Fractional Velocity Dispersion Analysis (FVDA)

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Contents

FVDA contains two approaches

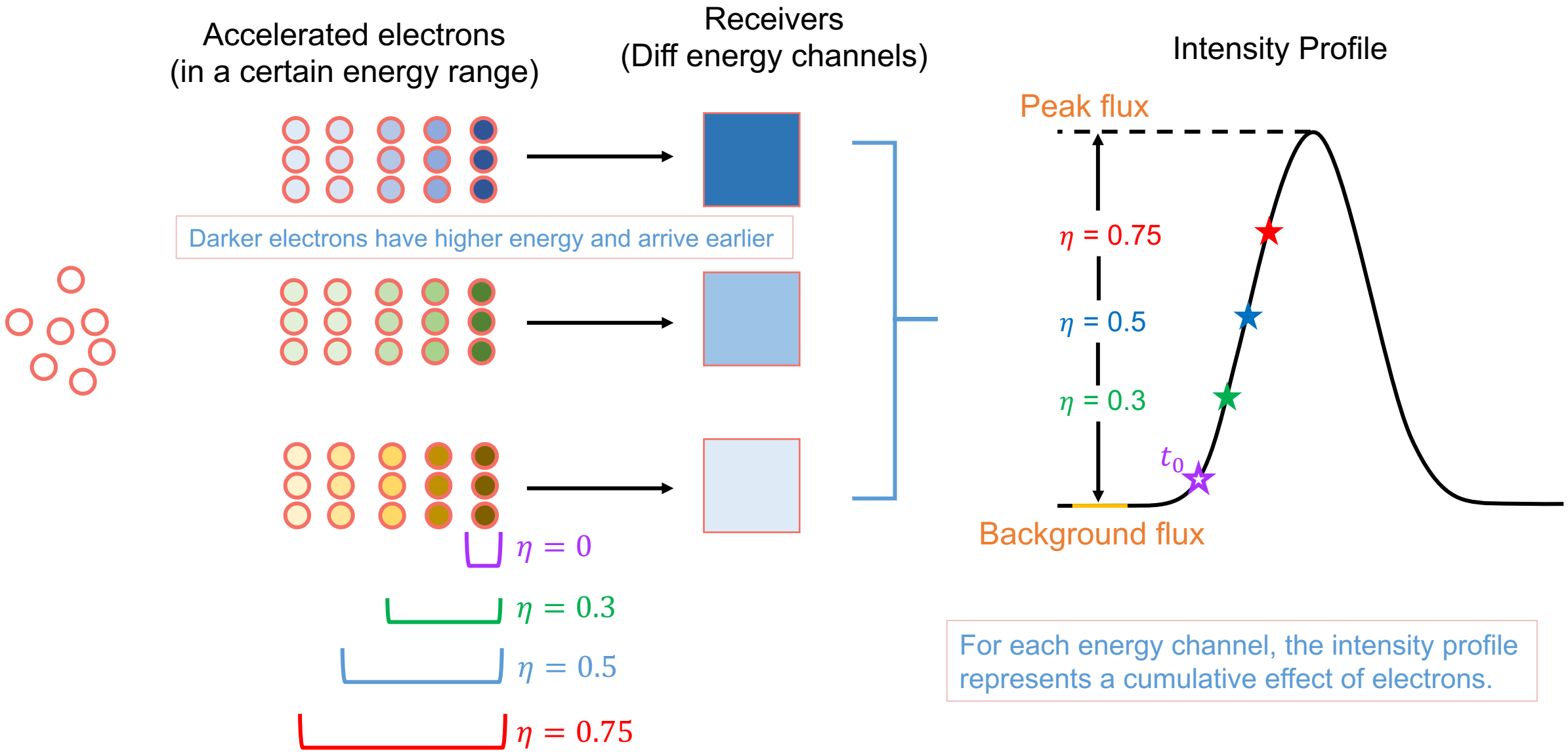
- Original paper of the FVDA

  Lulu Zhao, Gang Li, Ming Zhang, et al. Statistical Analysis of Interplanetary Magnetic Field Path Lengths from Solar Energetic Electron Events Observed by WIND. The Astrophysical Journal, 878:107 (9pp), 2019 June 20.

