Max-Planck-Institut
für Plasmaphysik

Status of Yacora for atomic and molecular hydrogen

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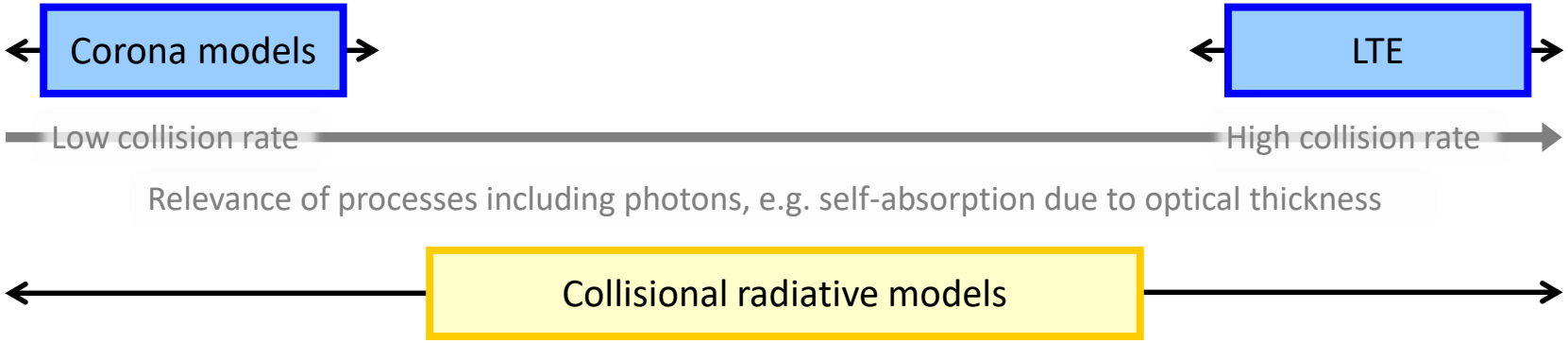
Population models for fusion edge plasmas.

Population models

- Predict population densities in dependence of plasma parameters (T_e, n_e, ground state densities).
- Main field of application: plasma diagnostics.



Collisional radiative models

Balance all relevant exciting and de-exciting reactions.

⇒ Needed: extensive data base of reaction probabilities.

⇒ Drastically increased complexity for molecules (vibrational and rotational excitation).

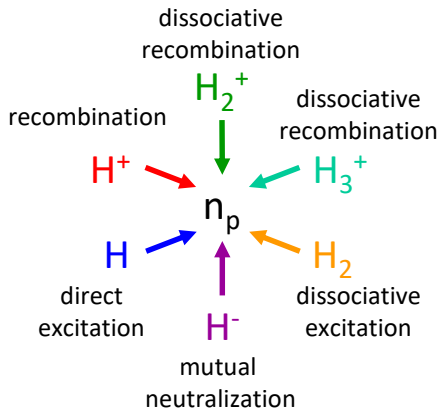
Error bar of model results directly correlates with the quality of the used input data.

Yacora for H in different plasma regimes.

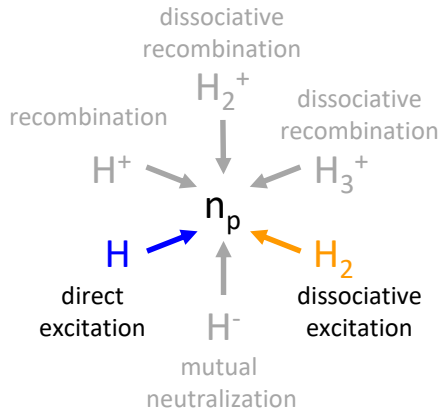
Yacora collisional radiative model for the hydrogen atom:

- In principle a complete set of input parameters, but some are base don simple assumptions.
- Some improvements were done in the last years.

