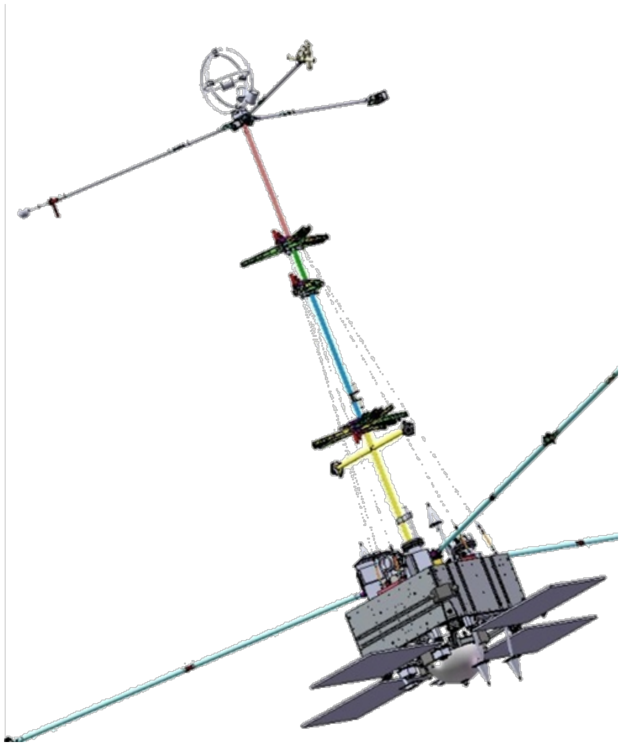
RESONANCE

Project for Studies of Wave-Particle Interactions in the Inner Magnetosphere

Anatoly Petrukovich and Resonance team

РЕЗОНАНС RESONANCE

Resonance



Inner magnetospheric mission

- **Space weather**
  Ring current, outer radiation belt, plasmasphere
- **Resonant wave-particle interactions**
  Magnetospheric cyclotron maser
- **Auroral region acceleration**
  Small-scale active zones, precipitation
- **Two pairs of spacecraft**
- **Magneto-synchronous orbit**

To be launched in 2014

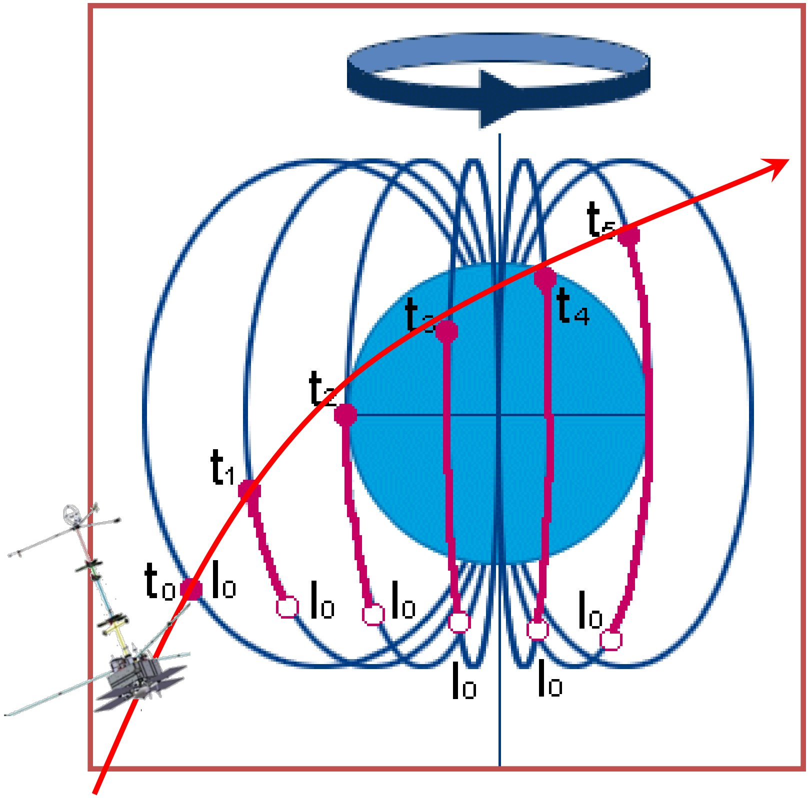
2011: Engineering models delivery

Resonance team

- **Russia –** Space Research Institute,
  NPO S.A. Lavochkin,
  Institute of Applied Physics,
  IZMIRAN, PGI, NIRFI, …
- **Austria –** Space Research Institute
- **Bulgaria –** Space Research Institute
- **Czech Republic –** Institute of Atmospheric Physics
- **Finland –** Oulu University
- **France –** LPC2E/CNRS, CESR/CNRS
- **Germany –** MPI Lindau
- **Greece –** Thrace University
- **Poland –** Center for Space Research
- **Slovakia –** Institute of Experimental Physics
- **Ukraine –** Lviv center, Space Research Inst., Inst. of Astronomy
- **USA –** Maryland University

