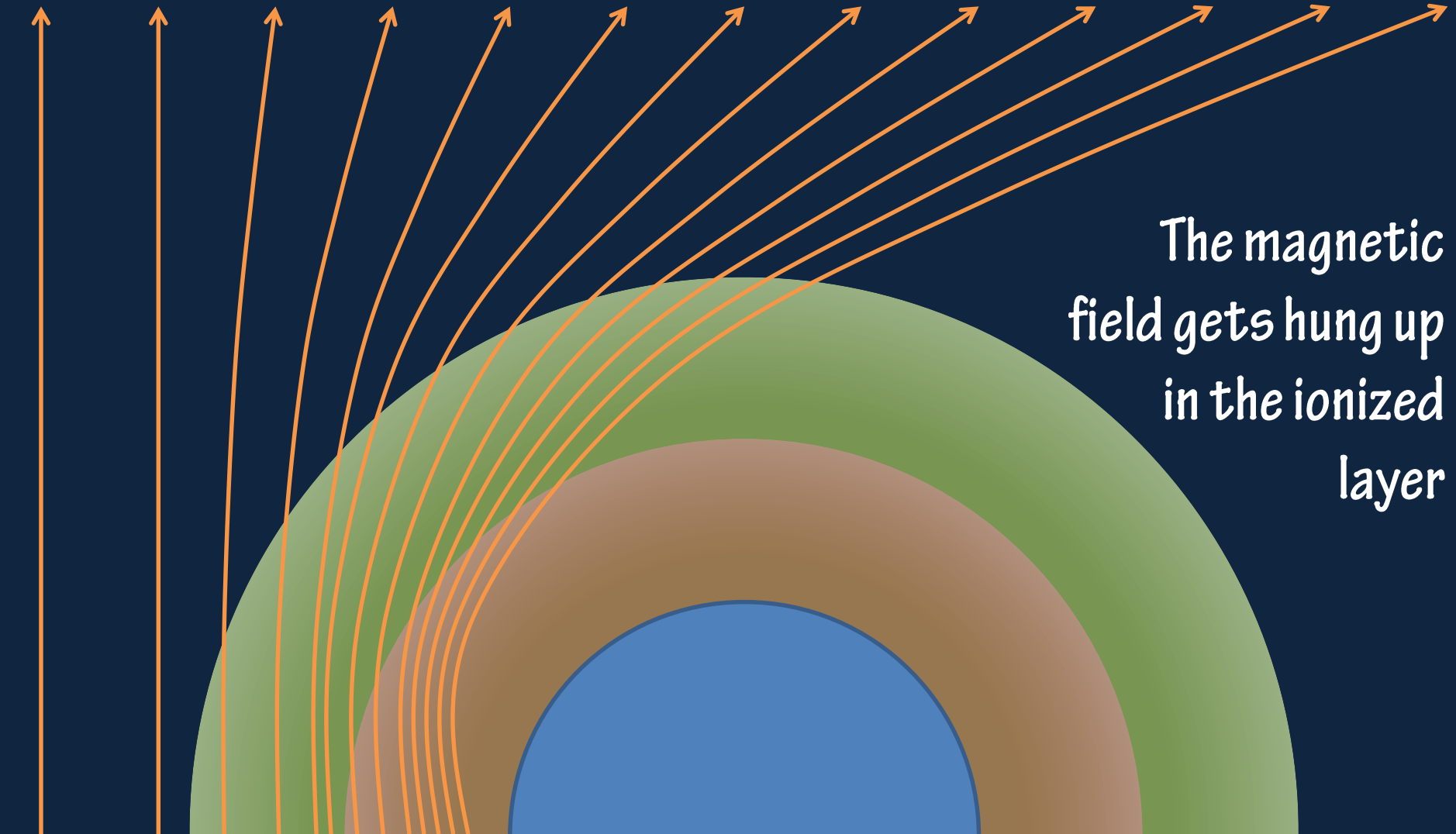
Gas Layer and Magnetic Field

With Solar Wind Velocity!

