The COronal Diagnostic EXperiment (CODEX) and its potential synergies with PUNCH

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CODEX

The **COronal Diagnostic EXperiment** (**CODEX**) is a next-generation solar coronagraph.

CODEX combines, for the first time, simultaneous measurements of **density**, **temperature**, and **velocity of the electrons in corona.**

CODEX will be launched in September 2024, and it will observe the corona as external payload of the **International Space Station** (ISS) for a **baseline 6-months mission**.

The **NASA-Goddard Space Flight Center** (PI: Jeffrey Newmark) leads the scientific and technical breakthroughs, supplemented with expertise from the Naval Research Laboratory (**NRL**), the Korea Astronomy and Space Science Institute (**KASI**), and National Institute for Astrophysics (**INAF-OATo**).

M. Casti - CUA at NASA-GSFC

Science Objectives

Are there signatures of hot plasma released into the solar wind from previously closed fields?

What are the velocities and temperatures of the density sub-structures that are observed so ubiquitously in streamers and coronal holes?

Provide first observational constraints to empirical solar wind models of electron heating and acceleration in the key region of 3 - 8 $R_{\odot}$.

Method

- Temperature and speed measurements are based on the theory formulated by Cram (1976) for the formation of the solar corona and extended by Reginald (2001) .
- Modelling the pB signal for the K-corona:

$$pB = I^T_{Total} - I^R_{Total}$$

- Van de Hulst (1950) & Billings(1966)

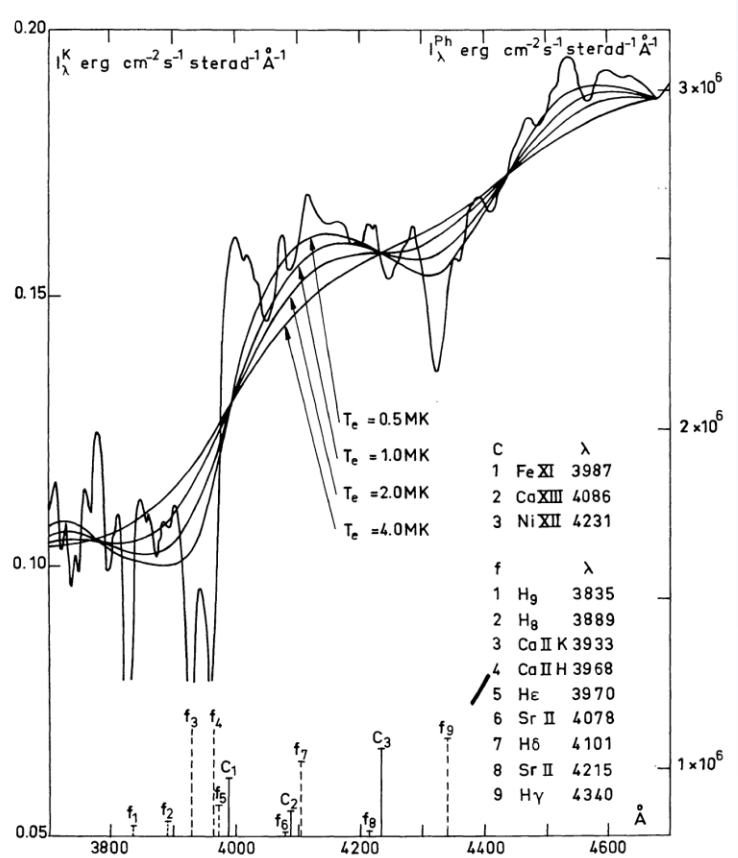
$$pB = I^T_{Total}(N_e) - I^R_{Total}(N_e)$$

- Cram(1976)

$$pB = I^T_{Total}(N_e, T_e) - I^R_{Total}(N_e, T_e)$$

- Reginald (2001)

