Molecular Deuterium Behaviour in Tungsten Divertor on JET

G. Sergienko[1], G. Arnoux[2], S. Brezinsek[1], M. Clever[1], A. Huber[1], U. Kruezi[1], A. G. Meigs[2], Ph. Mertens[1], U.Samm[1], M. Stamp[2]
and JET EFDA contributors*

JET-EFDA, Culham Science Centre, Abingdon, OX14 3DB, UK

[1]*Institute of Energy and Climate Research –Plasma Physics, Forschungszentrum Jülich, EURATOM Association, Trilateral Euregio Cluster, D-52425 Jülich, Germany.*
[2]*EURATOM/CCFE Fusion Association, Culham Science Centre, Oxon. OX14 3DB. UK.*
** See the Appendix of F. Romanelli et al., Fusion Energy 2010 (Proc. 23rd Int. FEC Daejeon, 2010) IAEA, (2010)*

MOTIVATION

Recycling in the divertor plays an important role for plasma fuelling in a tokamak. Neutral particles are formed on the target surface due to neutralization of the impinging plasma ions. Then the neutrals are reemitted from the surface and ionized in the plasma. Depending on the material and the surface temperature, deuterium can be reemitted as an atom or molecule. In contrast to an atom, a molecule has a longer ionization chain in the plasma due to the additional dissociation process. The source position of the charged particles inside the plasma strongly depends on the type of reemitted particles. In addition, the presence of vibrationally excited deuterium molecules can increase the recombination rate in cold plasmas and have vital impact on the divertor operation. The previously performed JET measurements with the full carbon divertor [1] have confirmed that deuterium release from the divertor walls dominates in the form of molecules as in TEXTOR [2]: molecules contribute more than 70% to the total deuterium influx.

MOLECULAR DEUTERIUM SPECTROSCOPY

- Fulcher-α band ($d^3\Pi_u \rightarrow a^3\Sigma_g^+$) is brightest transition in the visible spectral range 600-660 nm
- Vibrational bands with Δv=0 are visible : v''=0 → v'=0 ,1→1, 2→2, 3→3, 4→4, , 5→5
- Each band consists of R (ΔN=+1), Q (ΔN =0) and P(ΔN=-1) rotational branches
- At present time only Q rotational branches are suitable for data analysis

DIVERTOR SPECTROMETER SYSTEM KT3B [3]

- 22 viewing chords across outer divertor
- Spectrometer equipped with CCD camera grating 1200 l/mm slit width 20 µm dispersion about 0.0128 nm/pixel, 1024 pixels, pixel size 13 µm.

