UVCS/SOHO Measurements of Heating in Coronal Streamers

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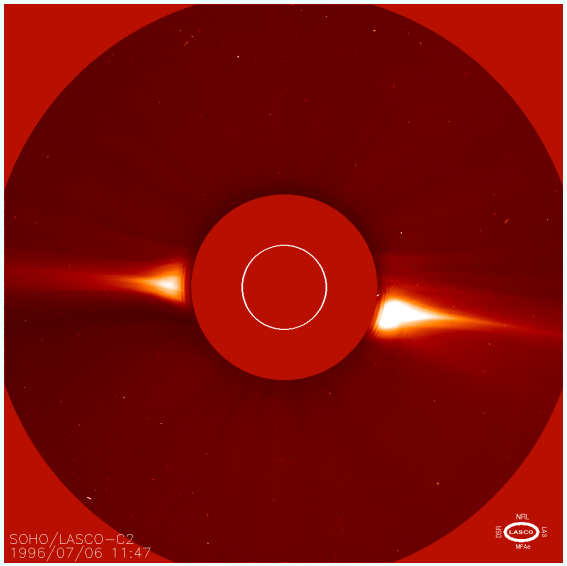
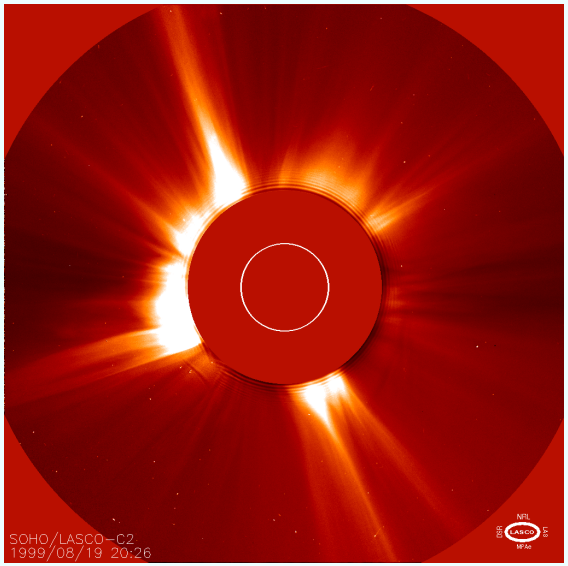




Introduction

- Purpose of UVCS Streamer Study:
  - To characterize the physical properties of coronal streamers to provide constraints on *heating* theories and to identify sources of solar wind
  - Measurements include (LOS velocity distributions, line intensities, line ratios, and Doppler shifts)
- Some related work on streamer (not wind) properties:

Streamer absolute abundances (Raymond et al. 1997)
Active region streamer properties (Li, et al. 1998)
Line profiles in streamers (Zangrilli et al. 1999)
Physical properties of streamers (Parenti et al. 2000)
Solar minimum streamer properties (Strachan et al., 2002)
Anisotropic vel. distributions (Frazin, Cranmer & Kohl 2003)
Active region streamer abundances (Uzzo et al. 2003)