Project Leader
Prof. L.M.Zelenyi
Project Scientist
Dr. M.M.Mogilevsky

Orbit design

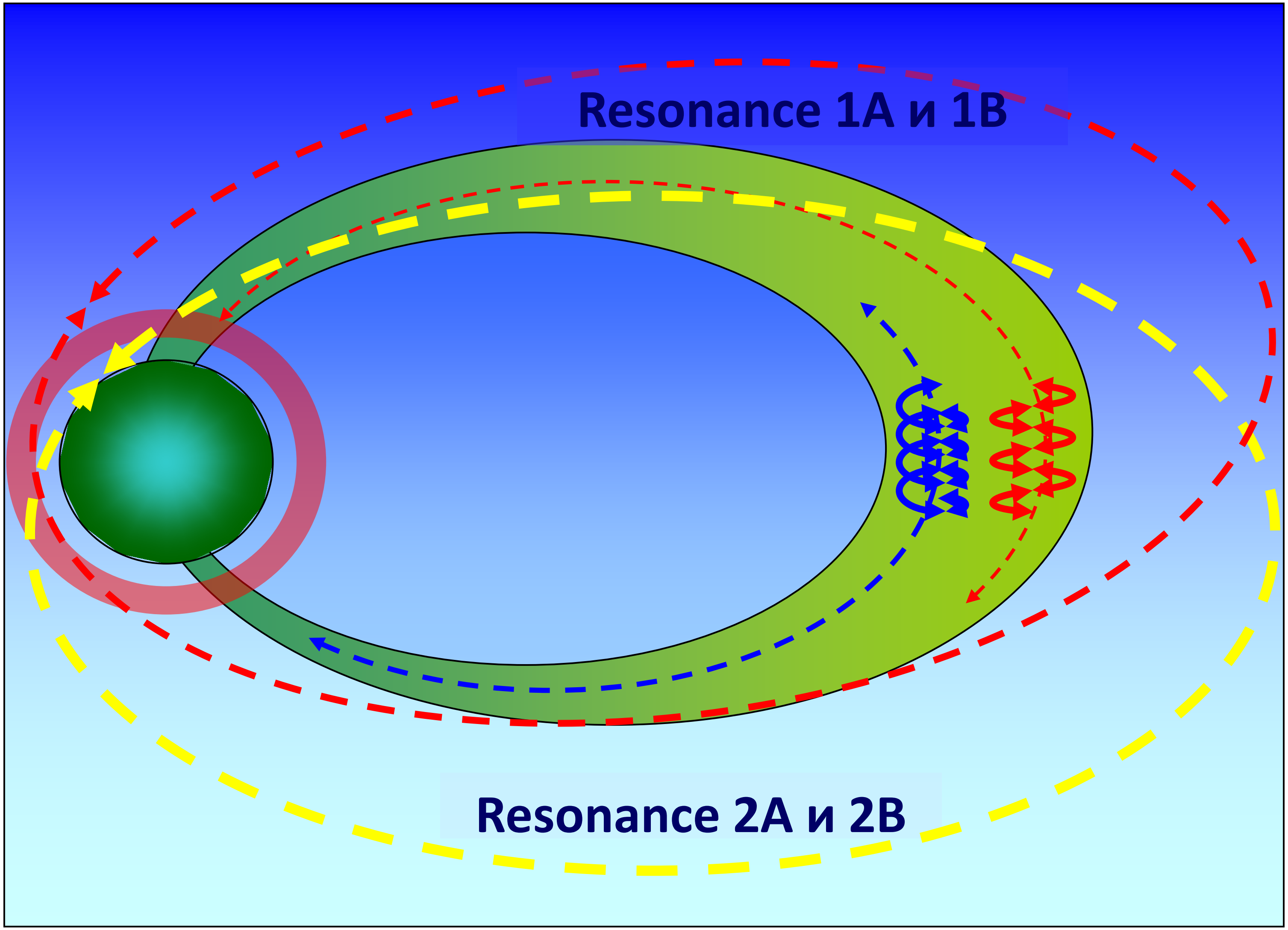


Goal: corotation with a flux tube

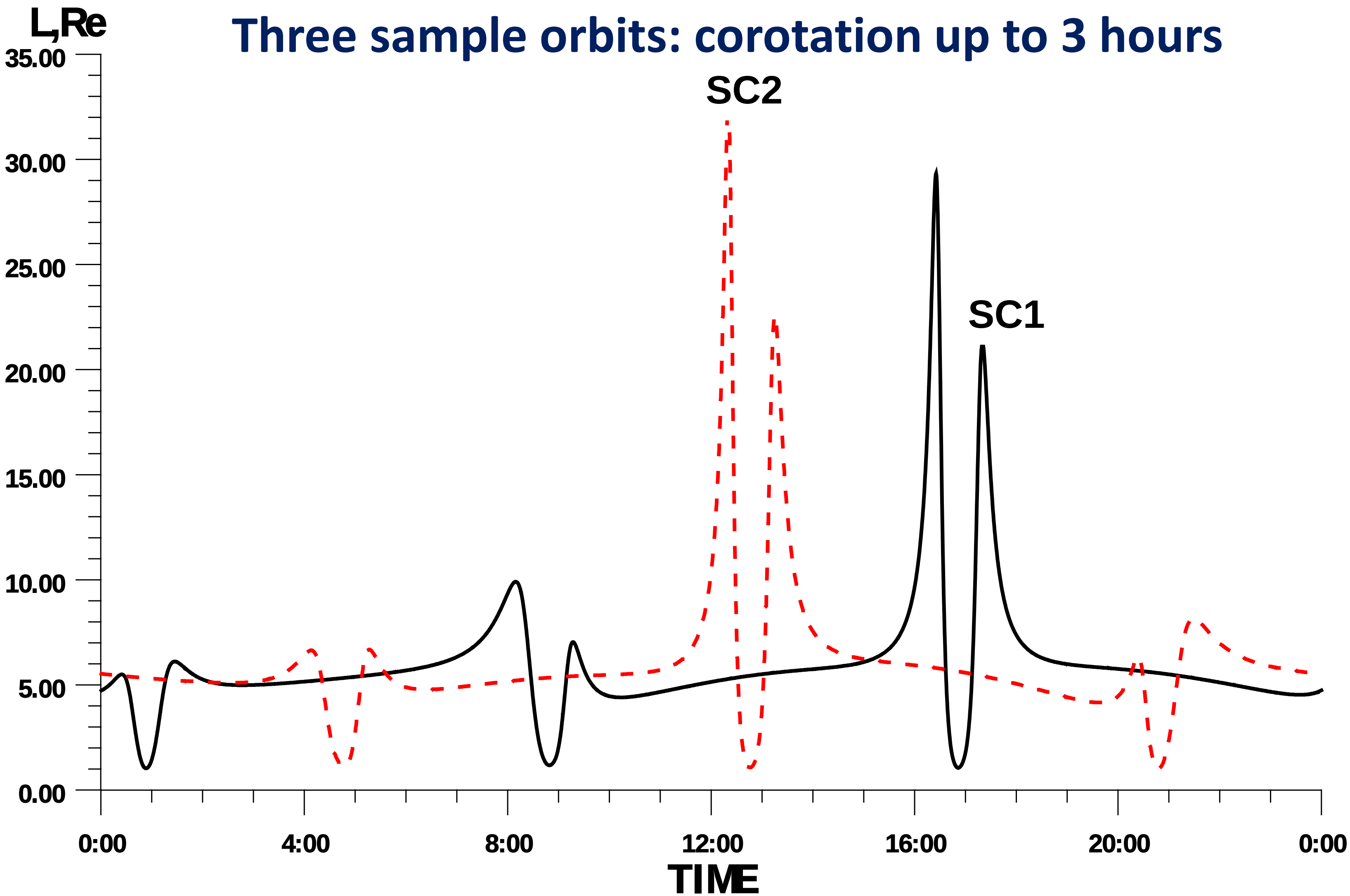
Magnetosynhronous orbits

Apogee: ~28 000 km,
Perigee: ~ 500 km,
Period: ~ 8 hours
Inclination: +63.4^o and -63.4^o