Ionized Layer and Magnetic Field



With Solar Wind Velocity!



The magnetic field gets hung up in the ionized layer

Alfvén's Explanation Works

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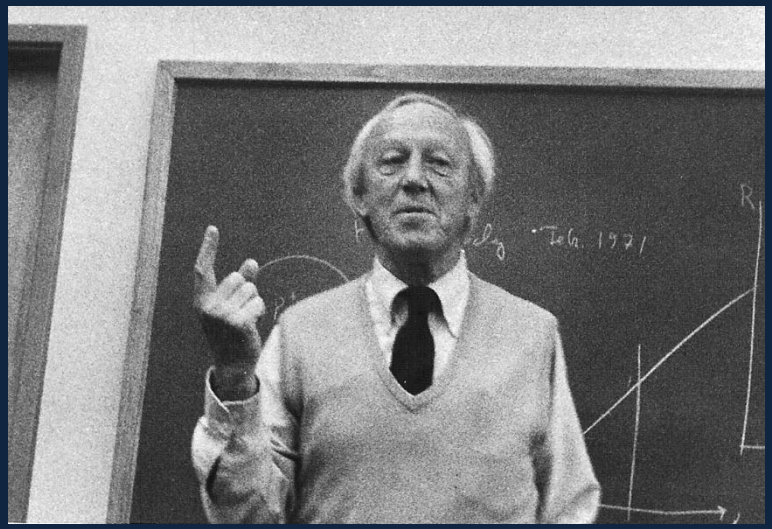

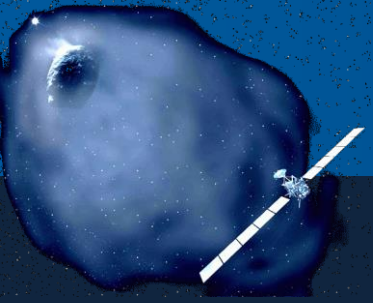

The Origin of a Cometary Ion Tail

Alfvén's Explanation Works

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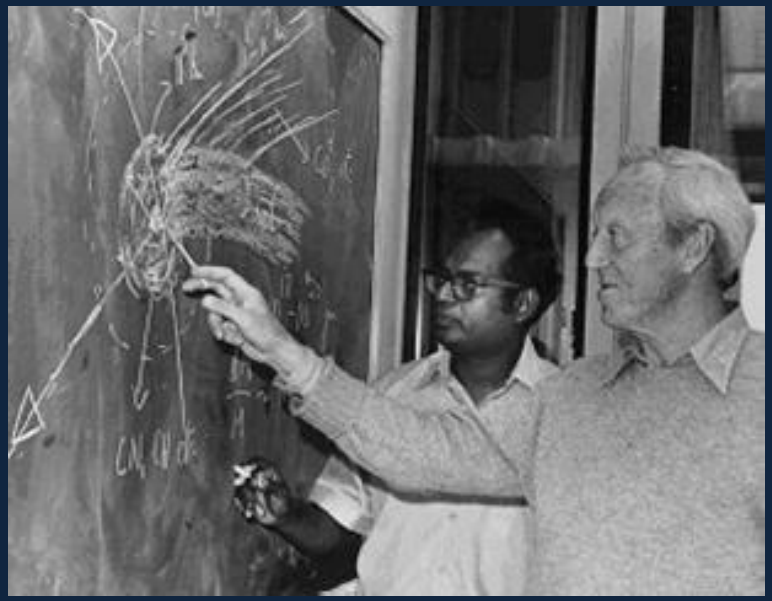