Streamer Line Width Measurements

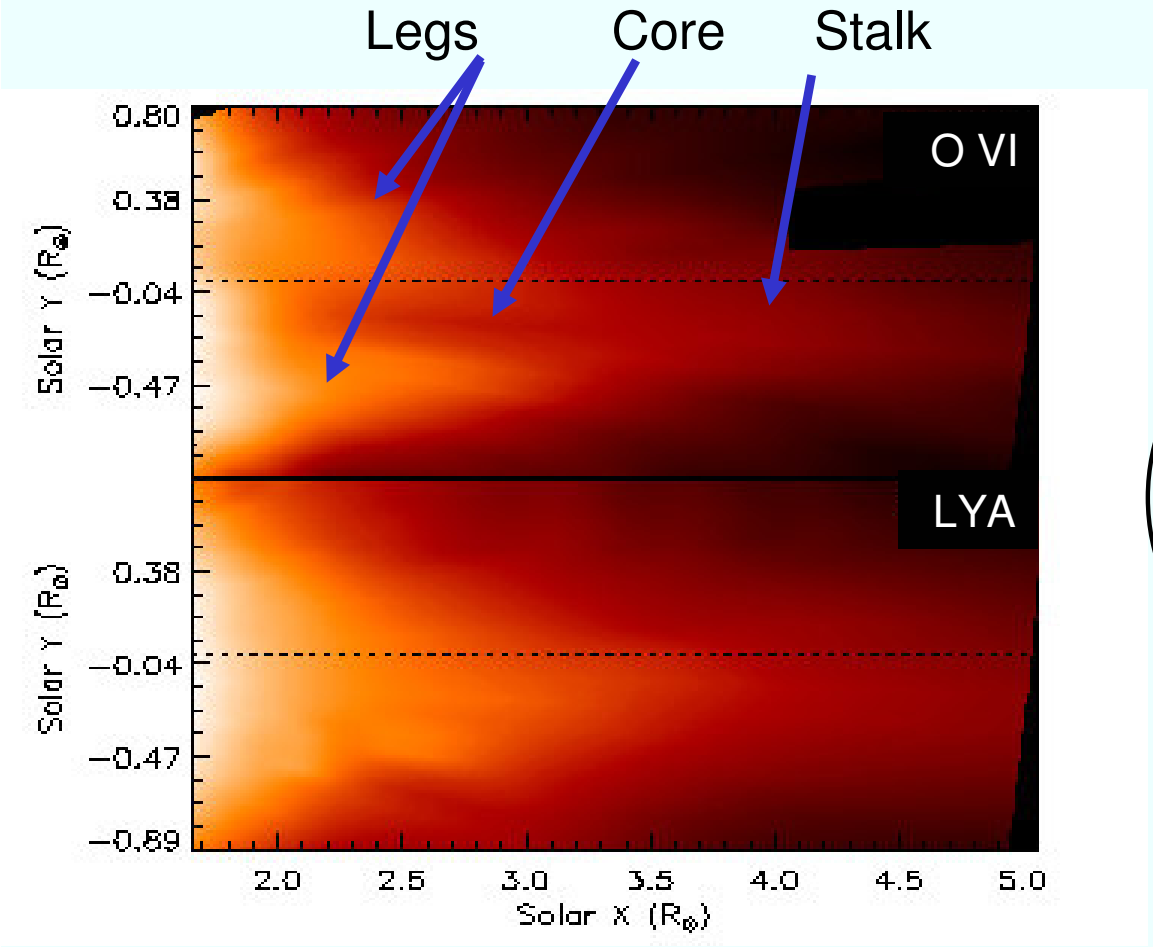
Some important questions:

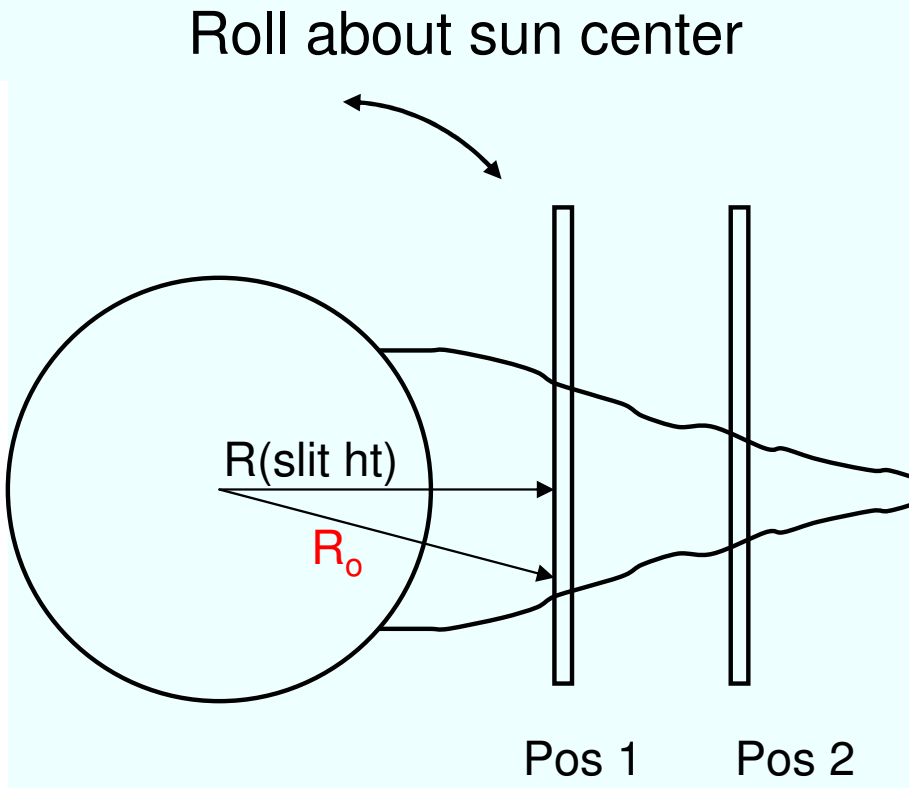
- How do the kinetic temperatures (from thermal + non-thermal broadening) of protons and O^{5+} ions vary as a function of height and distance from the streamer axis?

