Summary of observation of interplanetary and interstellar dust by Mars Dust Counter on board NOZOMI

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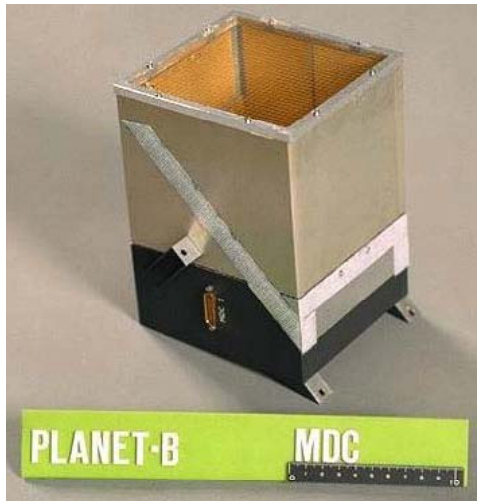
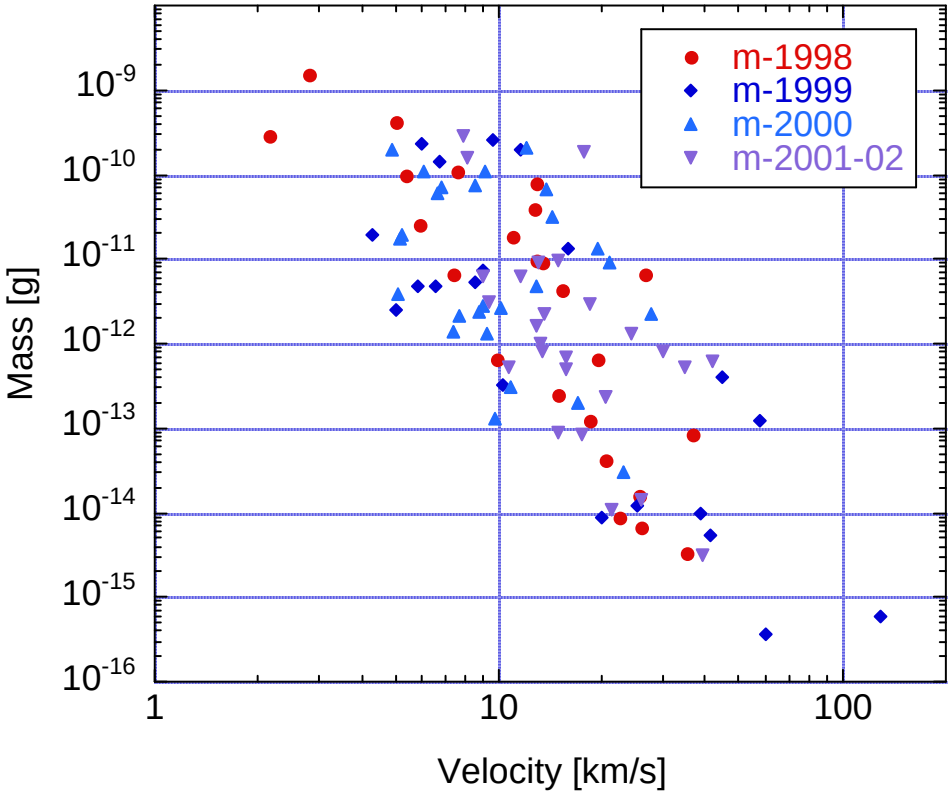
Mars Dust Counter (MDC)

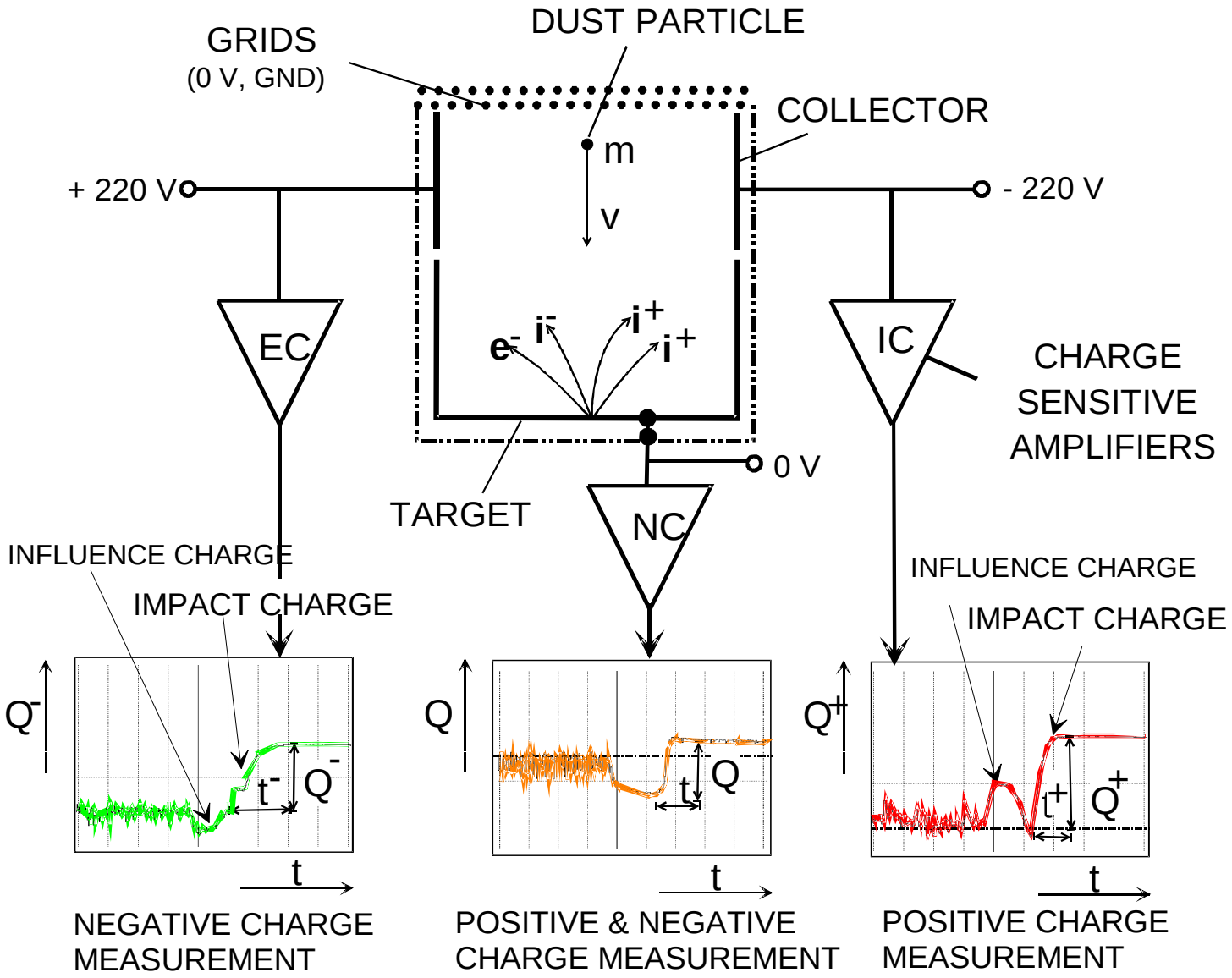


- Impact-ionization type
- 730g including electronics
- 124 x 115 mm^2 aperture

- 4-Year operation.
- 120 dust impacts detected. (100: v & m estimated)
- Most dust particles are Keplerian IDPs around the sun.
- A few particles probably of interstellar origin were detected in 1999.

