EFDA

EUROPEAN FUSION DEVELOPMENT AGREEMENT

Task Force
INTEGRATED TOKAMAK MODELLING

ITM Code Camp 2012
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IMP5: Energetic Particles

G. Vlad

Associazione Euratom-ENEA sulla Fusione, Frascati

Interim TF Leader : G. Falchetto,
Deputies: R. Coelho, D. Coster

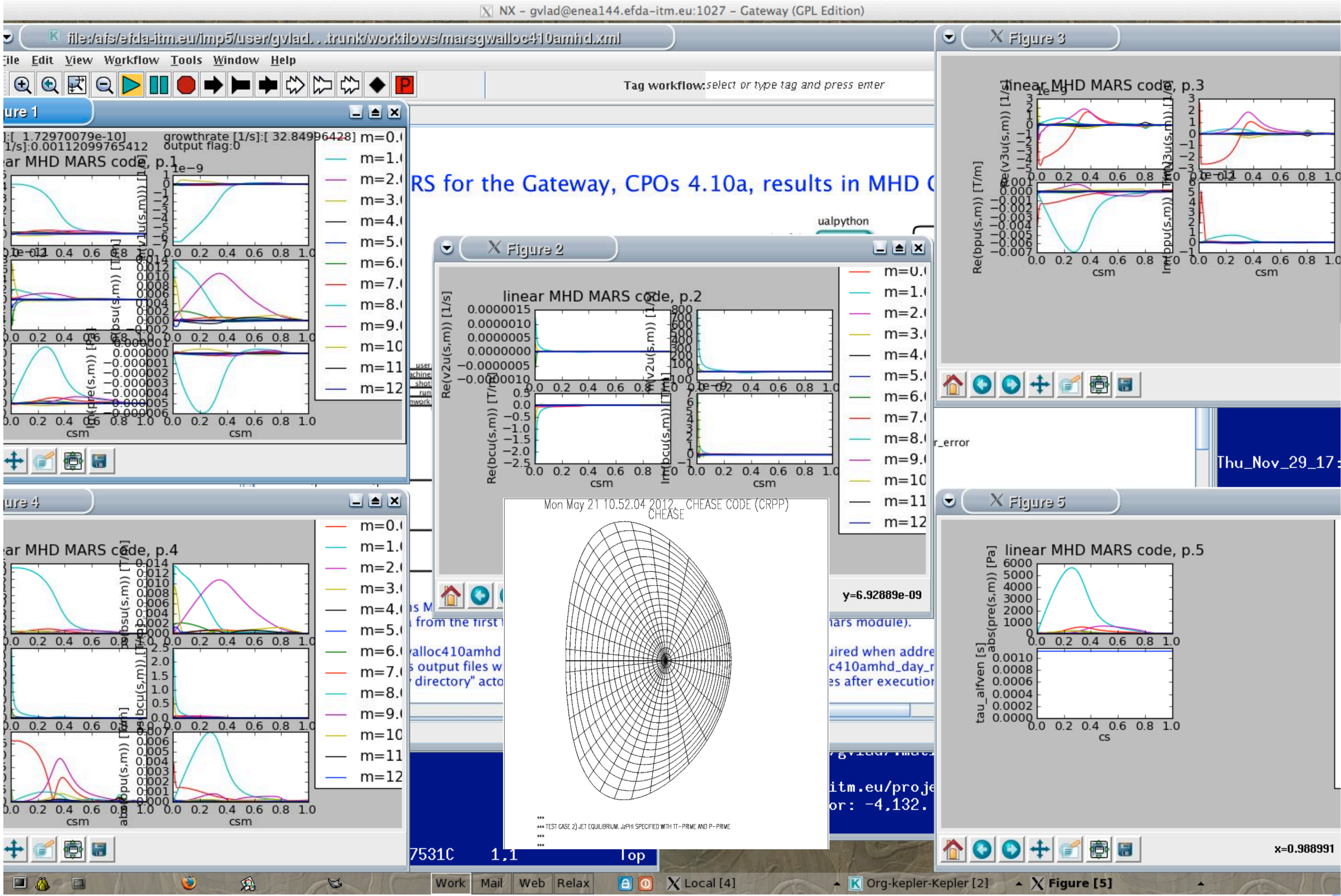
EFDA CSU Contact Person: D. Kalupin

MARS: benchmark activity

WP12-ITM-IMP5-ACT1-04 & WP12-ITM-IMP12-ACT3-01

- The MHD field solver MARS (from which the field solver module for HYMAGYC is derived) is under testing with other IMP12 codes
  - Agreed on first benchmark cases (Jet like shape, fixed boundary *n*=1 internal kink, free boundary…, etc.)
  - Generated CPOs for first test case in 4.10a (JET shaped, ntcase=2) using CHEASE (shot 180 run 210, normalized units, shot 180, run 300 dimensional case to check units transformations)
  - First benchmark cases for MARS available on output MHD CPOs (gvlad itmdb, shot 180 runs 211, 310)