- Summary of both approaches can be found:

  Xiangyu Wu, Gang Li, Lulu Zhao, et al. Statistical Study of Release Time and Its Energy Dependence of In Situ Energetic Electrons in Impulsive Solar Flares. Journal of Geophysical Research: Space Physics,128, e2022JA030939.

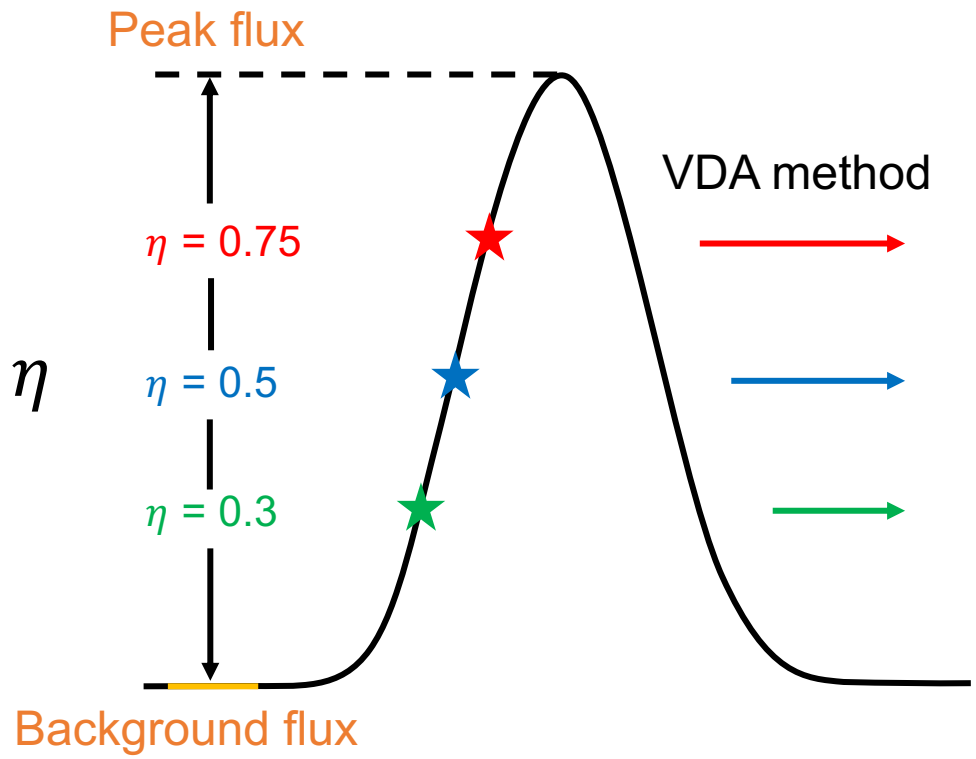
Explanation of the idea of FVDA



For each energy channel, the intensity profile represents a cumulative effect of electrons.

Fractional Velocity Dispersion Analysis (FVDA)

- Simultaneous release
- Scatter-free propagation
- Less affected – determine onset/peak time, contamination effect



VDA method

$L_{0.75}$ = 1.28 ± 0.07 AU, $T_r(\eta = 0.75)$

$L_{0.5}$ = 1.21 ± 0.05 AU, $T_r(\eta = 0.5)$

$L_{0.3}$ = 1.18 ± 0.04 AU, $T_r(\eta = 0.3)$

A self-consistent check and uncertainty measure

$L - \eta$
$T_r - \eta$
extrapolating

L_0 = 1.15 ± 0.08 AU, $T_r(\eta = 0)$

Zhao et al. (2019)