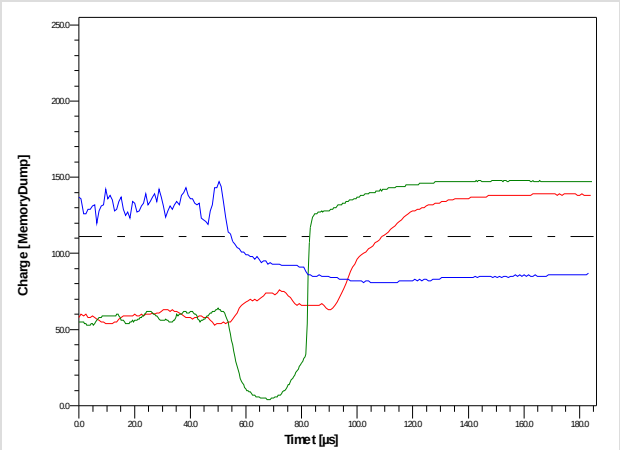


3 Channel Impact Ionization Detector



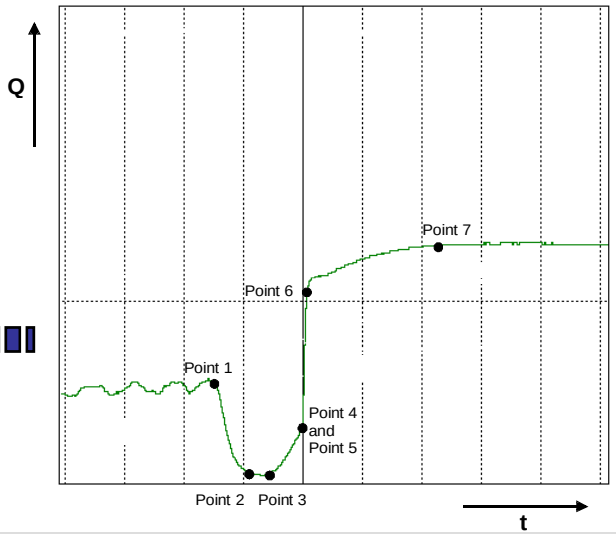
Data Analysis

MDC Raw Data

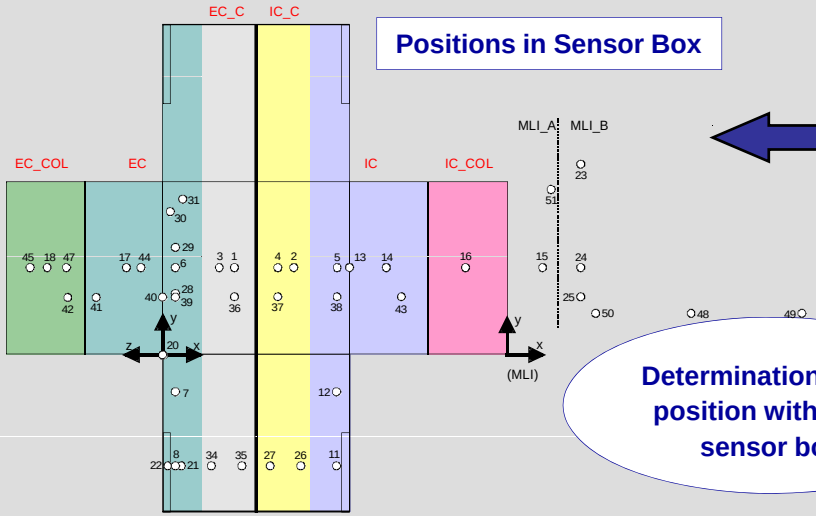


Determination of 7 characteristic points for each channel

Electron Channel Signal



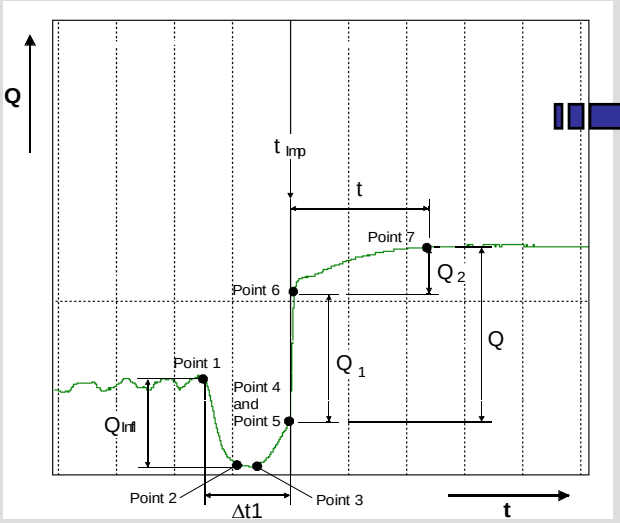
Positions in Sensor Box



Determination of the position within the sensor box

Calculation of Particle Mass and Velocity

Electron Channel Signal



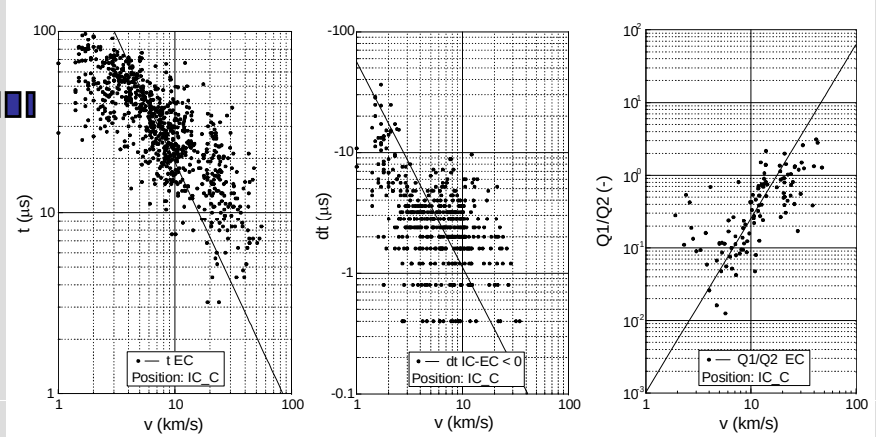
Calculation of velocity and mass using parameters of determined postion

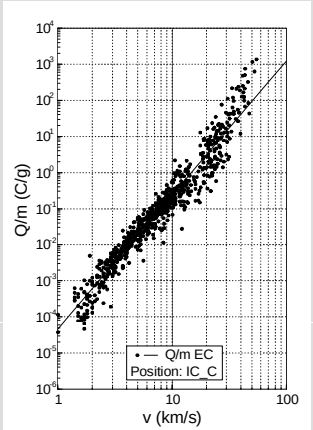
Risetime : $v = C_t \cdot t^{\eta}$

Delaytime : $v = C_{dt} \cdot dt^{\kappa}$

Charge Ratio : $v = C_{12} \cdot \left(\frac{Q_1}{Q_2} \right)^{\delta}$

$\Rightarrow v_{mean}$





$$m = \frac{Q}{C_{\rho} \cdot v_{mean}^{\beta}}$$

Main Objective of NOZOMI-MDC
=(was) Detection of Martian Dust Ring

- Phobos and Deimos
  - Covered with regolith (< mm particles)
  - Low escape velocity (10m/s)
- Collisions of interplanetary dust particles
  - Ejection of regolith particles
  - Source of a dust ring
- All of Jovian planets have dust rings