- What do kinetic temperatures reveal about the nature of extended heating in streamers?

- How do streamer properties change over the solar cycle?

1997 April 23-27 UVCS Streamer Intensity Maps





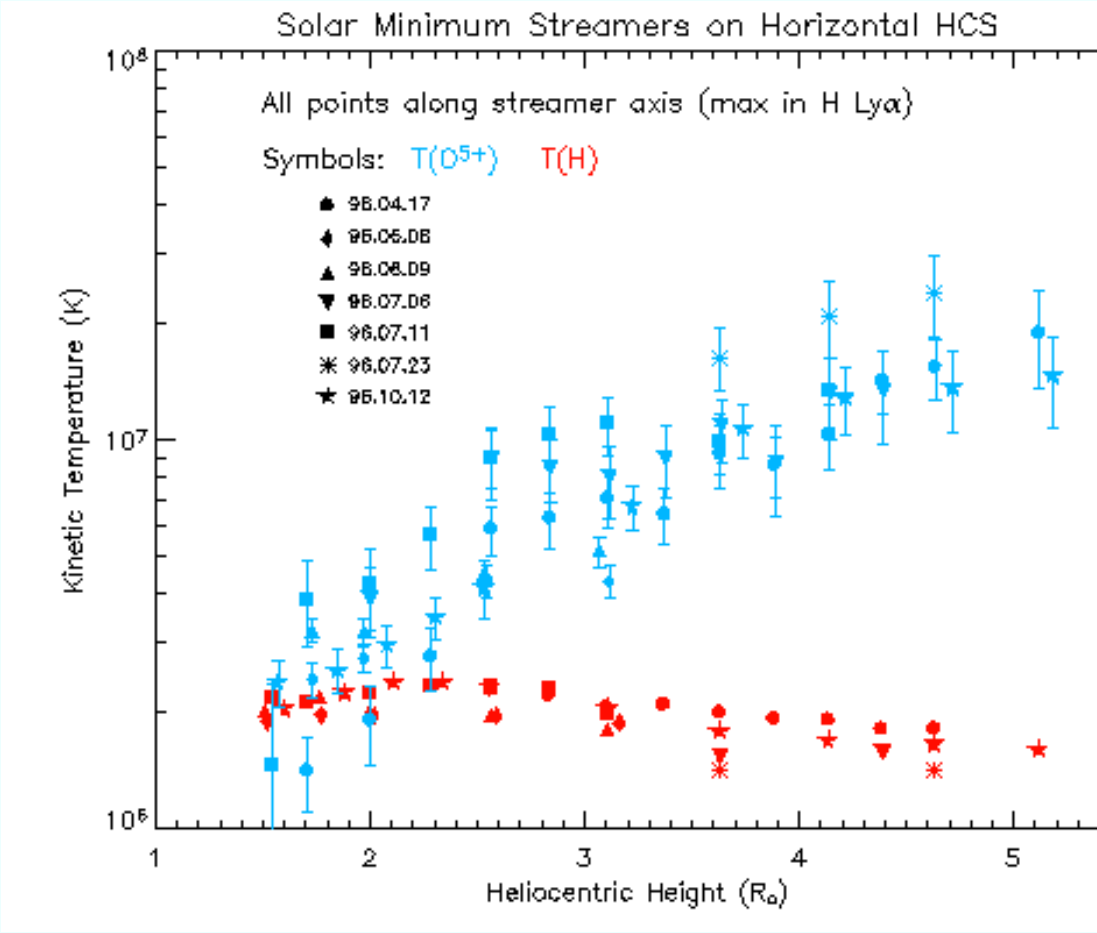
Selection Criteria for this Study

- Only quiet region streamers were used since most observations require several hours to scan in height.
- All streamers were observed along the large-scale neutral current sheet.
- Observations with wide UVCS spectrometer slits were rejected. Smallest slit width used is 0.050 mm (~0.18 Angstrom FWHM)
- Spectral line profiles typically have more than a few thousand counts (for accurate line fitting results).