MARS: benchmark activity

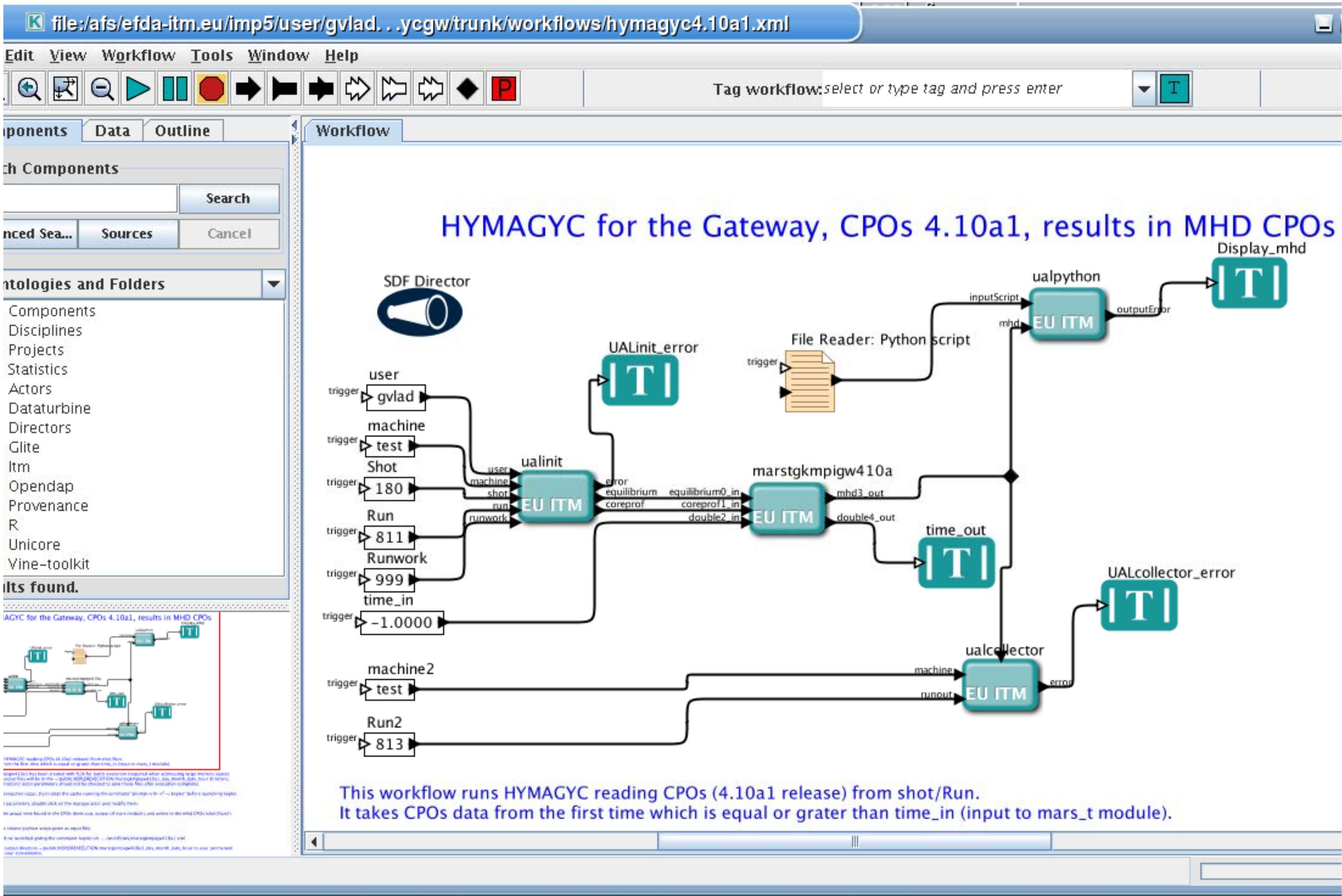


HYMAGYC: Kepler actor and workflow

WP12-ITM-IMP5-ACT1-01:

- HYMAGYC equilibrium related inputs reconstructed form equilibrium CPOs
  - Metric tensor compionents, Jacobian, eq. magnetic field, current, pressure, R,Z(s,χ), s,χ(R,Z), Christoffel symbols, eq. field versors and scalars…
- Equilibrium input files => fortran modules
- Static arrays => allocatable arrays
- Kepler actor with 4.10a.1 test UAL release (MPI not working properly with 4.10a; OpenMP not working properly with pgi/8.0, OK with pgi/10.2, intel/12.0.2, …)
- CPOs version of HYMAGYC gives correct results w.r.t. stand-alone version (using a driver to allow compilation w/o pgi/8.0…)

HYMAGYC: Kepler actor and workflow



HMGC, workflow for HYMAGYC on HPC-FF/IFERC

WP12-ITM-IMP5-ACT1-03:

- Maintaining equilibrium interface of HMGC with new equilibrium and coreprof CPOs releases

WP12-ITM-IMP5-ACT1-06:

- Workflow to execute HYMAGYC on HPC-FF/ IFERC machines
  - Delayed because of 4.10a compilation problems with MPI/OpenMP: some progresses this week thanks to ISIP support
  - Stand-alone code compiles fine on HPC-FF

HYMAGYC progresses and benchmarks

WP12-ITM-IMP5-ACT1-05:

- Benchmark HYMAGYC with HMGC (reduced-MHD $O(\varepsilon_0^3)$+drift-kinetic GK) and analytical models

