

Absolutely calibrated edge neutral inferences on MAST-U and first comparisons with edge models

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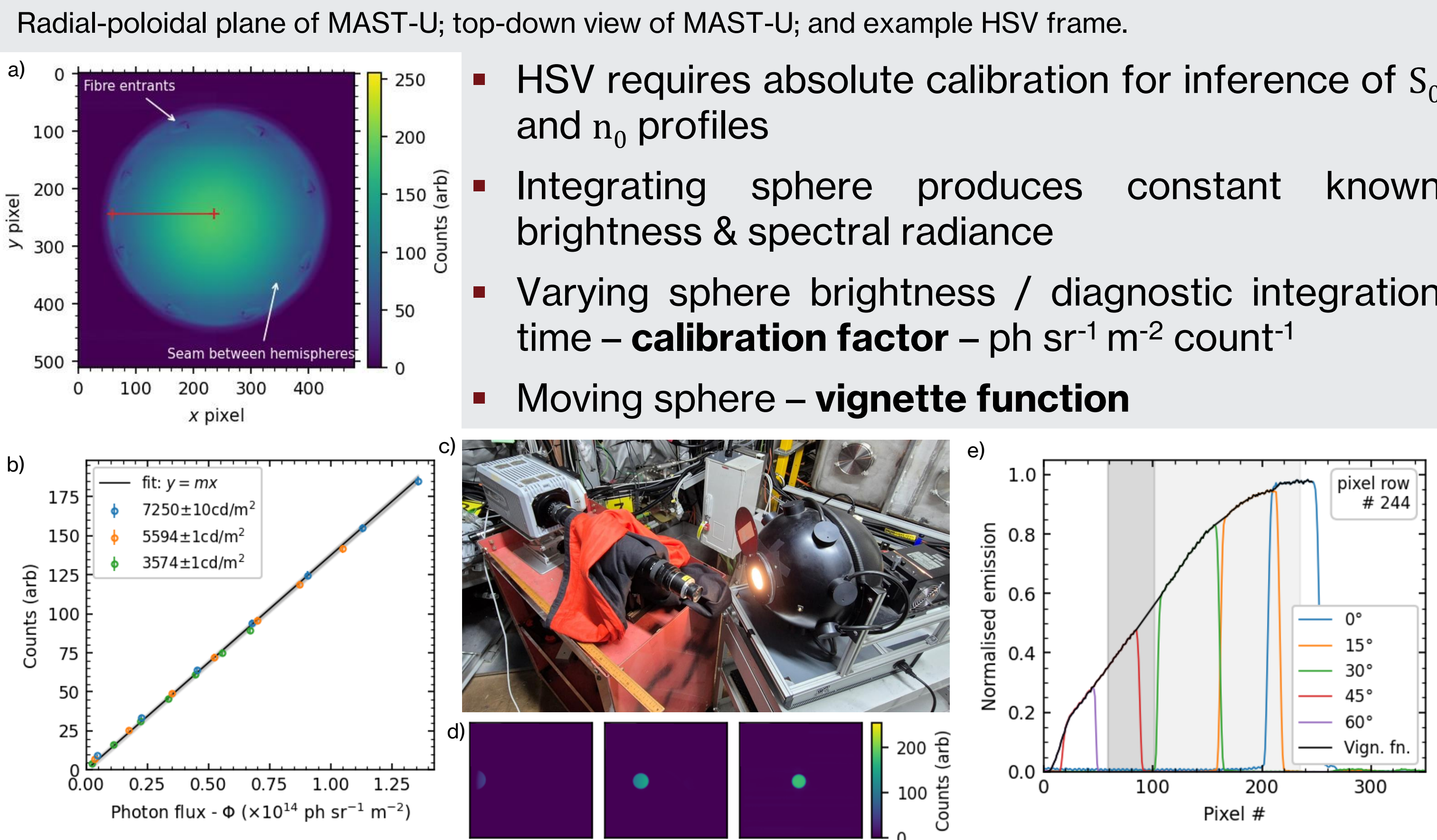
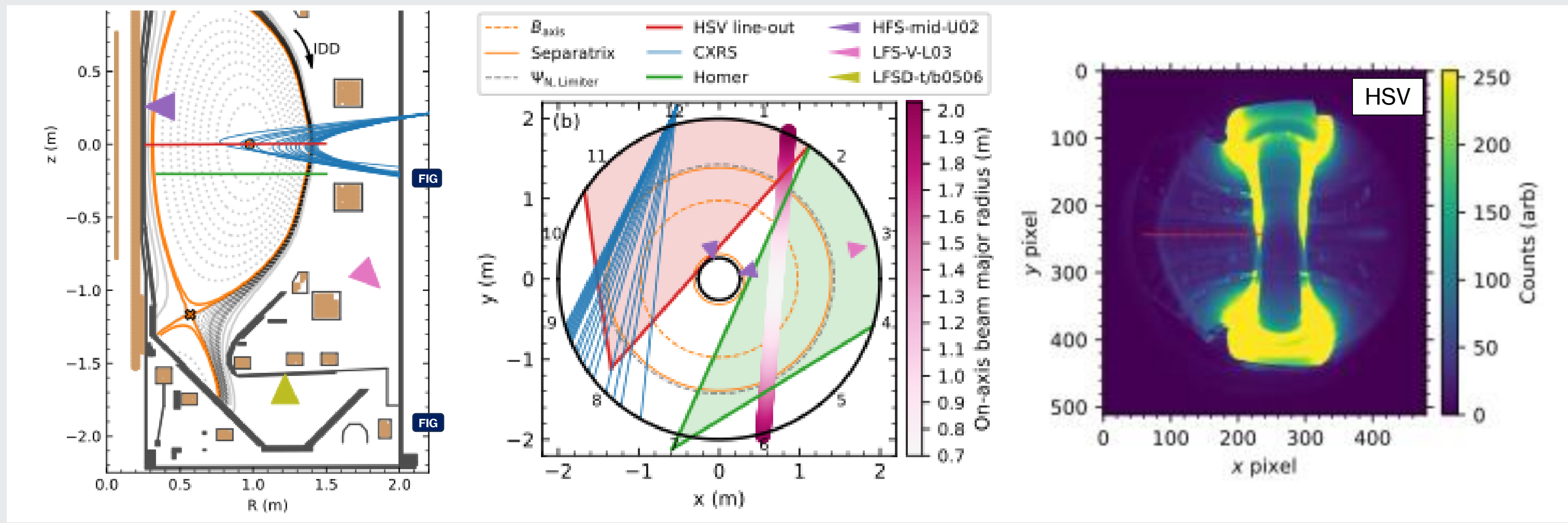
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1 - Introduction and key conclusions