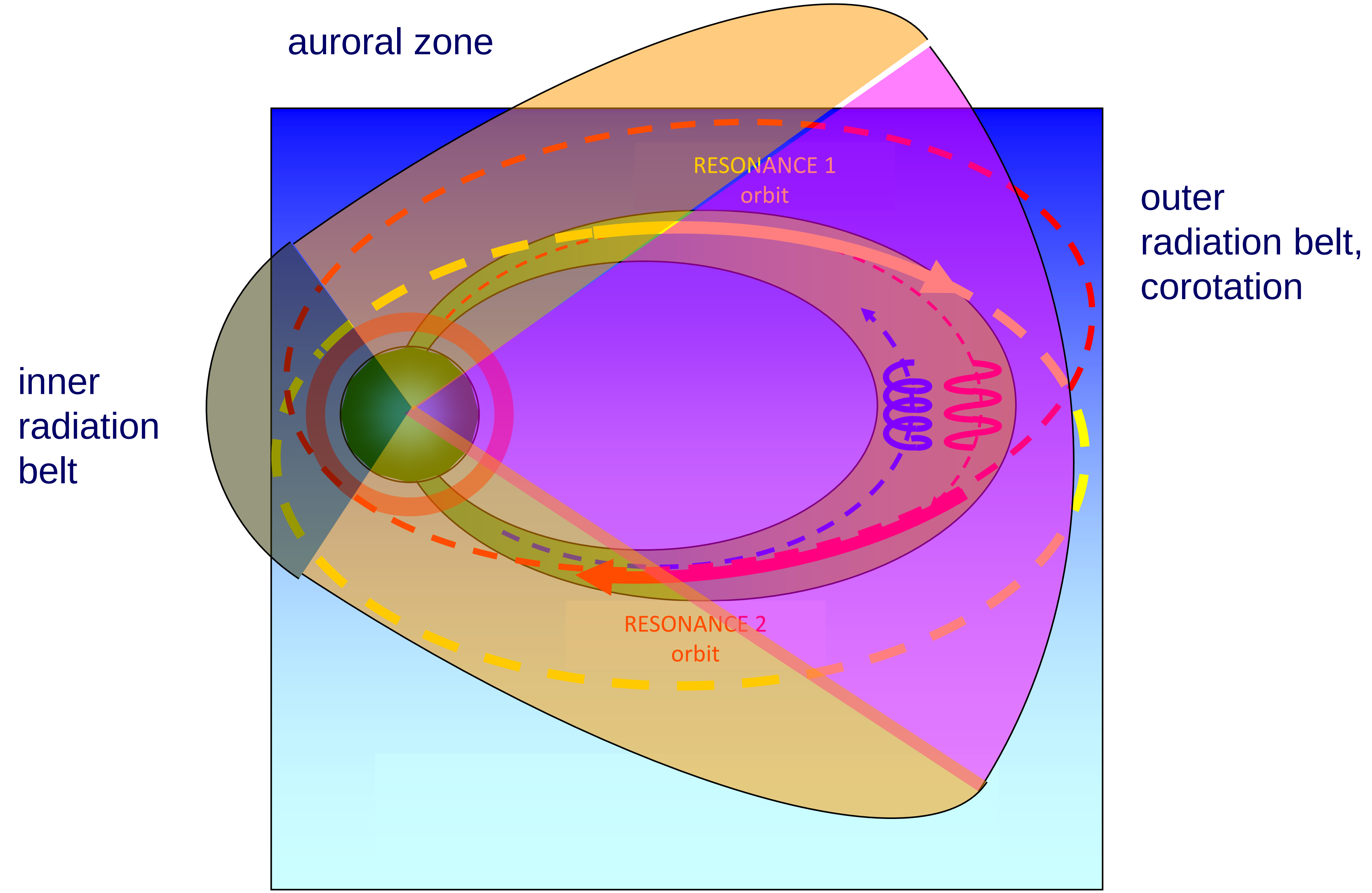
Magnetosyncronous orbit



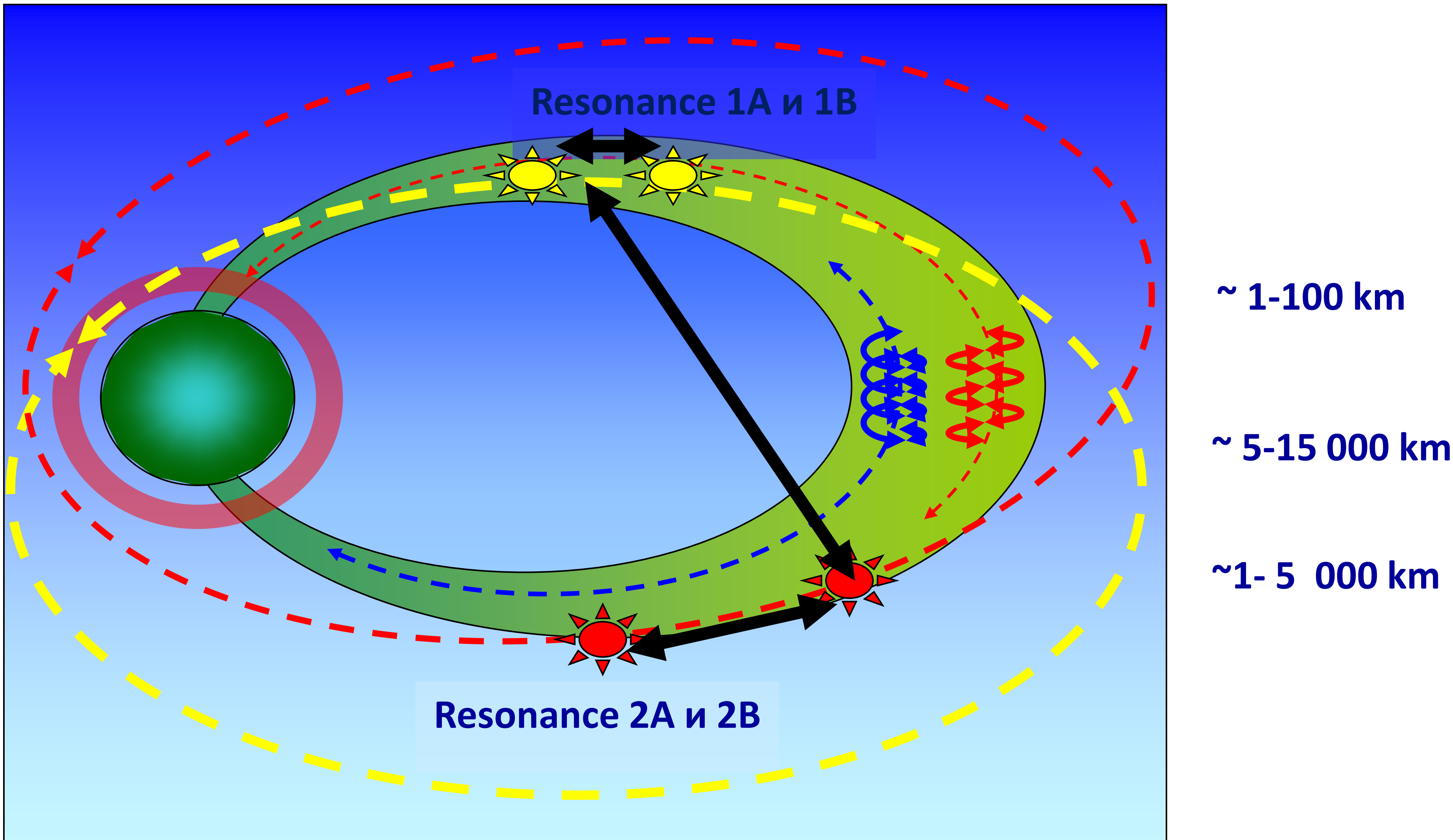
Three sample orbits: corotation up to 3 hours



Zones along orbit



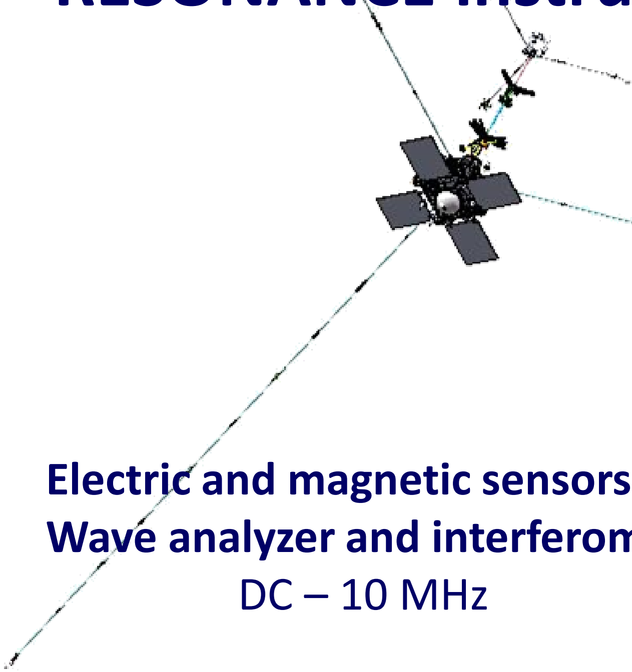
Separation strategy with four spacecraft