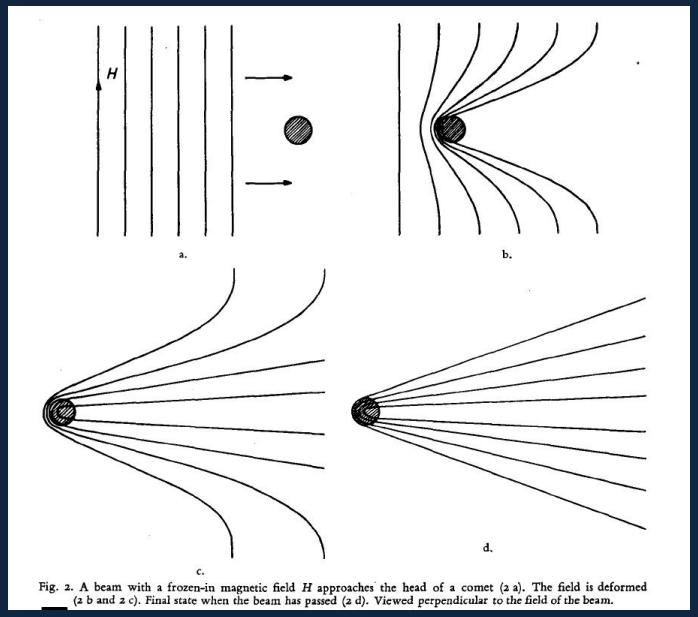
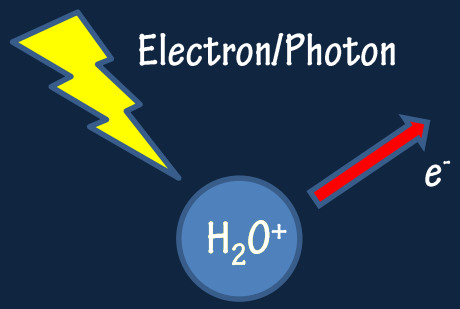


Fig. 2. A beam with a frozen-in magnetic field H approaches the head of a comet (2 a). The field is deformed (2 b and 2 c). Final state when the beam has passed (2 d). Viewed perpendicular to the field of the beam.

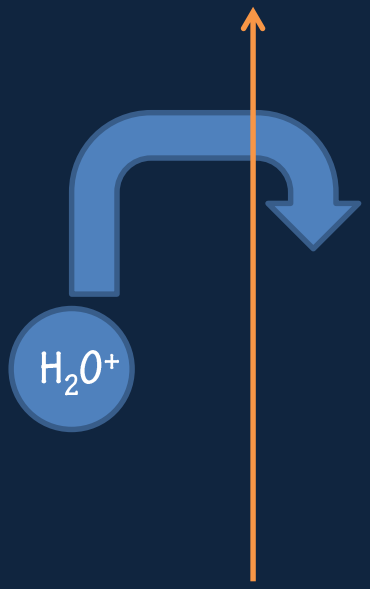
The magnetic field lines, frozen into the solar wind (MHD) are draped around the cometary nucleus.

Determination of Ion Species

without measuring actual particles?

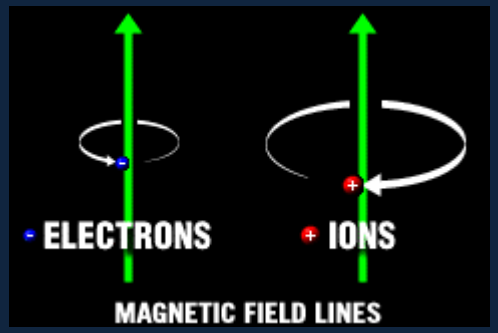


Ionisation



Magnetic deflection

Cyclotron Waves



Spiralling around the magnetic field

Cyclotron Waves in Magnetometer Data

- Ions gyrate around the magnetic field lines
- The frequency is dependent on the mass and charge of the ion and the field
  - $f = q B / 2 \pi m$
- Generation of waves in the magnetic field
  - Water ($m = 18\ m_p$, $q = 1\ e$) and $B = 20$ nT
  - $T = f^{-1} \approx 59$ seconds

Glaßmeier & Neubauer [1993]

