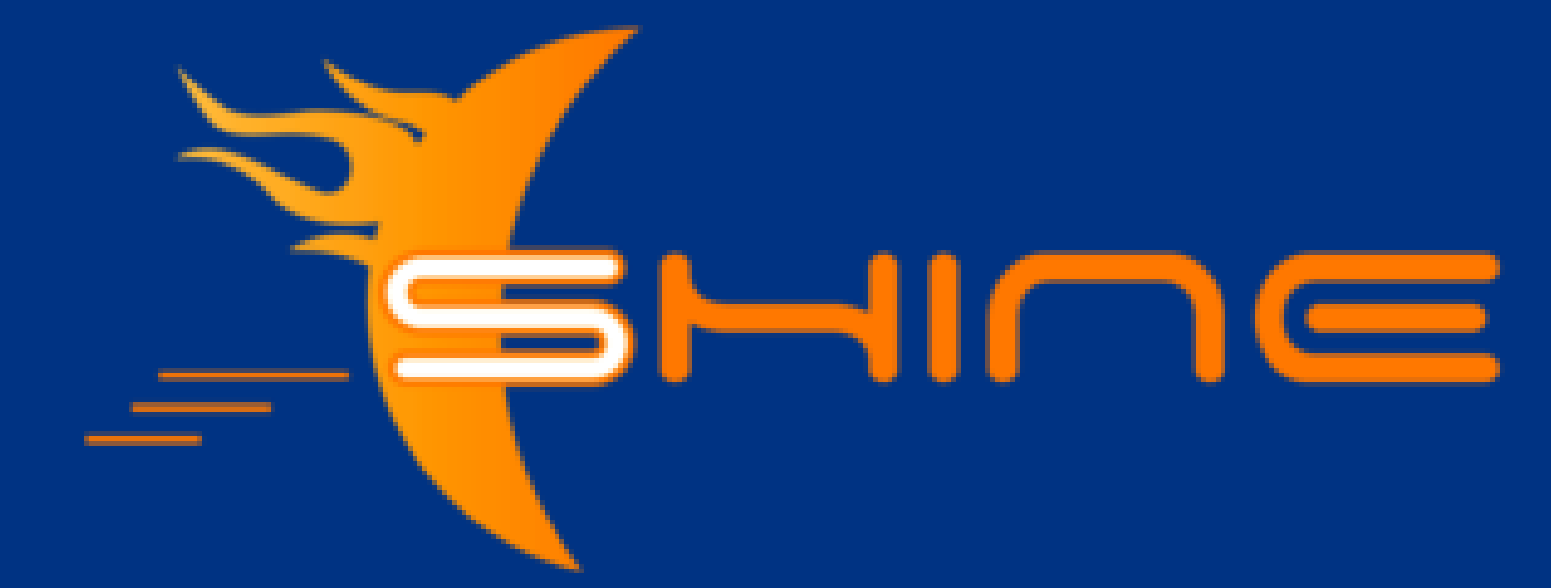


# Proton Temperature Anisotropy Across Interplanetary Shocks: A Statistical Analysis with WIND observations

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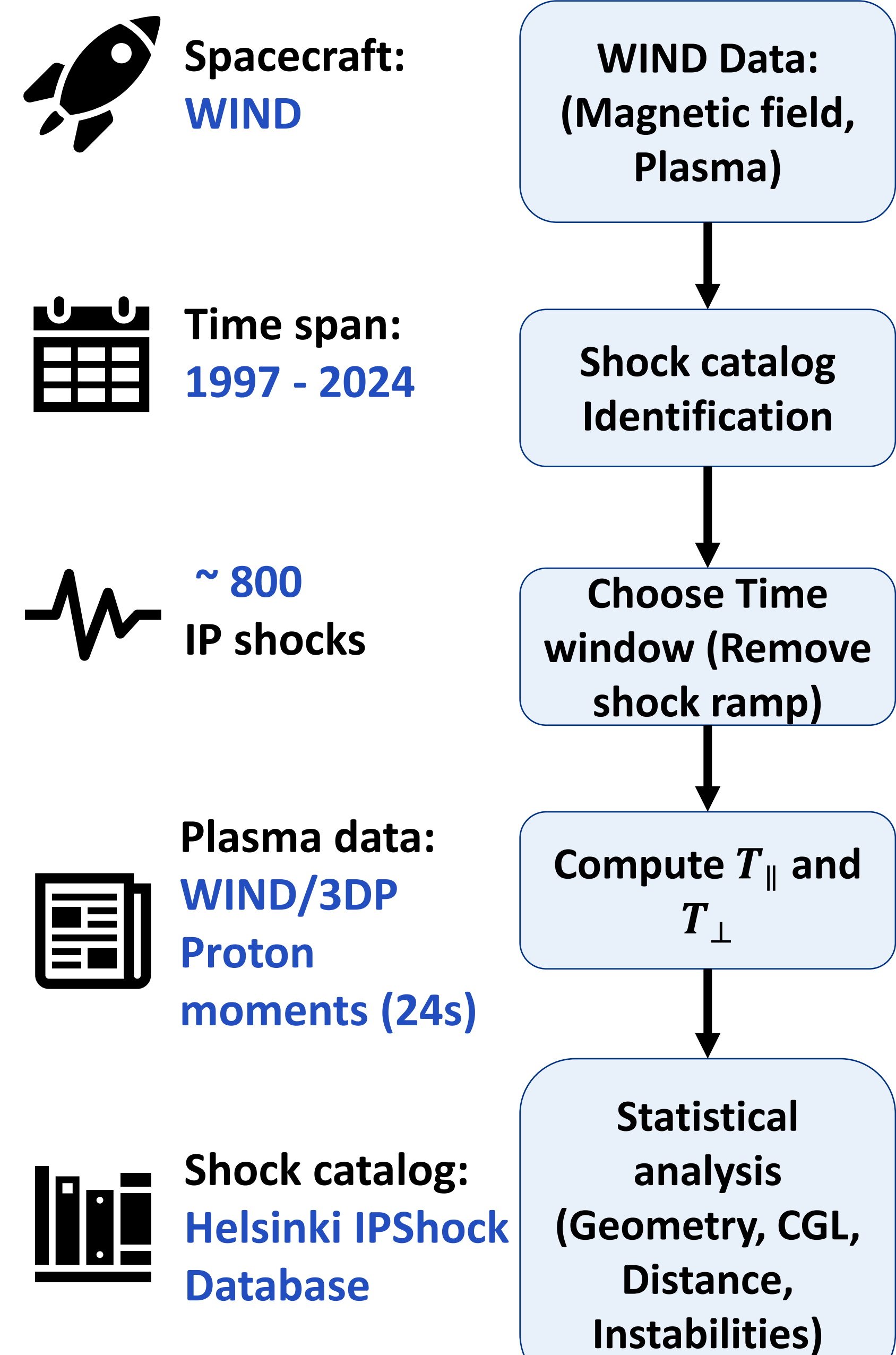


Interplanetary shocks efficiently modify proton temperature anisotropy. We analyze ~ 800 shocks observed by WIND (1997-2024) to investigate the roles of shock geometry, distance from shock, and kinetic instabilities.

