

FAST Spacecraft Reveals Fundamental Plasma Wave Emission Mechanism

NASA's Fast Auroral Snapshot (FAST) Small Explorer has traveled to the source region of the Earth's most powerful radio emission – Auroral Kilometric Radiation (AKR).

FAST's high resolution particles and fields measurements have revealed the mechanism responsible for these waves, with major implications for other planetary and astrophysical radio emissions.

FAST has demonstrated that AKR is generated by the Electron Cyclotron Maser, and that the maser requires parallel electric fields to create the population inversion in the plasma that drives the instability.

Background:

AKR discovered by space probes in the 1960's and 1970's

- Intense (1 GW) radio emission.
- Makes the Earth a radio-astronomical object.

AKR has astronomical and astrophysical counterparts:

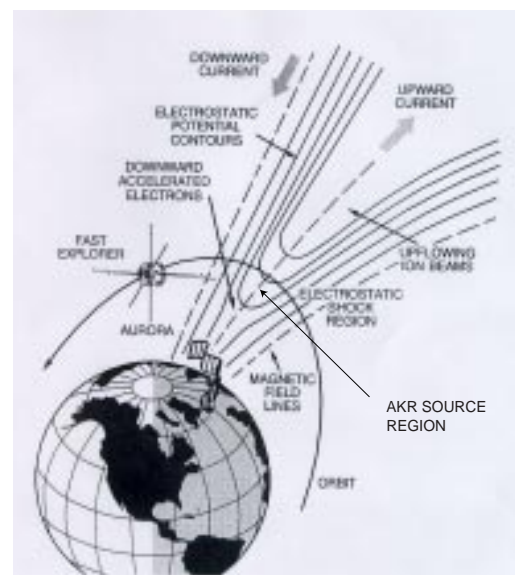
- Jovian Decametric Radiation from Jupiter.
- Solar Type V radio bursts.
- Solar microwave bursts.
- Radio emissions from binary systems.
- Radio emissions from dwarf M stars.

AKR generation is a fundamental plasma process:

- AKR escapes from the source region – escaping waves have phase speeds faster than light.
- In a plasma, waves are usually generated by resonance between particles and waves travelling at the same velocity – such waves are trapped.
- The cyclotron maser allows electrons to resonate with faster-than-light waves – the resonant particles see waves oscillating at their gyration frequency.

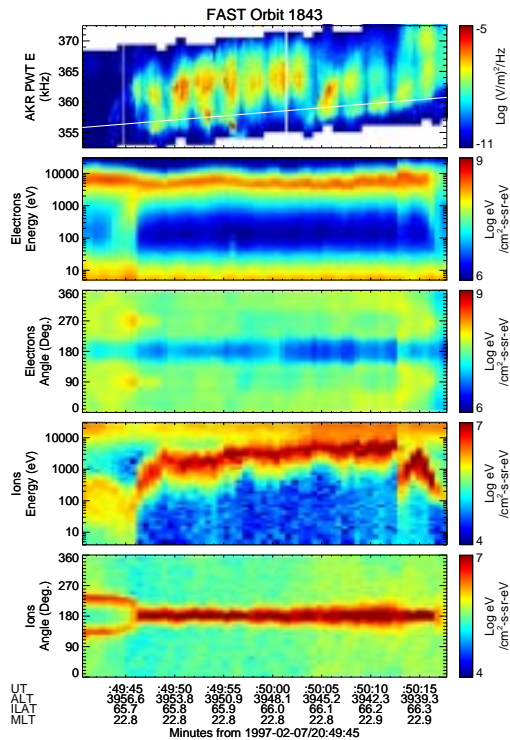
The cyclotron maser requires low plasma densities. It was thought that parallel electric fields played a minor role for the maser, mainly acting to reduce the density.

FAST has demonstrated that the parallel electric fields which accelerate the precipitating electrons to auroral energies do more than allow the instability to occur – *they are the energy source for the waves.*



Sketch of auroral acceleration region:
Source of Auroral Kilometric Radiation

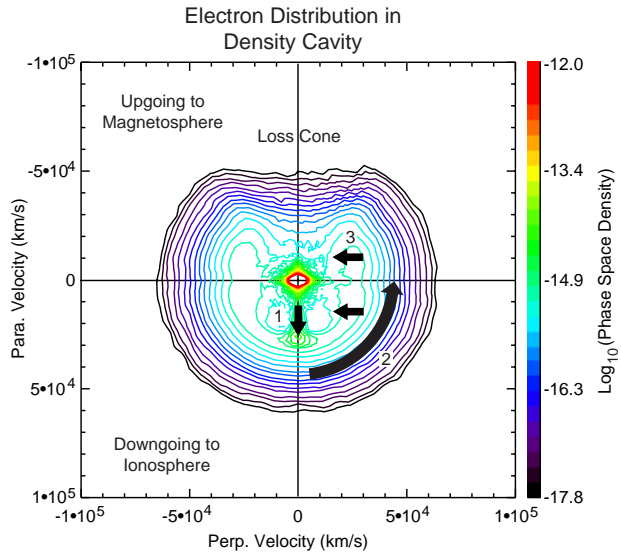
FAST Spacecraft Reveals Fundamental Plasma Wave Emission Mechanism



- ← Plasma Wave Tracker (PWT) measures AKR in the source region – waves below gyro frequency (white line) – relativistic dispersion
- ← Energetic electrons (~ 5 keV) – auroral electrons accelerated by parallel electric field
- ← Loss-cone (dark blue at 180°) present throughout interval – standard loss-cone driven maser insufficient to generate AKR
- ← Energetic ion beam (~ 1 keV) marks AKR source region – evidence that parallel electric field blocks cold ionospheric electrons
- ← Ions strongly field-aligned – confirms presence of parallel electric field below FAST

The absence of cold electrons allow relativistic effects to modify the wave dispersion, with the waves occurring below the cold electron gyro-frequency. This allows the accelerated and mirroring electrons to resonate with the waves.

The parallel electric field therefore is the free energy source for the waves. The sketch, using an observed distribution, shows how energy flows from the electric field to the waves.



- Energy Flow
1. Acceleration by Electric Field
 2. Mirroring by Magnetic Mirror
 3. Diffusion through Auroral Kilometric Radiation

FAST results have major implications for radio astronomy

- Parallel electric fields resupply free energy to the electron distribution, increasing the efficiency of the maser.
- The maser is unstable over extended regions, not quenched through filling of the loss-cone.