Dust Particles Around Mars

- Lorentz force (r < 1μm)
- Solar radiation pressure ⇒ eccentricity↑
- Martian oblateness
  - Small dust are trapped by Mars and lost quickly
- Dust from Phobos r > 22μm
- Dust from Deimos r > 12μm, inclination ↑

  ➔ Phobos' ring and Deimos' torus

- Self-Sustaining mechanism
  - No (η < 1) small dust abundance
    - Direct detection by NOZOMI is difficult
    - Statistical analysis is necessary
  - Yes (η > 1) large dust abundance
    - Detectable by NOZOMI-MDC
    - A few particles at Phobos' ring crossing

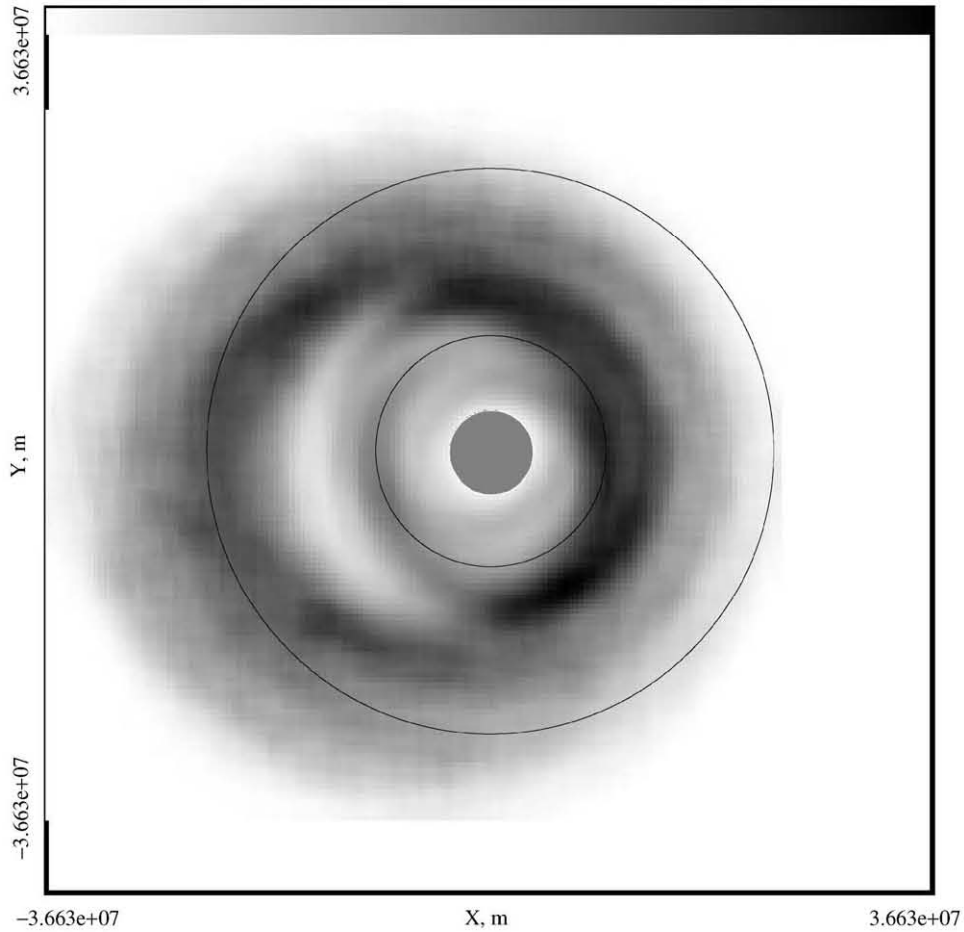


Fig. 1. Both dust belts in martian spring, projected onto the equatorial plane of Mars. Circles mark Mars itself and the orbits of Phobos and Deimos. X-axis points toward Mars' vernal equinox point (coincides with the direction toward the Sun). We used scatter plots produced by numerical integration routine for 20 μm-sized Phobos and 10 μm-sized Deimos grains, distributed 250,000 instantaneous positions of particles into 135×135 bins in the XY-plane, and used sliding averaging over three adjacent bins in each direction. For each of the two belts greyscale is proportional to the column density of dust particles. However, the column density of the Phobos dust is artificially increased by a factor of 50 (otherwise the Phobos torus would not be visible in the plot).

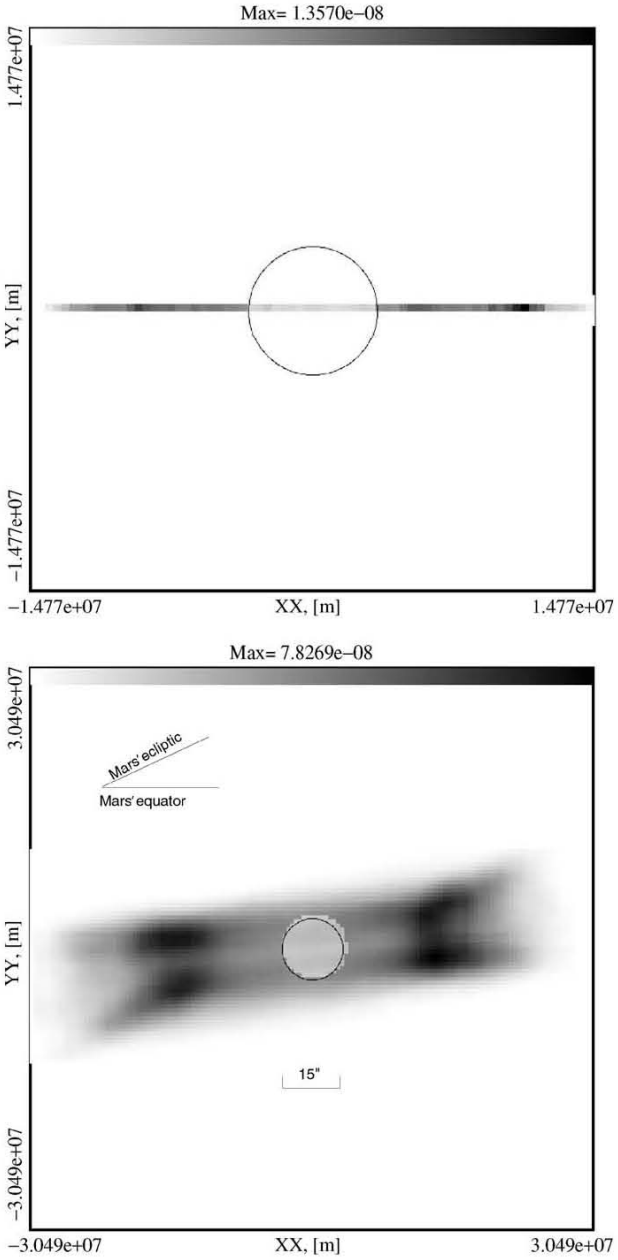
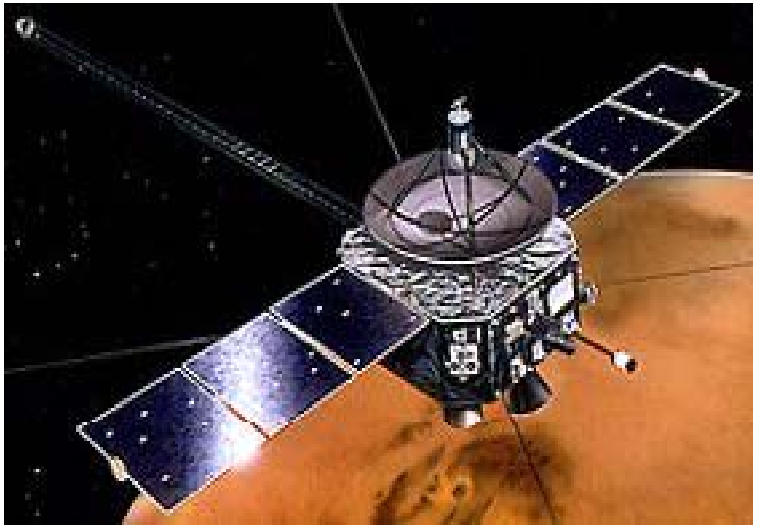