- HSV diagnostic has been absolutely calibrated, regularly producing quantitative photon radiance on MAST Upgrade. Used with a simple collisional radiative model, inferences of neutral quantities can be made - edge ionisation sources, S_0 , neutral density, n_0 , and radial flux, Γ
 - Can be used in diffusive-convective ansatz to infer transport coefficients^[1]
- Inversion of data is difficult – recent work suggests reflections in the data
 - KN1D can provide confirm components of emission from difference processes
- HSV data is informing additional constraints on KN1D and SOLPS modelling

2 - MAST Upgrade and the high speed video diagnostic

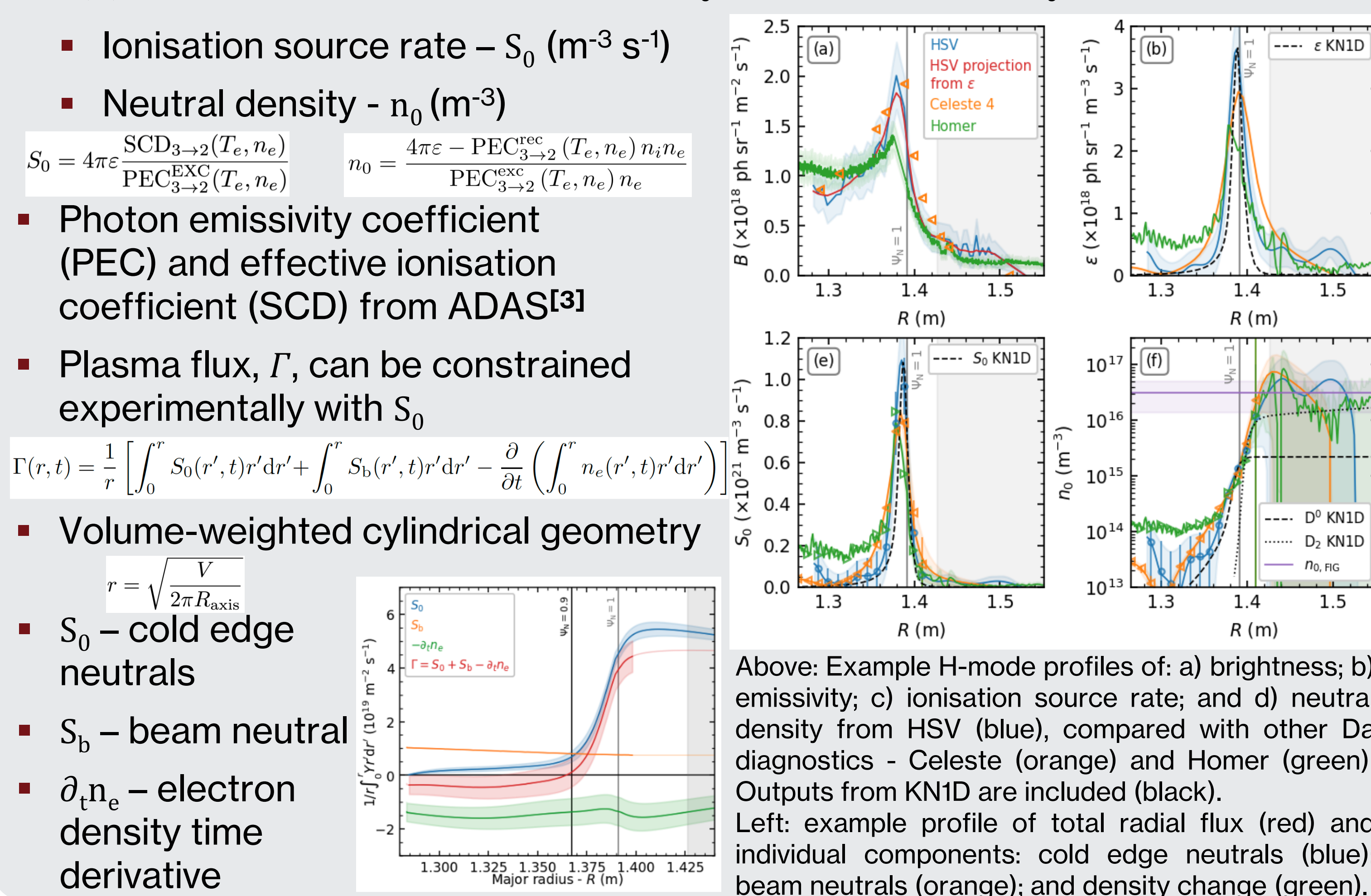
- MAST Upgrade is a spherical tokamak ($R=0.85\text{m}$, $a=0.55\text{m}$, $R/a\approx 1.5$) with on-axis beam heating and an array of poloidally distributed fuelling valves
- High-speed video (HSV) – absolutely calibrated fast camera (30kHz) with 10nm D_α optical filter and ~5mm spatial resolution in the plasma edge^[1]



HSV on MAST-U now absolutely calibrated! Good agreement between diagnostics!

