Neutral physics in TSVV-4 and TSVV-C

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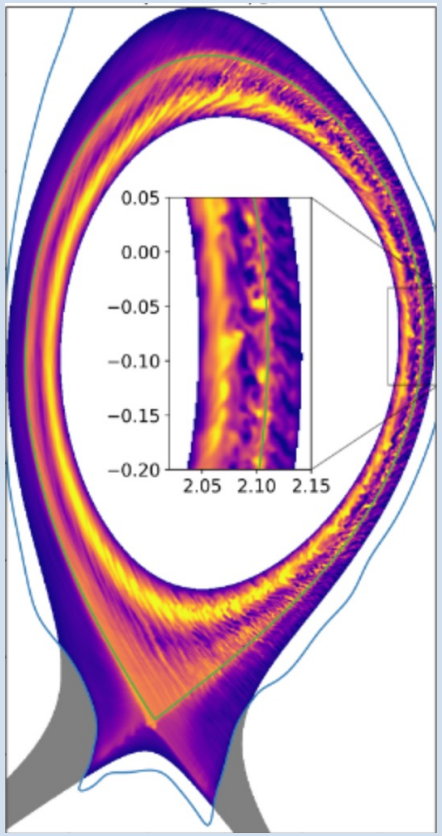
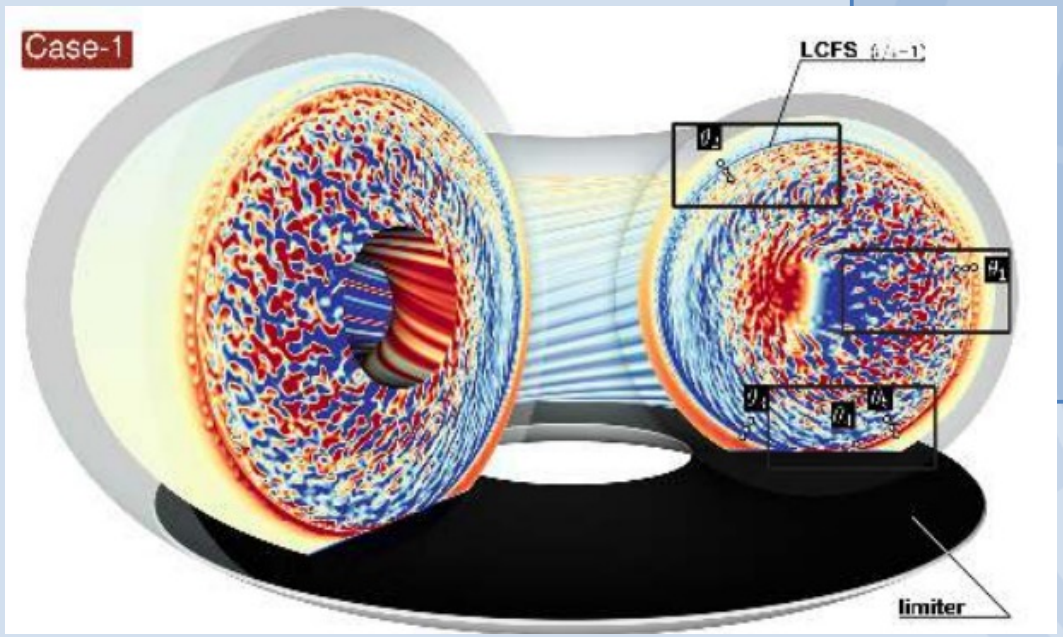
In TSVV-04: Developed three SOL-capable gyrokinetic codes