Fig. 3. Distribution of the optical depth of (or radiation fluxes from) the Phobos ring (top) and Deimos torus (bottom), as seen during the observations from Earth in December 2007. Pixel size adopted: $1'' \times 1''$. Note different scales on the two panels: each is adjusted to the spatial extent of the corresponding dust belt.

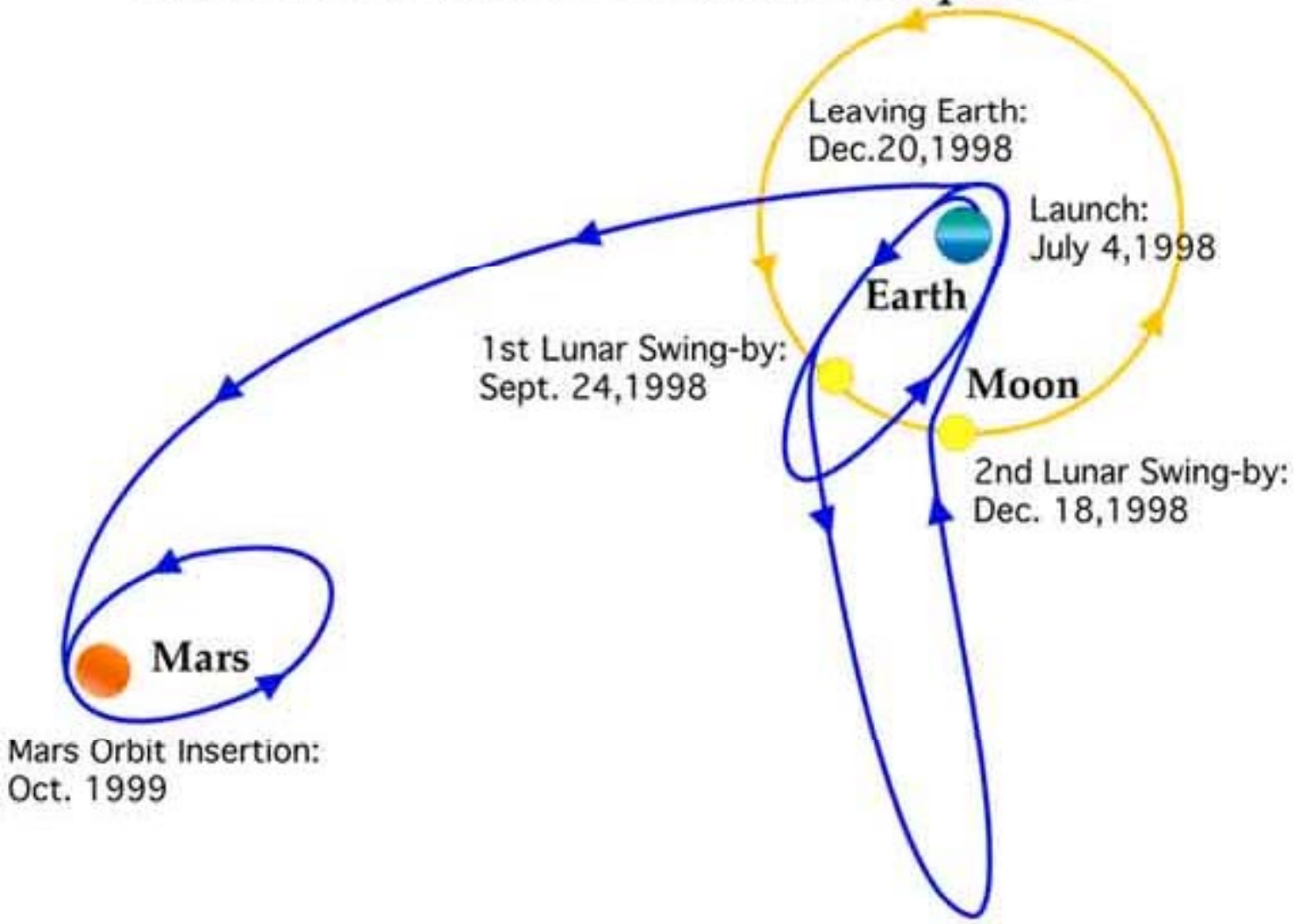
NOZOMI

- Mars aeronomy mission
- Interaction between the Martian upper atmosphere and solar wind
- Elliptic retrograde orbits whose apoapis is farther than Deimos' orbit.

- 98-07 Launch
- 98-12 Earth's flyby
- 99-10 => 02-10
  planned observation
  around Mars