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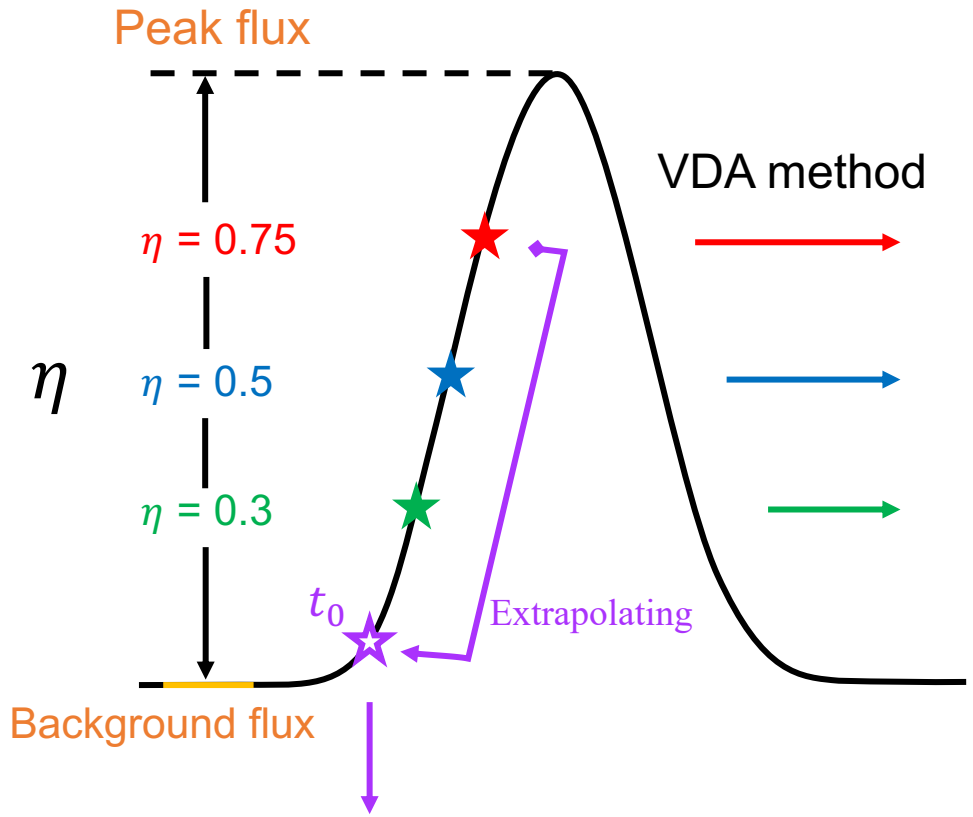

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Approach II

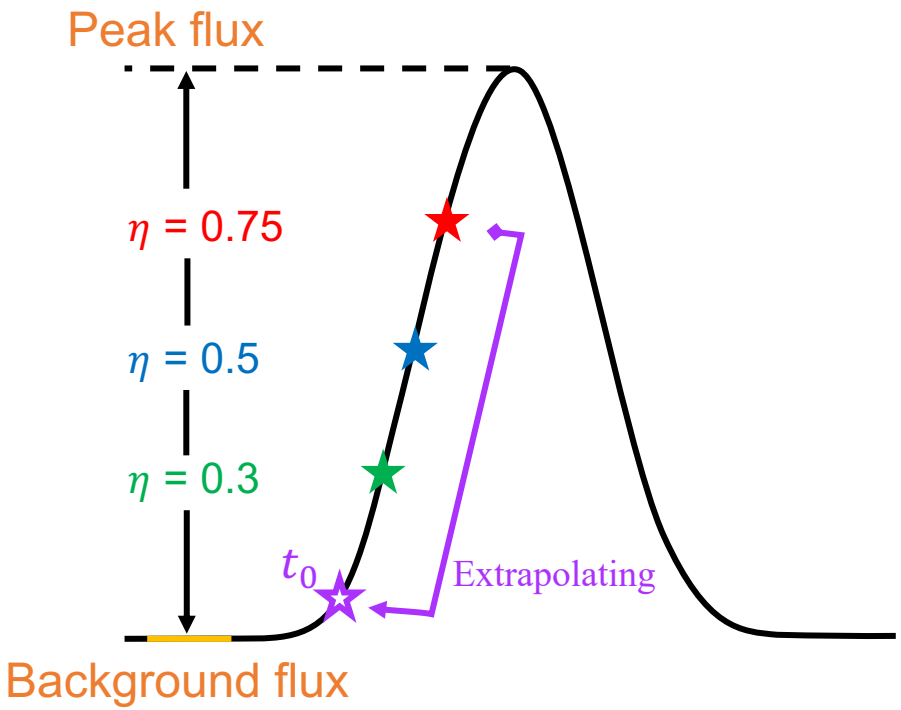
Wu et al. (2023)