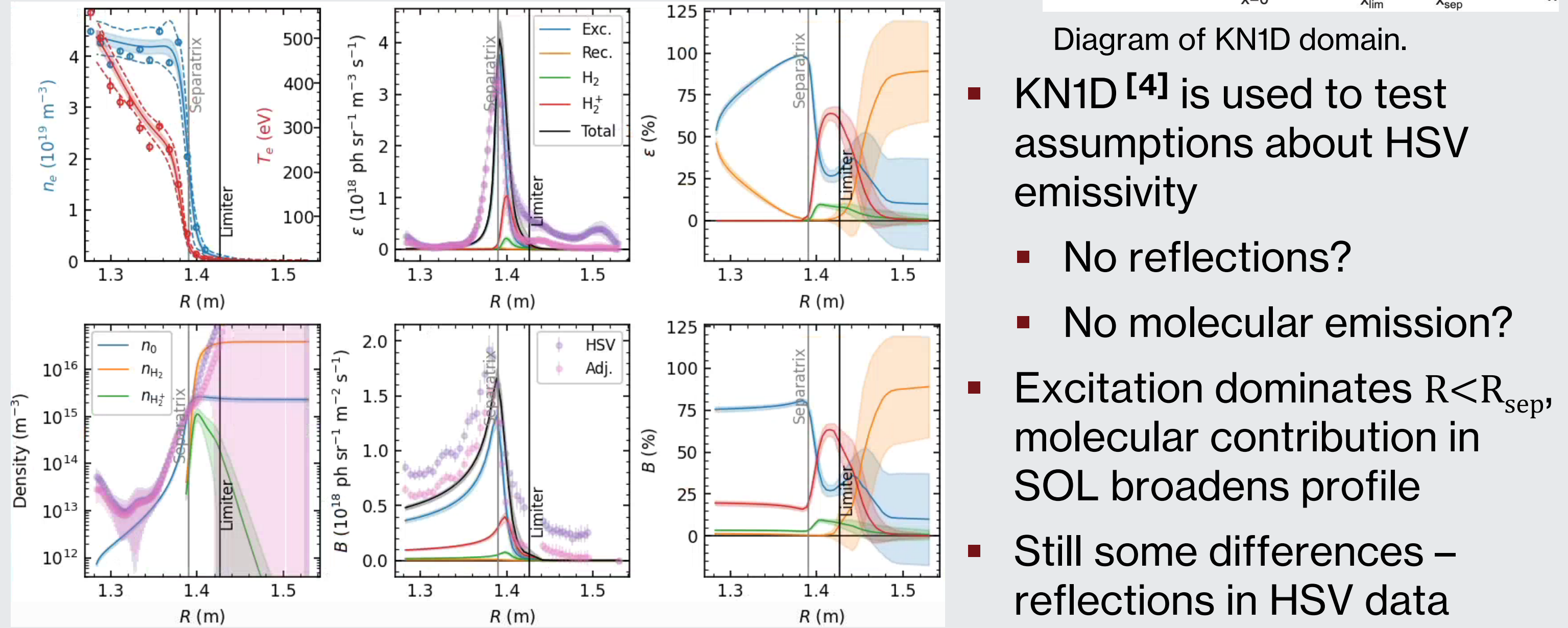
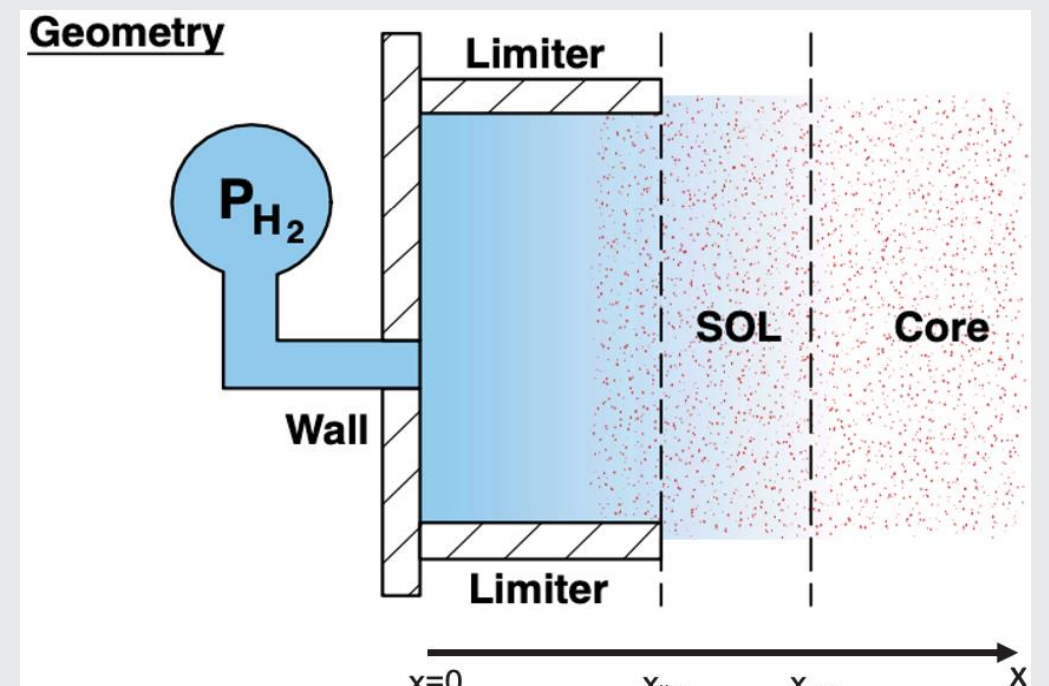
3 – Inferring neutral properties

