

(Dedicated) Interpretive Modeling of Divertor Plasmas

S. Lisgo

UKAEA / University of Toronto



- ❑ A brief introduction to “plasma reconstruction” modeling for the interpretation of experiments
- ❑ Detached divertor plasma modeling on C-Mod (Balmer series)
- ❑ *same* on DIII-D
- ❑ An attempt to determine n_e, T_e divertor profiles on MAST from He I line ratios (cameras)
- ❑ (Some naive ADAS questions)



- ❑ Lots of experimental data used as input + simple physical models (to start)
 - “manual inversion” of experimental data to determine 2D plasma profiles
 - “TRANSP for the boundary plasma”
 - “glorified curve fitting”

- ❑ Solution method optimized based on available data → accuracy of plasma solution determined by the overall level of agreement with the full experimental data set, throughout the divertor
 - numerical boundary conditions set in divertor and upstream
 - emphasis on detachment thus far (core fuelling, global SOL flows soon)



- ❑ Lots of experimental data used as input + simple physical models (to start)
 - “manual inversion” of experimental data to determine 2D plasma profiles
 - “TRANSP for the boundary plasma”
 - “glorified curve fitting”

 - ❑ Solution method optimized based on available data → accuracy of plasma solution determined by the overall level of agreement with the full experimental data set, throughout the divertor
 - numerical boundary conditions set in divertor *and* upstream
 - emphasis on detachment thus far (core fuelling, global SOL flows soon)

 - ❑ Intention is a step-wise increase in model sophistication, with a corresponding reduction in the amount of data required as input
 - fast / flexible / tractable modeling framework
 - improve understanding based on detailed interpretation of experiment, build model

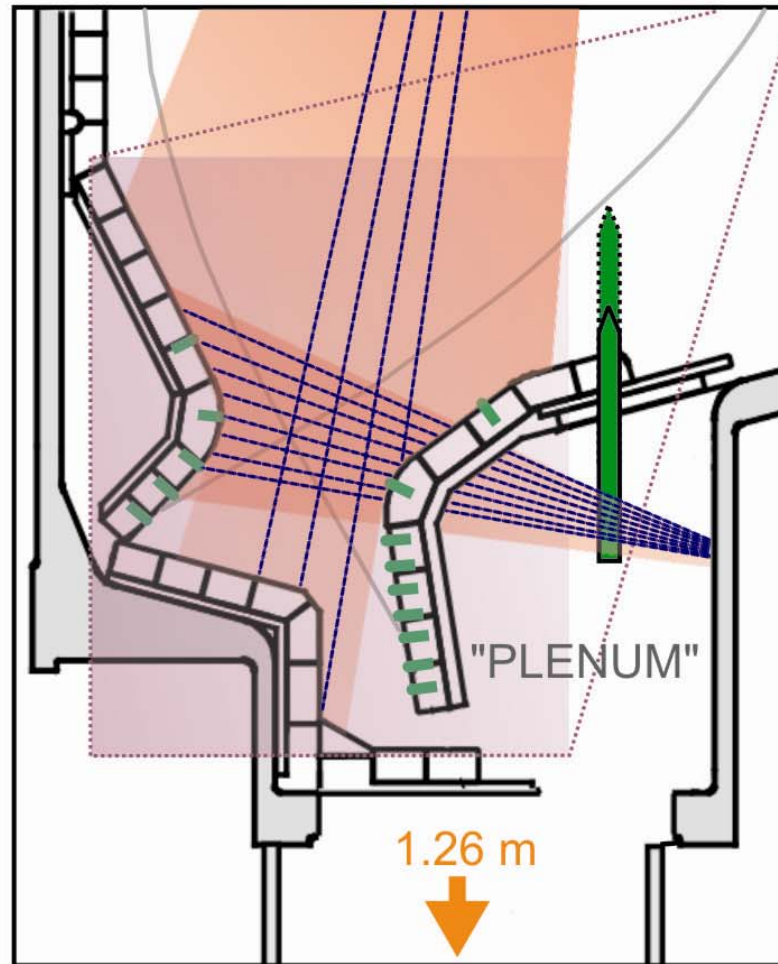
 - ❑ Progression: $n_e, T_e (=T_i)$ → **neutrals** → $v_{||}$, E → drifts → T_i → impurities
(OSM) (Eirene) (OSM) (Eirene/DIVIMP)
- ❑ Currently, reliance on spectroscopy for n_e, T_e constraints → atomic data (ADAS)



HIGH
RESOLUTION
DIODE ARRAYS
WITH D_{α} FILTER

TARGET
LANGMUIR
PROBES AND
UPSTREAM
RECIPROCATING
PROBE FOR
 n_e AND T_e

DIVERTOR GAS
PRESSURE
(25 ± 3 mTorr)