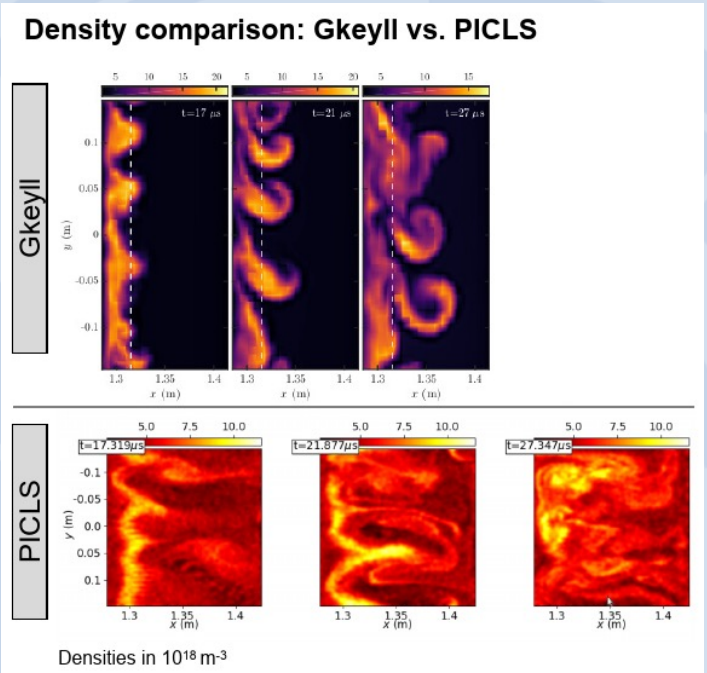


GENE-X /
D. Michels et al.,
Phys. Plasmas 2022



GyselaX /
G. Dif-Pradalier et al.,
Commun. Phys. 2022

PICLS /
A. Bottino
2021



From our work plan for 2025:

- **GENE-X**: Inclusion of **neutral and impurity physics**
- **GyselaX**: Inclusion of **neutral physics**, testing of **immersed boundary implementation** with kinetic ions and electrons
- **PICLS**: **Coupling with core codes** for limiter simulations, **finalizing the EM implementation**
- **BIT-1**: Continuation of **DEMO divertor** and **ITER SOL simulations**.
- **Semi-analytical sheath model**: Development of **coupling schemes** with gyrokinetic code(s)
- **Hybrid code ssV**: Continued characterization of **fully kinetic ITG physics**
- **GEMPICX**: Implementation of **cylindrical coordinates**
- **Gyro-moment approach**: Further development of **full-f moment approach**

GENE-X added 1-mom fluid neutrals model

Status of GENE-X neutrals (S. Ogier-Collin):

- In general, follows GRILLIX path thanks to shared infrastructure
- Add neutrals as simple in-code model before coupling to any external code

- Choice: pressure-diffusion model (1-moment) from Horsten (NF 2017), as already added in GRILLIX

(limiter)

$$\frac{\partial N}{\partial t} = \nabla \cdot \frac{\tilde{D}_\mathrm{N}}{T_\mathrm{i}} \nabla N T_\mathrm{i} - k_\mathrm{iz} n N + k_\mathrm{rec} n^2 \qquad \text{with} \qquad D_\mathrm{N} = \frac{c_\mathrm{s,N}^2}{\nu_\mathrm{cx}} = \frac{T_\mathrm{i}/m_\mathrm{i}}{k_\mathrm{cx} n}$$

Eqs. from Zholobenko NF 2021

What additional developments are needed beyond those done for GRILLIX?

- Need source terms for gyrokinetic distribution functions (ready for 3-moment model)
- Derive, add + test those terms (EF Pinboard: S. Ogier-Collin, #40191)

GYSELA: 1-mom fluid neutrals added to VOICE testbed

Neutrals in VOICE (Y. Munschy, M. Protais):

- VOICE = 1d1v fully kinetic, with same numerics as GYSELA (semi-Lagrangian)
- Within TSVV-4, focused on immersed boundary condition treatment of sheath physics
- Recently added pressure-diffusion model
- Use different grids for plasma + neutrals

Studied neutrals in combination with sheath physics:

- Observe ionization + CX, recycling
- How do those interact with ions accelerating towards the sheath?

Next:

- Physics studies, e.g. heat transmission factor

E. Bourne (JCP ’23), Y. Munschy (NF ’24 x2)

Preliminary plans for TSVV-C

GENE-X:

- Exploit current neutrals model (e.g. run TCV-X21 with neutrals)
- Move towards 3-moment model, add recycling
- Develop sources for spectral version of GENE-X

GYSELA:

- Not planning to focus on adding evolving neutrals, but…
- Focus on adding kinetic neutrals sources (2 populations, dissoc. + CX) and study their effect on the plasma

JOREK-GK:

- Gyrokinetic version of JOREK; not previously developed within TSVV-4
- JOREK (non-GK) already contains fluid and kinetic neutrals models
- Couple this model with the GK version

Synergies with TSVV-K?

In general:

- Our codes are unlikely to strive for external coupling in the 2026/27 (we are a few years behind the fluid turbulence codes)

- So far, none of our codes include ”advanced” physics beyond hydrogen. No molecules either. For these, we’ll likely resort to coupling, but later.

- But: Any changes made to EIRENE interface (STYX?) to improve coupling to fluid turbulence codes **will also benefit us**.

- Hybrid models like KDMC may be interesting, but (at least to me, now) the benefits of one vs. the other are not yet clear enough.