FINNISH METEOROLOGICAL INSTITUTE

Asteroid touring nanosat fleet with single-tether E-sails

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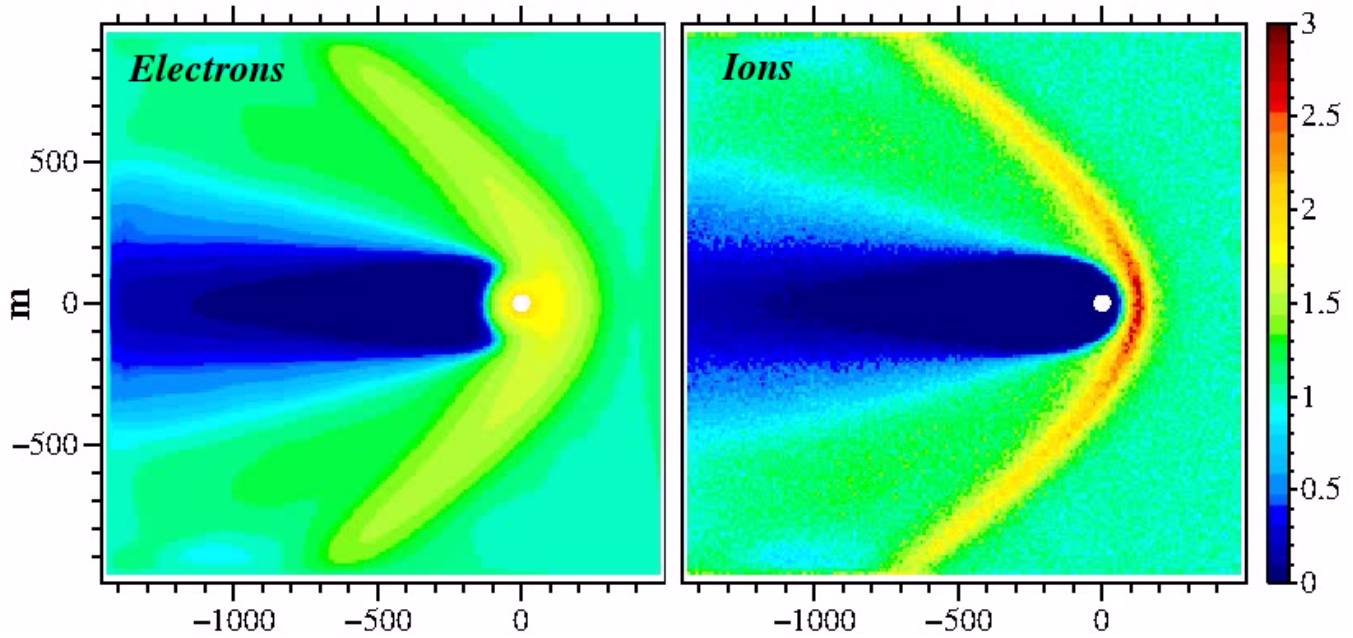
Coulomb drag propulsion

- Way to harness natural space plasma flow for propulsion
  - Charged thin tether taps momentum by deflecting ion flow.
  - One or more tethers: for cubesat, one suffices.
- Two application domains:
  - Solar wind → ***E-sail, interplanetary propulsion***
  - LEO → plasma brake, satellite deorbiting
- At least order of magnitude more efficient than existing methods (efficiency = impulse per propulsion system mass)