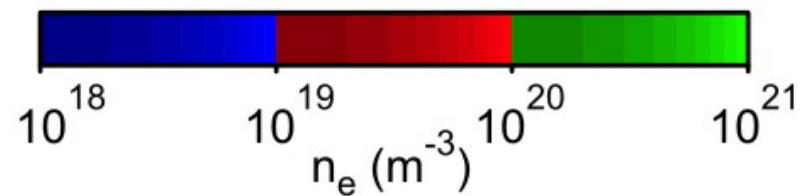
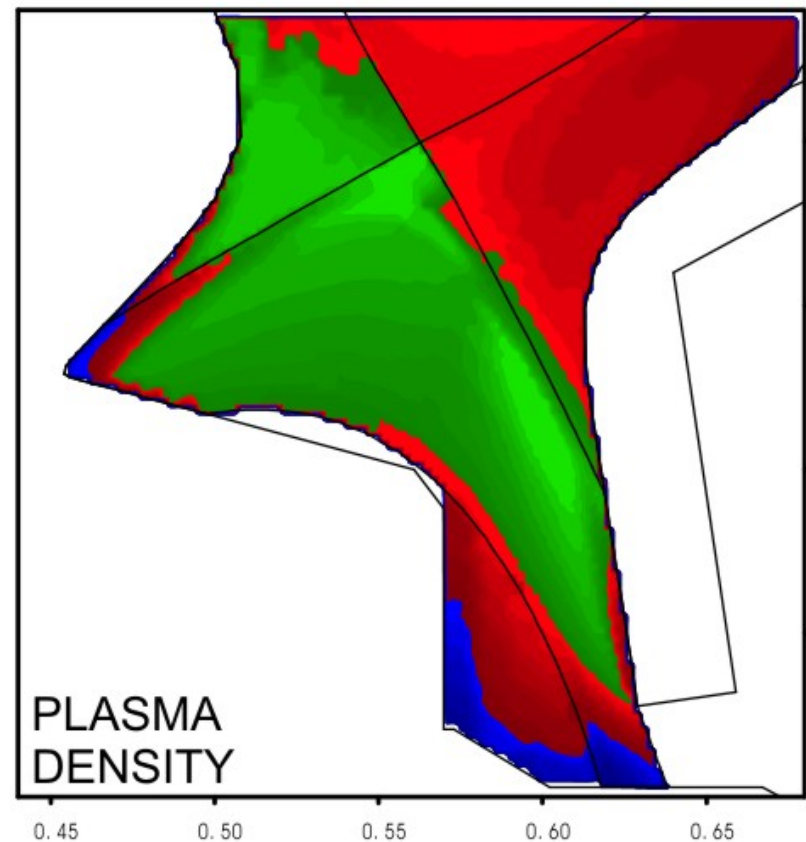
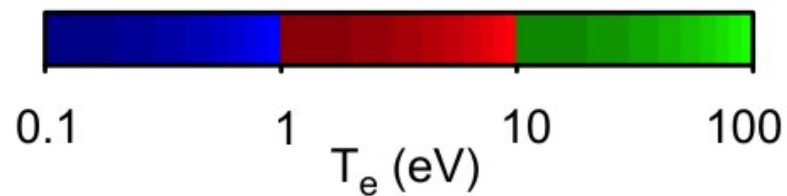
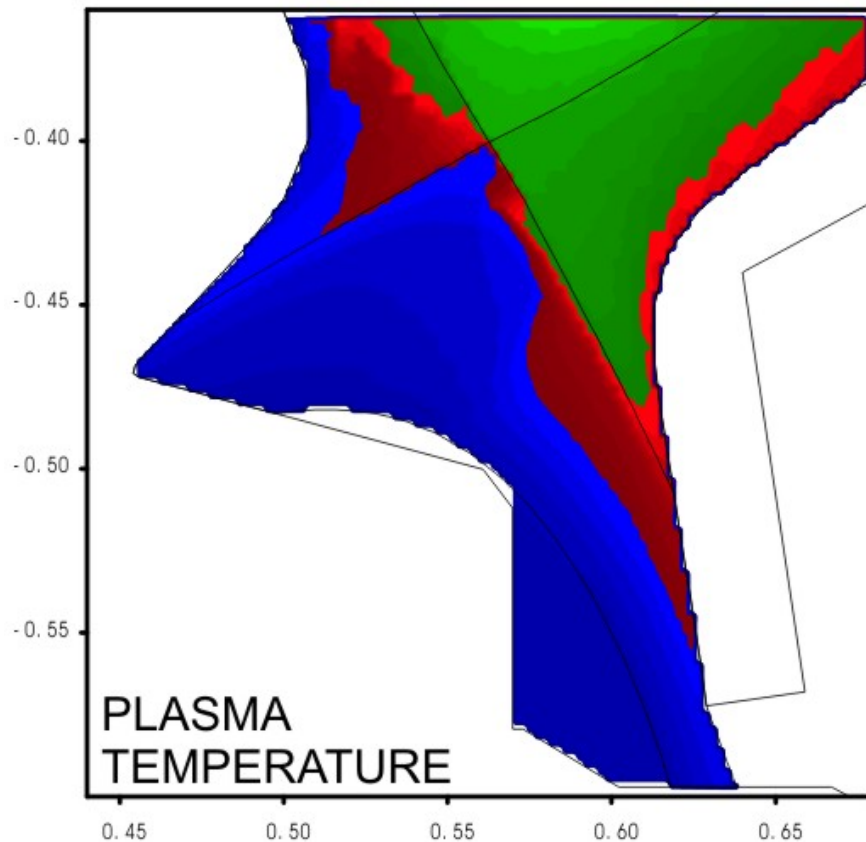
TOROIDALLY
VIEWING CCD
CAMERA WITH
 D_{γ} FILTER