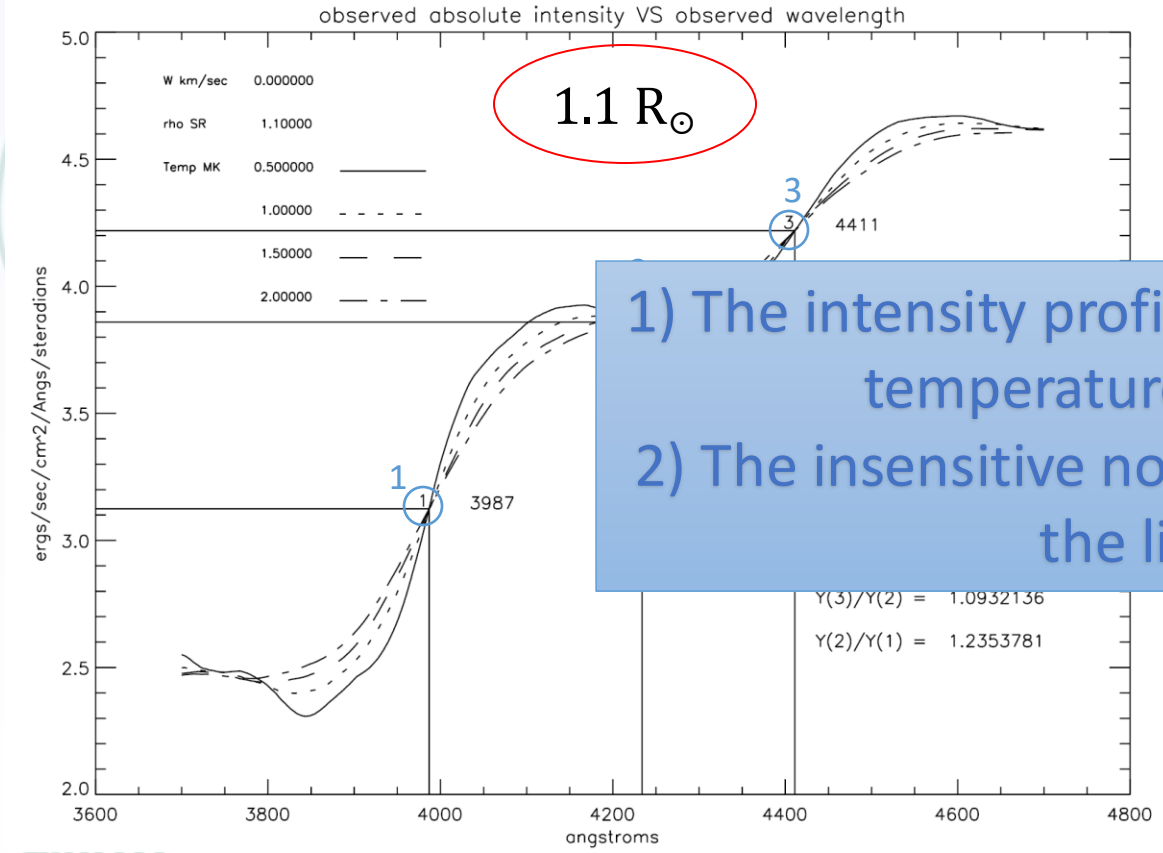
$$pB = I^T_{Total}(N_e, T_e, V_e) - I^R_{Total}(N_e, T_e, V_e)$$

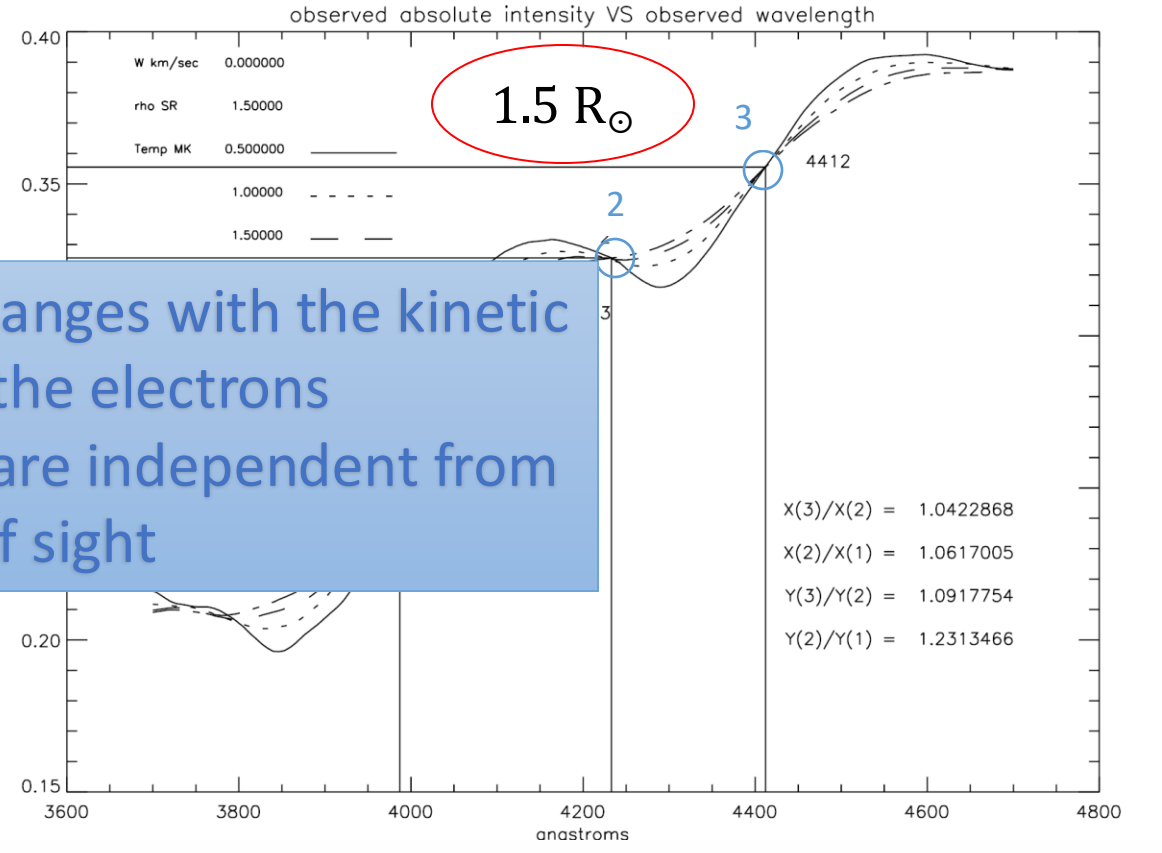


From Cram (1970)