Approach I

Zhao et al. (2019)

Fractional Velocity Dispersion Analysis (FVDA)

Approach II



$$t_i(\eta) = a\eta^2 + b\eta + t_i^0 (1)$$

$$T_r(E_i) = t_i^0 - {}^{L}/_{v_i} \ (2)$$

For each energy channel:

(1) Obtain onset time t_i^0 using Eq.(1)

(2) Compute the release time T_r from Eq.(2)

Advantages of Approach II

- Avoid contamination effect, less uncertainty than VDA
- More accurately determine the onset time → Energy-dependent Tr of electrons

Comparison of VDA and FVDA

VDA

$$T_r = t_i^0 - {}^{L}/_{v_i}$$

- Non-physical path length
  - (1) Energy-dependent Tr of SEE
  - (2) Incorrect determination of onset

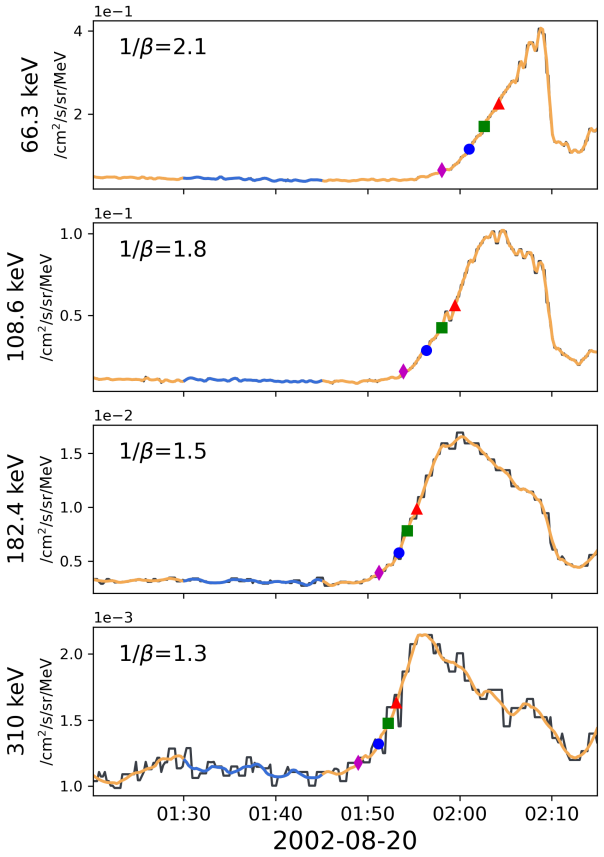
FVDA

- Two approaches
- Self-consistent check
  - Further analysis on the cause

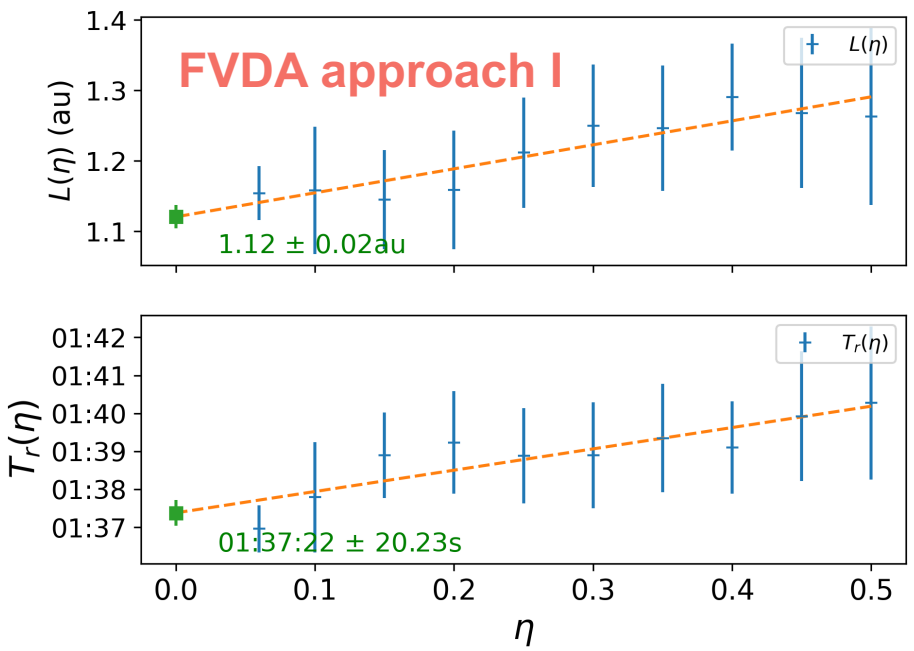
1 - Fractional Velocity Dispersion Analysis (FVDA)