"NOZOMI"(PLANET-B) Mission Sequence



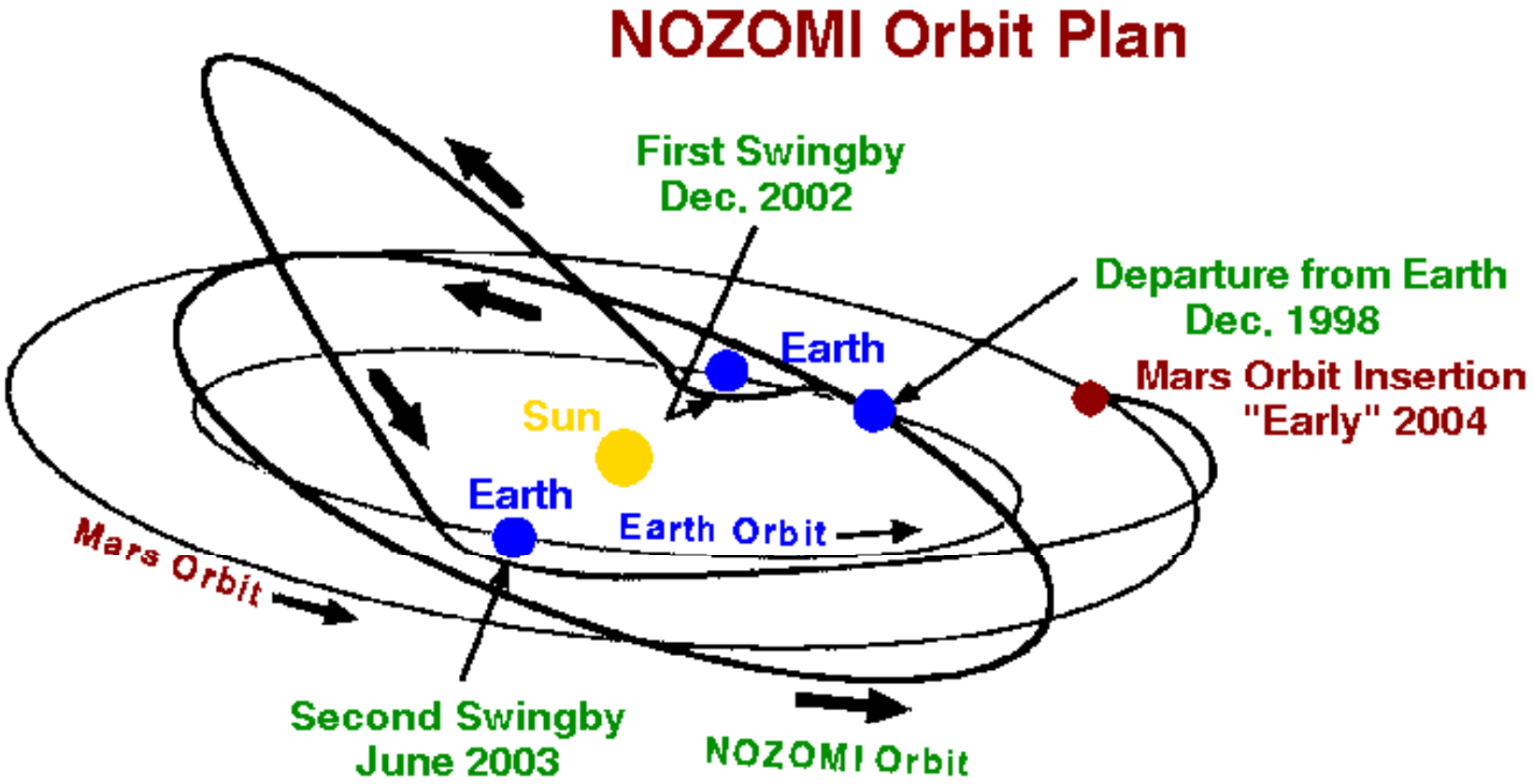
NOZOMI Schedule and Troubles

- 98-07 Launch
- 98-12 Use too much fuel at leaving from the Earth (powered fly-by).

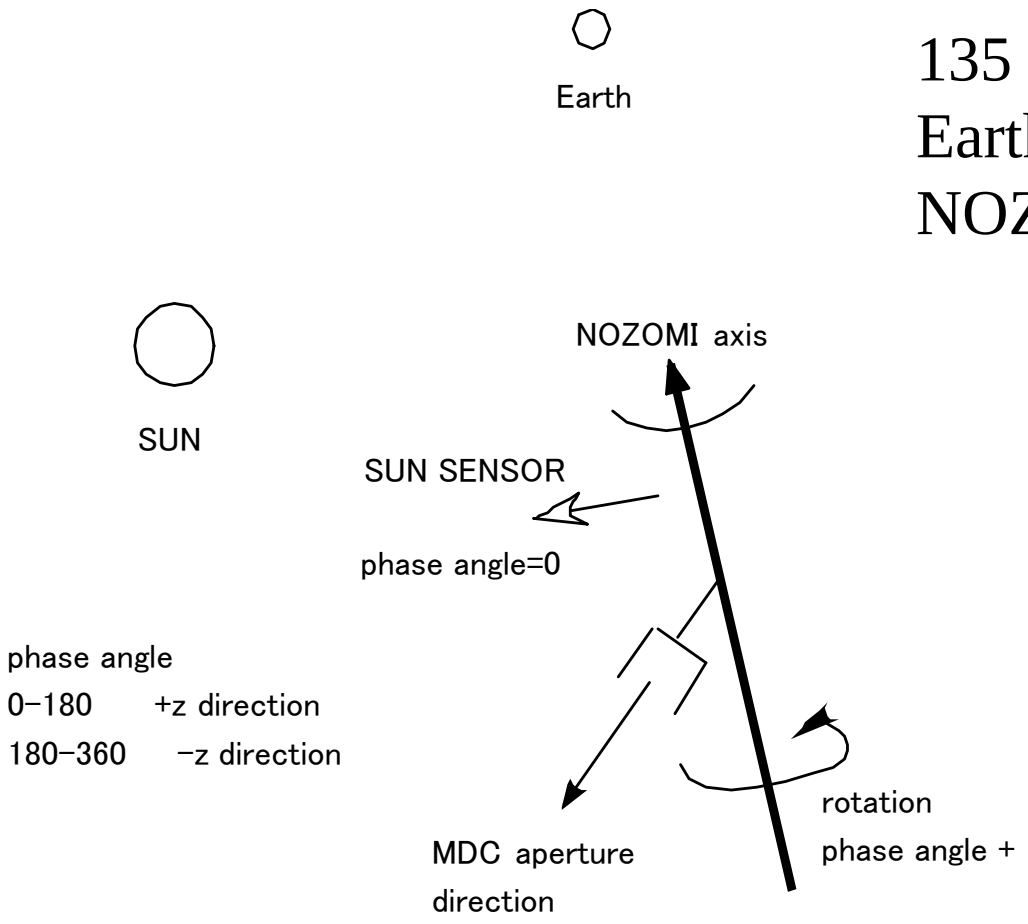
  Change of orbital plan.

  Mars arrival 99-10 => 03-12
- 99-07 Stop S-band downlink.

  Less problem except occultation experiment
- 02-04 Trouble on CI-PSU. Maybe a short-circuit.
- 03-12 Gave up insertion into circummartian orbits.


NOZOMI Orbit Plan
First Swingby
Dec. 2002
Departure from Earth
Dec. 1998
Earth
Mars Orbit Insertion
"Early" 2004
Sun
Earth
Earth Orbit
Mars Orbit
Second Swingby
June 2003
NOZOMI Orbit