Plasma simulation of E-sail



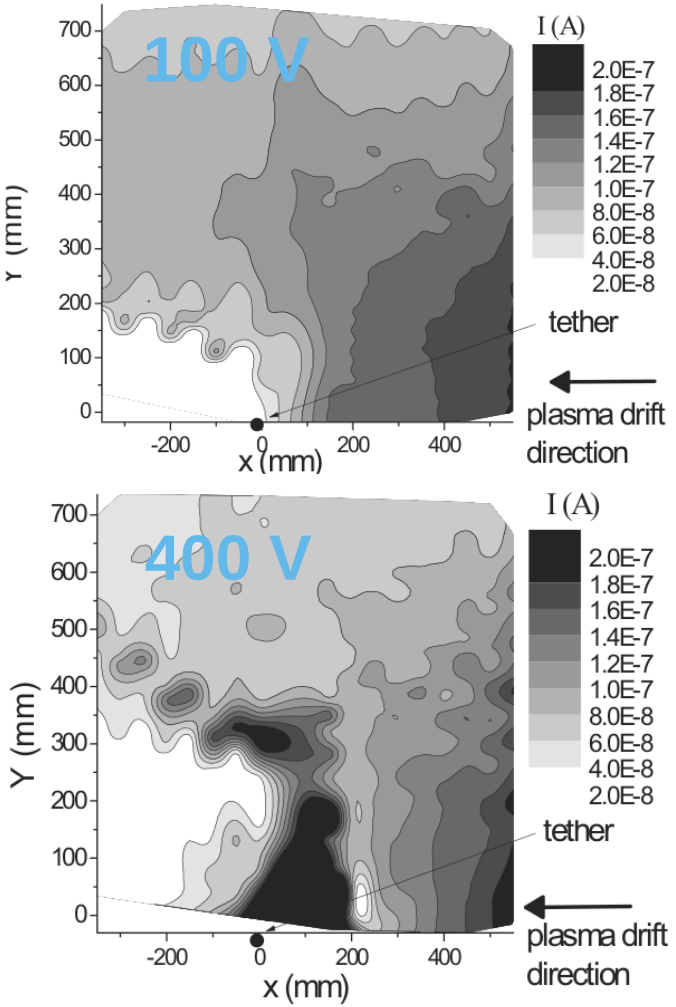
- Nominal solar wind parameters at 1 au

- Typical thrust per length 0.5 mN/km at 20 kV tether voltage
- Typical tether mass per length 10 grams/km
- Tether only: $a=F/m$ = 50 mm/s² = 130 km/s/month
- E-sail system: $a=F/m$ ~ 5 mm/s² = 13 km/s/month

http://www.electric-sailing.fi

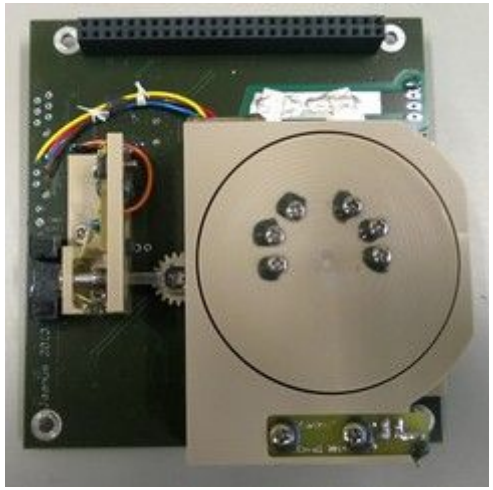
Laboratory experiment

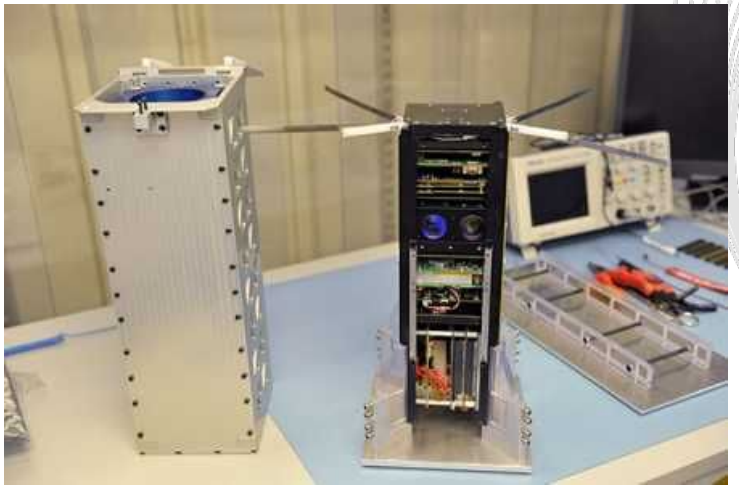
- Sheath width as function of tether voltage (Siguier et al., 2013*)
- LEO-like plasma, tether voltage 100 V and 400 V
- Good agreement with plasma simulation
- Sheath width is a proxy for thrust