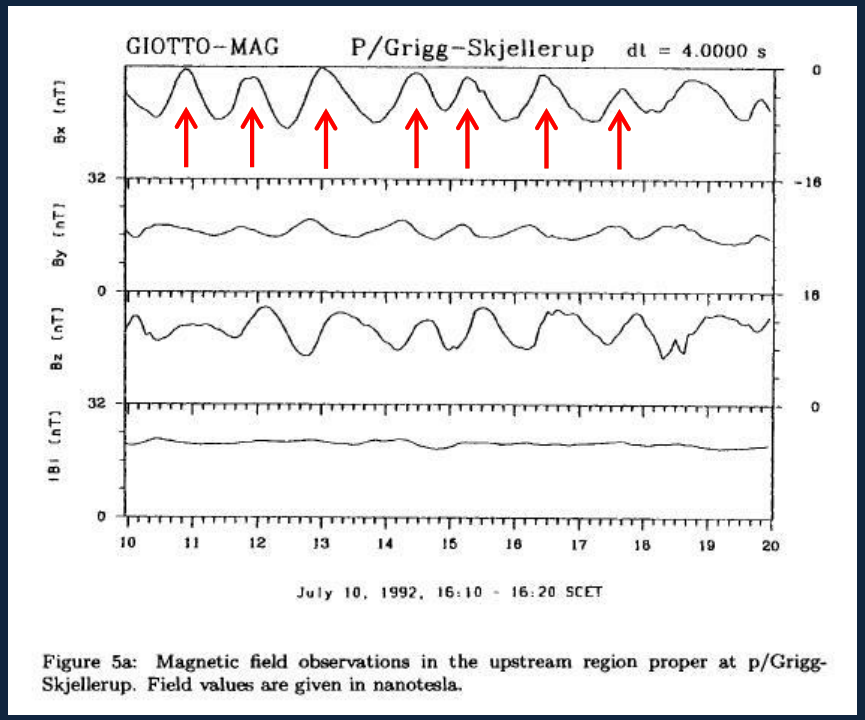


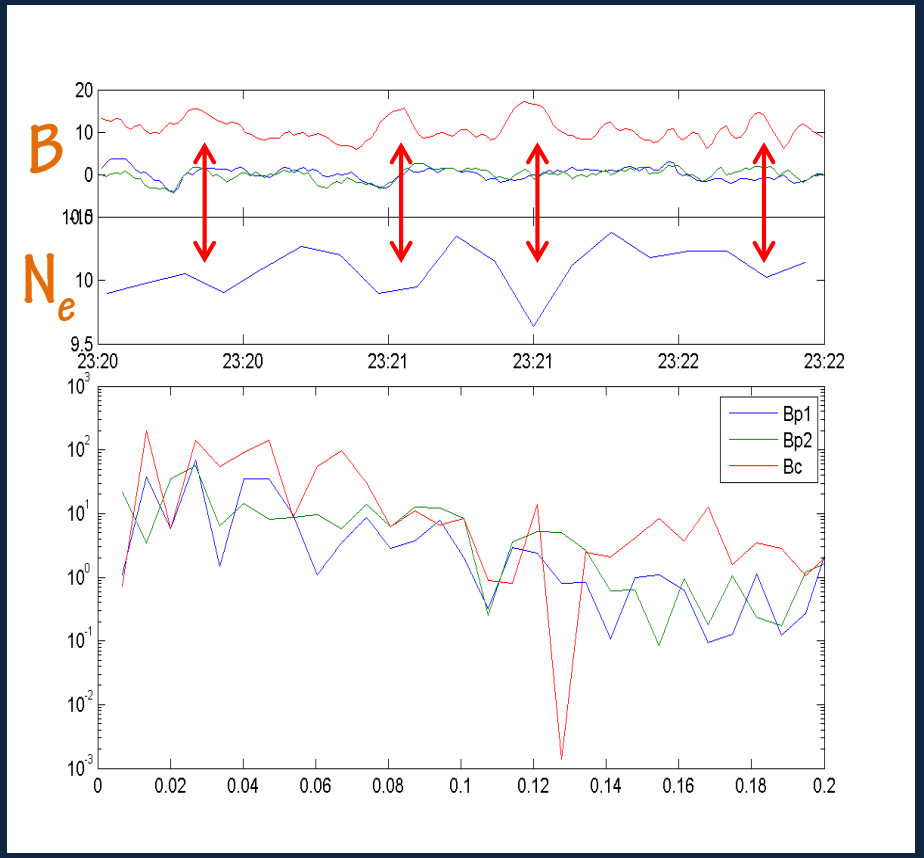
Figure 5a: Magnetic field observations in the upstream region proper at p/Grigg-Skjellerup. Field values are given in nanotesla.

