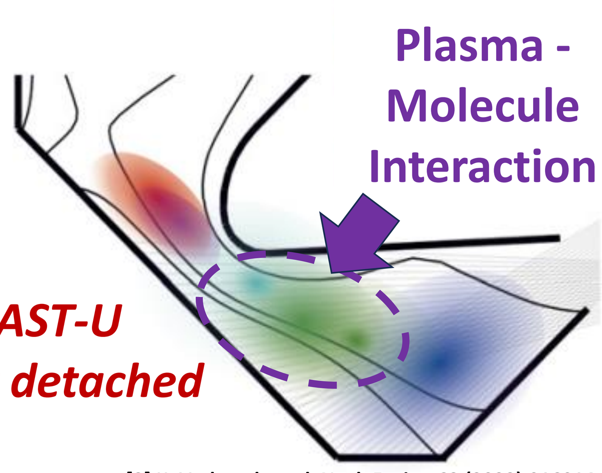
High res. Fulcher band analysis of rotational and vibrational distributions of D_2 molecules in the MAST-U and TCV divertors

Nick Osborne [1,2], Kevin Verhaegh[2], Mark D. Bowden[1], Tijs Wijkamp[3], Nicola Lonigro[2,4], L, Martinelli[5], H. Reimerdes[5], C. Theiler[5], N. Vianello[6], and the MAST-U* and TCV** teams.

[1]*University of Liverpool, Liverpool, United Kingdom*
[2]*Culham Centre for Fusion Energy, Culham, United Kingdom*
[3]*Eindhoven University of Technology, Eindhoven, Netherlands*
[4]*University of York, York, United Kingdom*
[5]*Swiss Plasma Center, Lausanne, Switzerland*
[6]*Consorzio RFX, University of Padova, Padova, Italy*

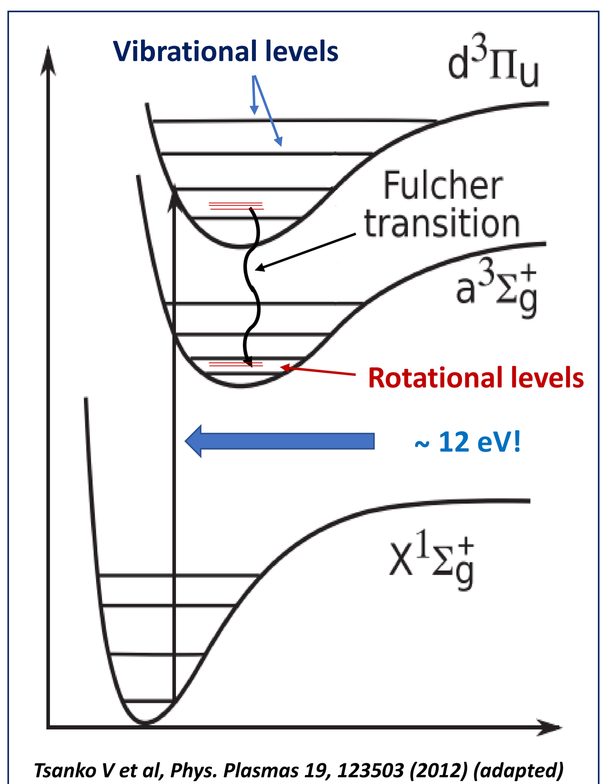
Plasma-molecule interaction plays an important role in detachment in both the MAST-U and TCV divertors.

Detachment **WILL** be necessary during ITER/DEMO operation for divertor survival! [1]