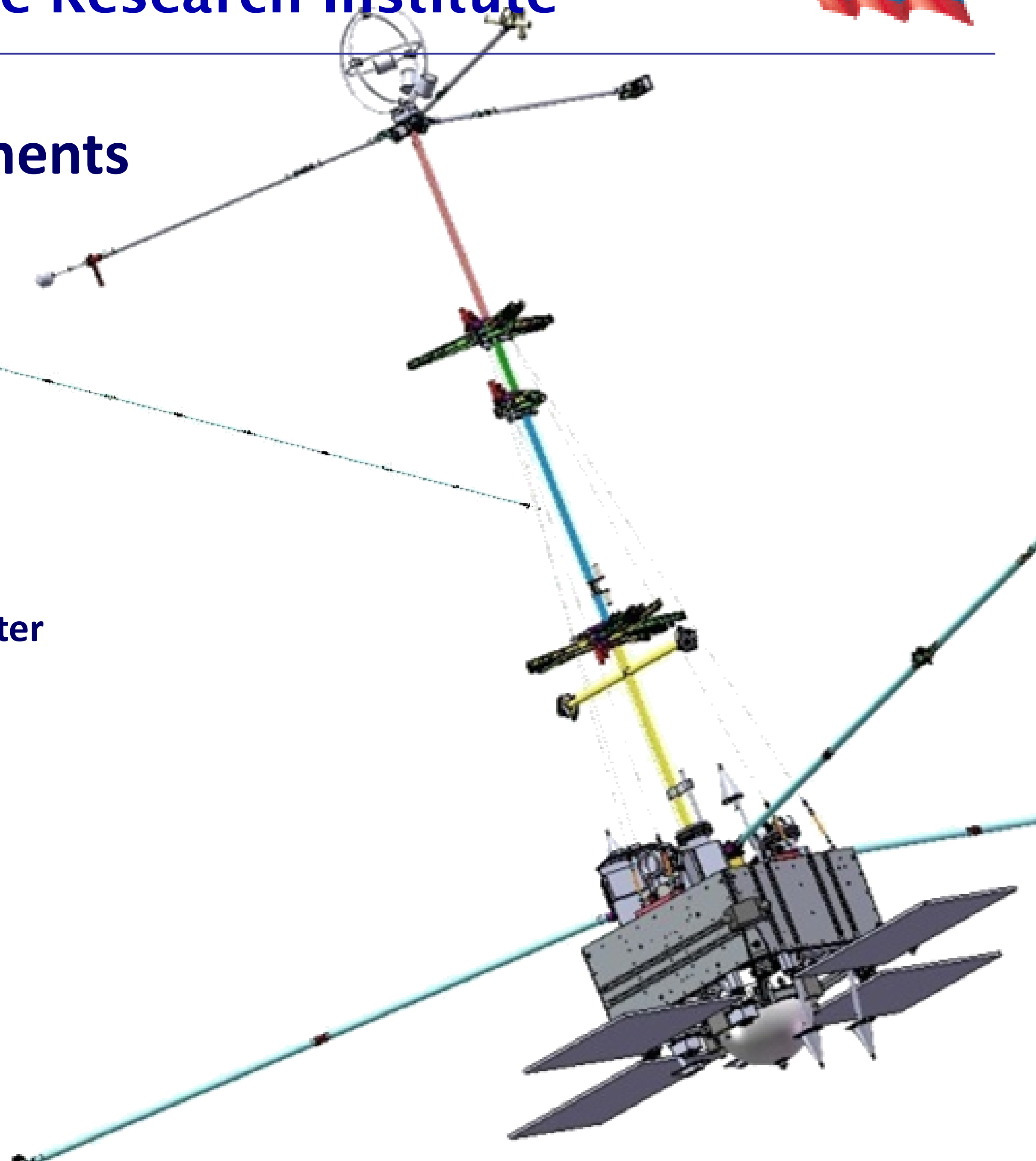


Preliminary strategy of satellite separation

	First pair (1A/1B)	Second pair (2A/2B)
1st phase (1-9 months)	1-10 km	1-10 km
2nd phase (9-18 months)	1-10 km	10-100 km
3rd phase (18-27 months)	10-100 km	100-1000 km
4th phase (27-36 months)	100-1000 km	1000-9600 km

RESONANCE instruments





Electric and magnetic sensors

Wave analyzer and interferometer

DC – 10 MHz

Plasma sensors

Cold plasma

Suprathermal plasma

Energetic particles

Relativistic electrons

Scientific instrumentation

EM field and wave measurements	
Flux-gate magnetometer	3 components of B field, DC – 10 Hz **~ 2.1 kb/s**
ULF electric field receiver	3 components of E field, DC – 10 Hz **~ 1.4 kb/s**
VLF receiver	3 electric and 3 magnetic components of EM field, 10 Hz – 20 kHz ~ **5.76 Mb/s**
HF receiver	3 electric and 3 magnetic components of EM field, 5kHz – 1 MHz, 5 MHz, 15 MHz ~ **2.16 Gb/s**
Space radio interferometer	5-15 MHz

Scientific instrumentation

Plasma and particle measurements	
Cold plasma analyzer	0 – 20 eV
Suprathermal electron spectrometer	10 eV – 15 keV
Suprathermal ion spectrometer with composition	10 eV – 30 keV
Fast electron analyzer (10 ms)	5 keV – 50 keV
Ring current ions and energetic electrons spectrometer	20 keV – 0.4 MeV
Relativistic electrons	300 keV – 5 MeV

Some issues to be resolved

Verification of chorus generation theory

Existing theories of chorus generation connect characteristics of chorus (frequency sweep-rate, time interval between chorus elements) with chorus amplitude which, in turn, depends on cold plasma density, plasma inhomogeneity, and resonant electron distribution function.