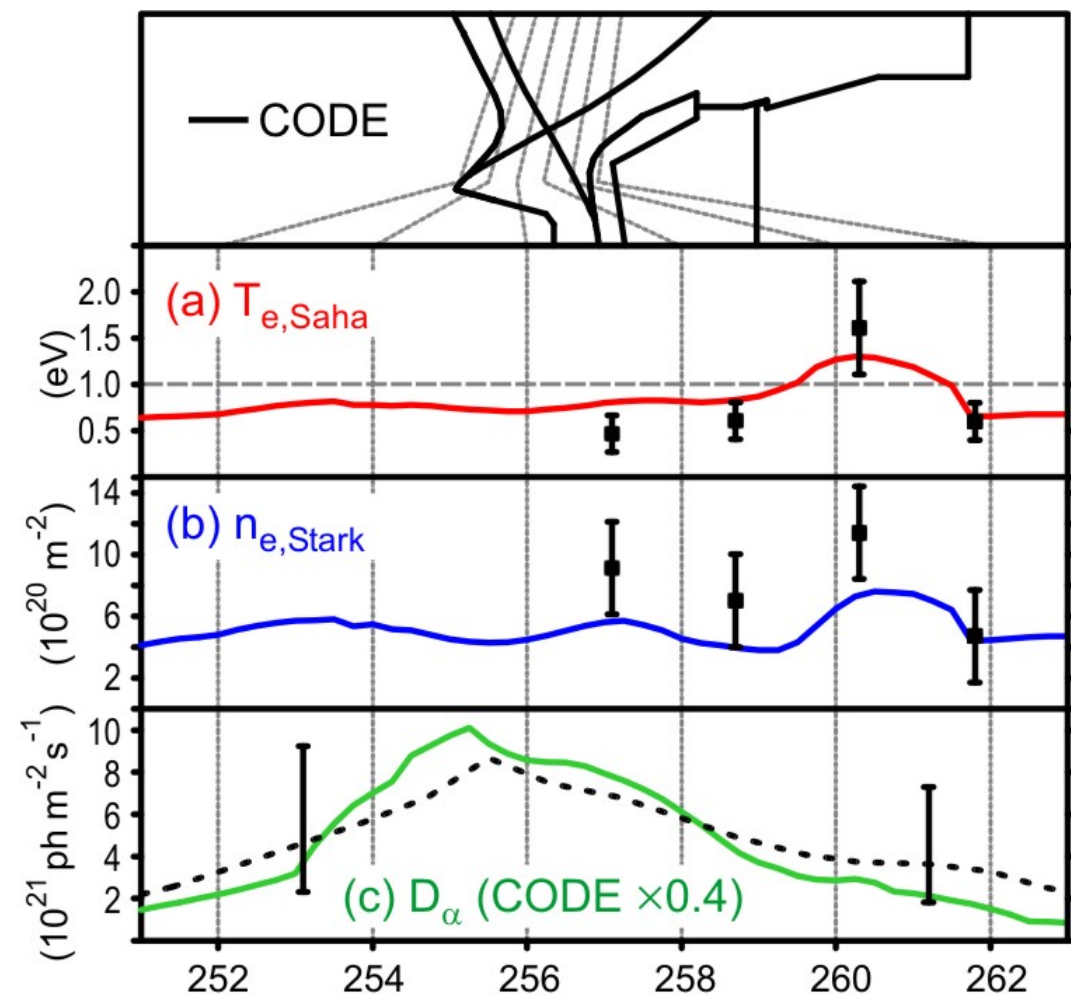
SPECTROMETER
FOR VOLUME
 n_e AND T_e

C. BOSWELL
B. LaBOMBARD
B. LIPSCHULTZ
A. NIEMCZEWSKI
S. PITCHER
J. TERRY



- PFZ + inner SOL detached, large regions with $T_e < 1$ eV



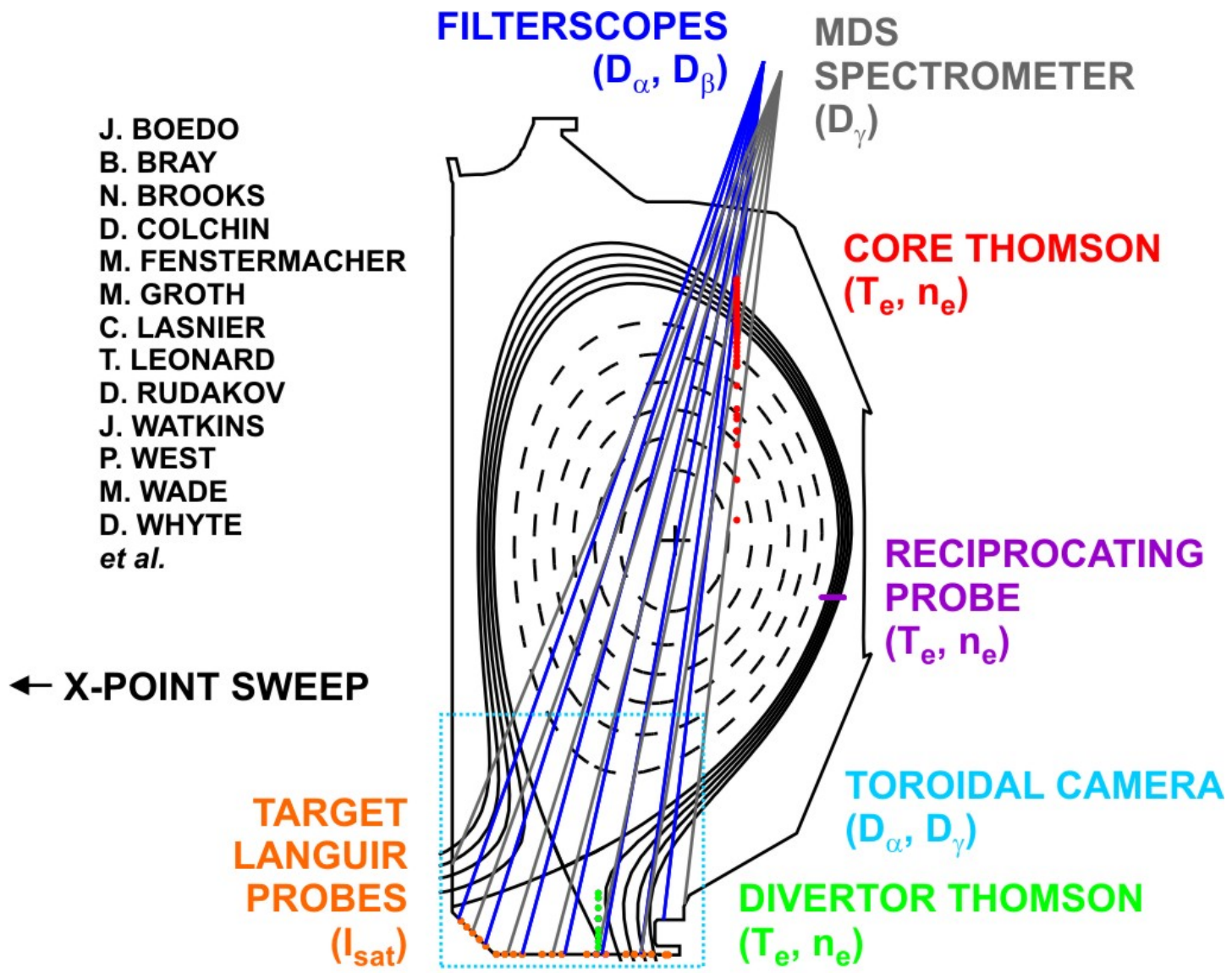


- T_e, n_e pushing the error bars
- $D_{\alpha,\gamma}$ higher in model by a factor 2–3
- (Latest Stark theory suggests n_e is *higher* than shown here)
- Perhaps unrealistic to try to resolve remaining discrepancies, but trying anyway
- Several possible explanations:
 - plasma solution
 - diagnostic calibration
 - diagnostic interpretation
 - atomic data

□ ADAS: Recent R-matrix calculations for hydrogen did not include volume recombination processes – true? an issue? accuracy of sub-eV, high n_e data?