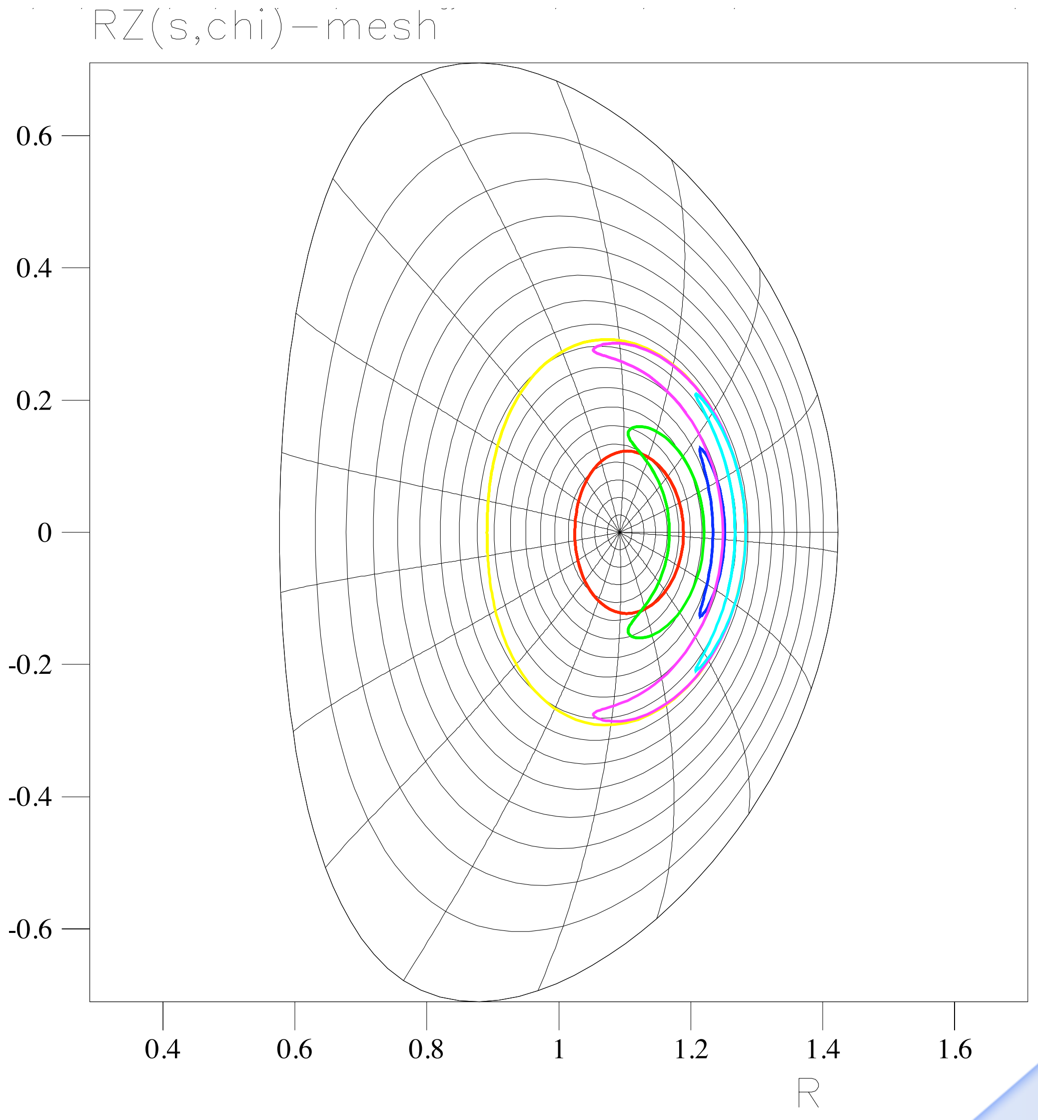
WP12-ITM-IMP5-ACT4-01:

- Code development… HYMAGYC
  - Construct suited limits of GK equations in order to reduce to analytically solvable equations to compare with or to HMGC equations.
  - Collaboration with HLST team (ParFS project) in order to substitute the actual (scalar) field solver with a parallel one (note that GK module is, instead, fully parallelized)

HYMAGYC progresses and benchmarks

Energetic particles motion in equilibrium field, projected in the poloidal plane:

- circulating particles (yellow, red)
- Trapped particles (green, blue, magenta, cyan)