Magnetic field data from Giotto at Comet 27P/Grigg-Skjellerup, nice waves at the water cyclotron period

Magnetic Bottles

- Not always cyclotron waves
- E.G. at Comet 1P/Halley

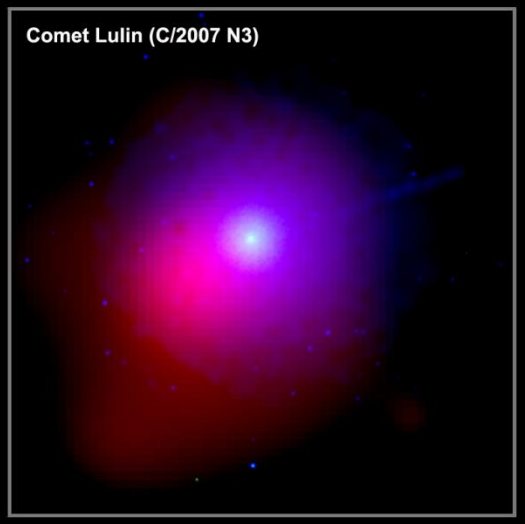
- Mirror-mode-waves
- Particle pressure perpendicular to B-field
- Creation of magnetic bottles



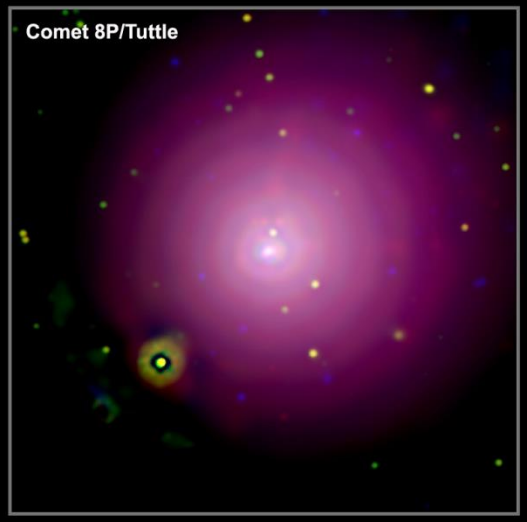
The size of the bottles is about 1-2 gyro radii

Swift Observations

A trio of recent comets seen by NASA's Swift



Swift imaged Lulin on Jan. 28, 2009, in ultraviolet and visible light (blue, green) and X rays (red).