Electron pitch-angle diffusion and precipitation

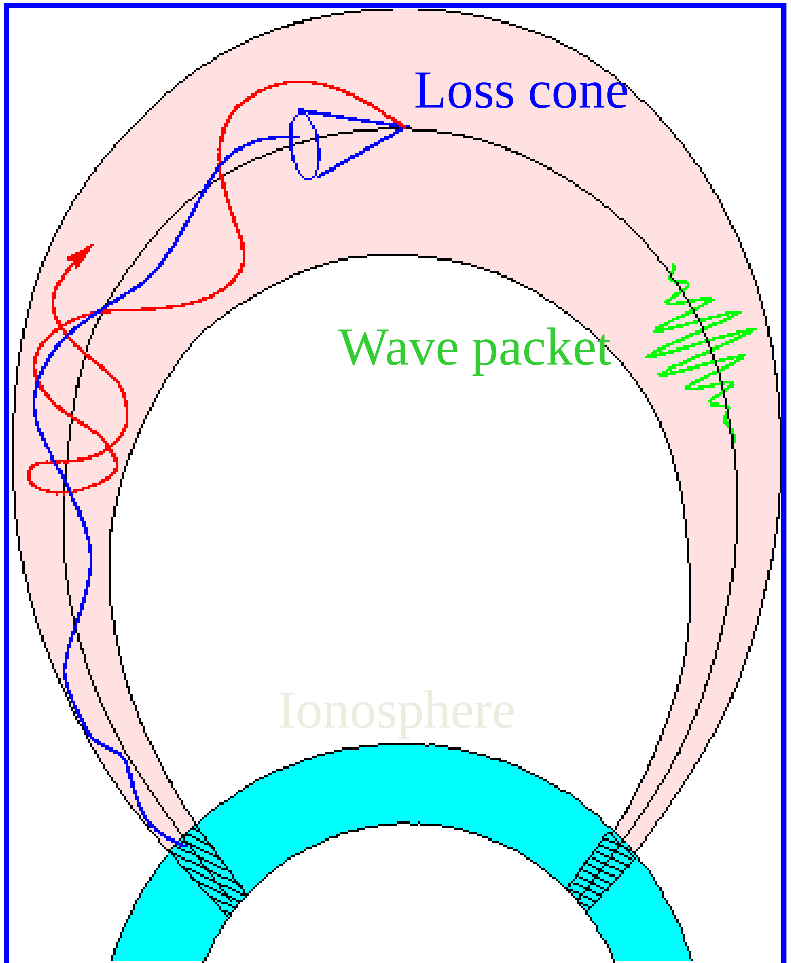
Various wave-modes (whistlers, whistler-mode chorus, electromagnetic and electrostatic ion cyclotron waves, upper hybrid waves) have been suggested.

Proton precipitation with the operation of ground-based VLF transmitters

Nature of particle energization (acceleration) via wave-particle interactions

RESONANCE mission measures all necessary quantities simultaneously in the magnetic flux tube of effect

Magnetospheric maser



Active substance:
Energetic electrons > 5 keV

Electrodynamical system:
magnetic tube with cold plasma,
ionosphere as mirrors

Operating modes:
whistler and ion cyclotron waves

Important for acceleration of MeV electrons

History

Discovery of radiation belts
Sputnik 3, Explorer 1 (1958)

First observations of ELF/VLF el.-m. waves
Alcock, Martin (1956)
Duncan, Ellis (1959)

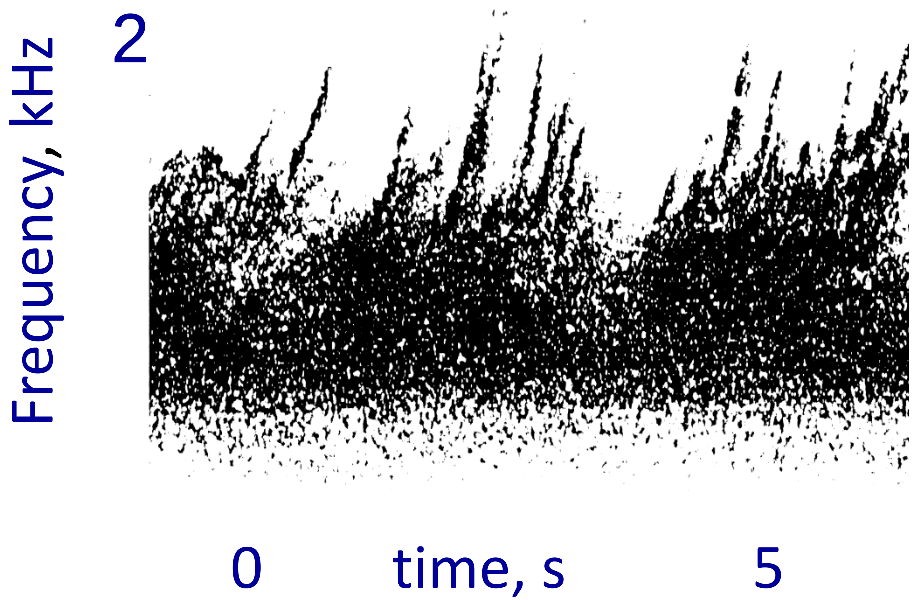
CM in the Earth magnetosphere
Brice (1964); Dungey (1963);
Trakhtengerts (1963);
Andronov and Trakhtengerts (1964);
Kennel and Petchek (1966)

Electronics
Gaponov-Grekhov (1959)
Andronov, Zheleznyakov, and Petelin (1964)

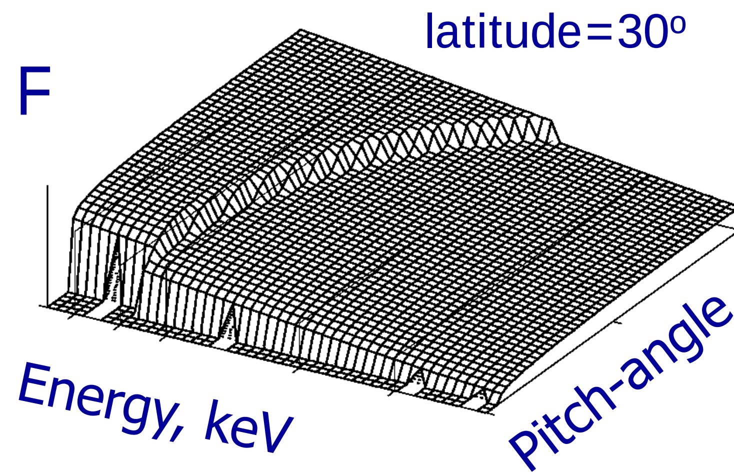
Plasma Physics
Zheleznyakov (1960)
Sagdeev and Shafranov (1960)
Vedenov, Velikhov, and Sagdeev (1961)