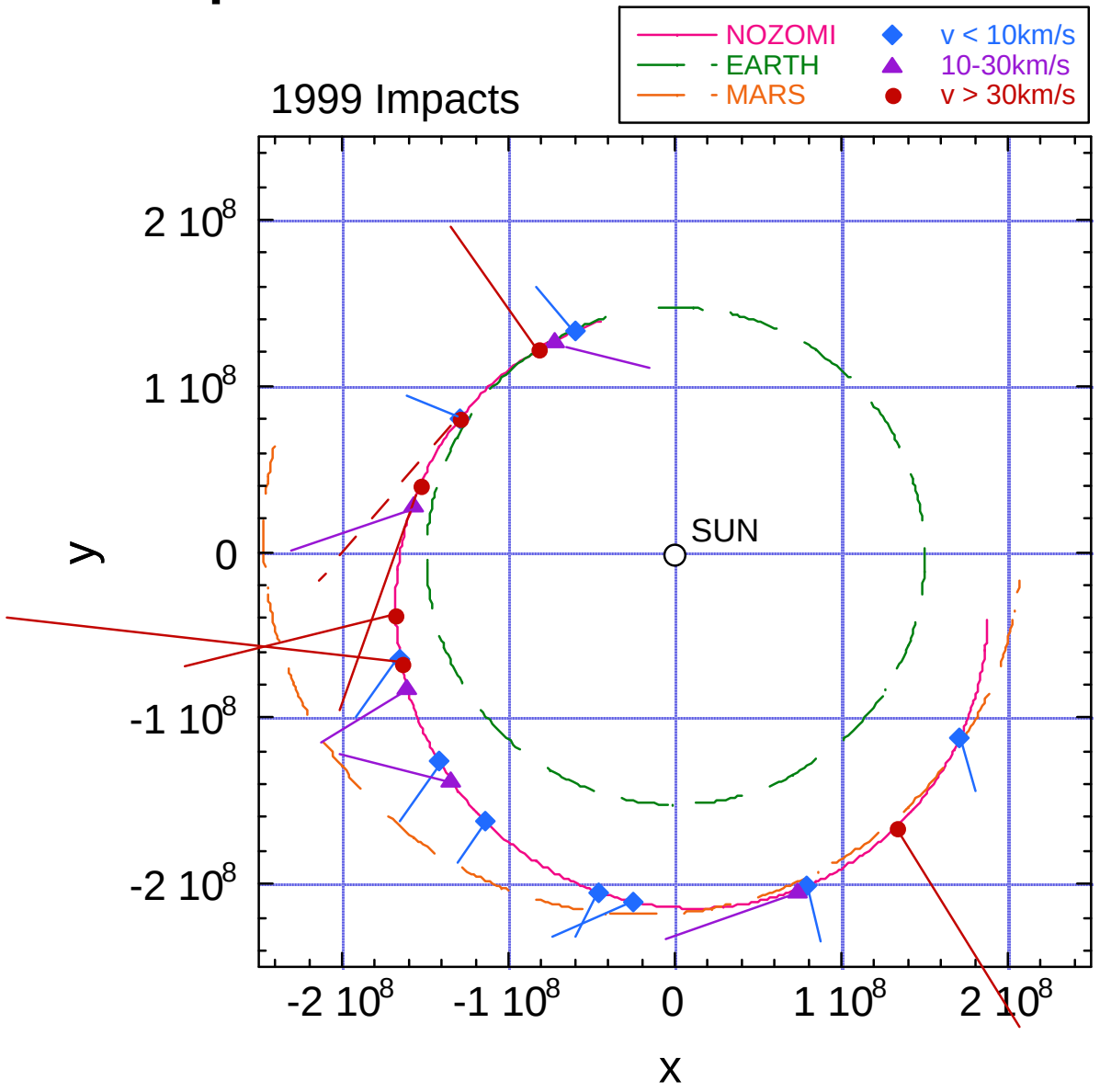
MDC - Aperture Direction



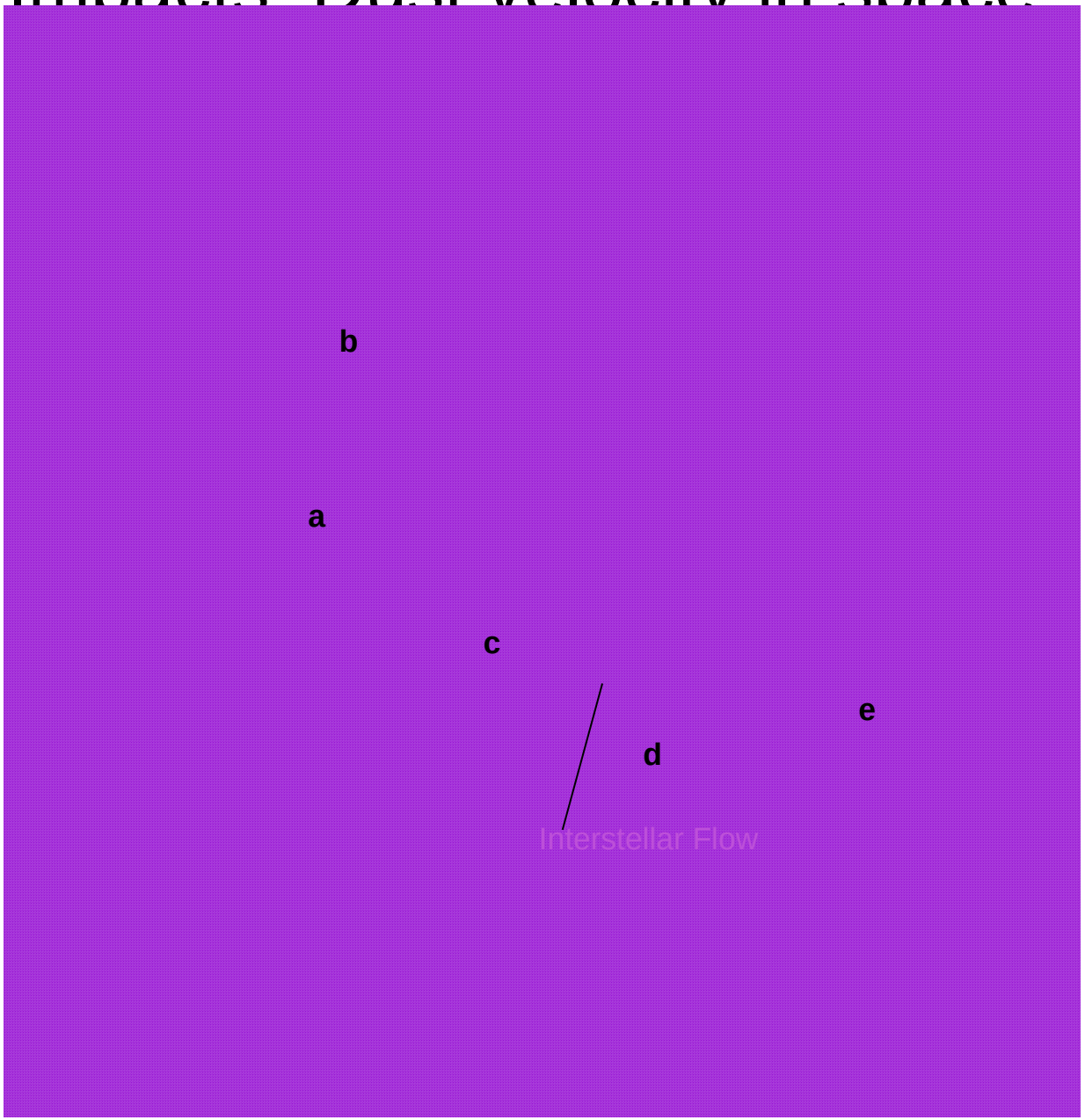
135 degree from the Earth-oriented NOZOMI axis