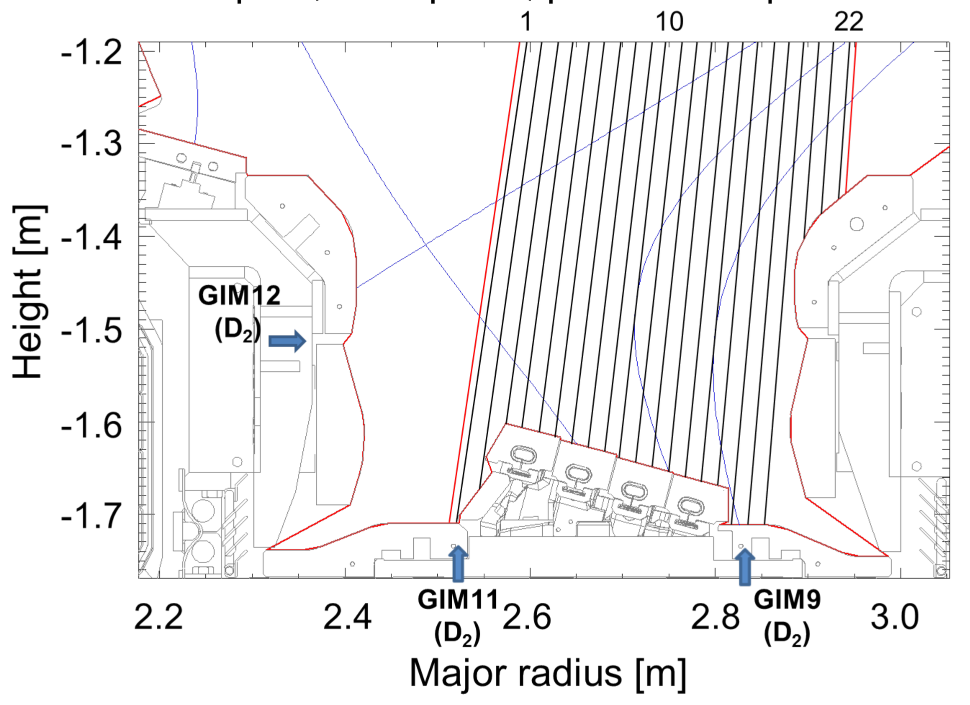

Fig. 1: Viewing chords of KT3 spectrometer and gas injection positions

Population measurements were performed in a series of reproducible pulses #81271-#81274.

600 nm – 630 nm wavelength range was covered within 3 pulses.

Plasma parameter flat-top 55 s - 64 s

B_t=2.4T

I_p=2.0MA,

n_e dl (core)~ 7.8x10^{19} m^{-2}

T_e(core) ~ 1.5 keV

1MW NBI + 0.5 MW ICRH

Plasma fuelled by GIM9 gas puff

EXPERIMENTAL RESULTS

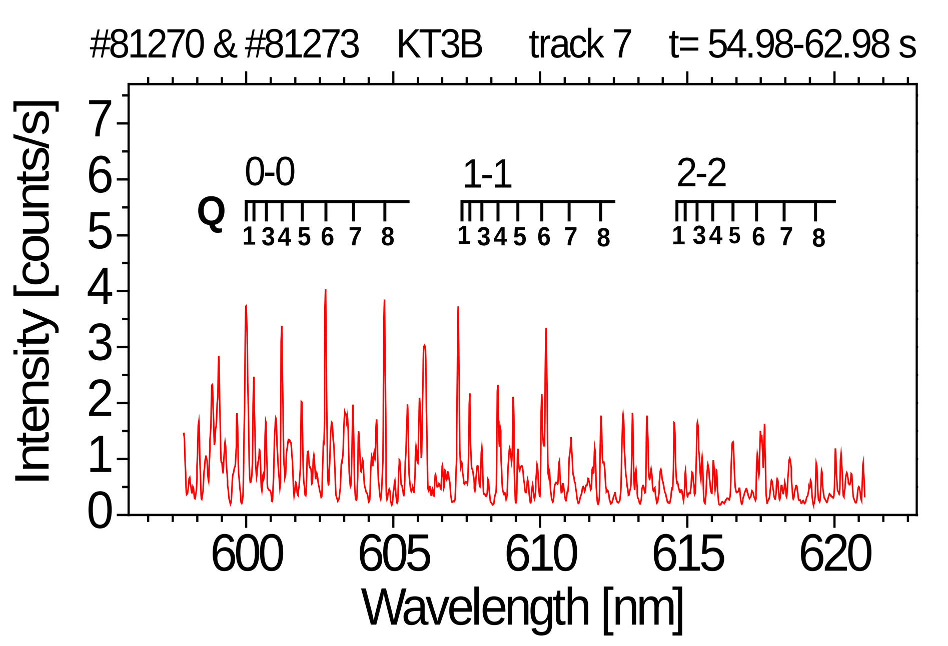

Figure 2: Combined molecular deuterium Fulcher-α band spectrum

- 17 first lines of Q(0-0) could be resolved
- Trot(v=0) almost factor of 2 higher Trot(v=1)
- Remarkably high population $d^3\Pi_u$ v=0
- non-Boltzmann population of ground state?