K-coronal intensity profile

$V_{SW} = 0$ km/s





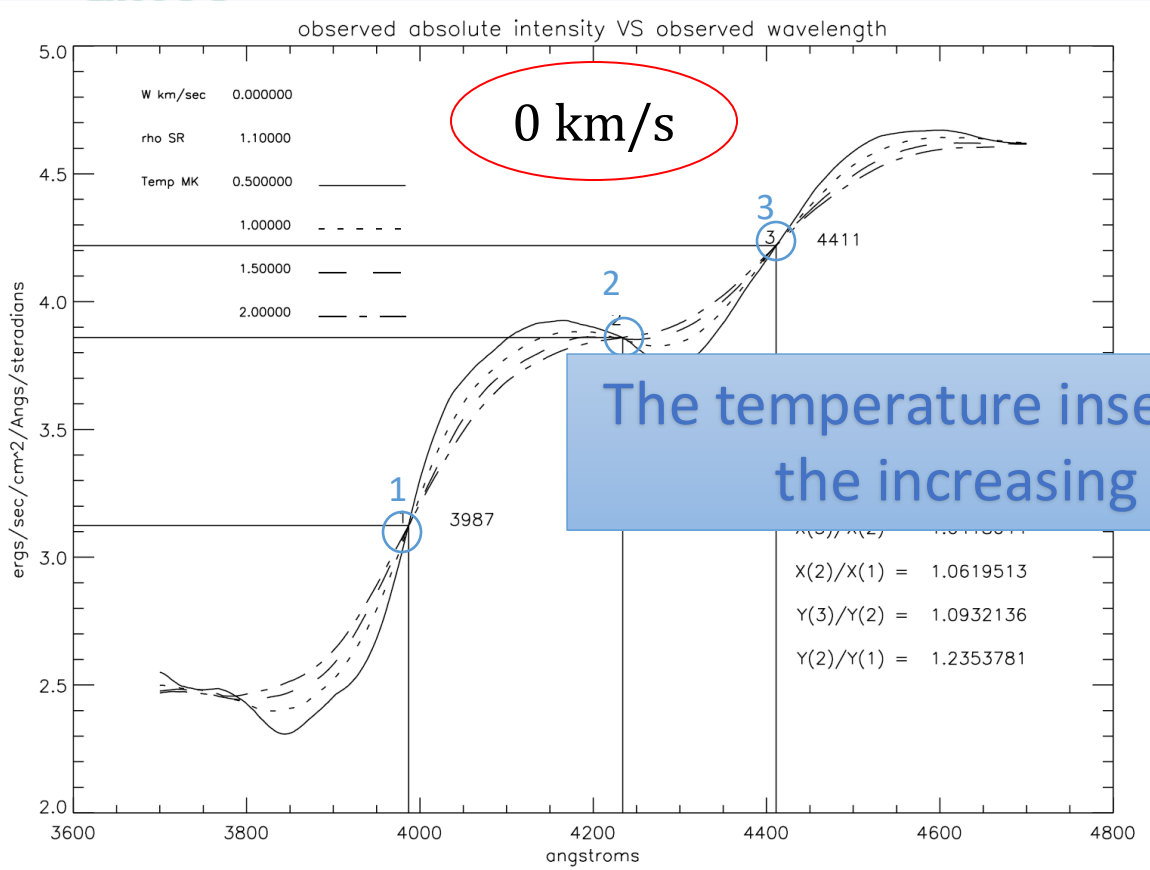
1) The intensity profile changes with the kinetic temperature of the electrons