(*)Siguier, J.-M., P. Sarrailh, J.-F. Roussel, V. Inguimbert, G. Murat and J. SanMartin, Drifting plasma collection by a positive biased tether wire in LEO-like plasma conditions: current measurement and plasma diagnostics, IEEE Trans. Plasma Sci., 41, 3380-3386, 2013

Cubesat testing

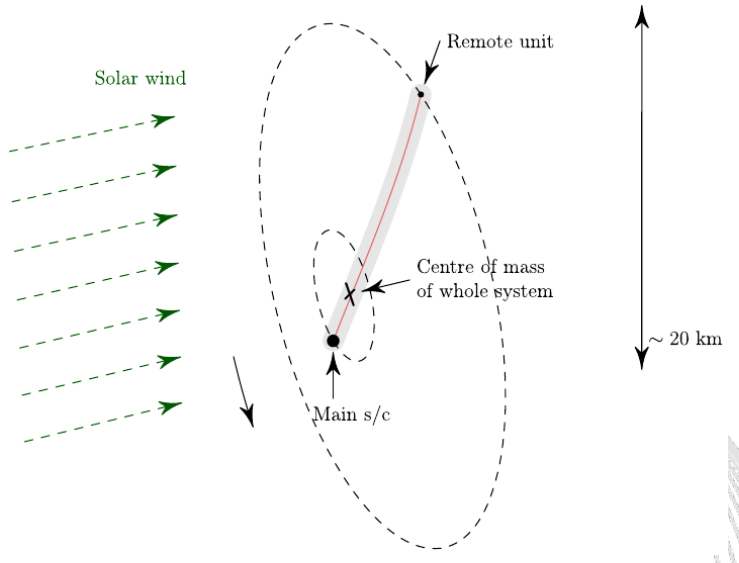


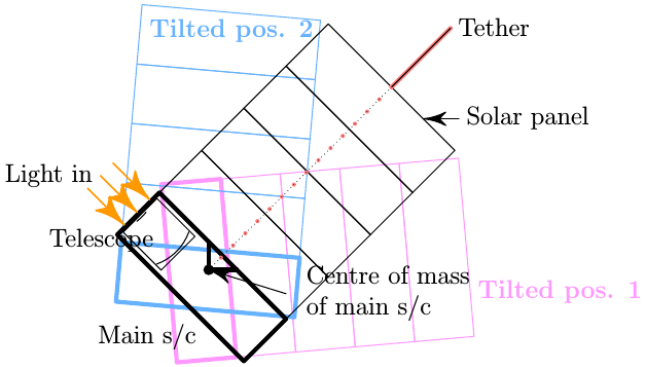


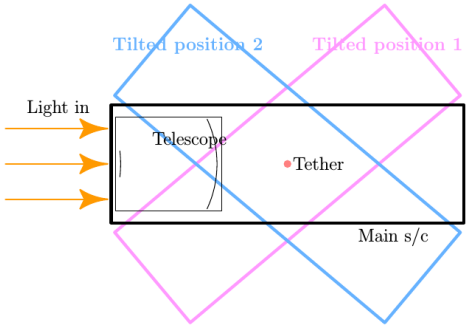
- Aalto-1 (3-U LEO cubesat):
  - 100 m tether
  - 2 PCBs: HV card and motor card, ~300 gram total mass
  - Launched June 23 2017
  - Coulomb drag experiment expected in late autumn/early winter
- Forthcoming: ESTCube-2, 300 m tether