DIII-D DETACHMENT MODELING

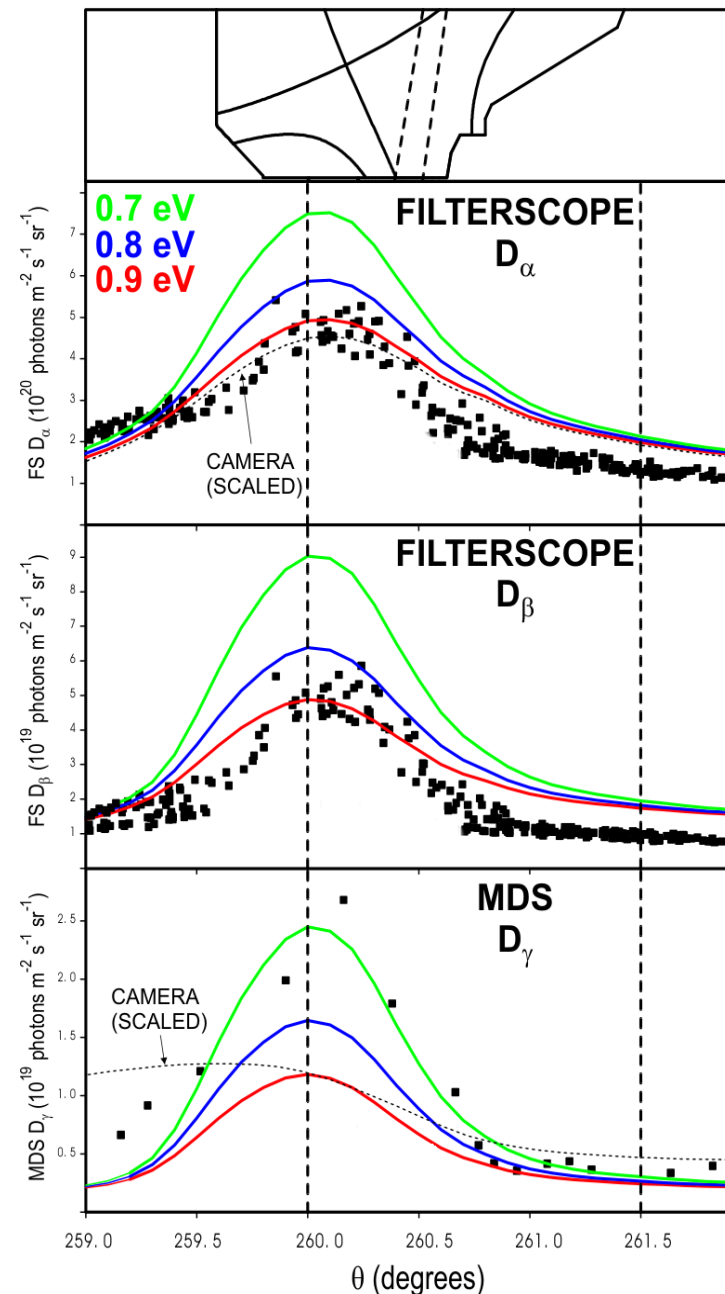
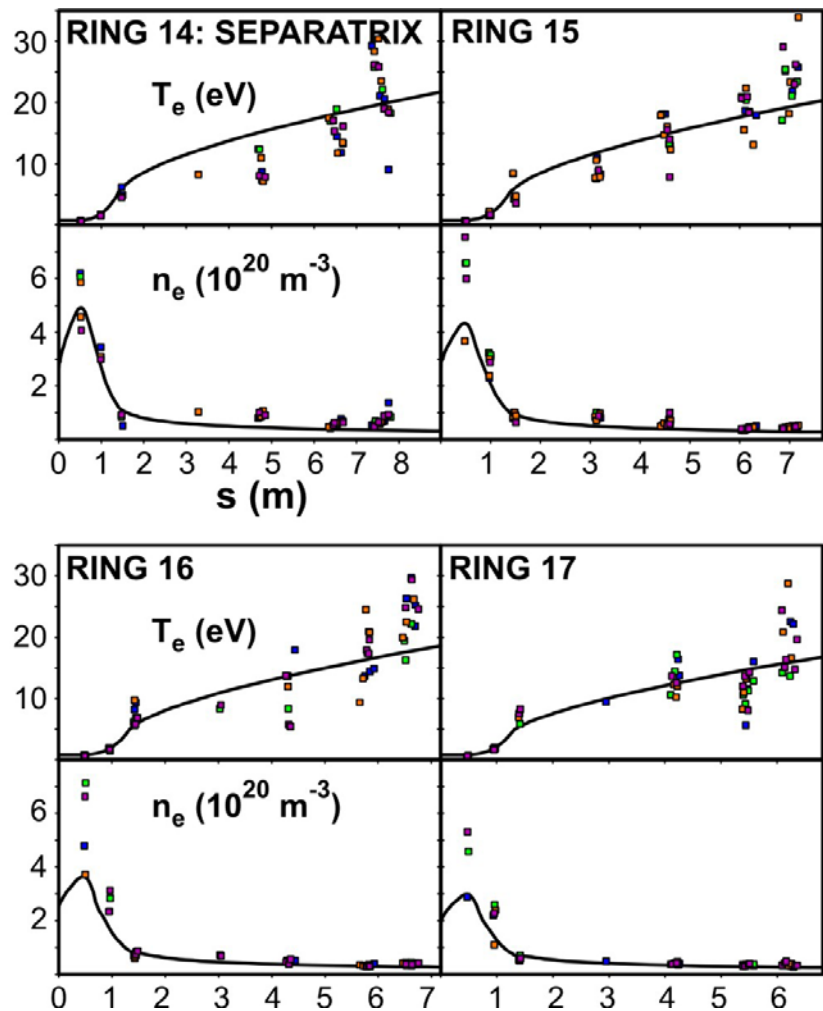
Plasma diagnostics in the DIII-D divertor