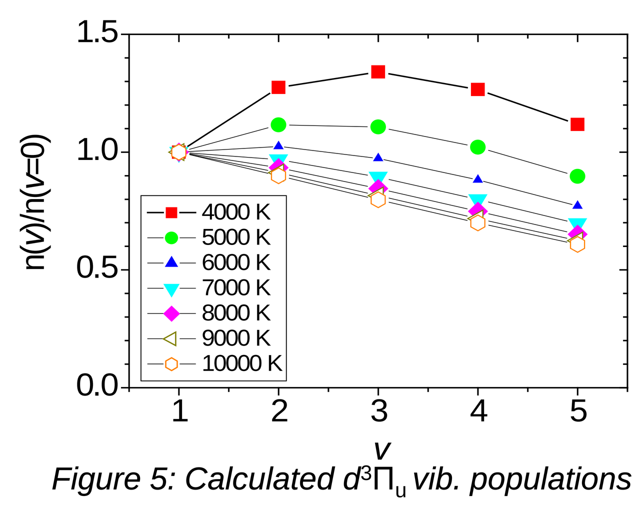

Figure 5: Calculated $d^3\Pi_u$ vib. populations

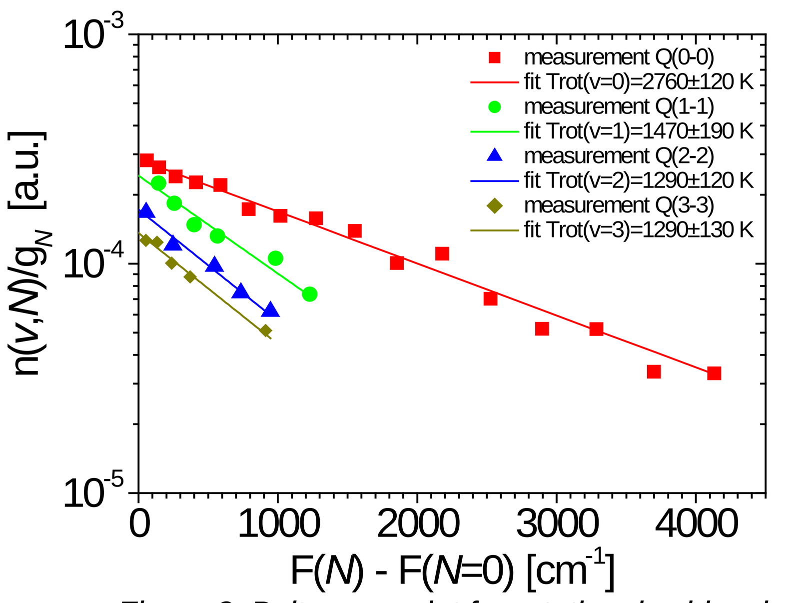

Figure 3: Boltzmann plot for rotational sublevels

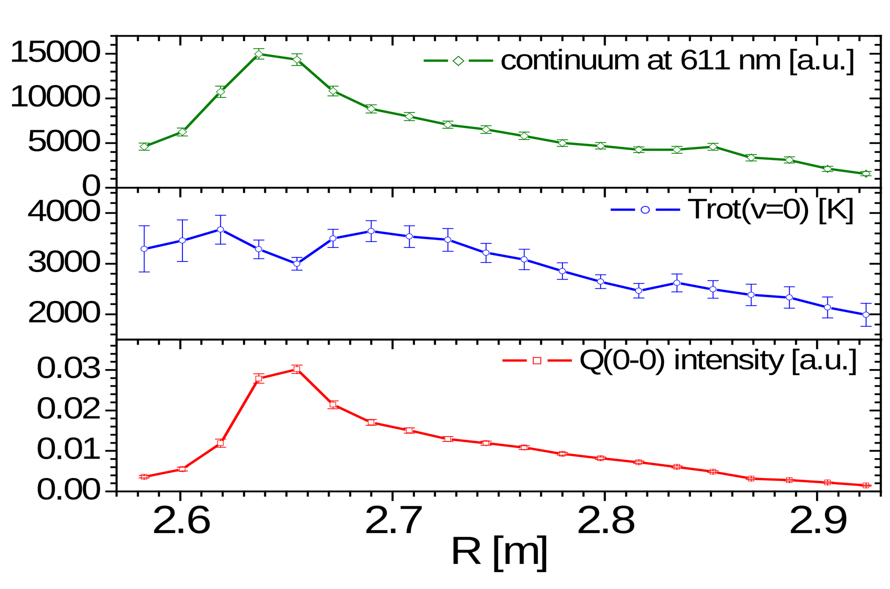

Figure 6: Measured profiles at t=55-63s, #81271