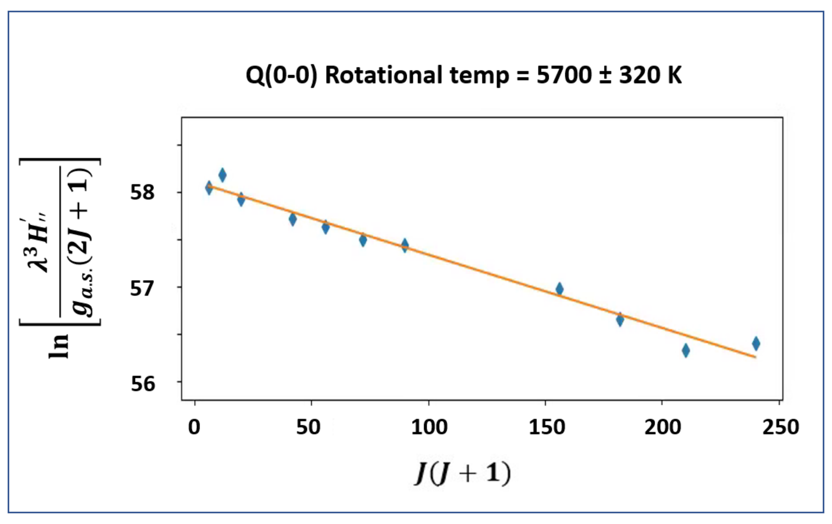


[2] K. Verhaegh et al Nucl. Fusion 63 (2023) 016014

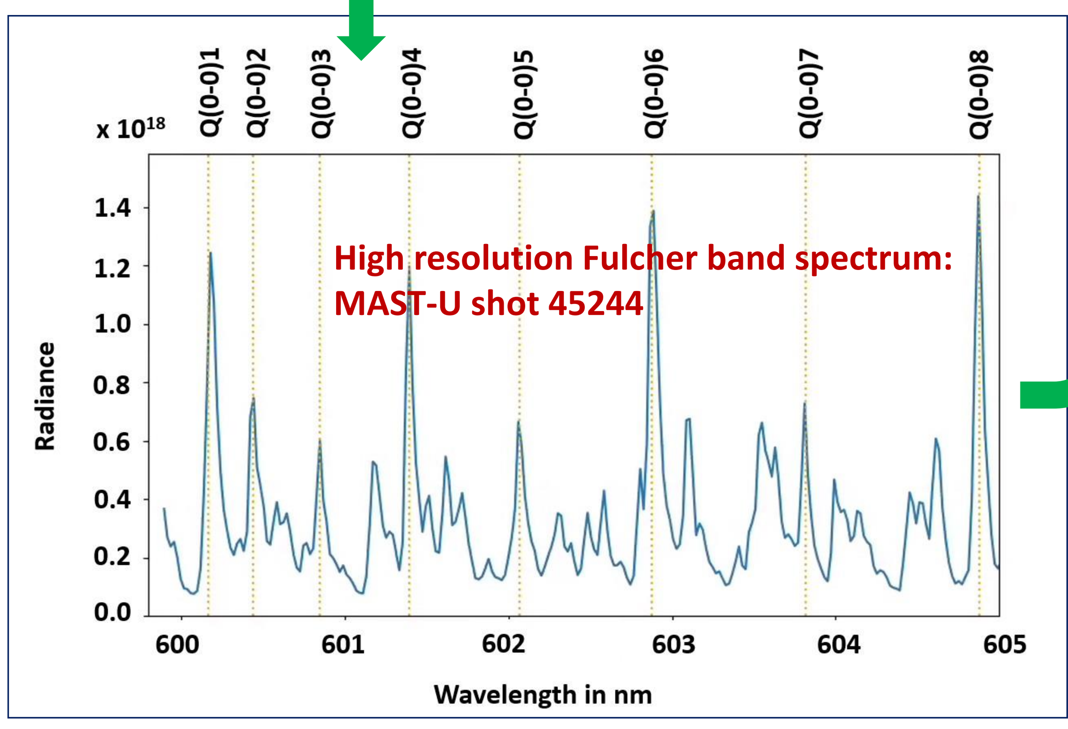
Studying D_2 molecules rotational and vibrational distributions via high res. Fulcher band spectroscopy



Tsanko V et al, Phys. Plasmas 19, 123503 (2012) (adapted)