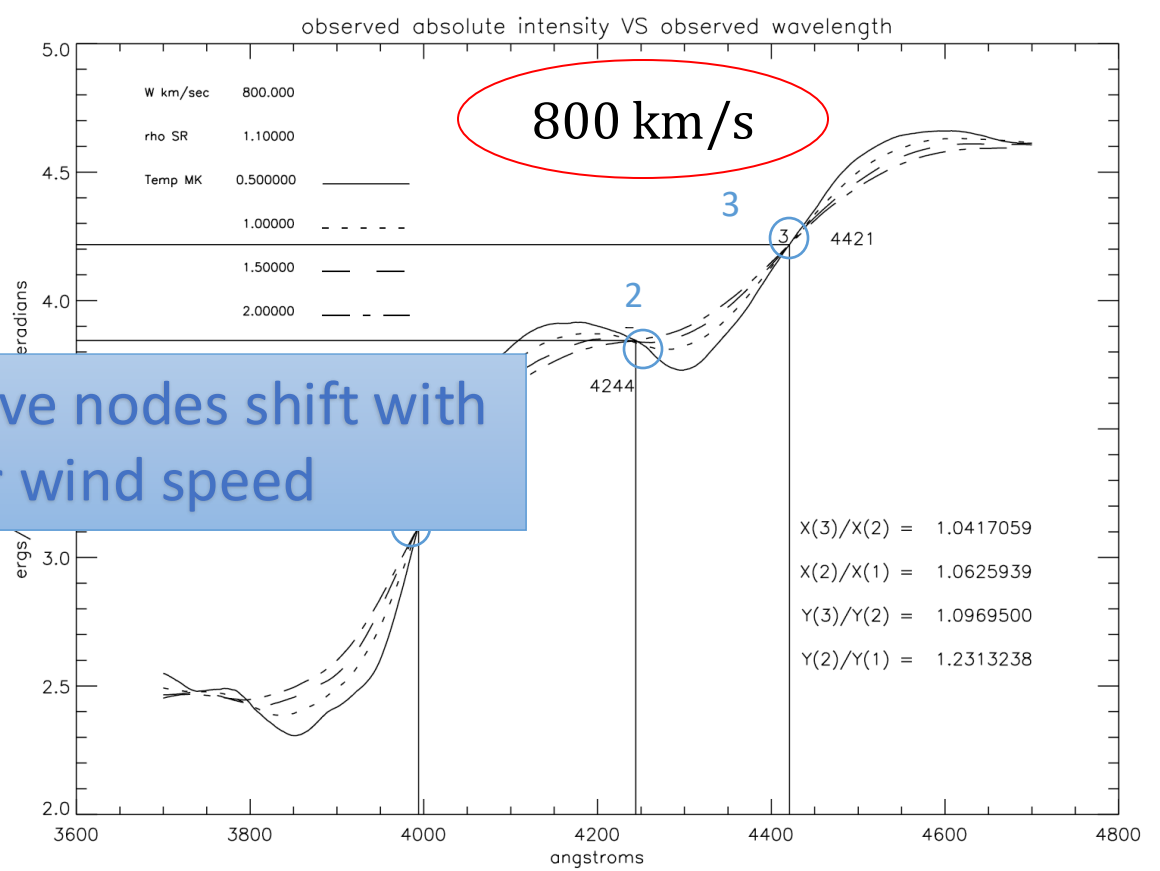
2) The insensitive nodes are independent from the line of sight

From Reginald, N.L., and Davila, J.M. Solar Physics 195, 111–122 (2000). https://doi.org/10.1023/A:1005251808764