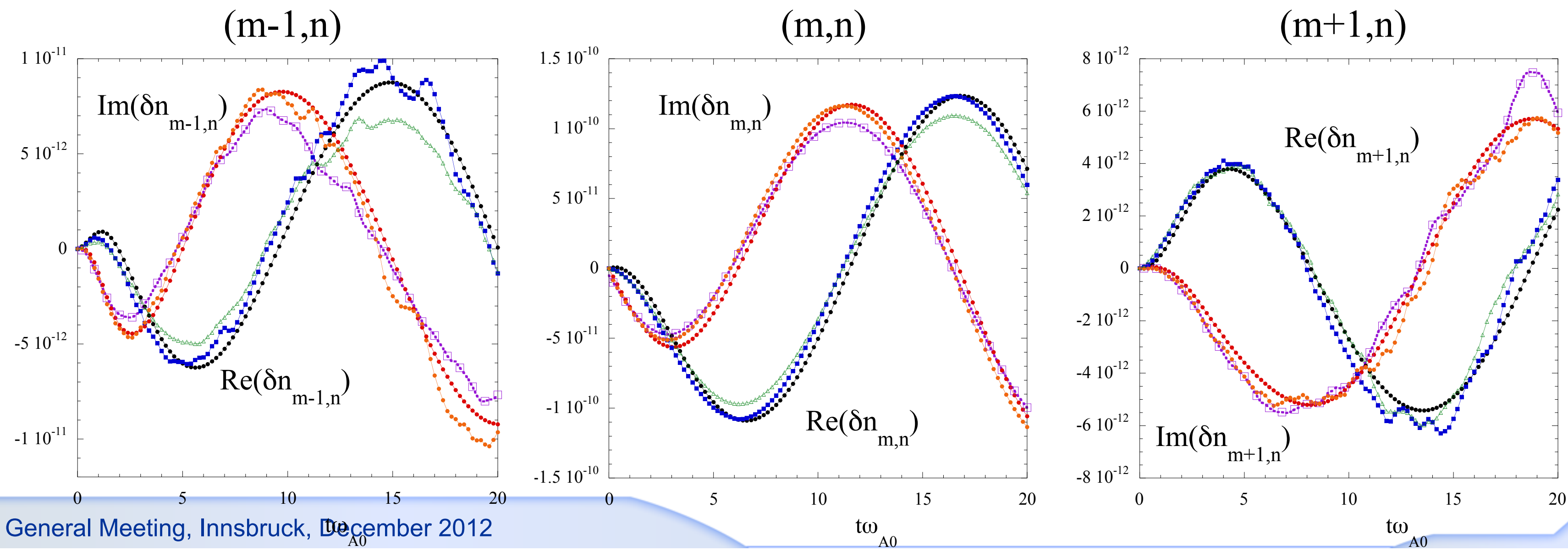
HYMAGYC progresses and benchmarks

Analytic energetic particle response compared with HYMAGYC and HMGC, assuming:

(a) unperturbed particles motion
(b) no mirroring term in the parallel velocity equation
(c) only linear terms in Vlasov equation
(d) large aspect ratio $\varepsilon_0 = a/R_0 << 1$
(e) circular magnetic flux surfaces
(f) flat q profile
(g) circulating energetic particles with $\rho_H/a << 1$
(h) electromagnetic fields with scalar potential ϕ and vector potential $\delta A_\perp << \delta A_{||}$.

Bi-Maxwellian distribution function with:
$T_{H\perp}/T_{H||} \rightarrow 0$,
$\phi, \delta A_{||} \propto \phi(r), \delta A_{||}(r) \times \exp[i\omega t + i(m\theta + n\varphi)]$,
$\omega/\omega_{A0} = (0.3 + i\ 0.01)$,
$(m,n) = (4,4)$,
$R_0/a = 100$,
$\rho_H/a = 0.001$
$v_{Hth}/v_A = 0.1$
Response of the perturbed components at $x_1 = 0.5$

Analytical response: black (Real) and red (Imm); HYMAGYC response: blue (Real) and orange (Imm); HMGC response: green (Real) and pink (Imm)



HYMAGYC progresses and benchmarks

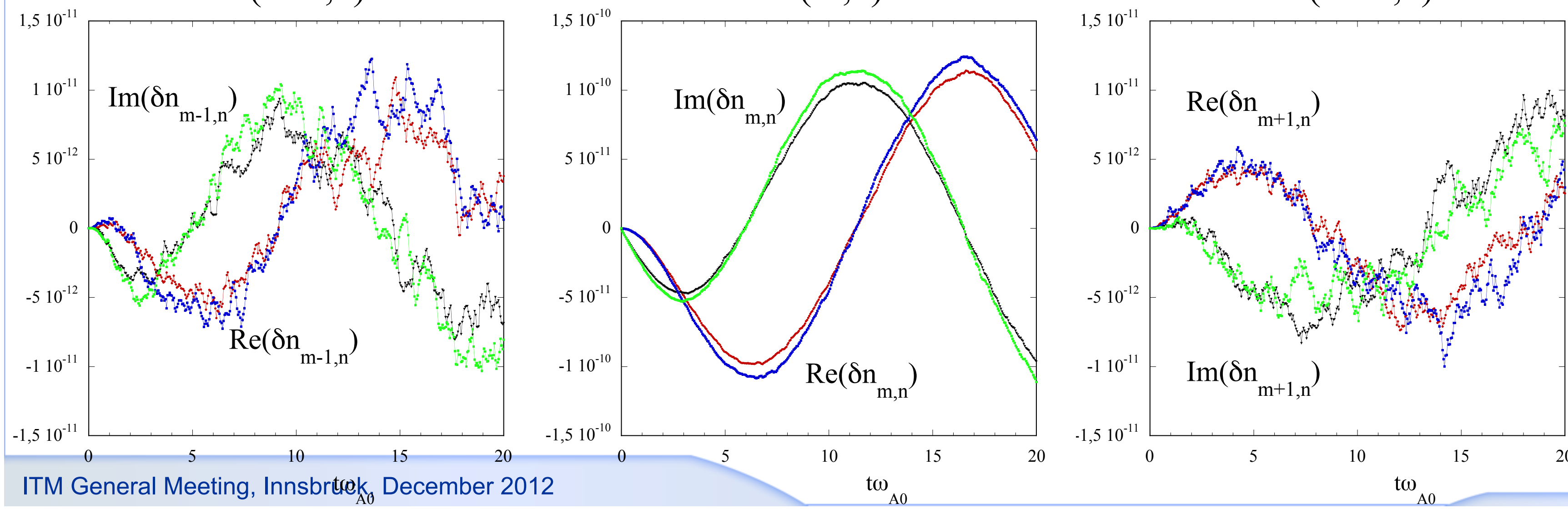
Compare HYMAGYC and HMGC, relaxing some of the prev. restrictions (no analytic. sol. available):