Excitation of atomic hydrogen…

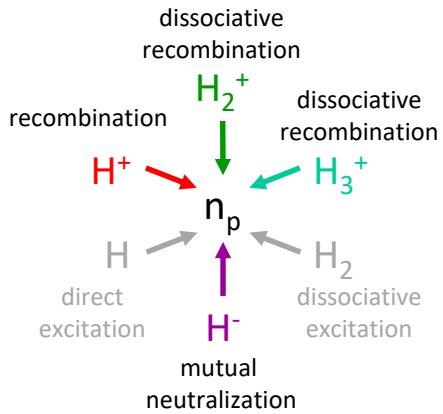


…in ionizing…



- Attached divertor plasma
- Driver region of NBI sources

…and recombining plasmas



- Detached divertor plasma
- Expansion region of NBI sources

Huge number of free parameters ⇒ Evaluation needs a lot of time and experience

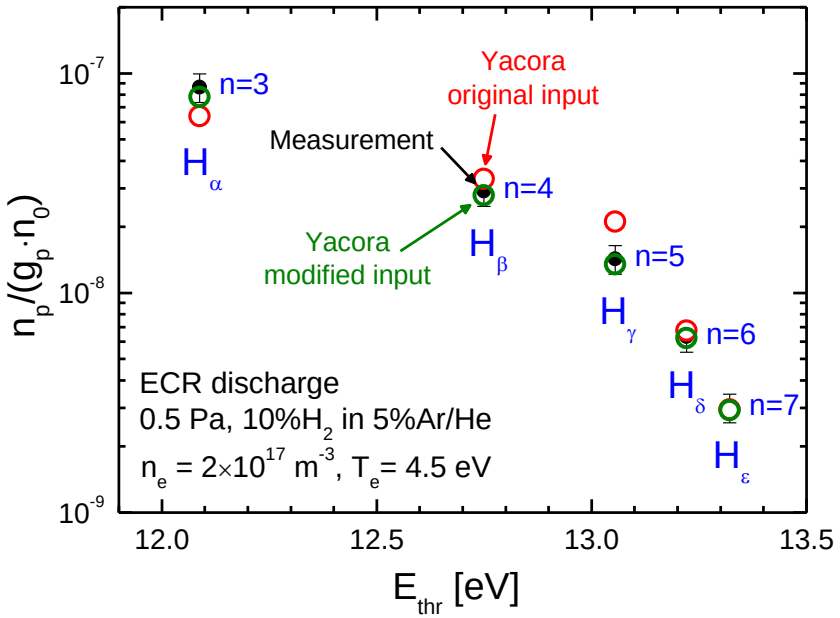
Input data for the different coupling channels.

Excitation channel…		Initial model (improved Sawada)	Yacora now
H	Direct excitation	Johnson formula & Vriens 1980	Wünderlich 2009
H^+	Recombination	Inverse ionization / Based on Gaunt factor	Inverse ionization / Based on Gaunt factor
H_2	Dissociative excitation	Measured emissivties, scaled	Measured emissivties, scaled
H_2^+	Dissociative recombination	Janev 1987, scaled.	Janev 2003
H_3^+	Dissociative recombination	Not included	Janev 2003
H^- with H^+	Mutual neutralization	Janev 1987	Stenrup 2009
H^- with H_2^+	Mutual neutralization	Not included	Janev 2003, Eerden 1995

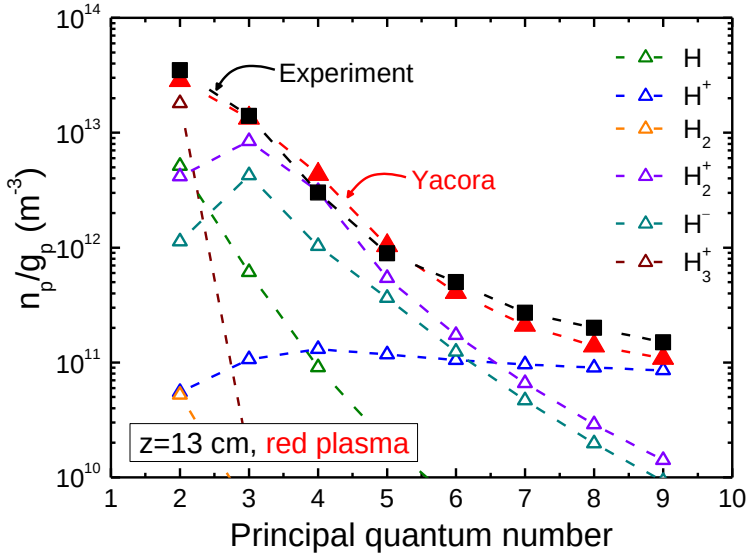
Highlights from the model for H.

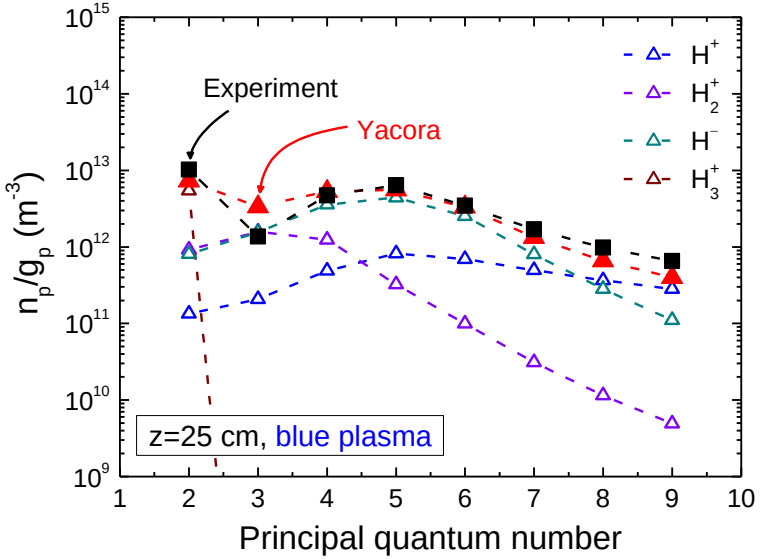
The performed improvements of the input data resulted in a very good agreement of model results with experiments.