K-coronal intensity profile

1.1 $R_\odot$

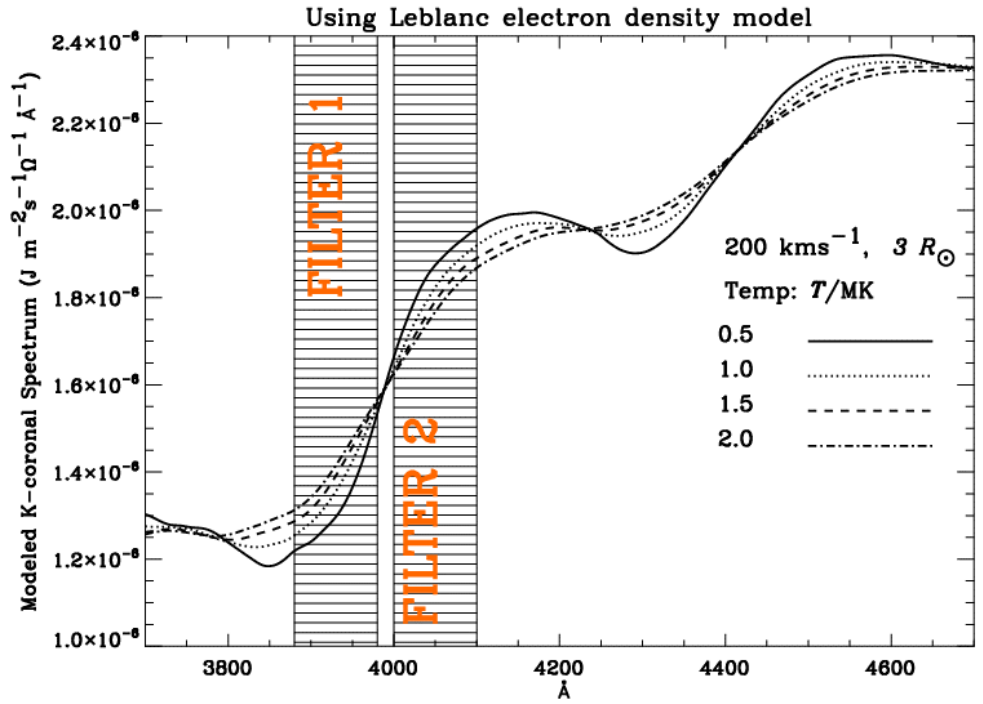


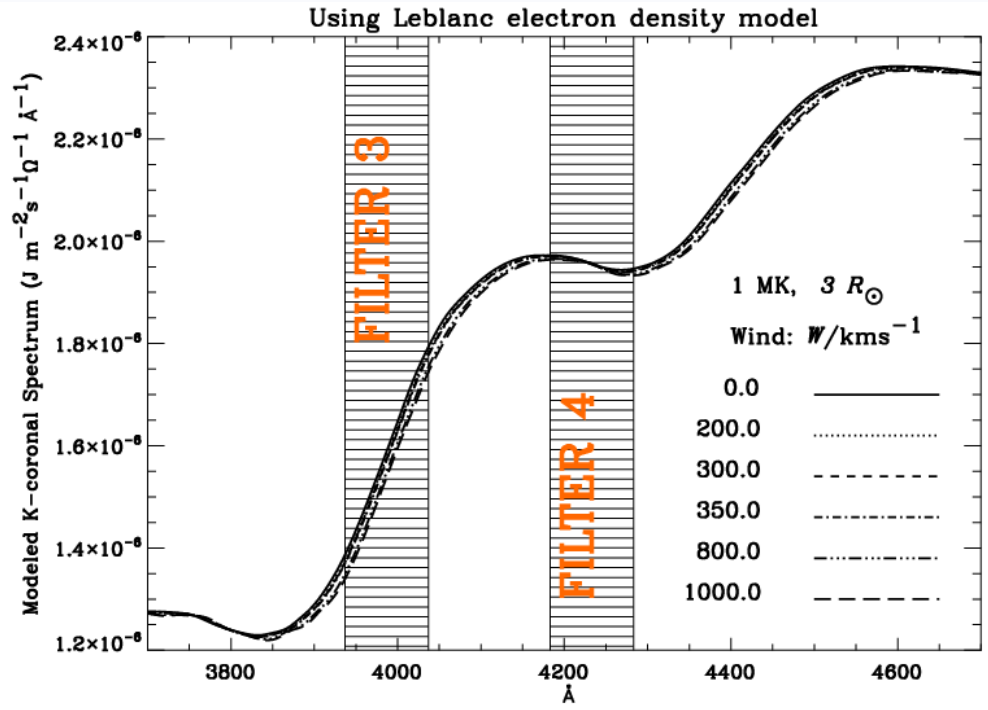


The temperature insensitive nodes shift with the increasing solar wind speed

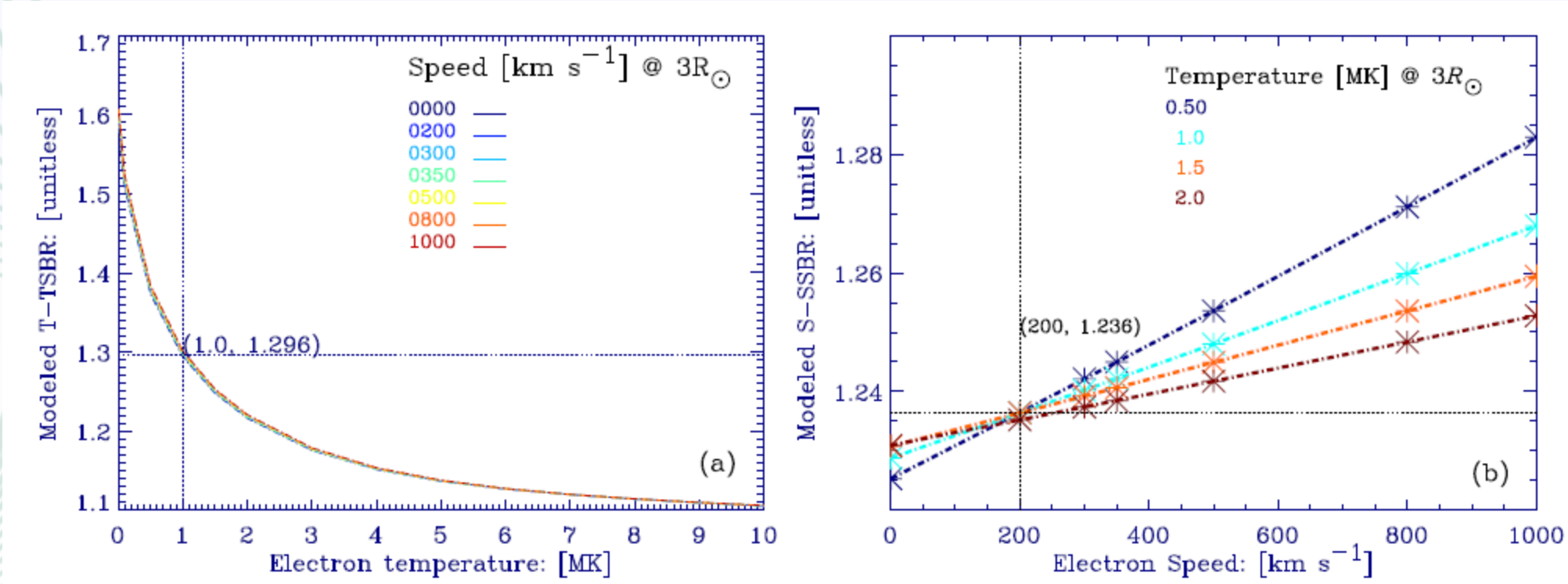
From Reginald, N.L., and Davila, J.M. Solar Physics 195, 111–122 (2000). https://doi.org/10.1023/A:1005251808764

