Mechanisms of Heavy Ion Heating in the In Situ Solar Wind

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Tuesday PM
Wednesday AM
- Solar wind ions are observed to be 
  perpendicularly heated in the corona and in situ wind.

- Heating is probably driven by dissipation of turbulent cascade.

- Heating in corona is directly responsible for the solar wind itself.

- Primary question:

  What is the specific kinetic mechanism(s) which transforms the 
  energy in turbulent fluctuations into 
  ion thermal energy?

- Four talks and lots of discussion.
Ben Maruca pointed out that alpha particles (only heavy, non-minor SW species) have a bi-modal temperature distribution which is not fully understood.

T-ratios of 1 and 4 are perhaps expected, since collisions will push \( T_\alpha/T_p \rightarrow 1 \) and heating to equal thermal speeds gives \( T_\alpha/T_p = 4 \).

But where do the \( T_\alpha/T_p > 6 \) cases come from?
Consider preferential heating model of Isenberg & Vasquez [2007]:

- Resonant cyclotron interaction can be preferential to heavy ions

- Simple dependences on $\beta$ and streaming speed of alphas yields predictions for three regions of parameter space.
Kasper et al., PRL, 2013:
Daniel Verscharen reviewing proposed theoretical mechanisms pointed out that the I&V mechanism assumed ion cyclotron dispersion in a cold plasma without significant alpha particles. This mechanism also requires counter-propagating resonant waves.
Also introduced an alternative mechanism from Chandran et al. [2010], which does not require high-frequency waves.

E-field fluctuations due to perpendicular turbulent cascade can disturb ion gyromotion enough to give stochastic perpendicular heating if

\[ \varepsilon = \frac{\delta v_\rho}{v_\perp} = \frac{(\delta E_\perp)_\rho}{B_0} \frac{c}{v_\perp} \] is large enough \((\varepsilon \geq 0.2)\)

This process yields a heating rate

\[ Q_\perp = \frac{c_1 (\delta v_\rho)^3}{\rho} \exp \left( - \frac{c_2}{\varepsilon} \right) \]
These electric fields, originally derived in the plasma (proton) frame, can be transformed into the frame of a streaming particle to adapt this mechanism to the Kasper et al. data. Transformation depends on normalized cross-helicity, $\sigma$ and $r_\Delta = \text{value of fluctuating } \delta E/\delta B$, both at the ion gyroscale.

$$\chi = \frac{2}{r_\Delta + 1} \left( r_\Delta + \frac{v_\parallel^2}{v_\Delta^2} \right) - \frac{2\sigma v_\parallel}{v_\Delta}$$

Averaging over ion distributions, taking best fit parameter values:
• Ben Chandran followed with further description of his mech., along with explanations of the less satisfactory results from different parameter values.

• Rob Wicks described his preliminary attempts to test these two mechanisms in the data.

    So far, the results are inconclusive at best
    (and inconsistent with both mechanisms at worst).

• Throughout all the talks, there were useful suggestions and active discussion of interpretations, improvements and exciting projects for the coming year.

    Very valuable session, lots to do, and we continue on this morning!