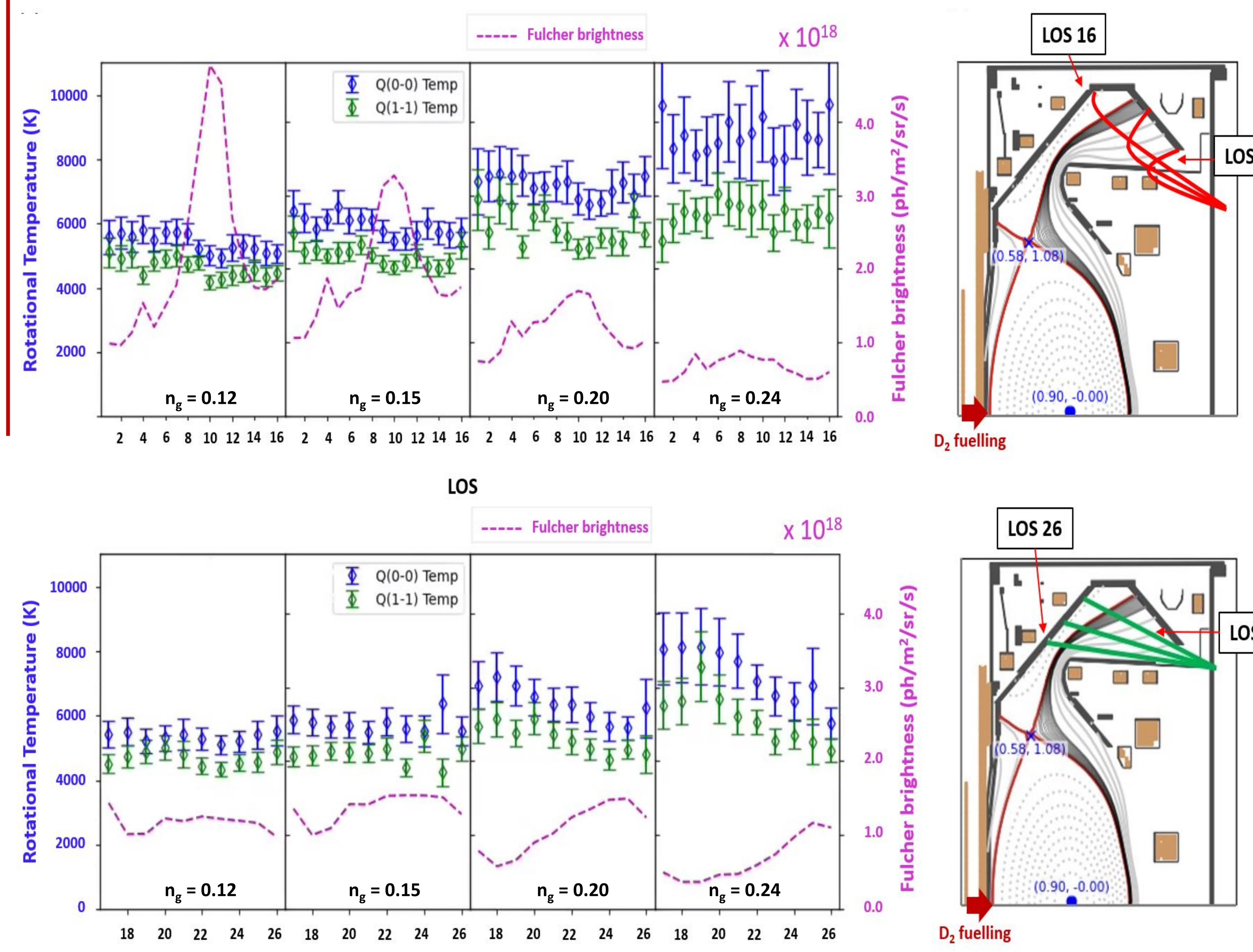
$$\ln\left[\frac{I'_{\nu'}\lambda^4}{g_{a.s.}(2J+1)}\right] = \frac{-hcBJ(J+1)}{kT_{rot}} + \text{const.}$$