Selected filters





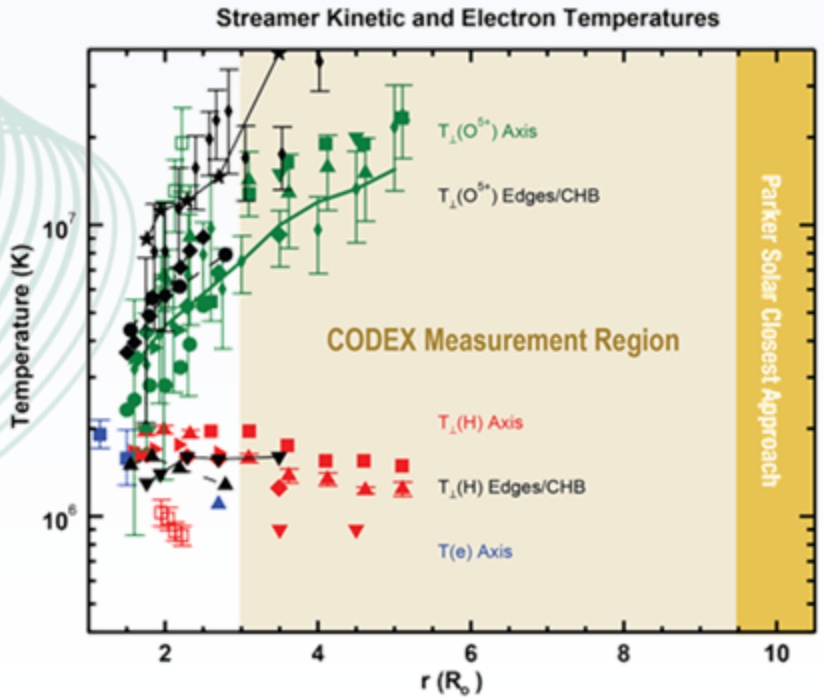
Interpreting the ratio

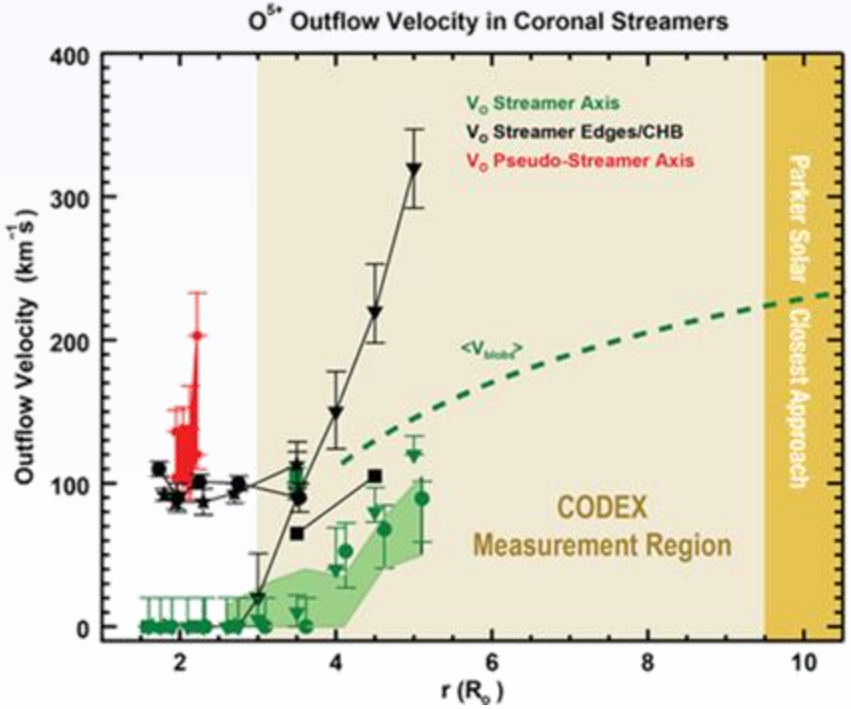


Reginald, N., Newmark, J. and Rastaetter, L., 2021. Solar Physics, 296(10), p.146.