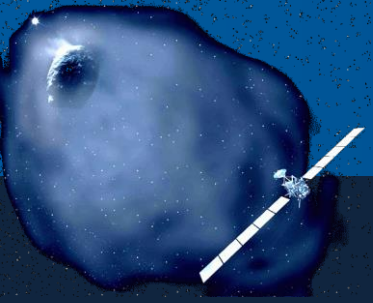


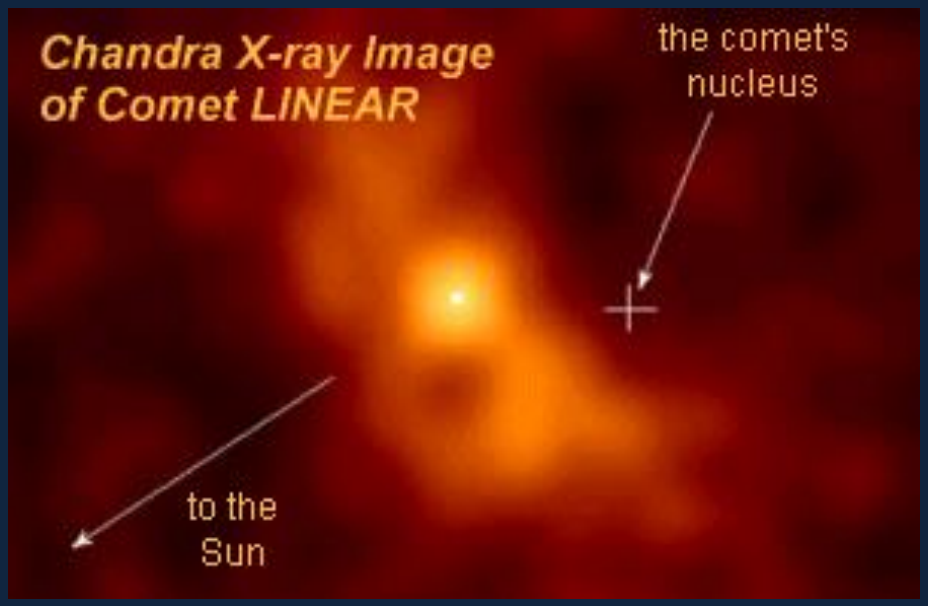
Swift imaged 8P/Tuttle on March 4, 2008, in ultraviolet (blue) and visible light (green and red).

Swift imaged this fragmenting comet May 2, 2006, in ultraviolet (blue) and visible light (green and red).

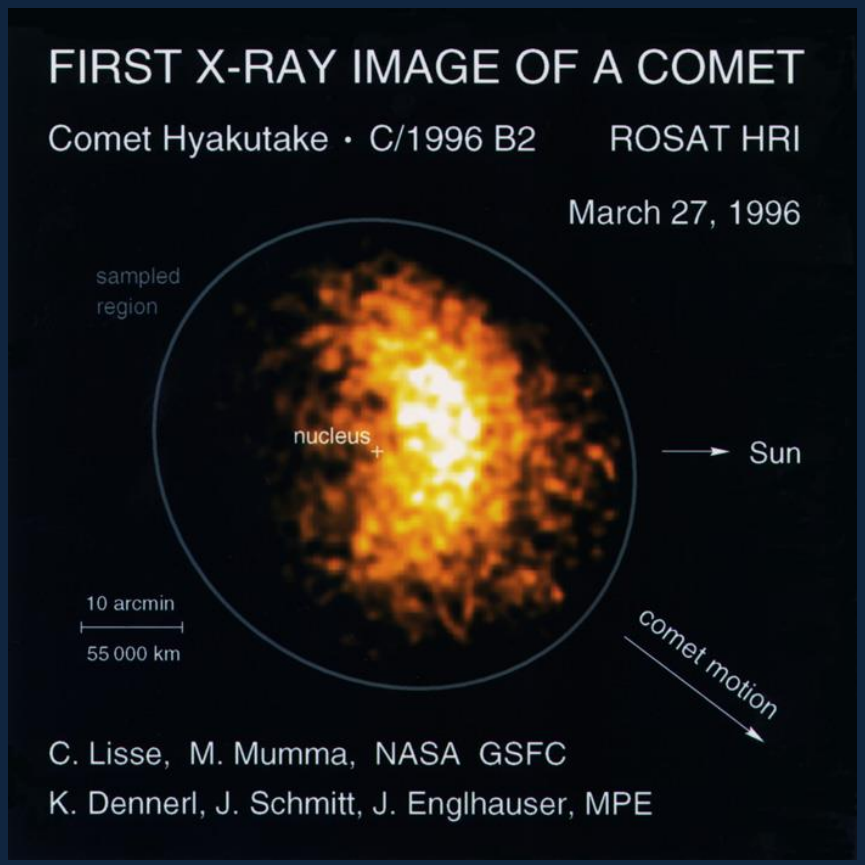
Credits: Lulin: NASA/Swift/Univ. of Leicester/Bodewits et al.; Tuttle, Schwassmann-Wachmann 3: NASA/Swift/Bodewits & Immler