No direct flux from sunward,
No sunlight illumination into the sensor box

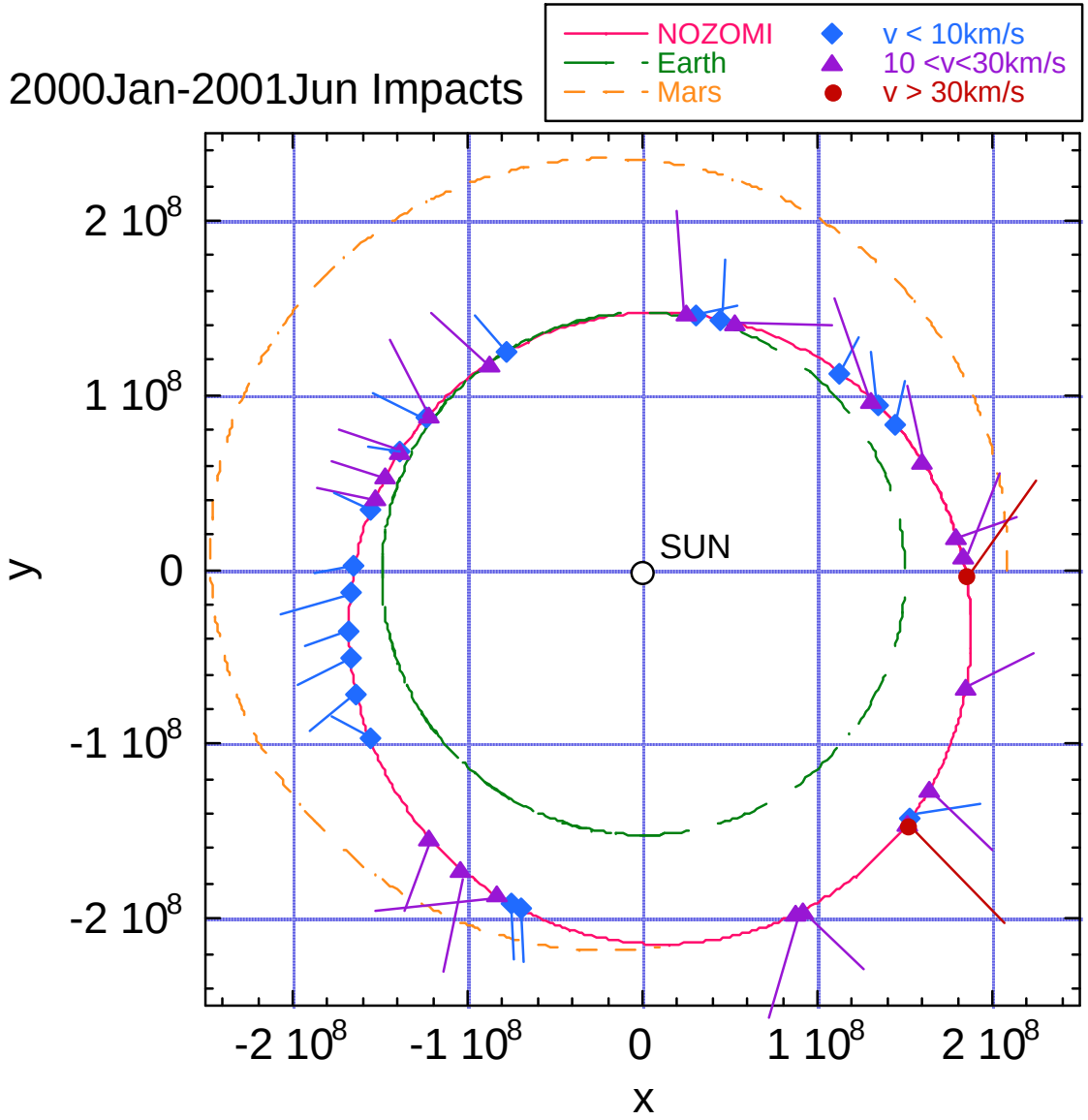
1999 Impacts



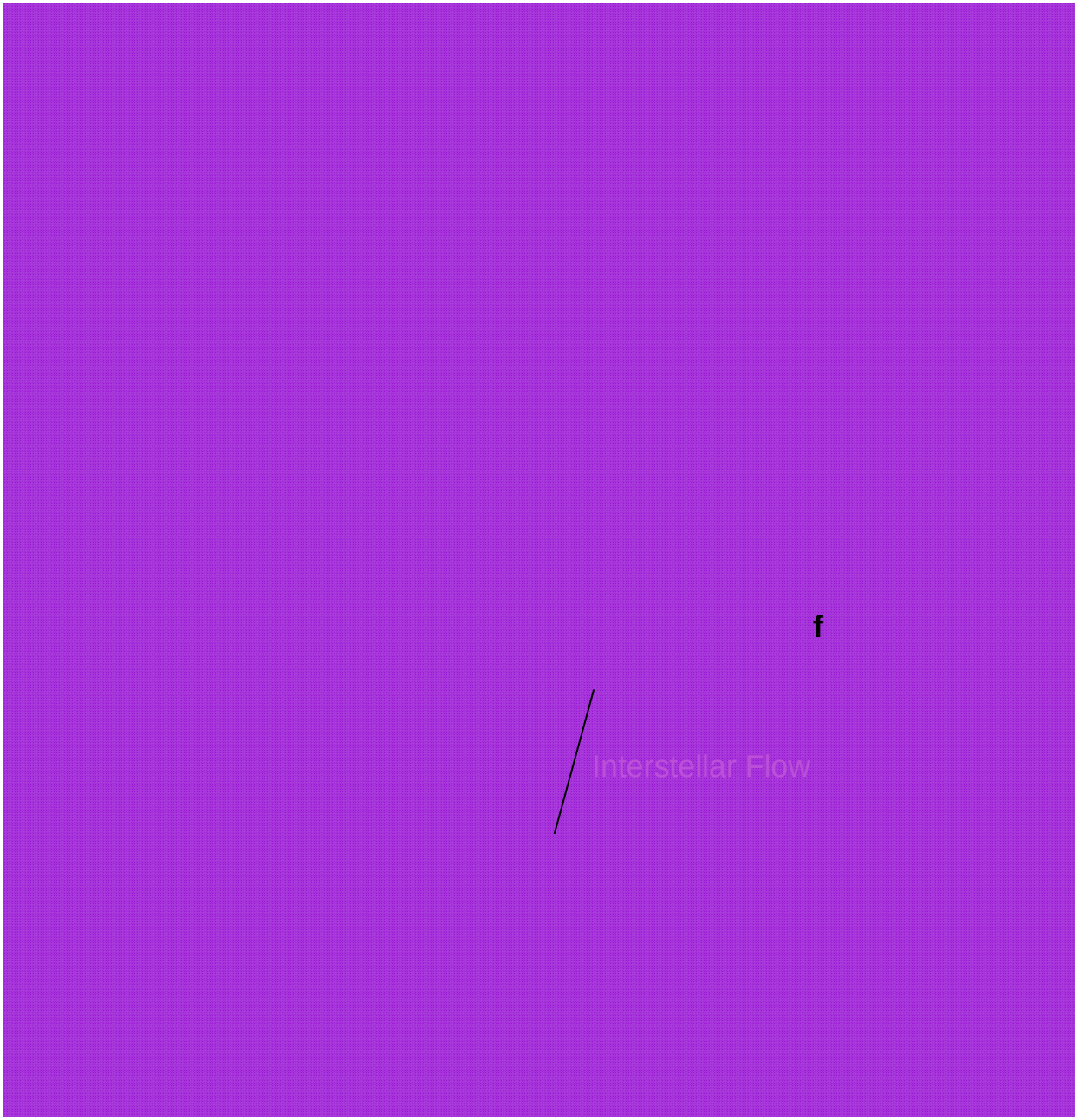
1999 Impacts: Dust velocity in space



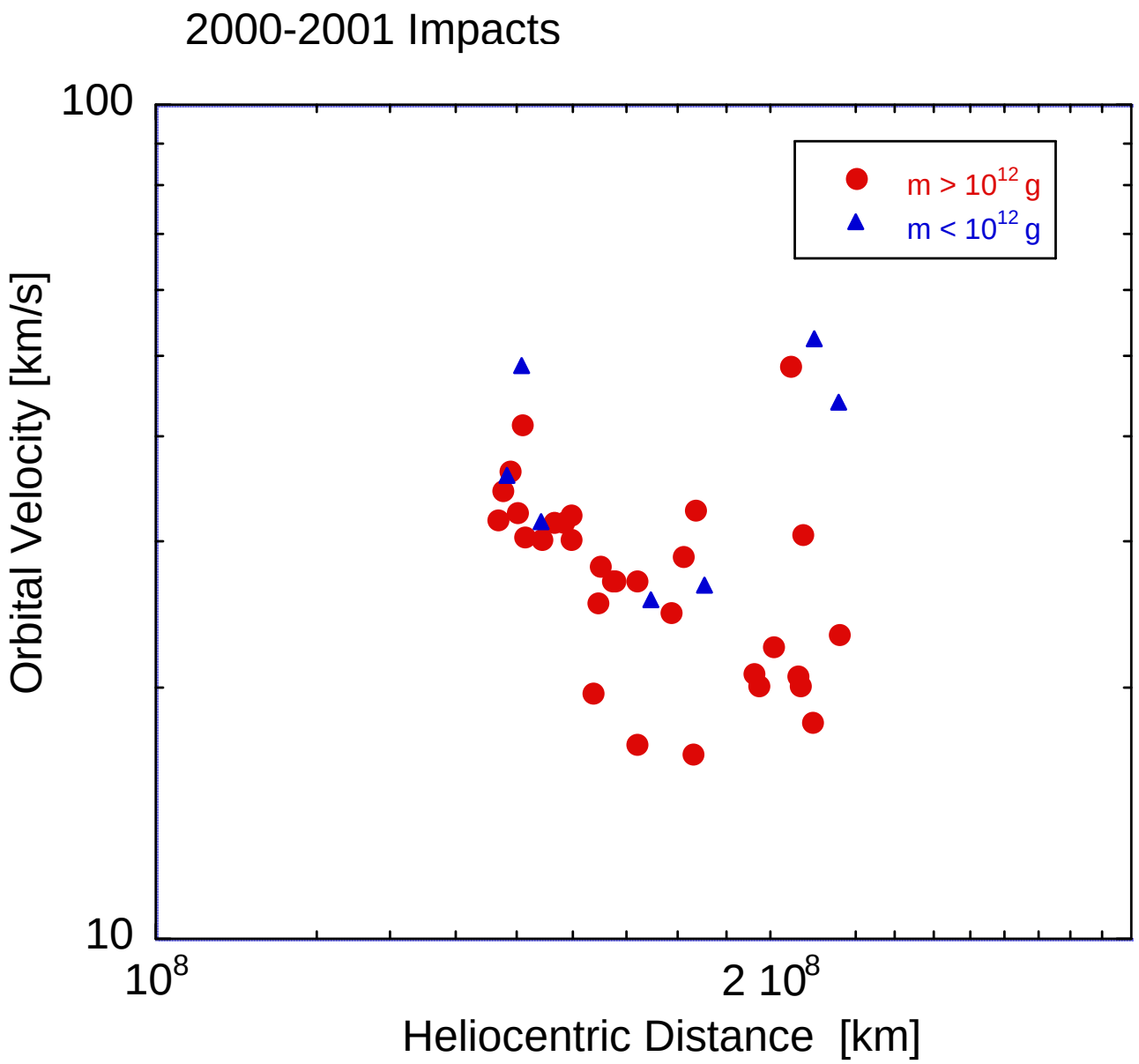
2000-2001 Impacts



2000-2001 Impacts: Dust velocity in space



2001-2002 Impacts: Dust velocity in space


2000-2001 Impacts
100
10
Orbital Velocity [km/s]
10^8
$2\ 10^8$
Heliocentric Distance [km]
m > 10^{12} g
m < 10^{12} g

NOZOMI Electronics Trouble

- 02-04-21 A giant solar flare was observed.
- 02-04-23 A proton monitor detected the highest flux so far.
- 02-04-26 Trouble

  CI-PSU (Power Supply Unit) off. Short?

  (Heater, Data recorder, Interface)

  SI's are OK. All SI's are powered on.
- 02-05-15 Lost NOZOMI carrier signals.
- 02-07-15 Recovered NOZOMI carrier signals.
- Recovery operation postponed to be after two Earth's flybys (02-12, 03-06).
- 02-10 MDC HV switched on (observation restarted)
- 03-06-19 Earth's flyby was successful. Orbital correction.
- From 03-07 Start recovery operation
- 03-12 Arrival at Mars

  Give-up insertion into circummartian orbit

NOZOMI condition between 02-07 and 03-07

- Uplink OK
  - We can send commands to NOZOMI
- Downlink NG
  - Radio is on ranging mode.
  - CI-PSU controls the switch between ranging mode and telemetry mode.
- Using carrier signal (on/off), we can confirm information of NOZOMI-Housekeeping.

NOZOMI Recovery Operation

- Uploading a command sequence which sends CI-PSU-ON commands successively in a short duration.
- Run the sequence until the short circuit is cleared

- Plan after the recovery
  - Detailed check of NOZOMI HK
  - Reschedule circummartian orbits
    - Larger apoapsis distance.