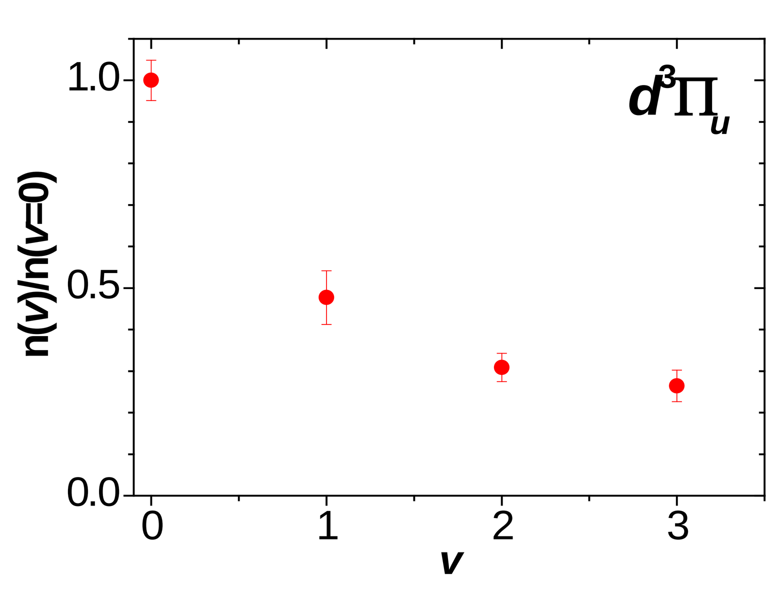

Figure 4: Vibrational population $d^3\Pi_u$ state

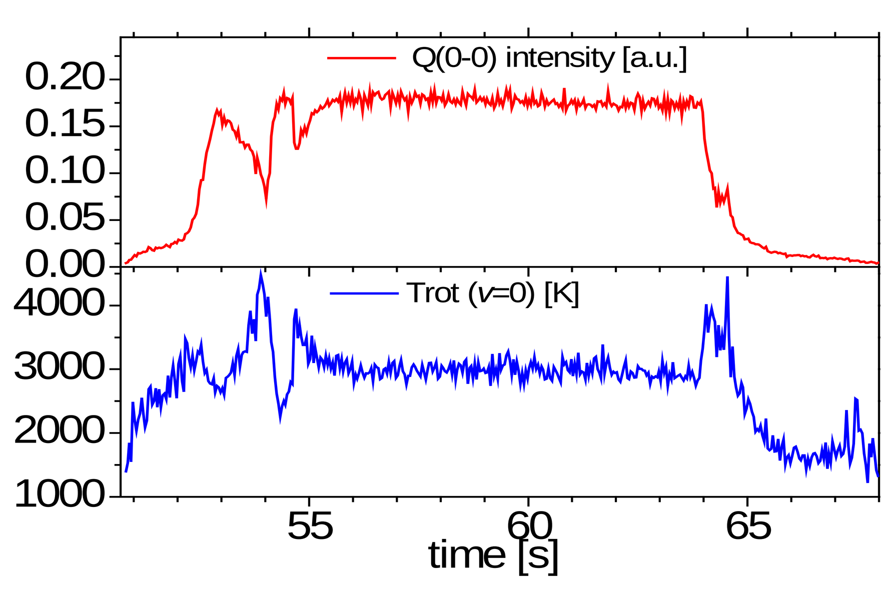

Figure 7: Trot and molecules density evolution at strike point

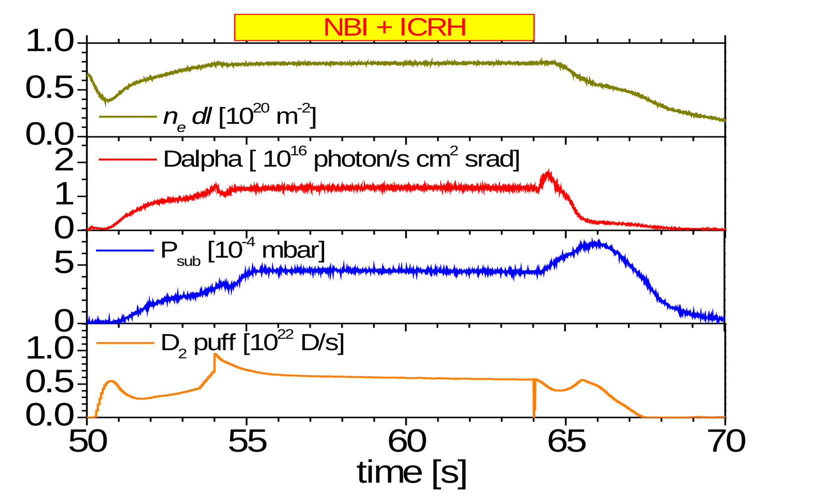