Cometary X-rays





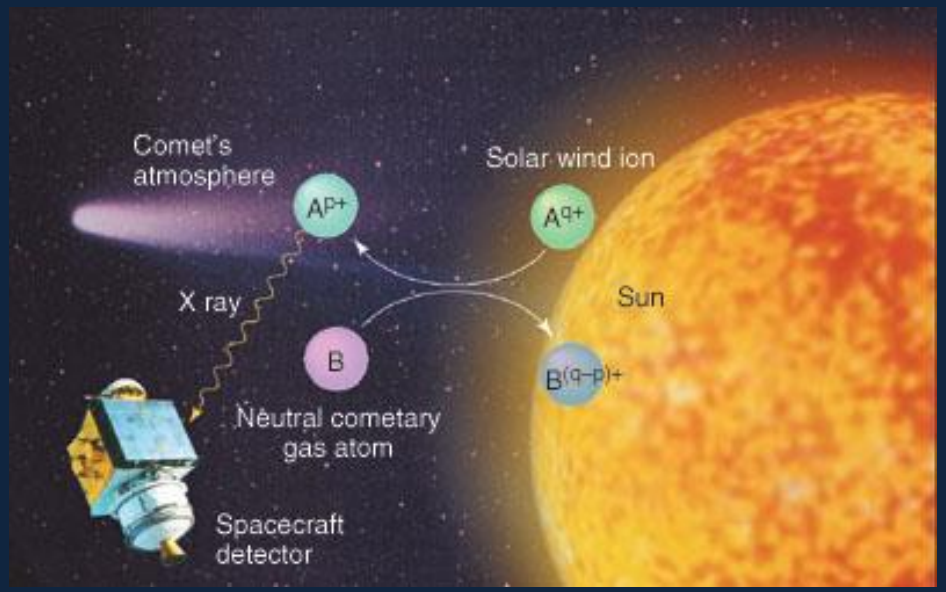
A surprise when X-ray satellites observed comets

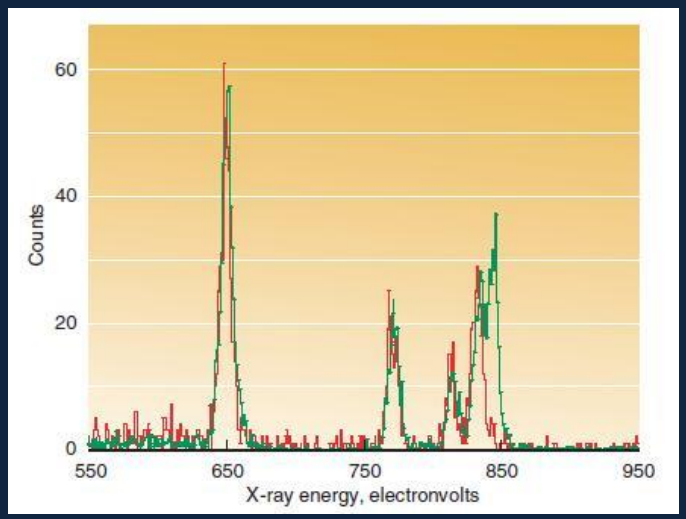


Low-energetic X-rays
(< 1 keV)

Wherefore?

Simply reflected solar radiation?





- No!
- Solar wind ion collides with a cometary molecule
- $A^{p+} + B \rightarrow A^{q+} + B^{(q-p)+}$
- An example:
- $O^{8+} + CH_4 \rightarrow O^{7+*} + CH_4^+$
- $O^{7+*} \rightarrow O^{7+} + Xray$
- Laboratory Experiments

And so it ends

The interaction of an outgassing comet with the solar wind :

- Creates a coma and ion and dust tail;
- Ion tail is created by hung-up IMF magnetic field
- Freshly ionized species create various wave modes
- Neutrals interact with SW ions to create X-rays

67P/Churyumov-Gerasimenko

IWF