## 1. MOTIVATION

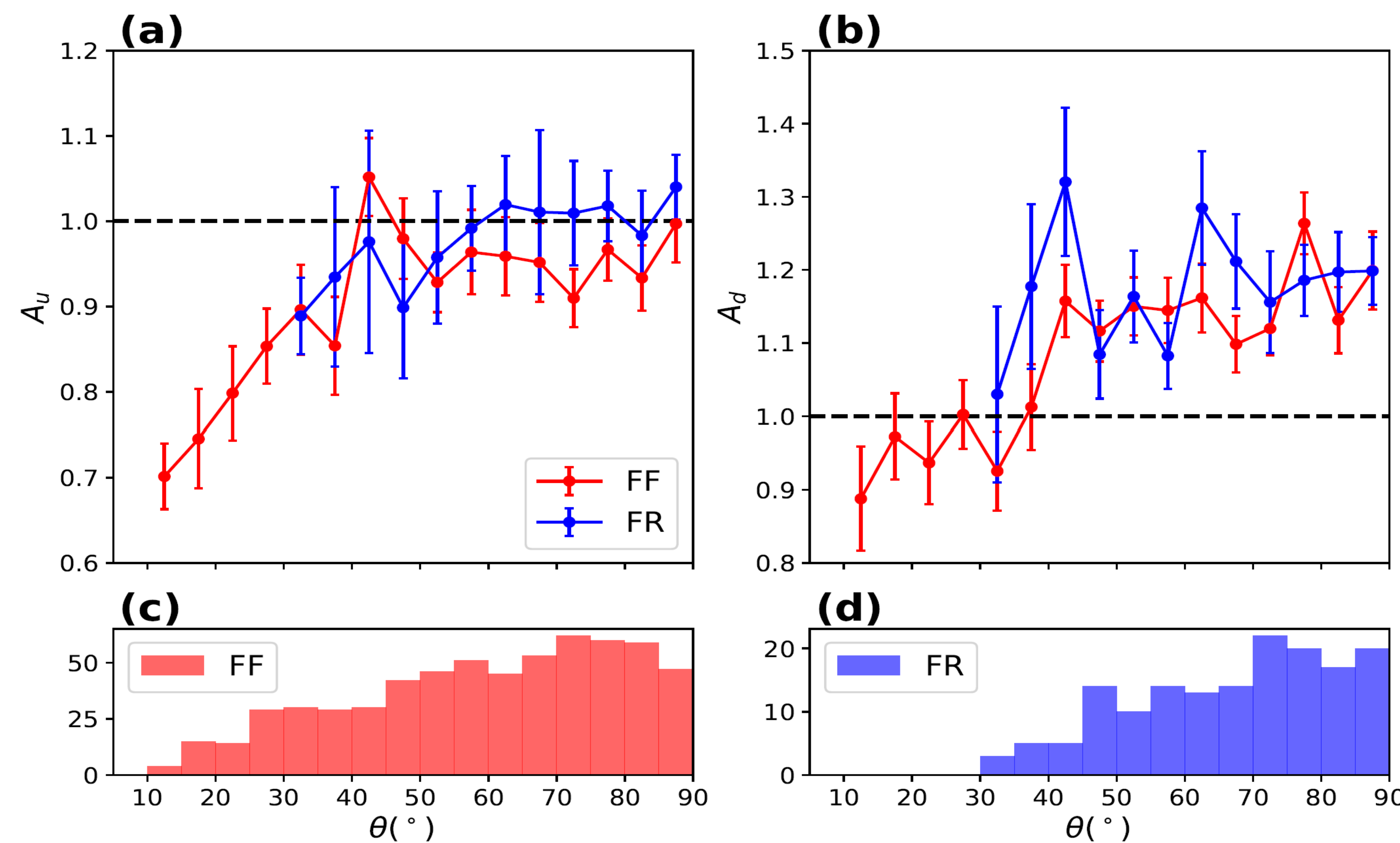
- Collisionless shocks are ubiquitous in space plasma and play a key role in plasma heating, particle acceleration, and energy dissipation.
- Proton temperature anisotropy  $A = T_{\parallel}/T_{\perp}$
- Anisotropy is controlled by shock geometry and regulated by kinetic instabilities.