Self-consistent check

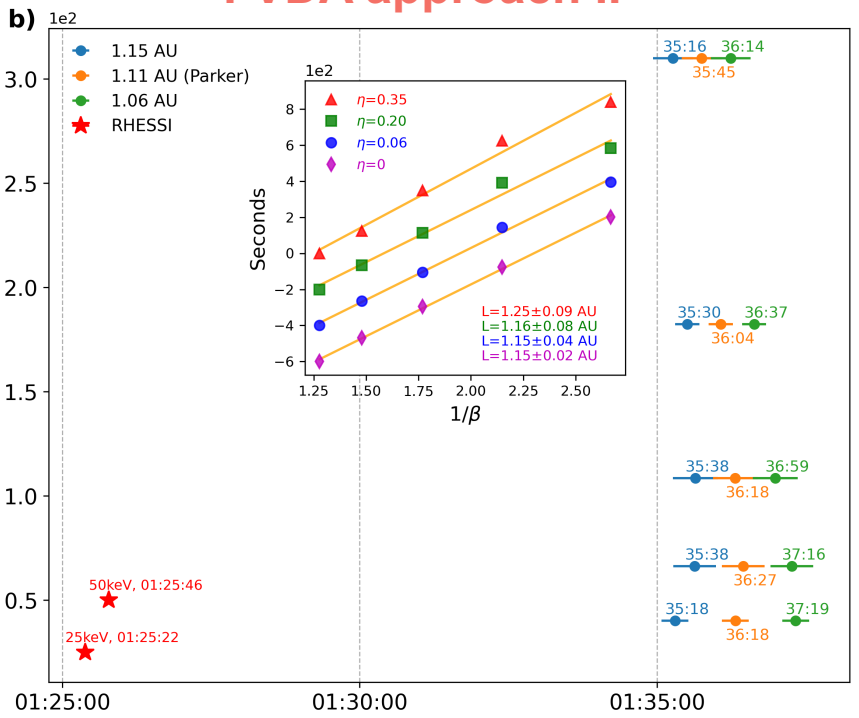
- For the cases with simultaneous release, T_r from **Approach I** and **II** should be close.
- An example event – 2002-08-20



Parker field length: 1.11 AU



FVDA approach II



1 - Fractional Velocity Dispersion Analysis (FVDA)