- HSV measures line-of-sight integrated brightness
- Signals inverted using Tikhonov regularisation with minimum Fisher information regularisation^[2] – emissivity, function of radius $\varepsilon(R)$ ($\text{ph sr}^{-1} \text{m}^{-3} \text{s}^{-1}$)
- $\varepsilon(R)$ combined with electron density, n_e , and temperature, T_e , gives:
 - Ionisation source rate – S_0 ($\text{m}^{-3} \text{s}^{-1}$)
 - Neutral density – n_0 (m^{-3})

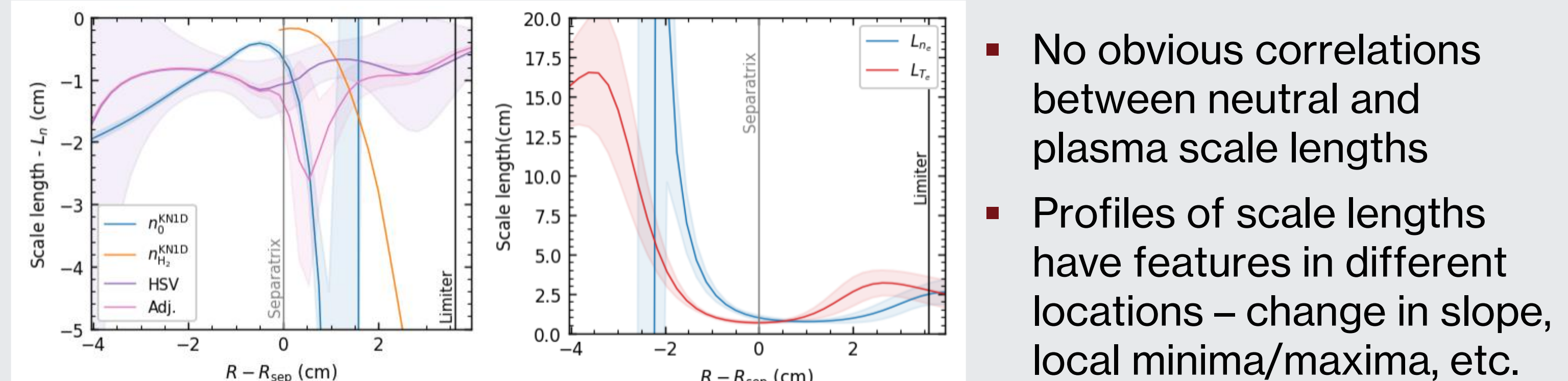


4 – comparisons with KN1D

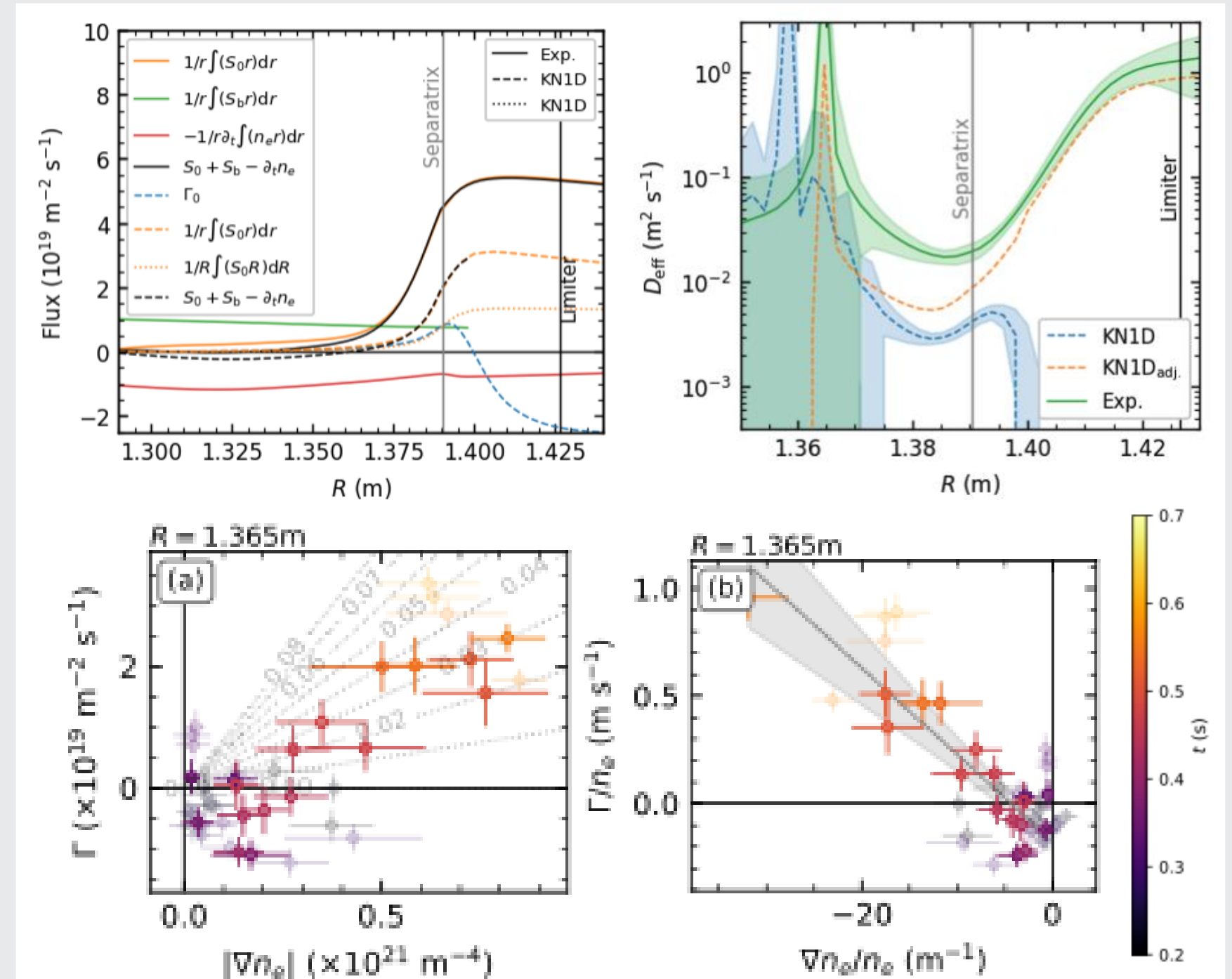
- 1D in space (x), 2D in velocity (x, r) kinetic neutral transport code solves the Boltzmann equation for atomic and molecular Deuterium neutrals from the wall to the core in a fixed plasma background
- Inputs: $p_{D2}(x=0)$, n_e , T_e , T_i , L_e , v_x
- Outputs: $f_D(x, v_x, v_r)$, $f_{D2}(x, v_x, v_r)$, derived quantities



- n_0 not significantly affected by correction to ε
- Biggest change to L_{n0} in SOL
- Experiment overestimates SOL/limiter neutral density due to large error
 - Low signal and low n_e / T_e (high uncertainty), but largest errors associated with low signal due to low n_e and T_e
 - Low signal in pedestal top - fails to recover second L_{n0} from CX process