Fig.8: L-mode pulse #81271,Bt/Ip=2.4T/2.0MA, PNBI/PICRH =1MW/0.5MW , Plasma fuelled by GIM9

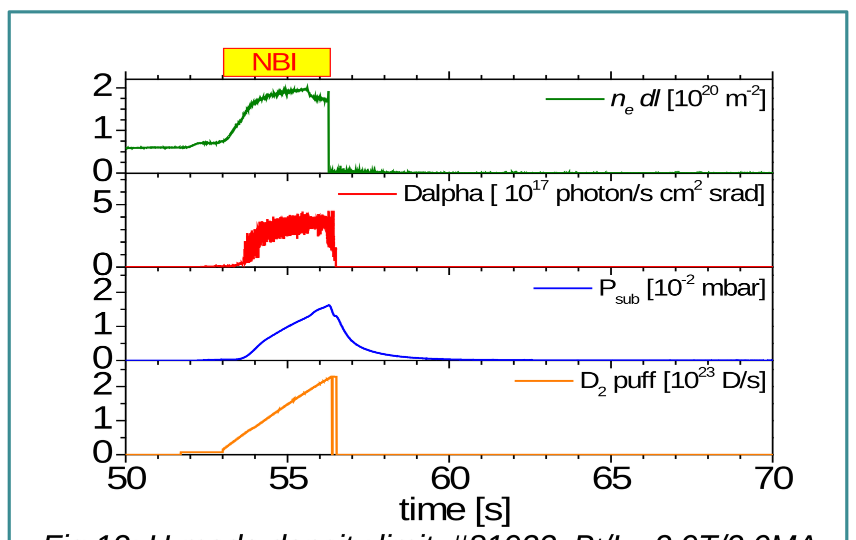

Fig.12: H-mode density limit, #81933, Bt/Ip=2.9T/2.0MA, PNBI=10.5MW Plasma fuelled by GIM9,GIM11,GIM12