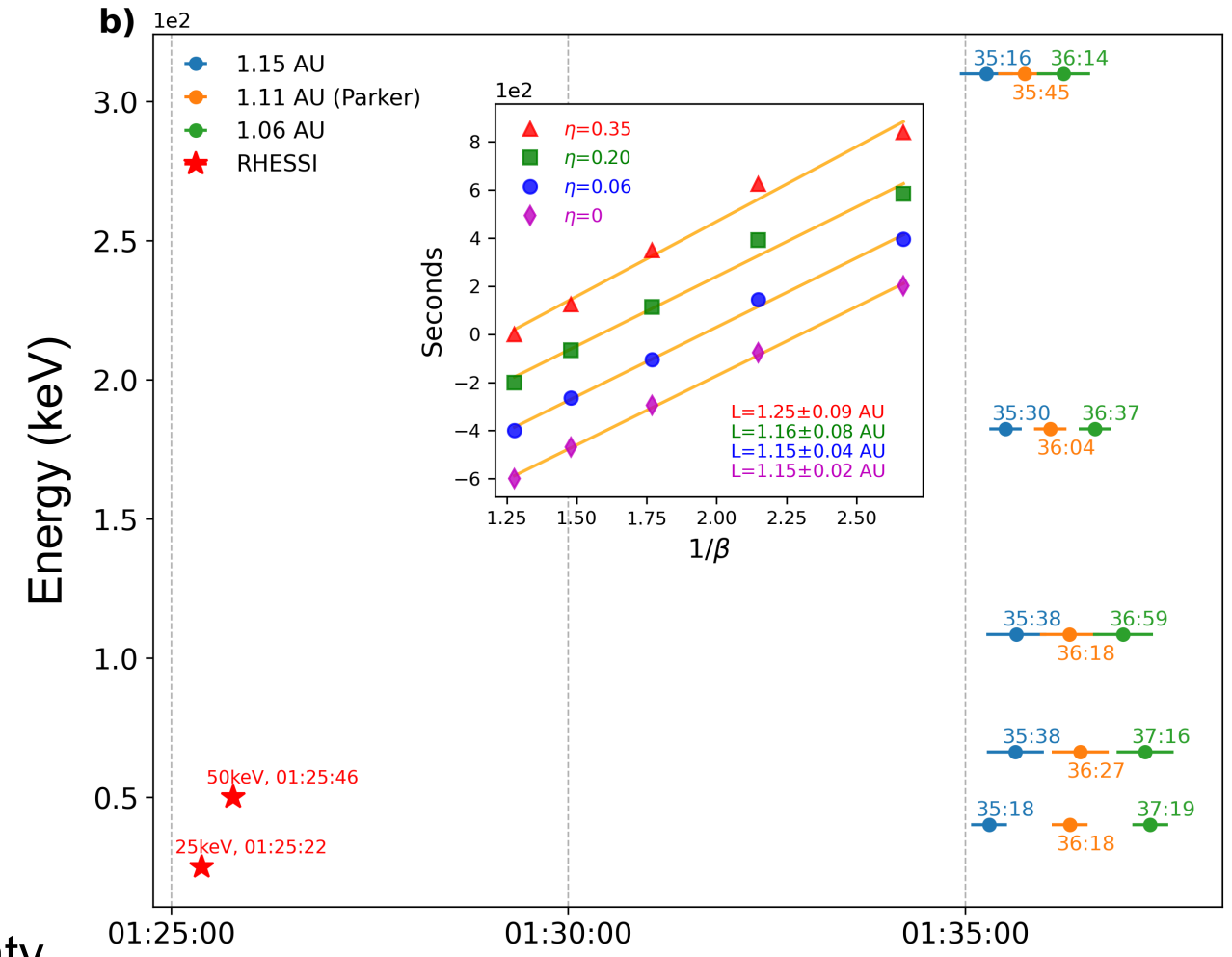
Self-consistent check

- Parker field length: 1.11 au

- Results from FVDA approach I
  - 1.12 ± 0.02 au
  - 01:37:22 $\pm$ 20 s
- Results from FVDA approach II

$$T_r(E_i) = t_i^0 - {}^{L}/_{v_i}\,, \quad L = [1.06, 1.15] \text{ au}$$

  - 01:35 ~ 01:37
  - Max dt < 2 mins, within the uncertainty.



1 - Fractional Velocity Dispersion Analysis (FVDA)

Summary

- An improved method – Release time & Path length of SEE
- Two approaches
- If electrons (different energy) are released simultaneously
  - I & II yield similar Tr
- If not
  - Path length from Approach I could be non-physical
  - Approach II should be used to obtain Tr of electrons

2 – Research based on FVDA

- Identification of two electron populations in an impulsive Solar Energetic Electron (SEE) event. G. Li et al 2020 ApJL 900 L16.

- Constraints on the electron acceleration process in solar flare. G. Li et al, Geophysical Research Letters, 48, e2021GL095138.

- Statistical study of release time and its energy dependence of energetic electrons in SEE events. X. Wu et al, Journal of Geophysical Research: Space Physics, 128, e2022JA030939.