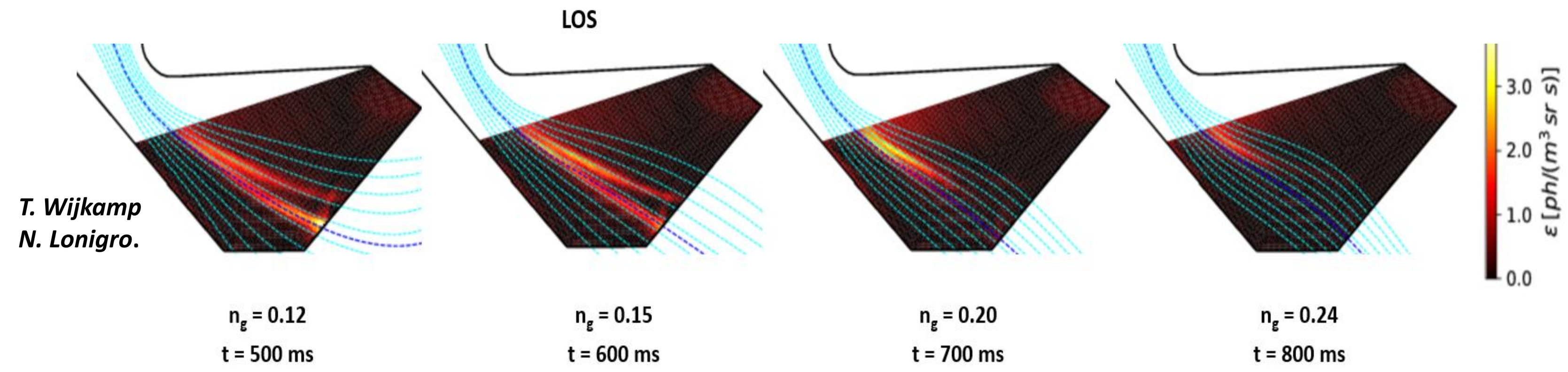


Fulcher band line data from Lavrov & Umrikhin [3]