Particles and fields

ELF/VLF chorus



energetic electrons



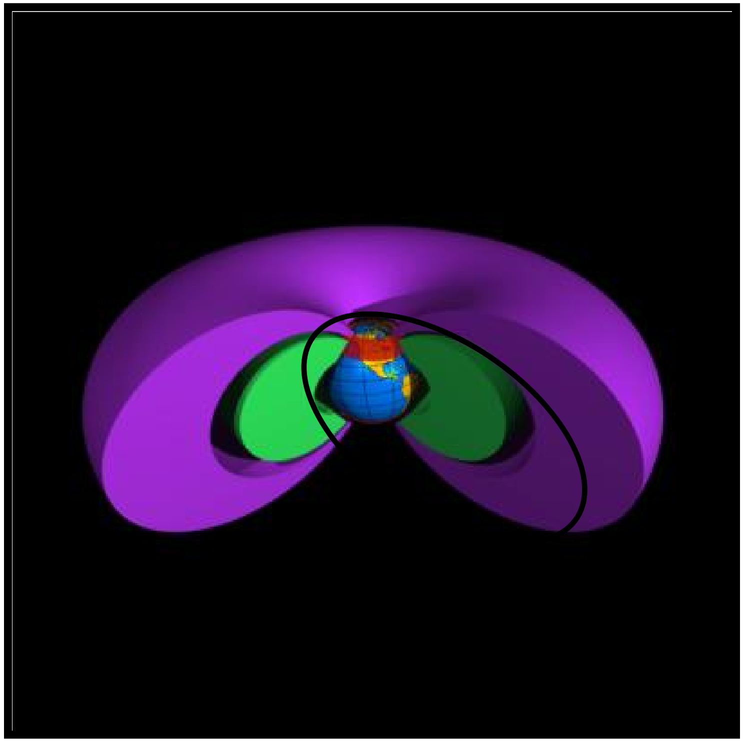
Waveform capability for E and B
up to 10-40 kHz

Electron distribution in keV range
~10 ms sampling,   dE/E ~ 1%

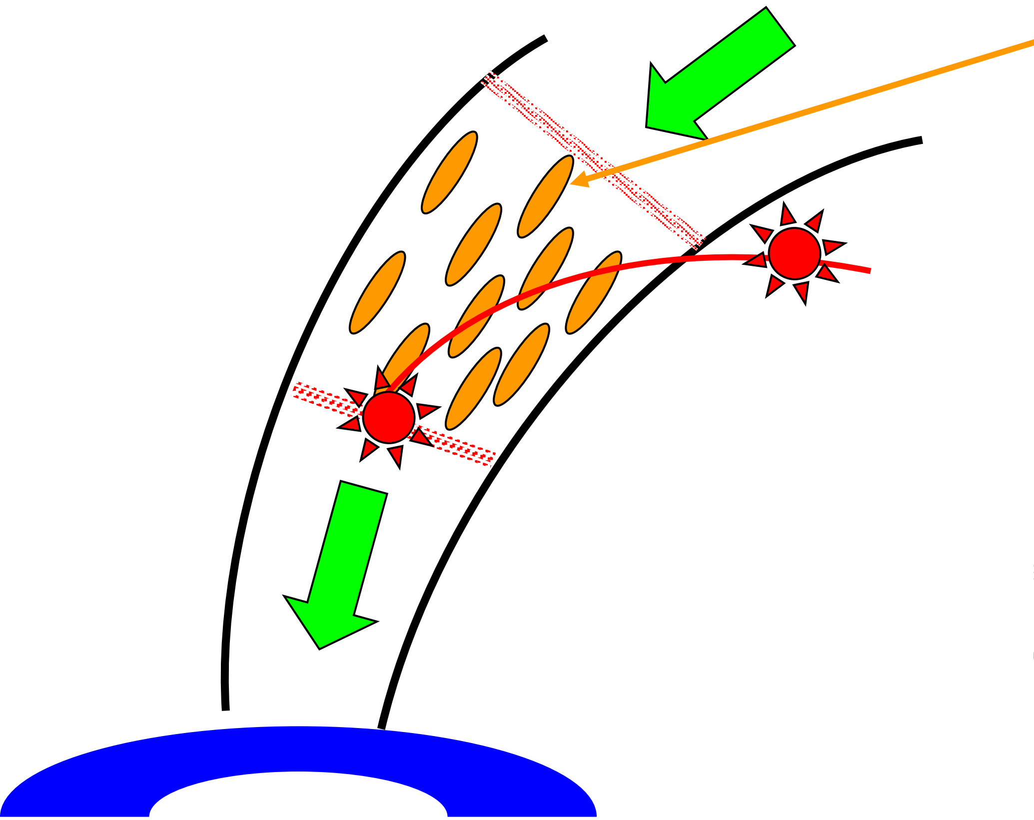
Theory by V. Trakhtengerz & A. Demekhov

Ring current, radiation belt, plasmasphere

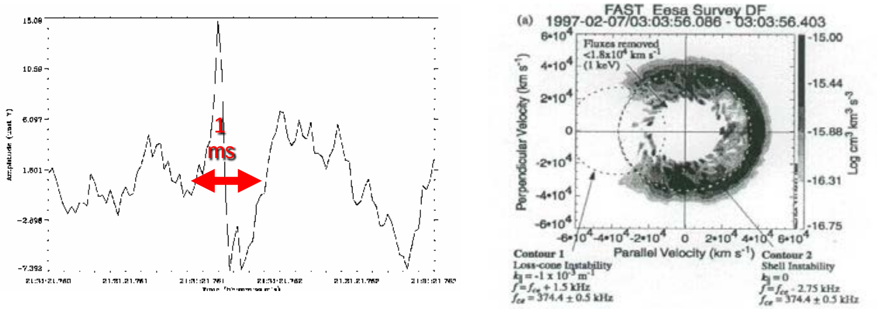
- Injection development
- MeV electron dynamics
- Ring current formation
- Wave-particle interaction
- Plasmasphere refilling and loss