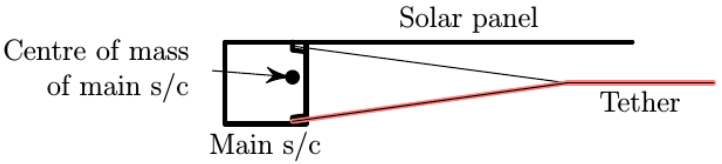
Single-tether E-sail for nanosats

- 10-20 km tether
- 10-20 kV voltage
- 2.5-10 mN thrust at 1 au
- Spacecraft pointing possible









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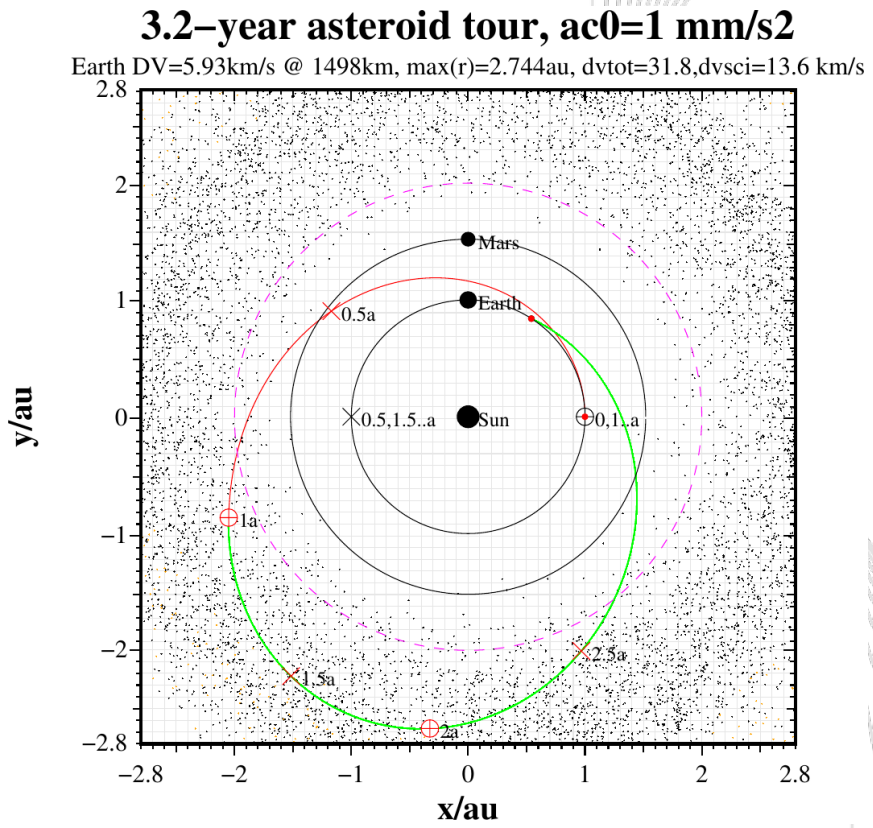
Flyby of 300+ asteroids

- Fleet of 50 nanosatellites (scalable)
- Launch to marginal escape (500kg)
- Each s/c makes flyby of 6-7 asteroids
- Ø=4 cm telescope + NIR spectrometer
- Use the telescope also for navigation
- Data (10 GB per s/c) retrieved at final Earth flyby: dipole antenna is enough
- Proposal "***Multi-asteroid touring***" to ESA's "Call for new science ideas" (submitted Sept 2016, selected 2017)



Mission design for a fleet of 50

1) 25 primary targets
   - Free selection: globally the most interesting bodies
   - Two spacecraft per target, by default
2) 250-300 other flybys
   - Random sample of numbered asteroids
3) Serendipitous discovery of small bodies
   - Size spectrum of the main belt
   - Equally efficient in this task as a monolithic telescope mission
4) Cruise phase solar wind from E-sail housekeeping data
   - Global, instantaneous structure of the heliosphere

Conclusions

- Low-cost mission concept to make flyby study of massive number of asteroids.
  - Few hundred k€ cost per asteroid.
  - Low DSN costs because data transferred at Earth flybys.
- Enabled by single-tether E-sail.
  - Needs pathfinder cubesat E-sail mission in solar wind.
  - Needs also autonav, but demonstrated already in DeepSpace-1.