Rotational temp. evolution with Greenwald fraction

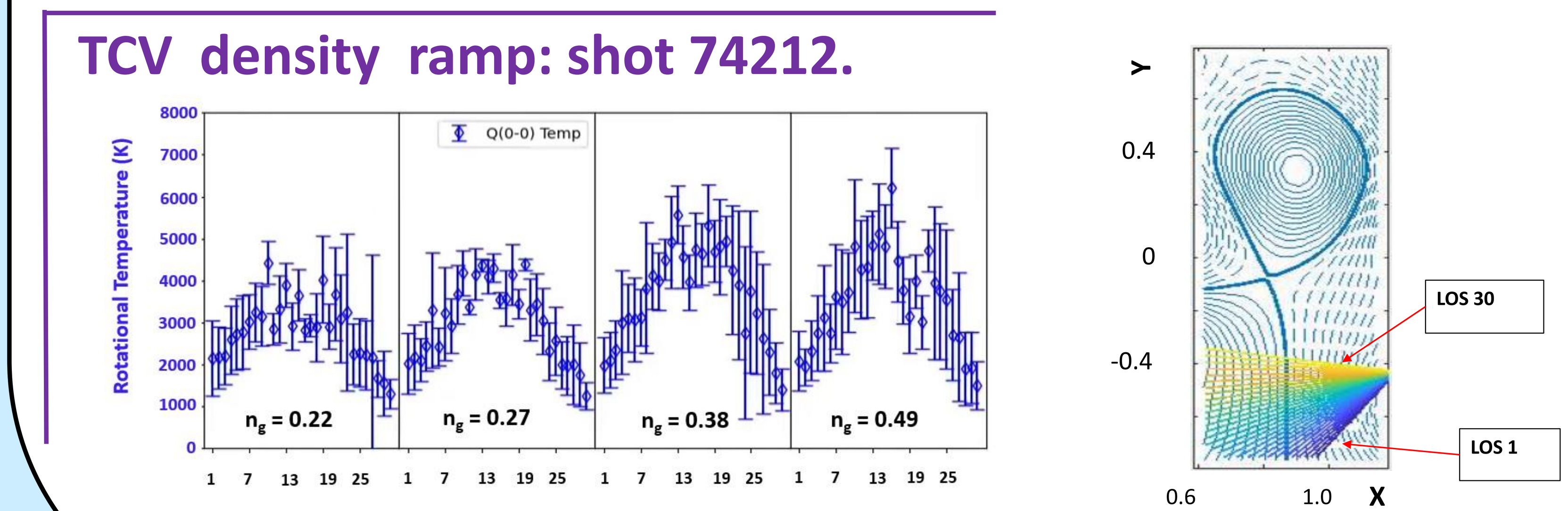
MAST-U Super-X density ramp: shot 45244





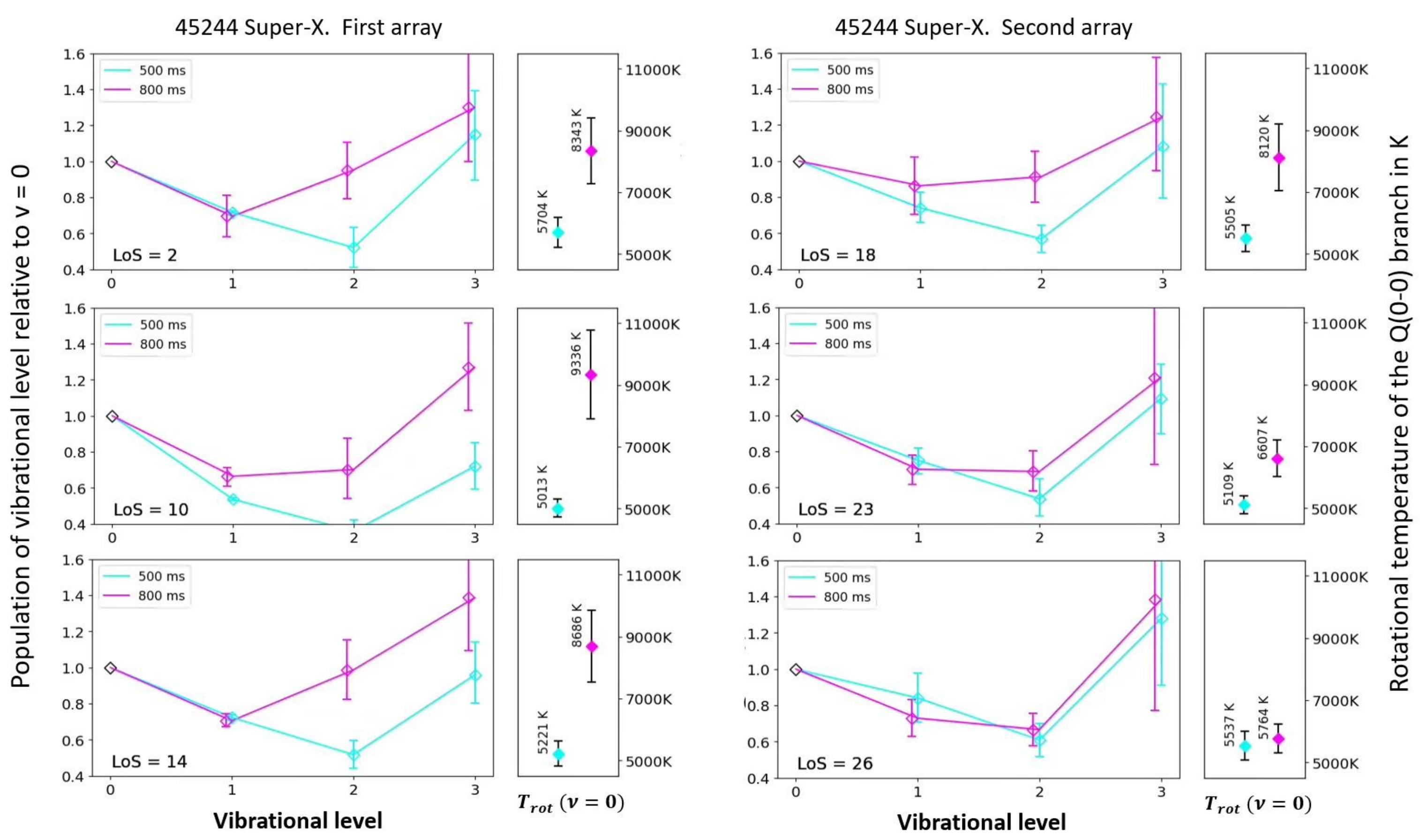
Lower divertor Fulcher band emission evolution inversion captured by multi-wavelength imaging system.