## 2. DATA & METHODS



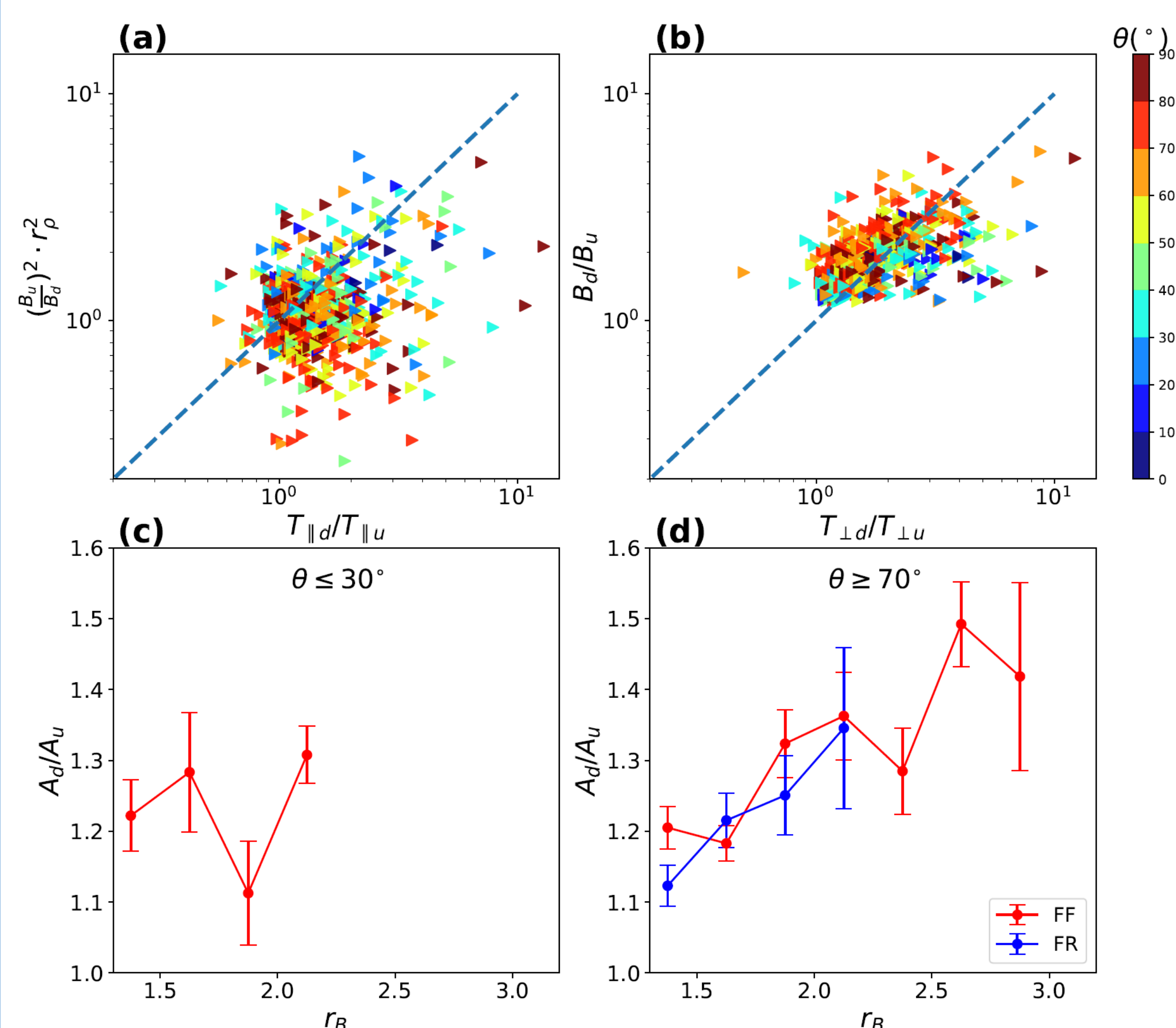
Contact:  
zeping.jin@uah.edu

## 3. RESULTS I: DEPENDENCE ON SHOCK GEOMETRY



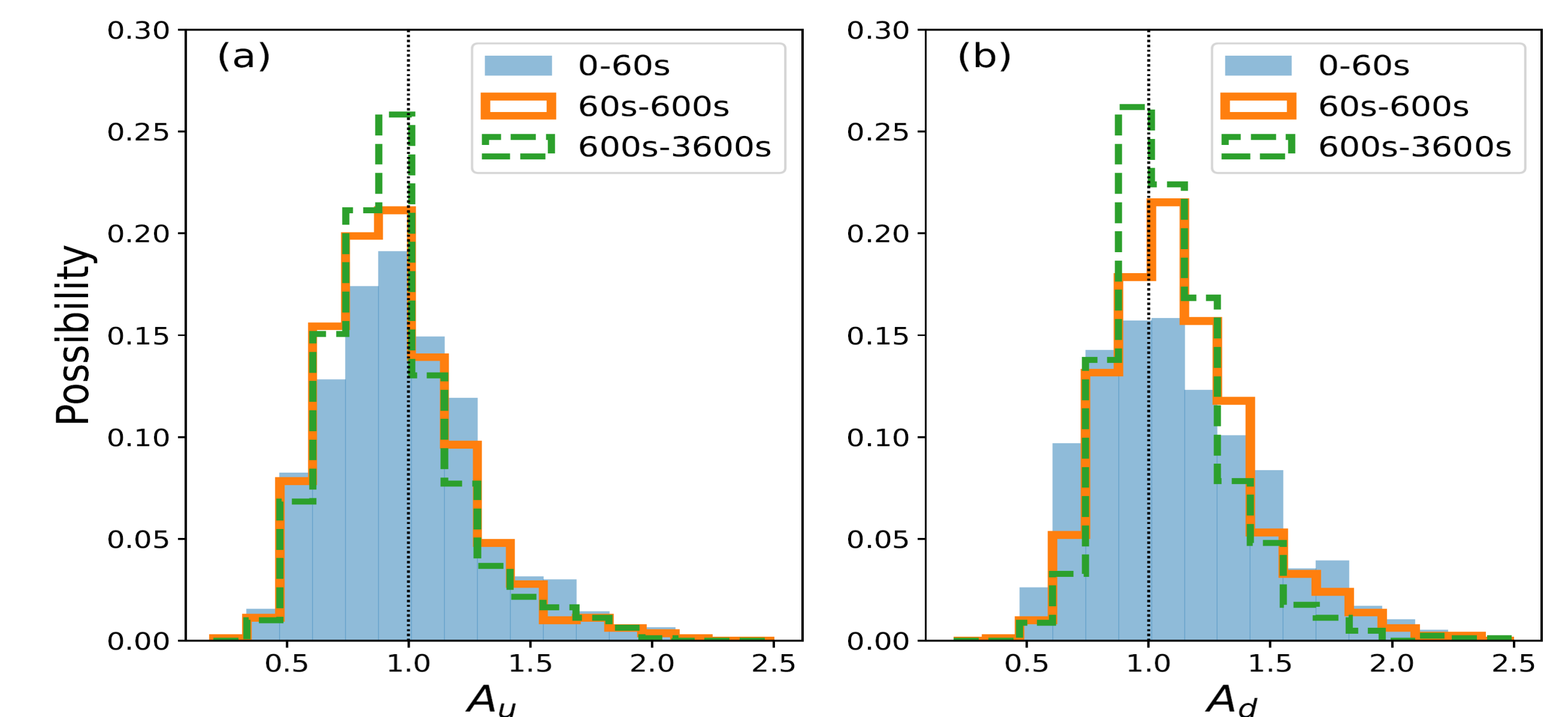
- Quasi-parallel shocks: Upstream anisotropy  $A_u < 1$ ; Downstream  $A_d \sim 1$  (nearly isotropy)
- Quasi-perpendicular shocks: Strong perpendicular heating,  $A_d > 1$ .
- Shock geometry plays a dominant role in anisotropy modification.