ECR discharge:

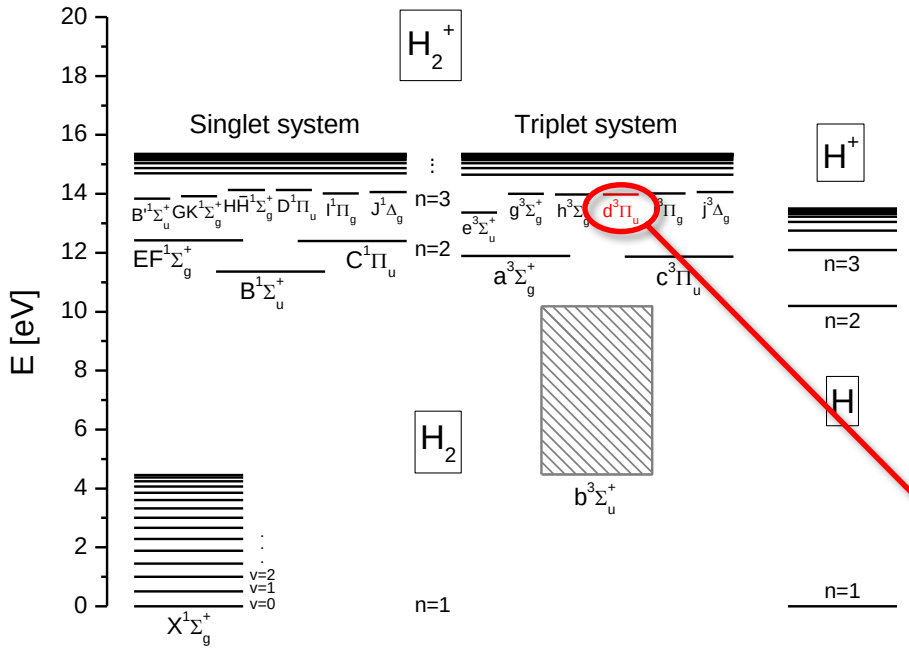


Magnetized plasma expansion at TU/e:

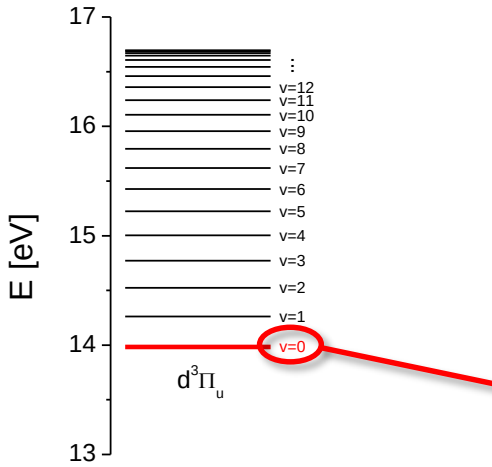




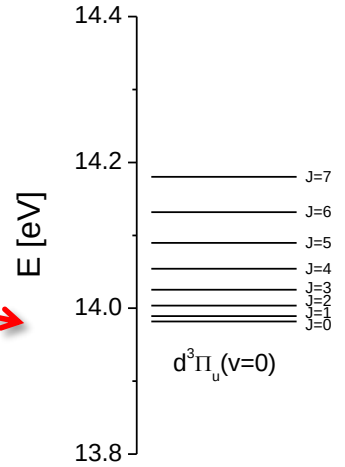
Yacora for H_2.



Electronic excitation



Vibrational excitation



Rotational excitation

Large number of excited states

Needed:

Probabilities for all reactions interconnecting all excited states

Input data used for H_2.

Excitation channel…		Initial model (improved Sawada)	Yacora now
$H_2(X^1) \rightarrow H_2^*$	Direct excitation	Miles 1971	Fursa / Scarlett (MCCC)
$H_2^* \rightarrow H_2^+$	Ionization	scaled results for H	Wünderlich 2011
$H_2(n=2) \rightarrow H_2(n=2)$	Excitation of excited states	Zygelman (for hydrogen-like ions)	Fursa / Scarlett (MCCC)
$H_2(n=2) \rightarrow H_2(n=3)$	Excitation of excited states	scaled results for H	Fursa / Scarlett (MCCC)
$H_2(n>1) \rightarrow H_2(n>3)$	Excitation of excited states	scaled results for H	scaled results for H
$H_2(a^3 \text{ or } c^3) + H_2 \rightarrow 2H_2$	Quenching of triplet states	Not included	Wedding 1988
$H_2^* + H^+ \rightarrow H_2^+ + H$	Charge exchange with H^+	Not included	Janev 2004
$H_2^* + e^- \rightarrow H^- + H$	Dissociative attachment	Not included	Hiskes 1996, Datskos 1997

Additionally:

- Available are ro-vibrationally resolved Corona models for Fulcher, Lyman, Werner, $a^3 \rightarrow b^3$ continuum. Partially for D_2 also.
- Planned next steps: use MCCC cross sections for fully vibrationally resolved model. H_2 and D_2.

Highlight from the model for H_2.

New comprehensive MCCC cross sections solved (after many years) a serious issue regarding the cross sections for direct excitation of H_2.