TCV density ramp: shot 74212.

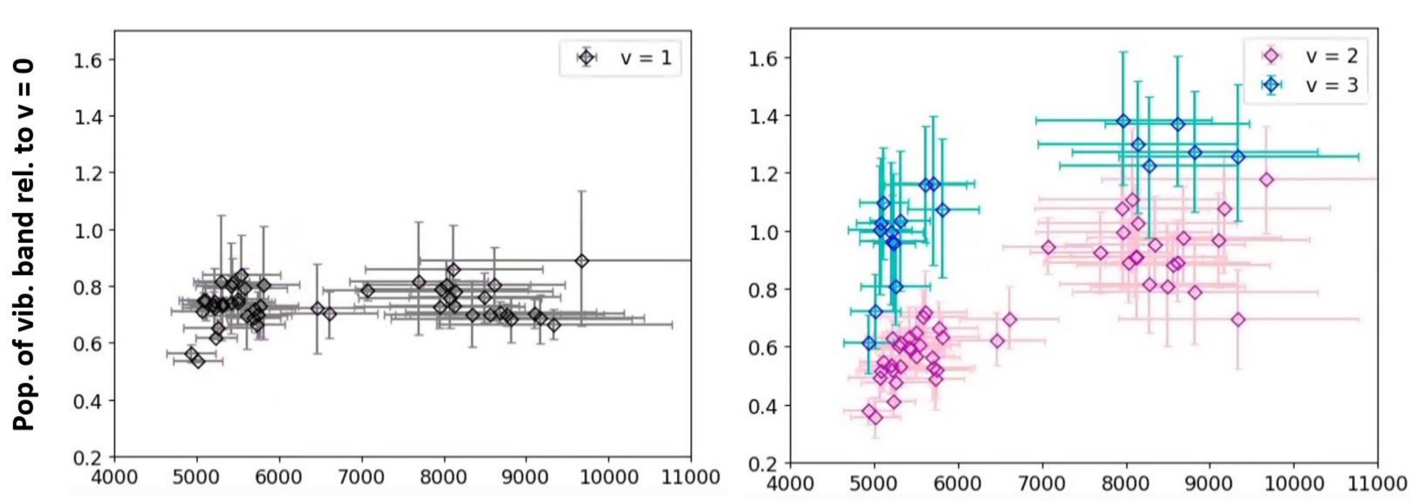


Rotational temperature (gas temperature) of 0.2 to 0.6 eV in TCV divertor.

Vibrational distribution of the first four vibrational bands at the start and end of the MAST-U Super-X density ramp: shot 45244.



Populations of v = 1, 2, 3 bands (relative to v = 0) vs ground state rotational temperature.



Deepening detachment in a D2 density ramp in the MAST-U and TCV divertors leads to an increase in the ground state rotational temperature of the molecules.

Kinetic processes transfer energy to the molecules.

The v = 2 and v = 3 vibrational band populations (unlike the v = 1 band) are being driven up during the density ramp as *rotational* temperature increases.

Future direction:

- Use of rotational temperature increase to estimate power transferred to the molecules.
- Vibrationally resolved modelling and Franck-Condon analysis to investigate what ground state vibrational distribution and processes lead to measured distribution.

* See author list of J. Harrison et al 2019 Nucl. Fusion 59 112011
** See author list of H. Reimerdes, et al. 2022 Nucl. Fusion 62 042018

References:

[1] K. Verhaegh et al, Nuclear Materials and Energy **26**. 100922 (2021)
[2] K. Verhaegh et al, Nucl. Fusion **63** (2023) 016014
[3] B. P. Lavrov and I. S. Umrikhin, arXiv: Chemical Physics (2011)

Acknowledgements:

- Thanks to my supervisors and the MAST-U team.
- Thanks to Ewa Pawelec, University of Opole, Poland for her help.
- This work has been part-funded by the EPSRC Energy Programme (grant number EP/W006839/1).

Nick Osborne: njo@liverpool.ac.uk