Filling the gap

- CODEX is designed to fill a ***crucial gap*** in the information on the physical conditions in the solar wind acceleration region (~3-10 $R_\odot$)





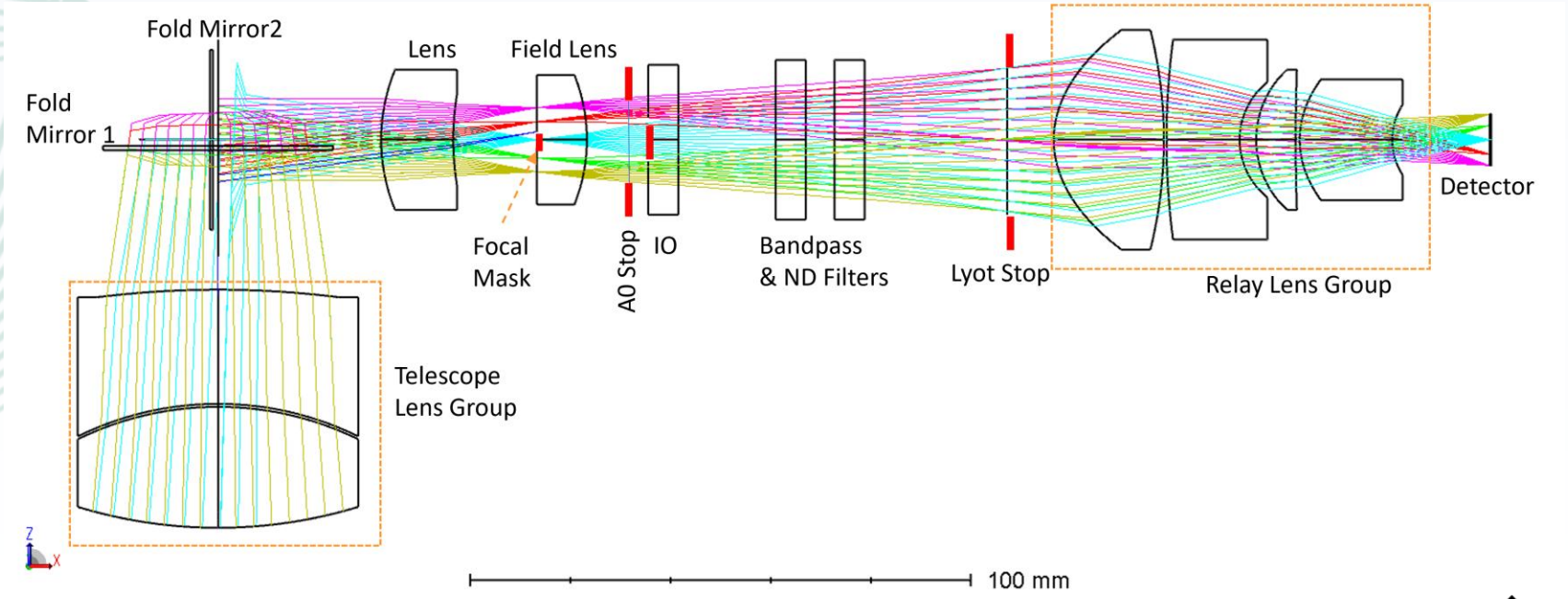
The Payload

- CODEX is a two-stage externally occulted coronagraph.
- Two filter wheels allow the instrument to acquire images of the solar corona at different wavelengths.
- Images of the K-corona in polarized light are acquired thanks to a polarization sensor (CMOS).
- The pointing system ensures the coronagraph is always pointing at the Sun, when in visibility, during the ISS orbit.

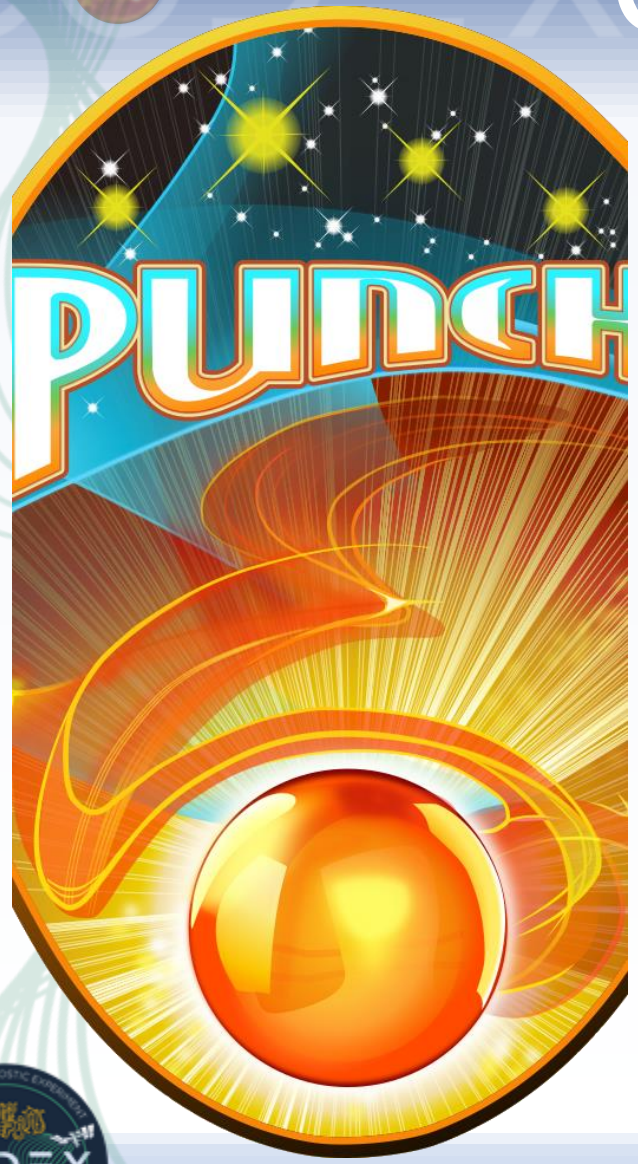
Field of View	3-10 R
Main filters	393.5 ± 5 nm: T1 405.0 ± 5 nm: T2 398.7 ± 5 nm: S 1 423.3 ± 5 nm: S 2 412.5 ± 27.5 nm: Broadband
Detector	Polarization Image sensor