  - MDC data (from 02-10) downloading.
  - MDC revised software.

- Recovery operation was not successful.

NOZOMI-MDC Results

- No detection of Martian dust ring --
  - because NOZOMI gave up the insertion into the Martian orbit

- However, more than 100 dust impacts were detected between 98-7 and 02-4.
- Circumterrestrial orbit (1998)
  Mainly around apogee
  Large frequency in Nov. (Leonids-related?)
- Interplanetary orbit (1999-2002)
  Most of particles are Keplerian, on the zodiacal plane
  4-5 possible interstellar particles - detected.
  (2-3 matches interstellar gas flow direction)
  More in 1999 than in 2000-2002.

Legacy of MDC-NOZOMI

- MDC-NOZOMI project has expanded community of dust measurements in Japan.
- Dust accelerator was installed at Univ. Tokyo.
- Future dust mission
  - MDM on board BepiColombo
  - Dust measurements around Mercury

Future detection of Martian dust ring/torus

- No approved dust detector plans in Mars missions
  - Phobos Soil?
- Constraint from HST observation. Dust number density is not high enough for optical detection?
- Theoretical expectation of Phobos-derived particles 20-200μm surface regolith size?
- Future mission
  - Impact ionization dust detector for retrograde satellite? Target on larger mass.
  - Piezo type / large area detector for prograde satellite? Better sensitivity for low-v (<1km/s) dust

HST observation

- Showman et al. 2006 PSS
- On May 28, 2001 Mars' hypothetical ring plane appeared edge-on to Earth within weeks of its opposition,
- No rings were detected. This result limits normal optical depths to 3×10^{-8} for the Phobos ring and 10^{-7} for the Deimos ring.

Subaru Observation

- 2007-12-17
- Takato, Ohtsuki, Yoshida, Sasaki et al.
- Scattered light from Mars was too bright.