(a) perturbed particles motion ON
(b) mirroring term in the parallel velocity equation ON
(c) relaxation term of the energetic part. initial distr. function in the Vlasov equation ON
(d) large aspect ratio $\varepsilon_0 = a/R_0 << 1$
(e) circular magnetic flux surfaces
(f) flat q profile
(g) circulating energetic particles with $\rho_H/a << 1$
(h) electromagnetic fields with scalar potential ϕ and vector potential $\delta A_\perp << \delta A_\parallel$.

Bi-Maxwellian distribution function with:
$T_{H\perp}/T_{H\parallel} \rightarrow 0$,
$\phi, \delta A_\parallel \propto \phi(r), \delta A_\parallel(r) \times \exp[i\omega t + i(m\theta + n\varphi)]$,
$\omega/\omega_{A0} = (0.3 + i\,0.01)$,
$(m,n) = (4,4)$,
$R_0/a = 100$,
$\rho_H/a = 0.001$
$v_{Hth}/v_A = 0.1$
Response of the perturbed components at $x_1 = 0.5$

HMGC response: black (Real) and red (Imm); HYMAGYC response: blue (Real) and green (Imm)

(m-1,n) (m,n) (m+1,n)



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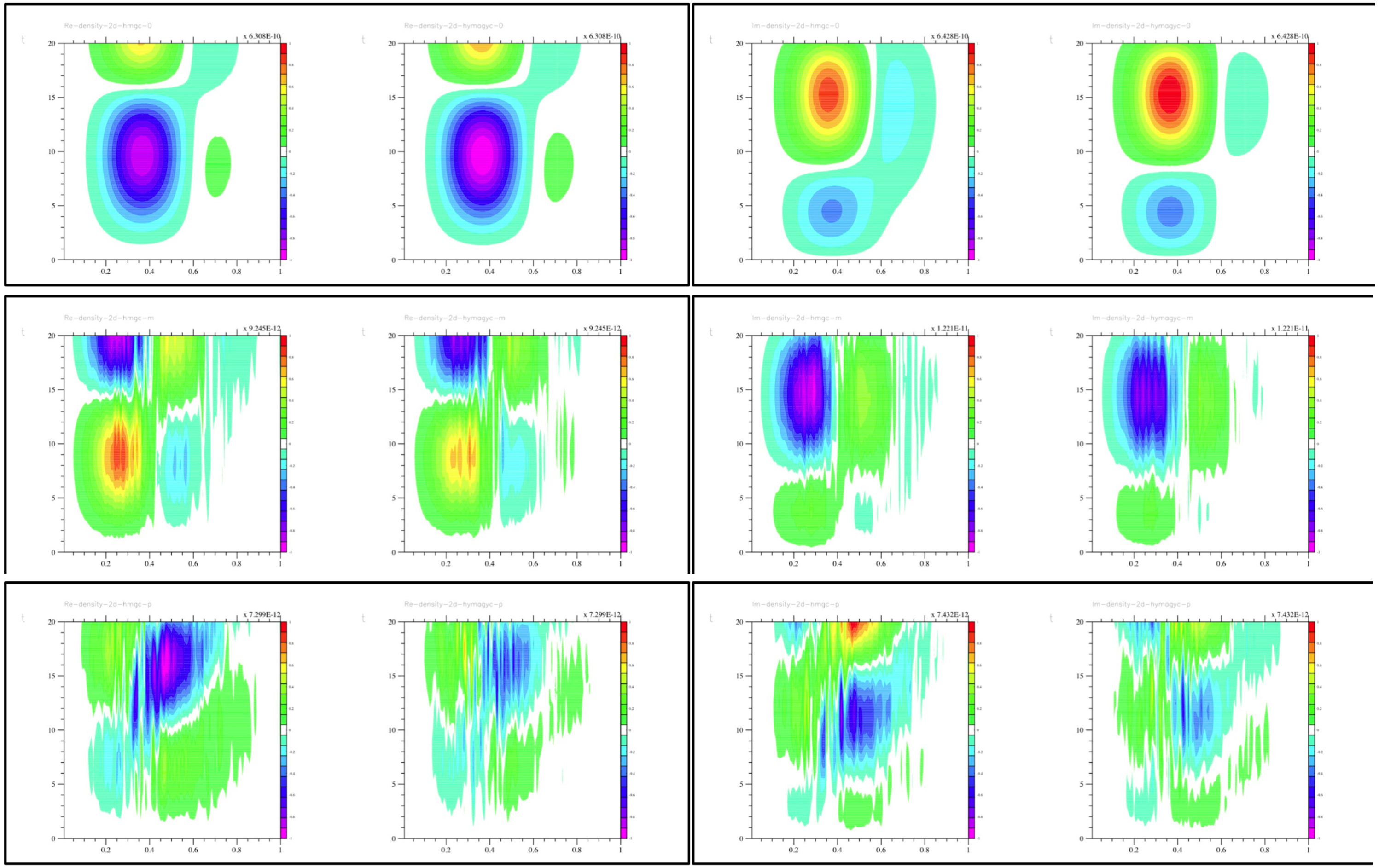
HYMAGYC progresses and benchmarks

Comparing HMGC and HYMAGYC , relaxing some of the previous restrictions (no analytical solution available):

Model and parameters as before but: Maxwellian distribution function; (2) (m,n)=(2,1)

Contour plots of the perturbed density response in the plane (r/a, t) for HMGC and (x1,t) for HYMAGYC:

HMGC (Real) HYMAGYC	HMGC (Imm) HYMAGYC



(m,n)

(m-1,n)

(m+1,n)