## 4. RESULTS II: COMPARISON WITH CGL PREDICTIONS



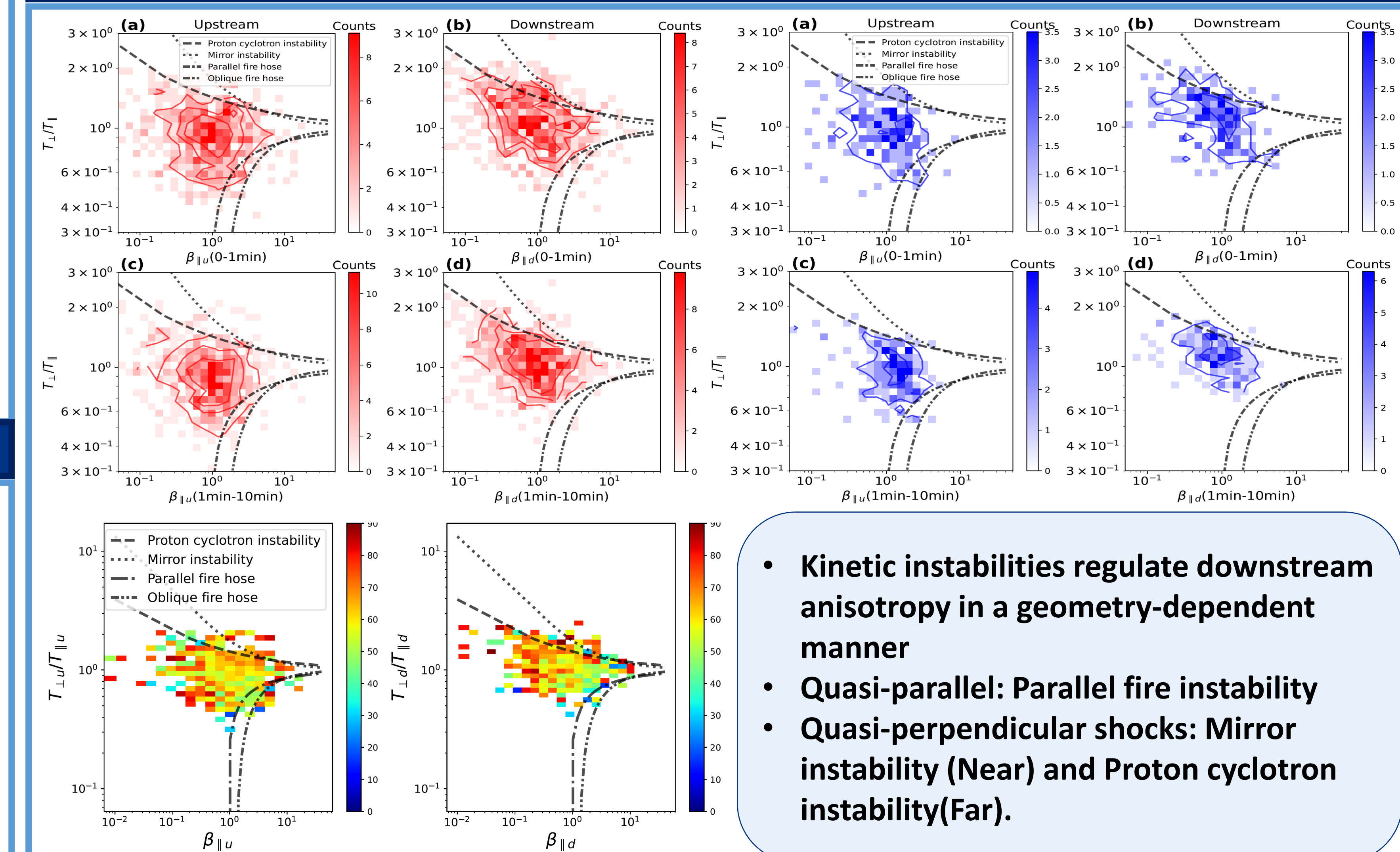
- Significant departures from CGL are observed.
- CGL overpredicts  $T_{\perp}$  and underpredicts  $T_{\parallel}$  at quasi-perpendicular shocks.
- Quasi-parallel shocks show excess perpendicular energization.
- Results indicate important non-adiabatic and kinetic effects.

## 5. RESULTS III: DISTANCE FROM SHOCKS



- Strong anisotropy occurs near the shocks.
- Anisotropy gradually relaxes toward isotropic solar wind conditions at larger distances.

## 6. RESULTS IV: INSTABILITY REGULATION



- Kinetic instabilities regulate downstream anisotropy in a geometry-dependent manner
- Quasi-parallel: Parallel fire instability
- Quasi-perpendicular shocks: Mirror instability (Near) and Proton cyclotron instability (Far).

## 7. CONCLUSIONS

- Shock obliquity is the primary factor controlling proton temperature anisotropy across IP shocks.
- Quasi-perpendicular shocks produce stronger perpendicular heating, leading to  $(T_{\perp} > T_{\parallel})$  downstream.
- Observed temperature changes deviate from CGL predictions, indicating significant non-adiabatic and kinetic effects.
- Shock-enhanced anisotropy is strongest near the shock and gradually relaxes downstream.
- Instability regulation is geometry-dependent: mirror/cyclotron at perpendicular shocks and firehose at parallel shocks.