- J. BOEDO
- B. BRAY
- N. BROOKS
- D. COLCHIN
- M. FENSTERMACHER
- M. GROTH
- C. LASNIER
- T. LEONARD
- D. RUDAKOV
- J. WATKINS
- P. WEST
- M. WADE
- D. WHYTE
- et al.*



- DTS only provides a weak T_e constraint for $T_e < 1$ eV, trying to use Balmer series emissions



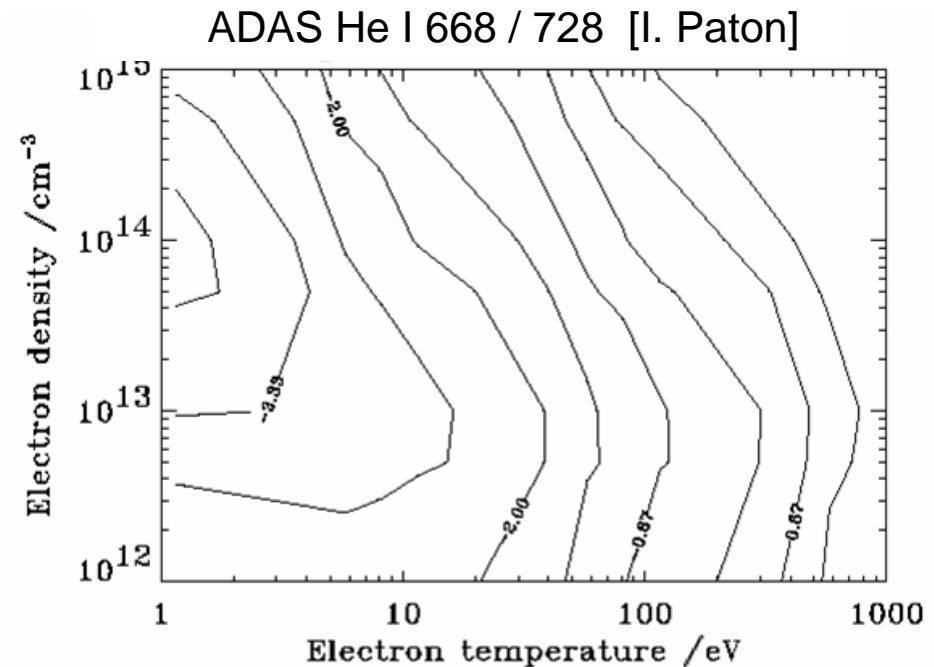
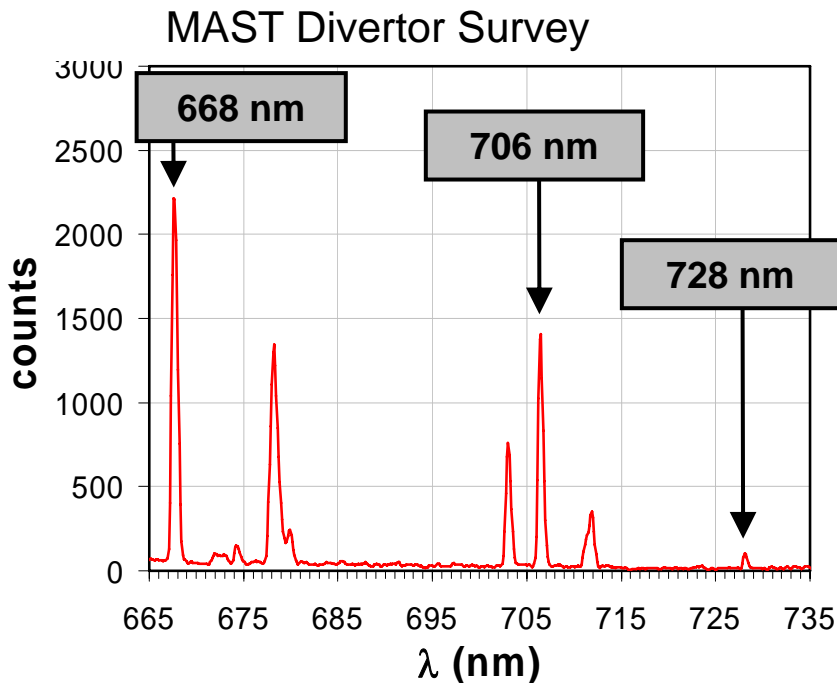


□ n_e, T_e information for divertor relevant conditions

- HeI 706 / 728 has weak T_e dependence ($5 < T_e < 40$ eV)
- HeI 668 / 728 has weak n_e dependence (10^{18} – 10^{19} m $^{-3}$)

□ Meta-stable states can be a problem → on JET, agreement with probes limited to near-separatrix region