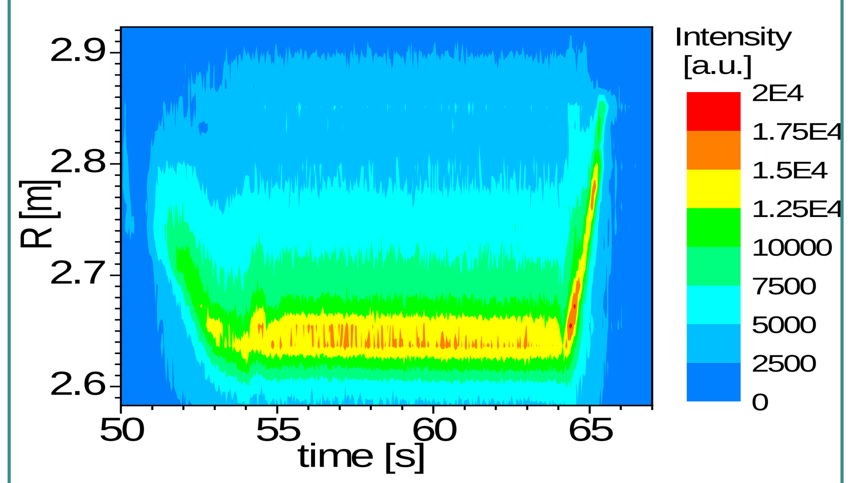

Figure 9: Intensity of continuum radiation at λ=611 nm

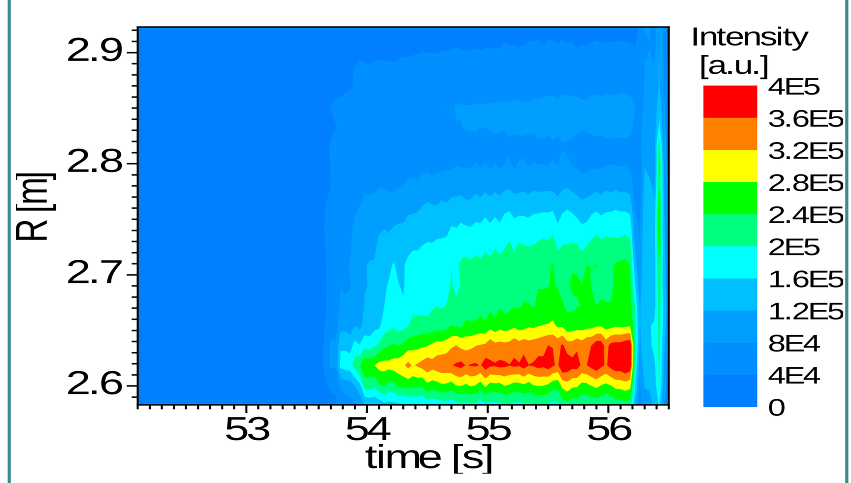

Figure 13: Intensity of continuum radiation at λ=608.4 nm

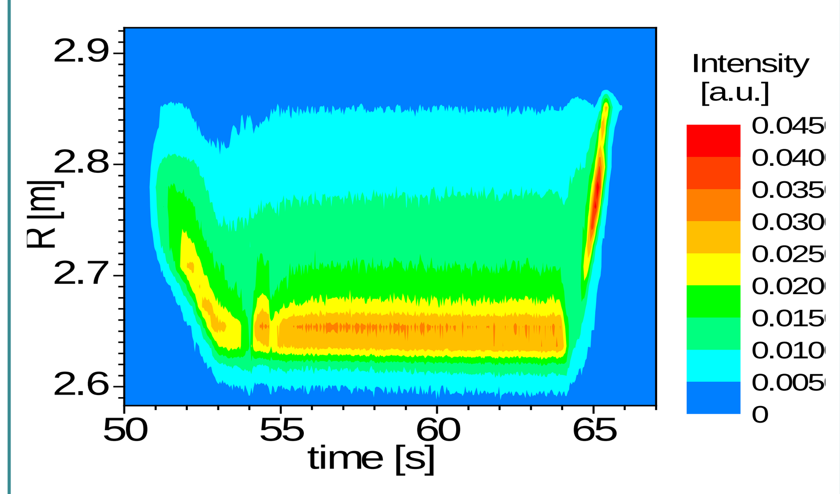

Figure 10: Intensity of Q(0-0) branch

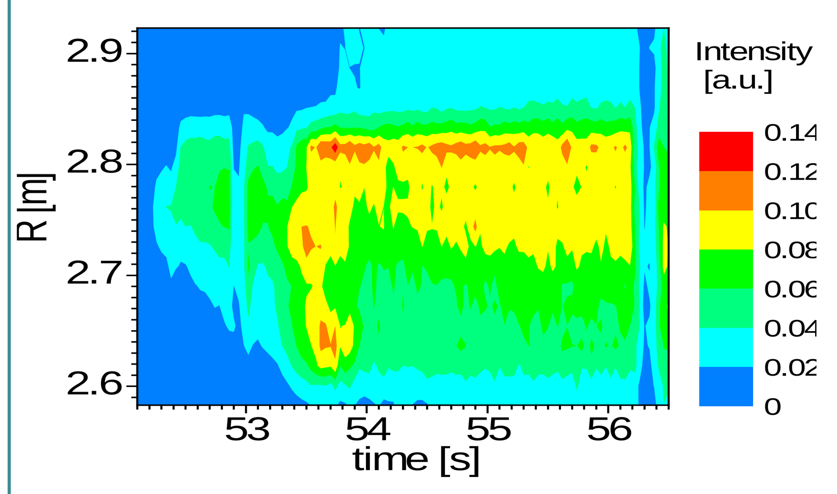

Figure 14: Intensity of Q(0-0) branch

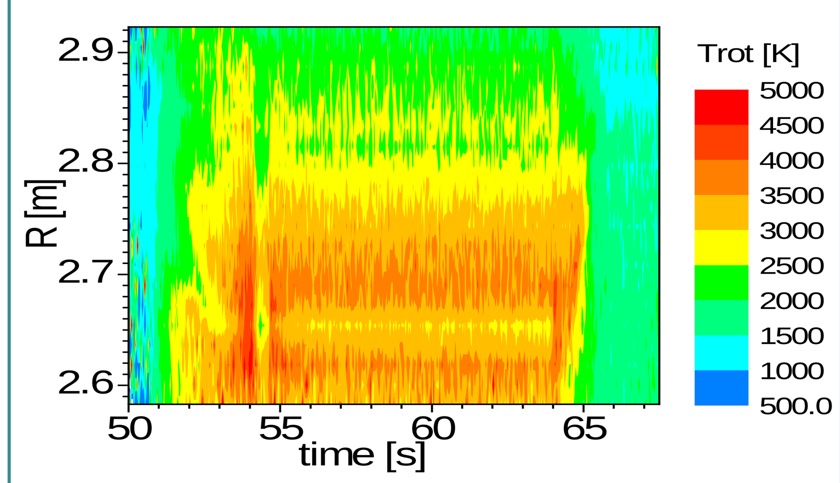

Figure 11: Rotational temperature of Q(0-0) branch

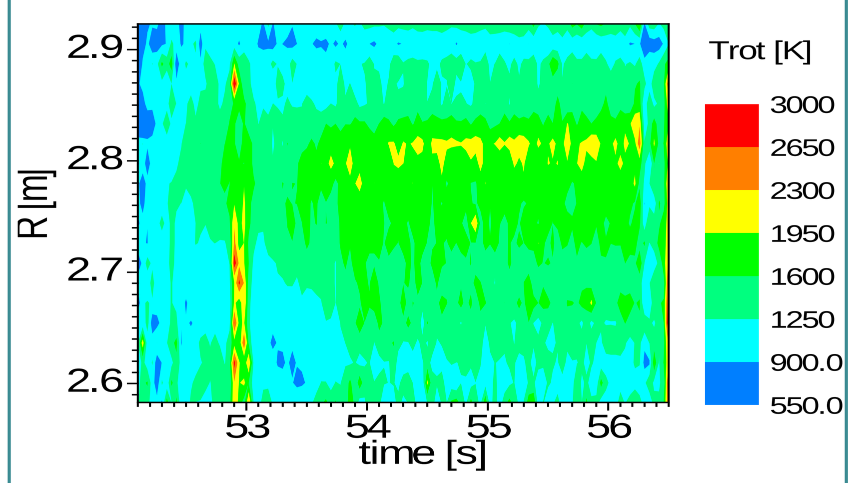

Figure 15: Rotational temperature of Q(0-0) branch

- Plasma continuum has maximum at the strike point in L- and H-mode plasma
- Minimum of molecular radiation at strike point during detachment due to an increase of D/XB with n_e
- Maximum molecular radiation from the edge of the divertor tile 5 (R= 2.81 m), probably due to the leak of molecules through the gaps between lamellae
- Minimum of rotational temperature at strike point. T_{rot} increase with n_e expected, the same behaviour was observed in carbon divertor [1]

CONCLUSIONS

- Molecular deuterium was spectroscopically observed in full tungsten JET divertor
- High rotational temperature of the excited $d^3\Pi_u$ v=0 correspond to rotational temperature of the ground state about 5500 K
- Remarkably high population of $d^3\Pi_u$ v=0 level can indicate non-Boltzmann vibrational population of the ground state of deuterium molecules at a strike point in the attached L-mode plasma
- In detached plasma the molecular line emission is strongly suppressed due to high local electron densities and dramatic increase of D/XB coefficient.
- The rotational temperature also reduces due to drop of local electron temperature at the strike point during detachment

ACKNOWLEDGEMENTS

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REFERENCES

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[2] S. Brezinsek et al., Plasma Phys. Control. Fusion **47** (2005) 615 – 634
[3] A. G. Meigs this conference