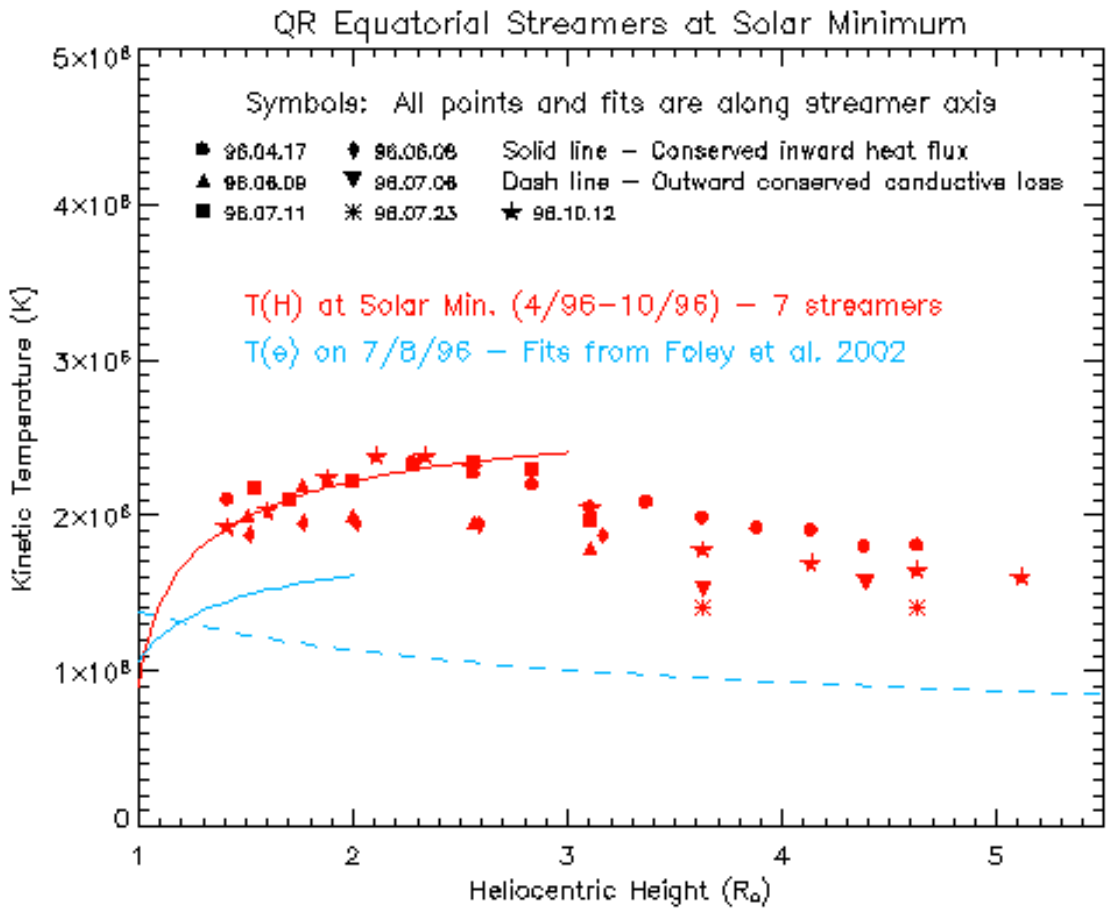
All profiles have disk stray light & interplanetary Ly-alpha removed. Profiles are also corrected for instrument profile.

Solar Minimum Streamers: Summary of Evidence for Wave Heating

- Line widths reveal $T(O^{5+})$ is much larger than T for ~1 MK thermal plasma → ICR wave heating?
- $T(O^{5+})$ continually rises up to highest obs. height → Extended non-thermal heating
- $T(O^{5+}) > T(H)$ → preferential heating of heavy ions
- $T(O^{5+}) = T(H)$ at base → ions and protons are in ~ thermal equilibrium at base
- Wave heating for T(H) not clear