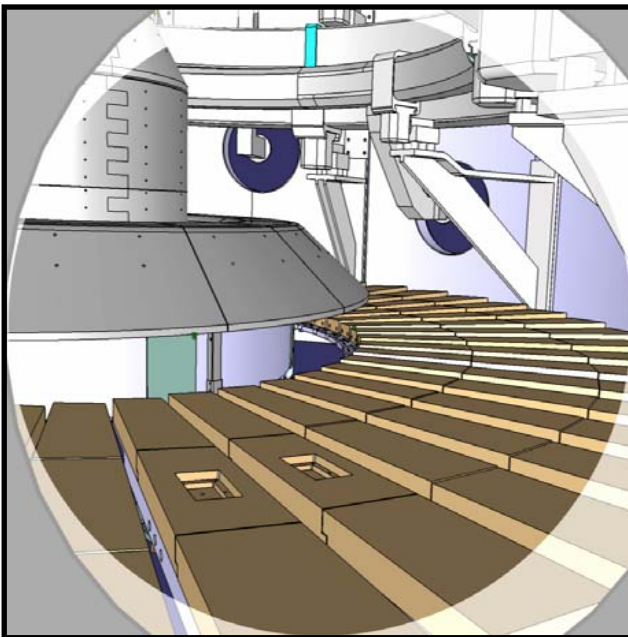
- some help from explicit Eirene modeling of meta-stable states





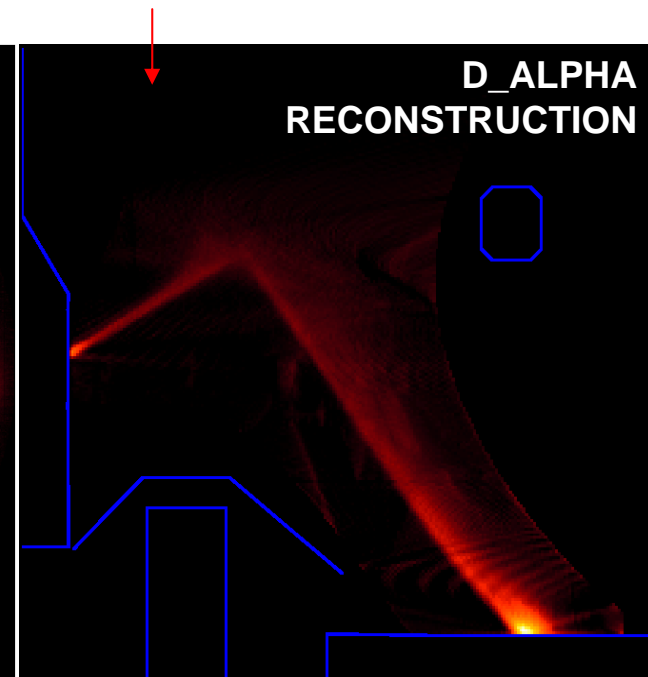
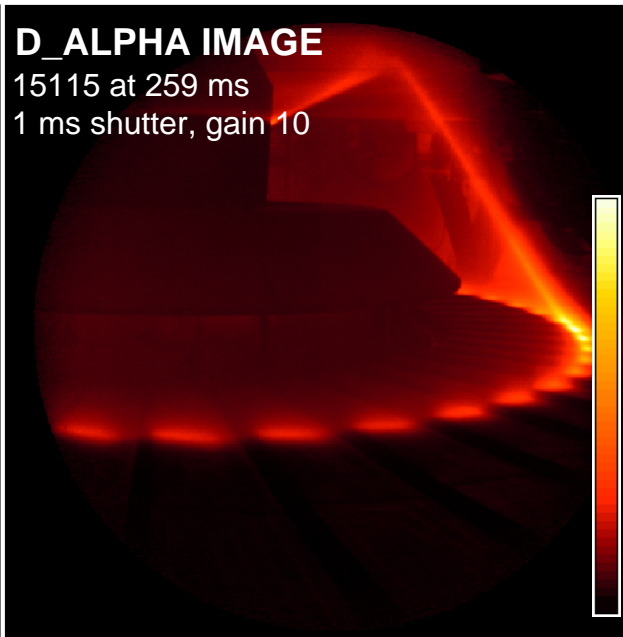
- Trying to use cameras for spatial coverage → high spectral resolution and sensitivity required, which is the case for DivCam (telecentric)