The Payload

- CODEX unique features:
  - Focal mask
  - Capability to observe the solar corona at four different wavelengths
  - Polarization camera



CODEX & PUNCH

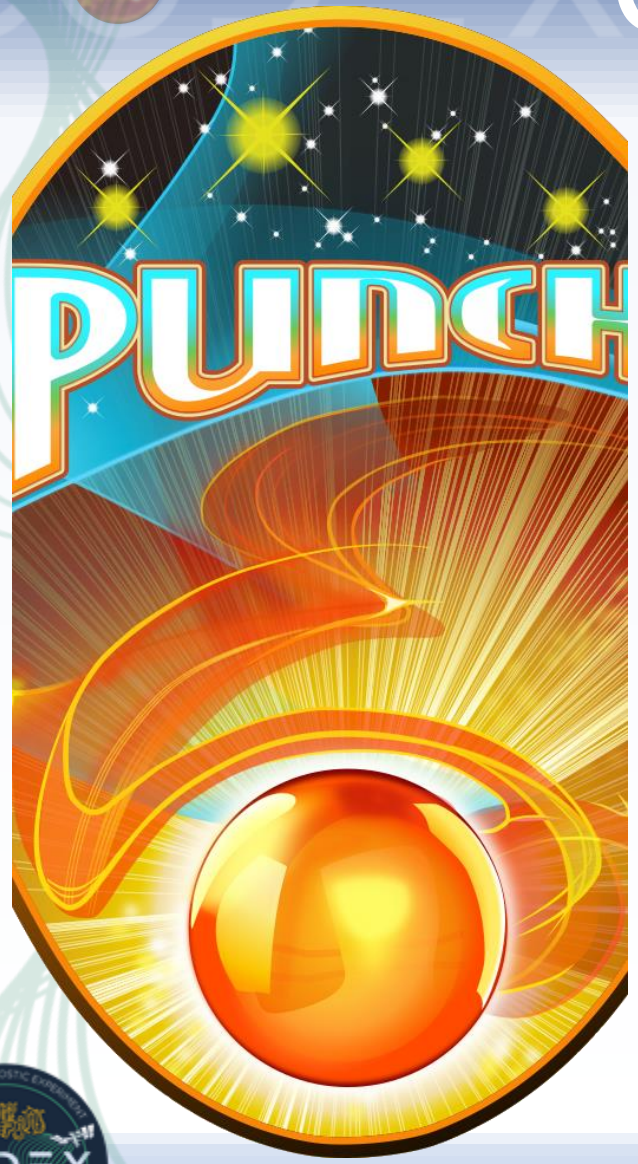


Overlapping field of view: ~5-10 $R_\odot$ →

Relationships between solar wind density structures with velocity and temperature, which are crucial tests of solar wind formation theories.

Field of view combination: ~3-180 $R_\odot$ → tracking of solar wind structures from ~3 $R_\odot$ out through the inner solar system and measure their velocity and thermal evolution in CODEX and their structural evolution through PUNCH.

CODEX & PUNCH



What if the missions do not overlap?

CODEX velocity measurements can be used to test PUNCH optical flow algorithms.

By applying the optical flow algorithms to the CODEX total (or pB) brightness and then comparing those to the direct CODEX velocity measurements, we can determine how much solar wind is comprised of a constant flow, versus how much flow is intermittent.

Conclusions

- CODEX is a next generation solar coronagraph that will be launched in September 2024 to observe the solar corona as an external payload of the ISS
- If CODEX nominal mission will be extended:
  - CODEX will extend the PUNCH field of view at lower heliocentric altitudes
    - CODEX FoV: Thermal and velocity evolution
    - PUNCH FoV: Structural and velocity evolution
    - Overlapping FoV: link Thermal and velocity evolution to structural
- Without CODEX mission extension:
  - CODEX data will be useful to test PUNCH optical flow algorithms.

GO CODEX!

GO PUNCH!