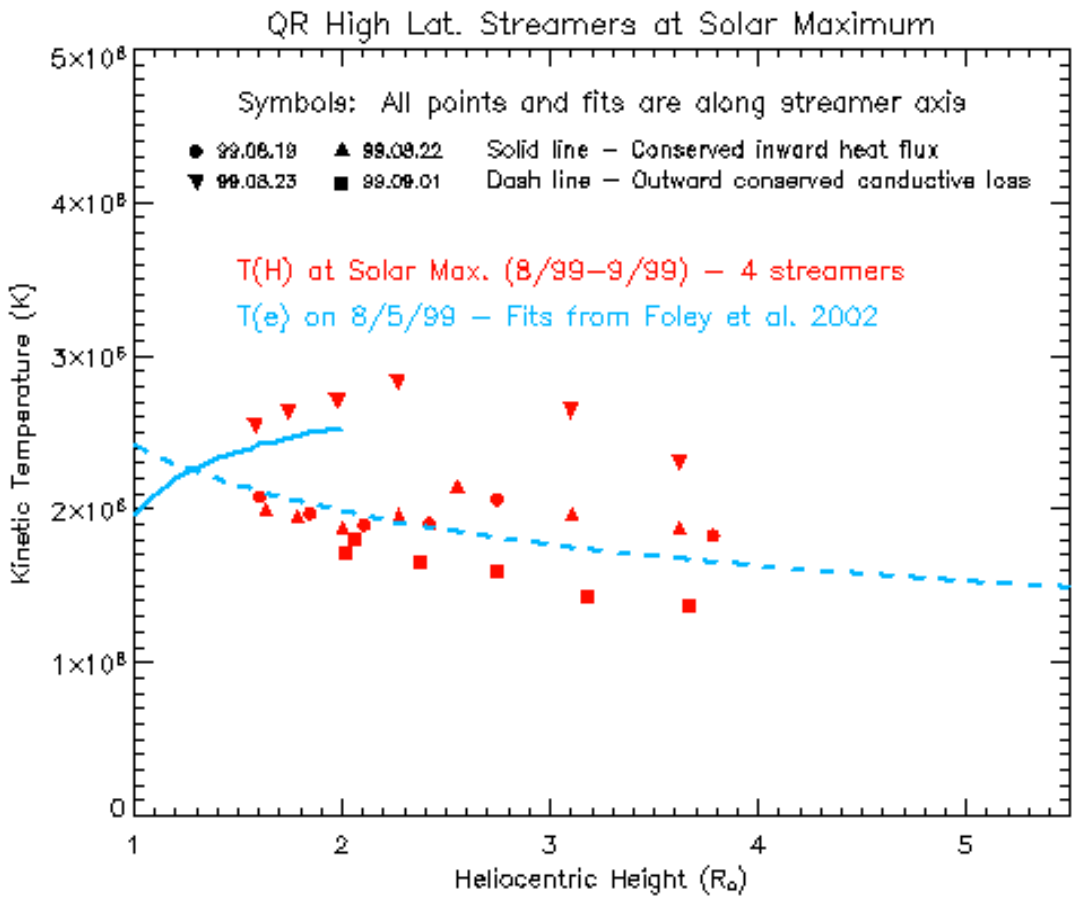


Solar Minimum Streamers: Proton vs. Electron Temperature Measurements



- T(e) determined from CDS line ratios (Fe IX – Fe V intensities).
- If T(e) is correct, T(H) > T(e) → non-thermal proton heating
- Break in T(H) may indicate start of outflow for slow wind. This differs from break in T(e) blue line
- Conductive flux at base F_o = 2.57 x 10^5 erg/cm^2/s (UVCS)
- T(H) = T(e) at base → protons and electrons are in thermal equilibrium at base T= 1 MK.