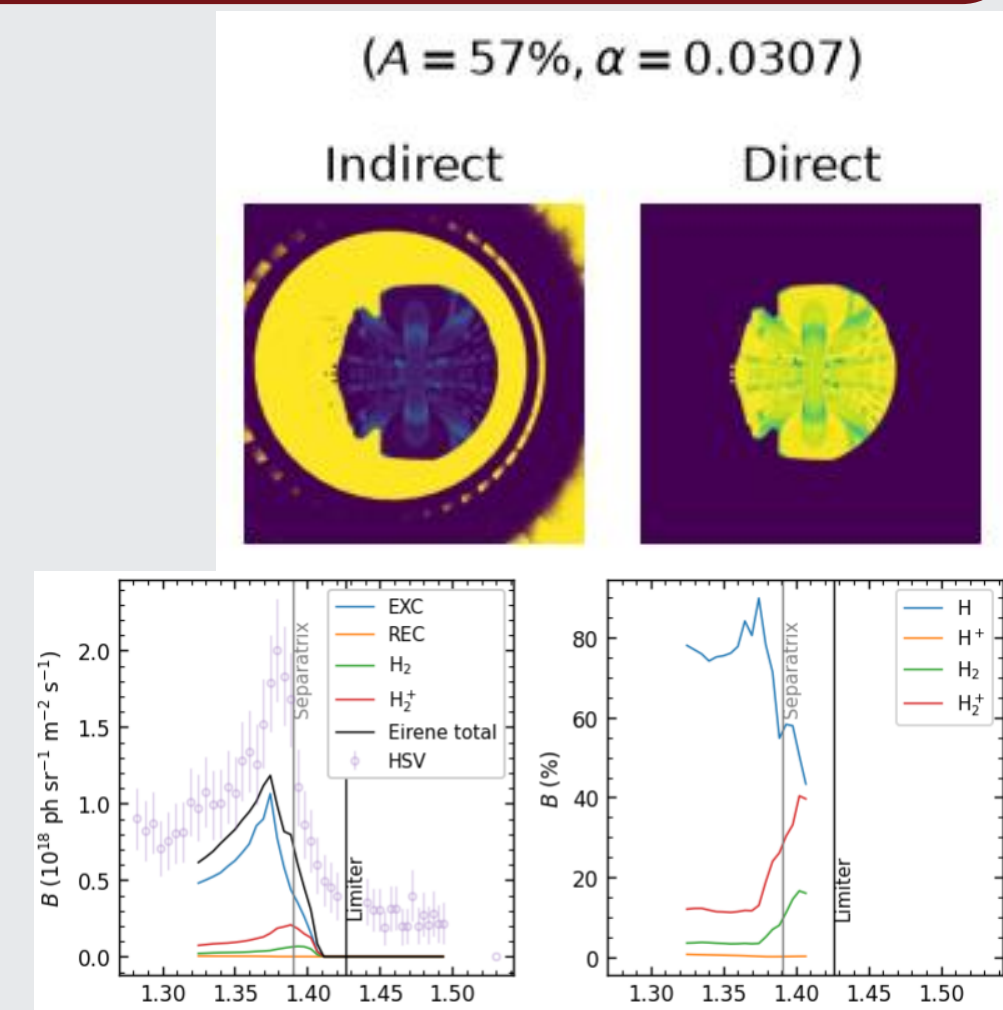


- Flux directly from KN1D is much lower than experiment
 - Volume averaged integral of S_0 is still lower – broader experimental S_0
 - Reflections in signal contribute to increase flux
- Overestimates $D_{\text{eff}} = -\Gamma / |\nabla n_e|$
 - D_{eff} increases with distance into SOL in experiment and KN1D
- Example D_{eff} , D , and v from experiment
 - Can we get this from KN1D?



5 – Future work and collaborations

- Inverse rendering of synthetic diagnostic for reflection quantification (E Öztürk, W&M, top right)
- HSV data for constraining SOLPS modelling (A. Reeja Biju, W&M, bottom right)
- Flux and D_{eff} mapping on sepOS space in MAST-U discharges (Y. Damizia, W&M)
- Further validation and comparison with KN1D (J. Dunsmore, MIT PSFC)
- 2D neutral inferences in MAST Upgrade



References

- [1] S. Thomas *et al.*, Plasma Phys. Control. Fusion **68**, 105033 (2026)
- [2] T. Odstrčil *et al.*, Rev. Sci. Instrum. **87**, 123505 (2016)
- [3] <https://open.adas.ac.uk>
- [4] KN1DPy repo: <https://github.com/W-M-plasma-group/KN1DPy>