3 The Python Package of FVDA

Objectives & Features

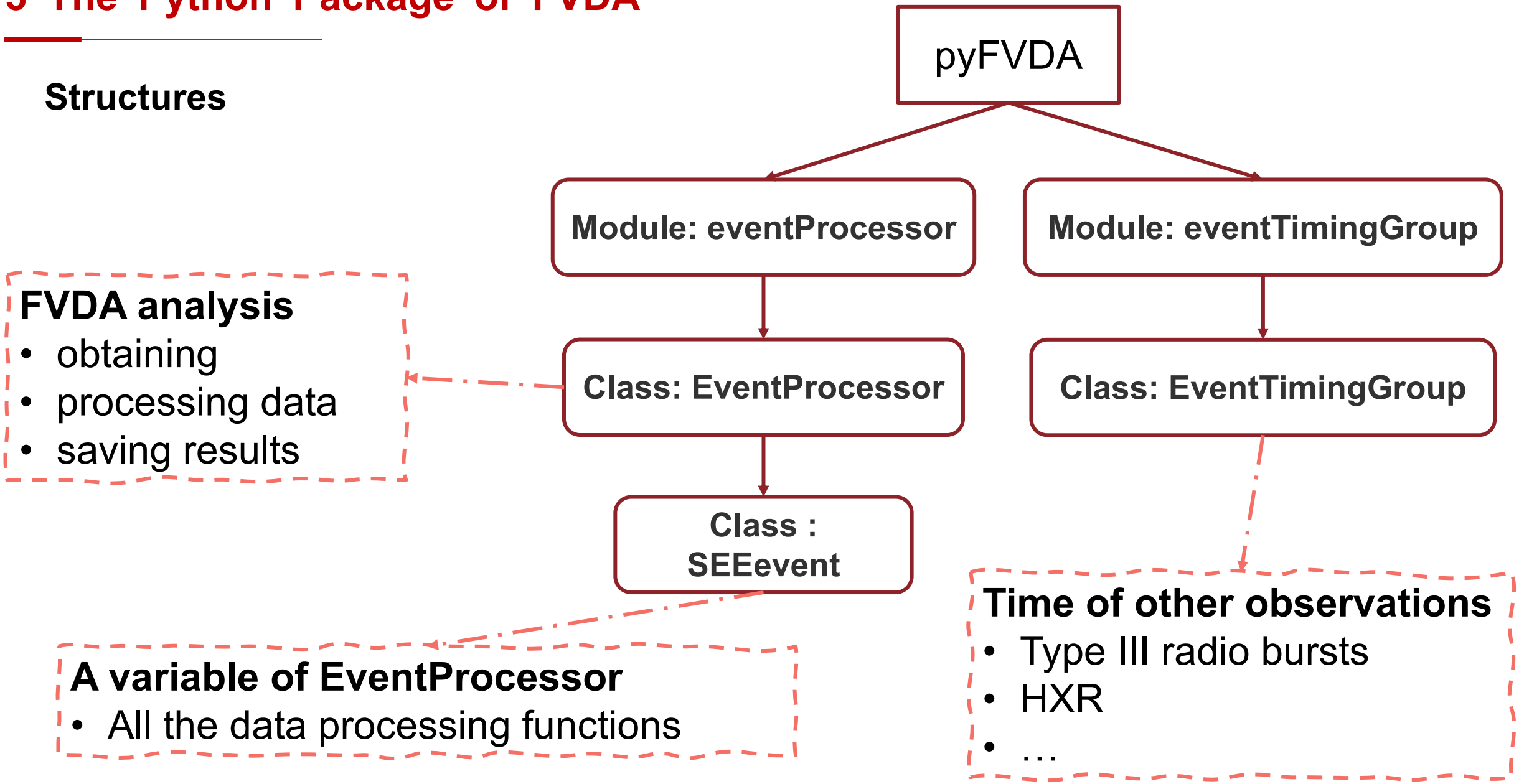
- Simple & Fast – calculate the Tr & Path length – Help analyze SEE events
- Include Approach I & II
- Obtaining data from the server, interactively processing data, and saving results

Updates

- An initial version is now available on Github
  - Approach I & II are included
  - Data from WIND & STEREO

3 The Python Package of FVDA

Structures



3 The Python Package of FVDA

Next steps

- Will be available on pypi soon
- Will include SolO

Github Page

https://github.com/Xiangyu-W/pyFVDA