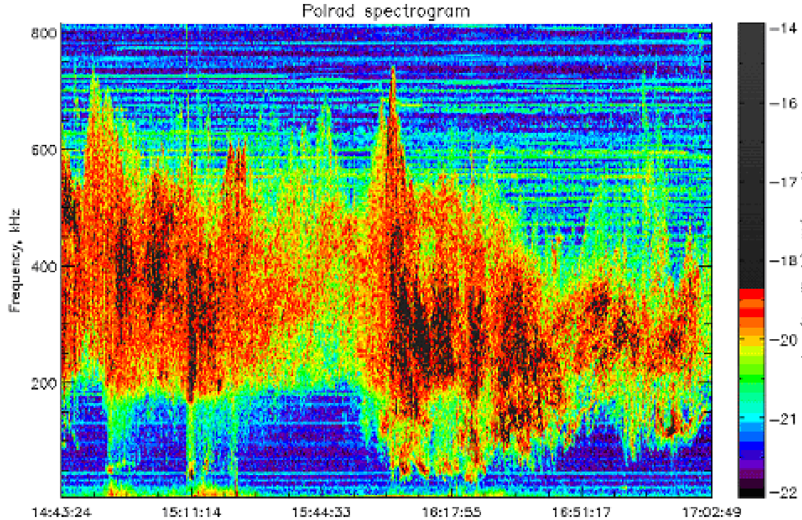
Auroral acceleration region



FAST electric fields and electrons



AKR onboard **INTERBALL-2**



International inner magnetospheric constellation

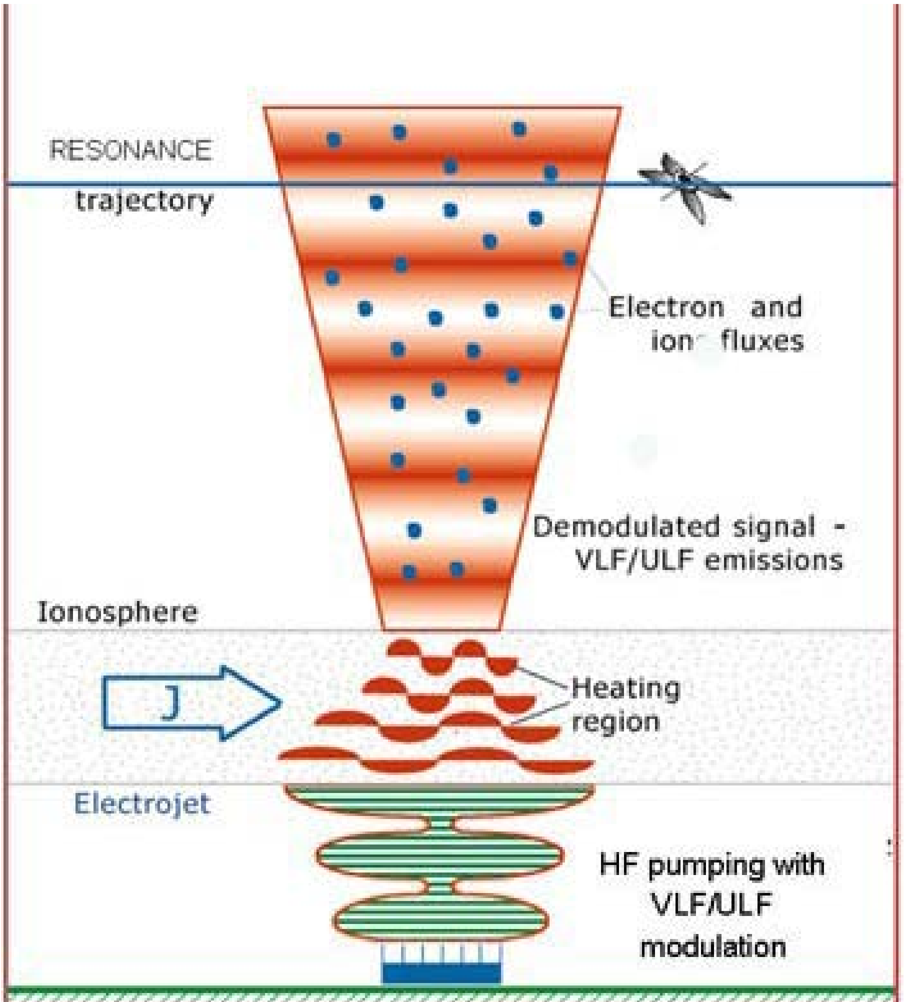
2012-2015

RESONANCE	altitude 27000 km	inclination 63 deg
ERG	4-5 Re	near-equatorial
RBSP	30000 km	near-equatorial

+ geostationary satellites, MMS, THEMIS, KUAFU-auroral

- Collaborative science topics in which synergy is possible ?
- Orbital conjunctions ?

Resonance - HAARP



- Artificial electromagnetic waves
- Modification of precipitation particles
- Modification of the reflection coefficient from the ionosphere