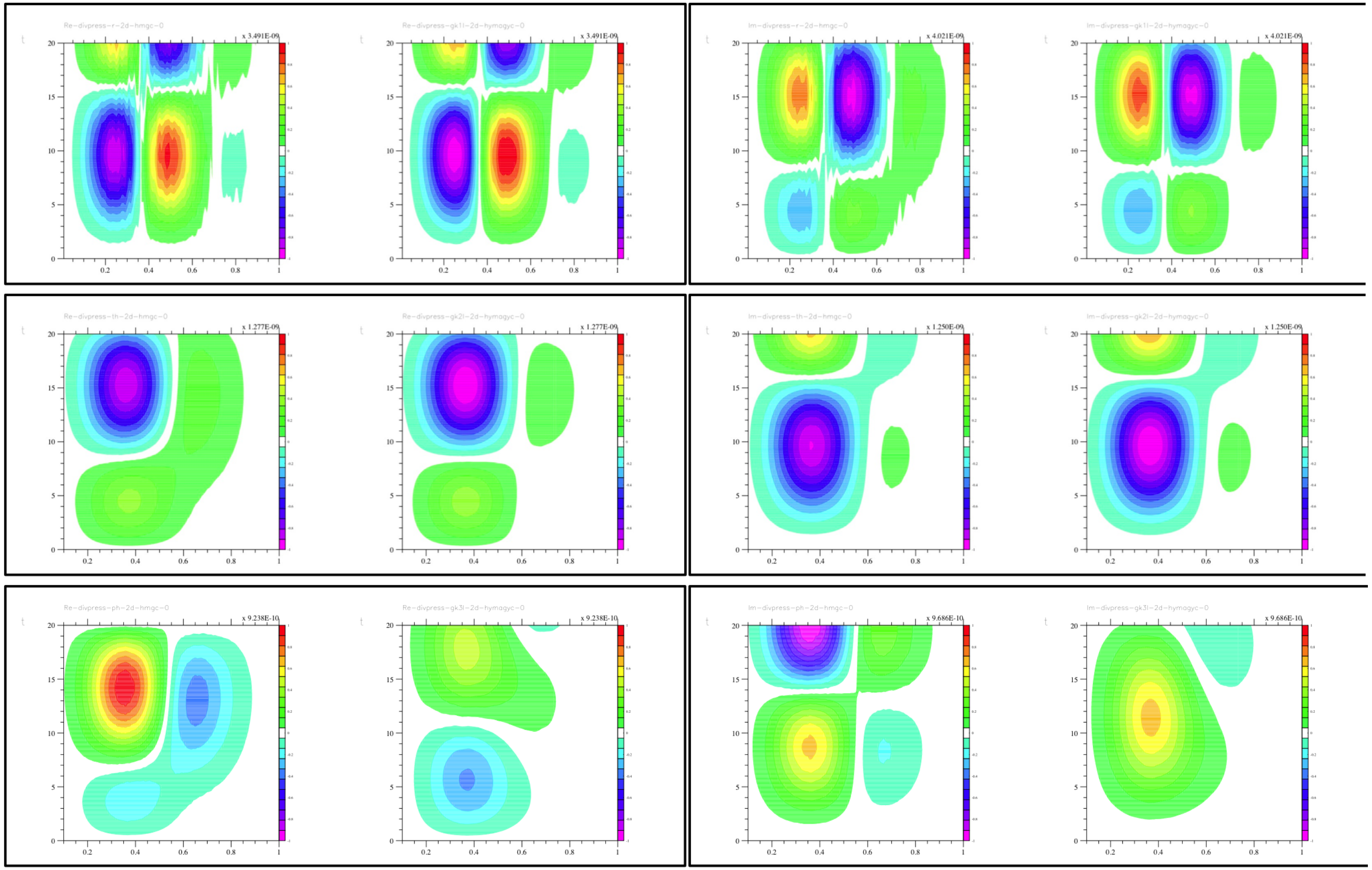
HYMAGYC progresses and benchmarks

Comparing HMGC and HYMAGYC , relaxing some of the previous restrictions (no analytical solution available):

Model and parameters as before but: Maxwellian distribution function; (2) (m,n)=(2,1)

Contour plots of the pert. components of vector $(\nabla \bullet \Pi)^i$ in the plane (r/a, t) (HMGC) and (x1,t) (HYMAGYC):

HMGC (Real) HYMAGYC	HMGC (Imm) HYMAGYC



$(\nabla \bullet \Pi)^r_{m,n}$

$(\nabla \bullet \Pi)^\theta_{m,n}$

$(\nabla \bullet \Pi)^\varphi_{m,n}$

HYMAGYC progresses and benchmarks

Comparing HMGC and HYMAGYC , relaxing some of the previous restrictions (no analytical solution available):

More deeper comparisons are required for the φ-components and satellites of the divergence of the pressure tensor (the divergence of the pressure tensor is the actual drive terms which enters in the extended MHD equations giving the feedback of the energetic particles to fields evolution…)

Simulations using complete versions (self-consistent evolution of fields and energetic particles) of HMGC and HYMAGYC (n=2, m=1,…,4); below is a scan on energetic particle density (intensity of the drive). Note that the details of continuous damping is different between the two codes…)