LOWER DIVERTOR VIEW



D_ALPHA IMAGE

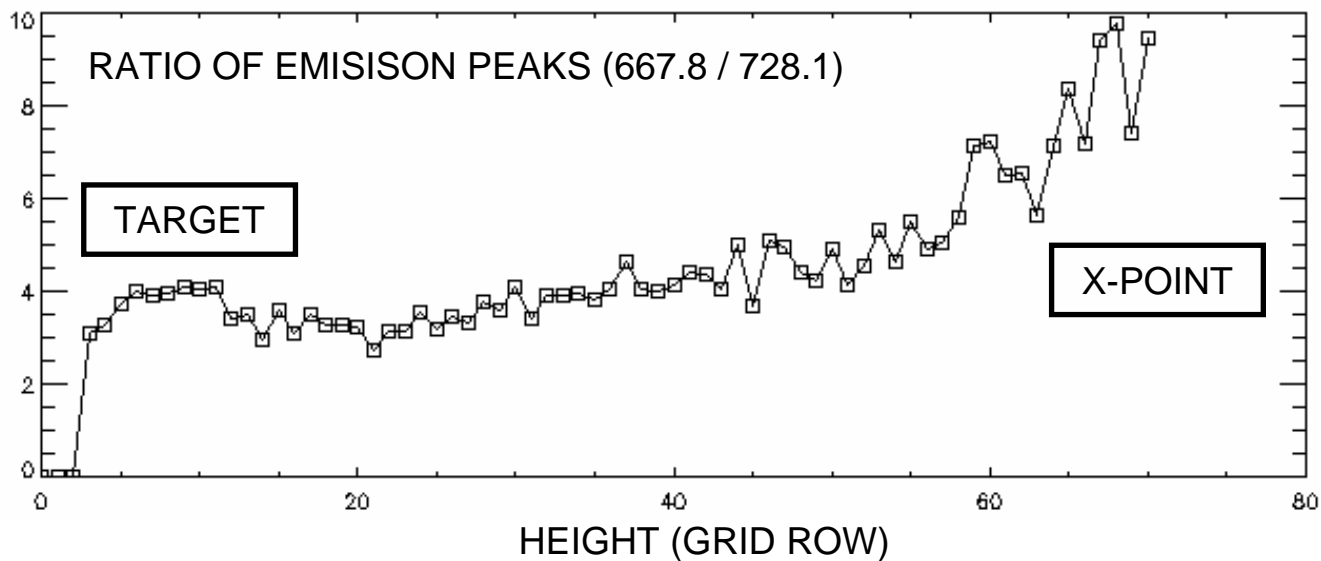
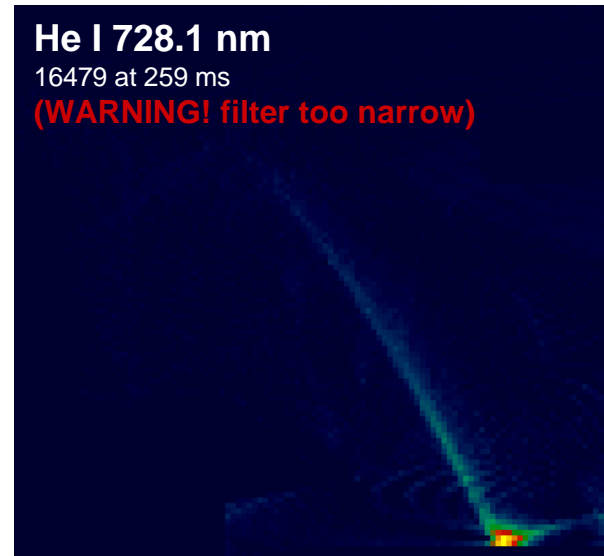
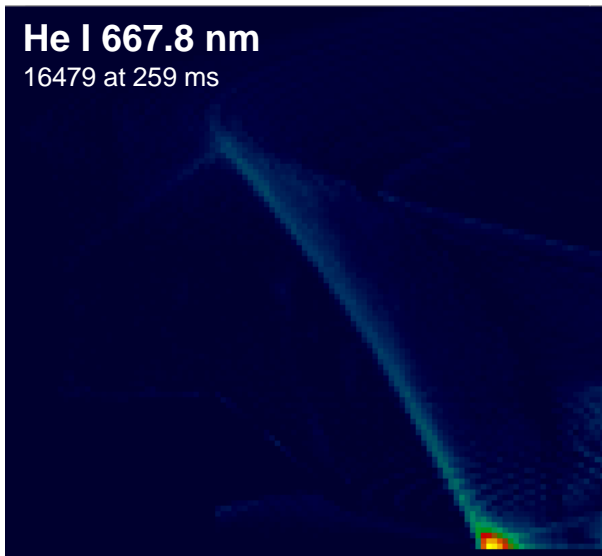
15115 at 259 ms
1 ms shutter, gain 10



D_ALPHA RECONSTRUCTION

He I LINE RATIOS ON MAST

Preliminary measurements



□ ADAS: Extension / uncertainties at low T_e ? 447, 528, 668, 706, 728 nm
enough / optimal?



❑ Divertor modeling currently focused on determining n_e, T_e poloidal profiles

❑ ADAS: Recent R-matrix calculations for hydrogen did not include volume recombination processes – true? an issue? accuracy of sub-eV, high n_e data?

❑ ADAS: Extension / uncertainties at low T_e ? 447, 528, 668, 706, 728 nm enough / optimal?