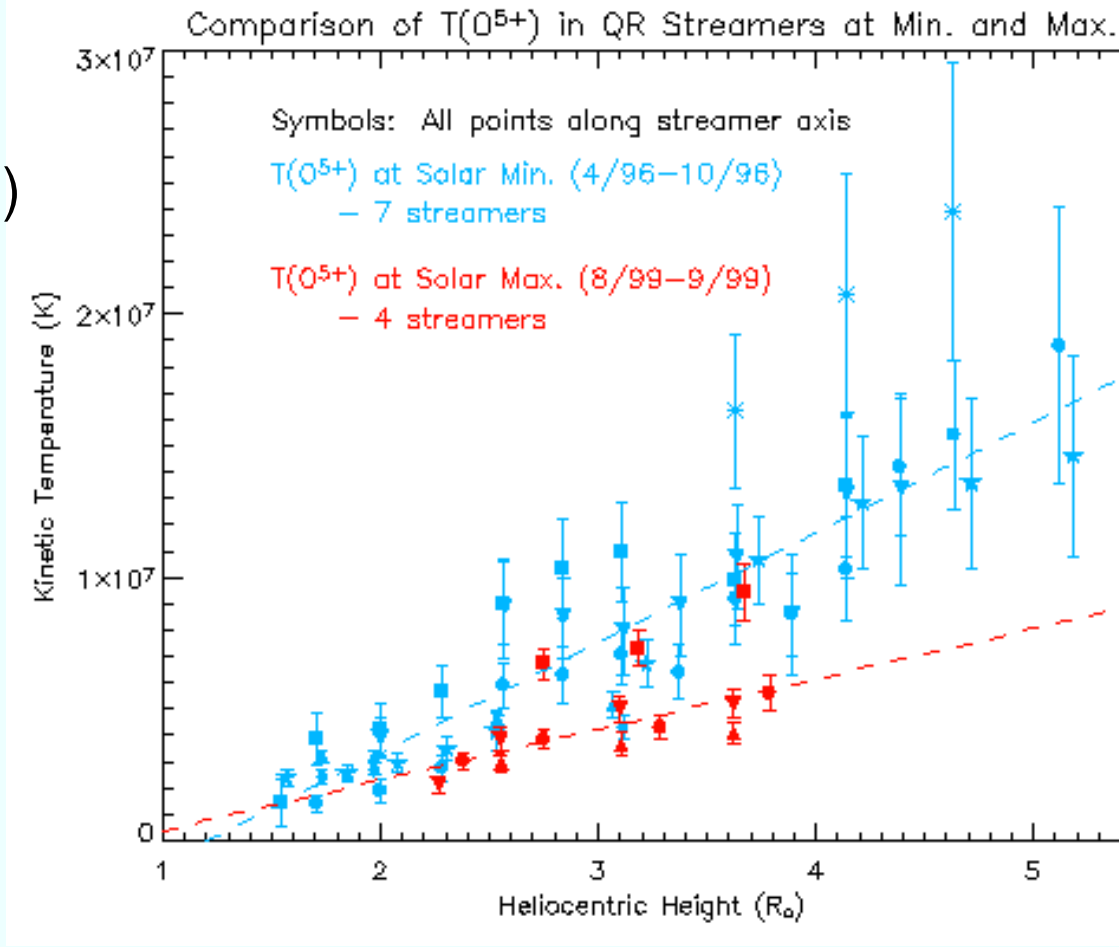
Solar Maximum Streamers: Proton vs. Electron Temperature Measurements



- Solar Max T(e) = 2 MK at base
  → T(e) ratio scales with power of **B**
- T(H) ~ T(e) for CDS streamer if their fit (blue solid line) at the low heights Is extended to the higher UVCS heights.
- Other Solar Max streamers have T(H) ~ T(e) [blue dashed line.]
- But these same streamers have T(H) ~ Solar Min T(H) → no chang in coronal T(H) with solar cycle!
- Data may imply that there is a different proton heating at Sol Max

Solar Cycle Changes for O^{5+} Heating

- $T(O^{5+})$ kinetic temperatures appear to change over the solar cycle (Frazin, Cranmer, Kohl 2003)
- Assuming linear fits, slope at Solar Max ~ 2 x Solar Min slope ➔ heavy ions do take advantage of the increase in |B| strength. [This is contrary to the T(H) data.]
- $T(O^{5+})$ for *some* streamers at Solar Max are similar to Solar Min $T(O^{5+})$ ➔ internal streamer structure may play a role.



Conclusions & Future Work

- UVCS determinations of $T(O^{5+})$ show strong evidence for non-thermal heating of ions in streamers in comparison with UVCS T(H) and CDS T(e) measurements.
- Large equivalent $T(O^{5+})$ perpendicular to B-direction implies large anisotropies that could be caused by high frequency ion cyclotron waves.
- T(H) results are more uncertain but some UVCS data suggest that T(H) and T(e) could be the same.
- Future Work (near term): Compare other measurements of T(e), T(H), $T(O^{5+})$ for the same streamers to better determine if the various coronal plasma components have different dependences on solar cycle variation.