Optimising TGLF for a Q=10 Burning Spherical Tokamak (BurST)

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1. Introduction

- ➢ A Q=10 burning ST (BurST) is analysed with parameters in Table 1
- ➢ To produce net energy on the grid it is necessary to
  - Minimise auxiliary heating
  - Maximise fusion power
- ➢ Equilibrium generated with the SCENE code
  - **Specified** temperature and density profiles
  - H^{98} factor used to estimate the required quality of confinement
- ➢ Predictive transport modelling required to assess feasibility

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- ➢ **TGLF**[1,2] is a quasi-linear gyrofluid turbulent transport solver used to estimate anomalous transport
- ➢ JINTRAC has been used to examine the energy confinement with TGLF calculating the anomalous heat transport
- ➢ TGLF standard settings are for tokamaks -> recalibration needed for STs
- ➢ Linearly benchmarked with GS2[3] -> optimise TGLF inputs for high performance ST plasmas

Parameter	Value
Major/Minor Radius (m)	2.5/1.5
Elongation	2.9
β_N	5.1
Safety factor on axis	2.5
Fusion Power (MW)	1100
Auxiliary Power (MW)	110
B at R_0 (T)	2.4
Plasma Current (MA)	21.2
H^{98} factor	1.2
$\overline{n}_e$ ($\times 10^{20}\ m^{-3}$)	1.5
Core $T_e \backslash T_i$ (keV)	28

Table 1: Baseline parameters of the Q=10 ST machine

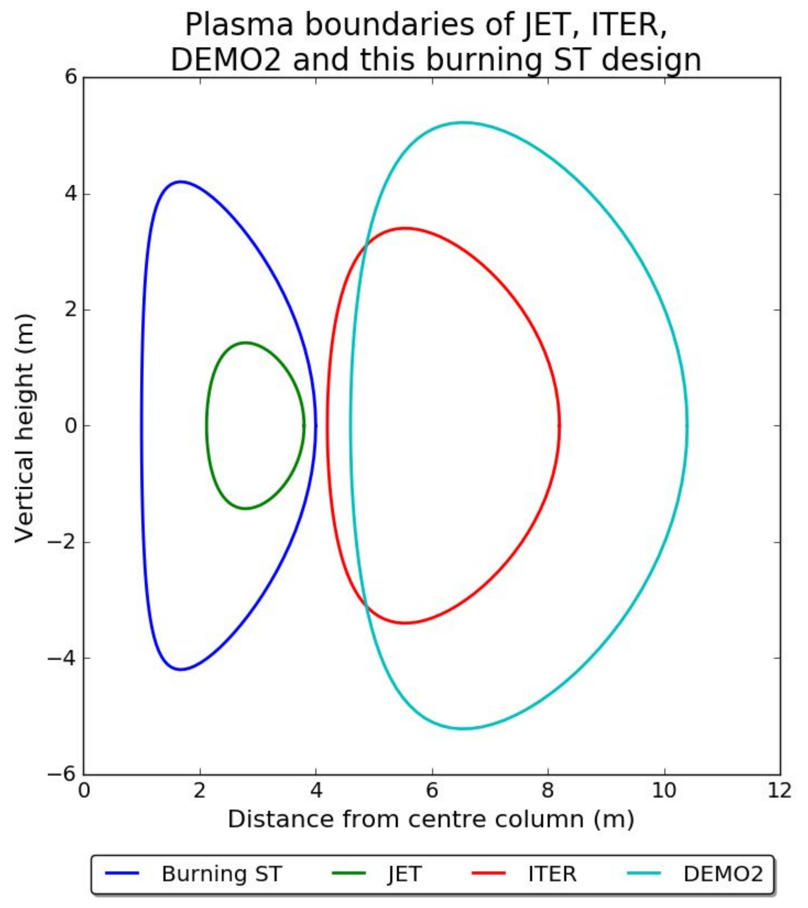


Figure 1: Comparison of plasma boundaries of JET, ITER and DEMO to the Q=10 ST illustrating the size.

2. Default TGLF parameters in Transport code

- ➢ Starting with target equilibrium, temperature profiles evolved forward until steady state using **default** TGLF parameters -> pedestal height fixed at 5keV
- ➢ Default settings predict poor confinement: Fusion power 1.1GW --> 350MW
  - Are these settings appropriate for BurST?
- ➢ Increasing number of parallel basis functions used from 4 to 8 to find the eigenmode predicts significantly reduced transport -> Fusion power 1.3GW
  - Need to find inputs that provides accurate solution

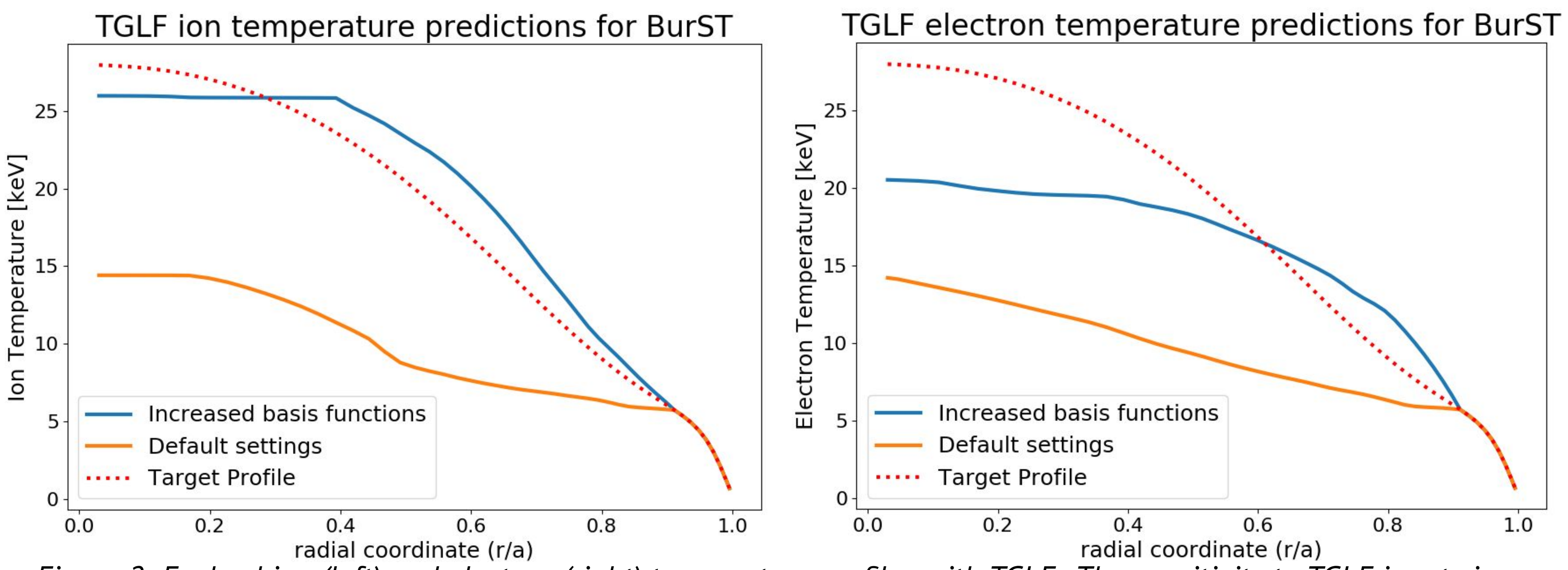


Figure 2: Evolved ion (left) and electron (right) temperature profiles with TGLF. The sensitivity to TGLF inputs in the BurST regime motivates this study to improve the model.

3. GS2 vs TGLF - Simplified geometry

- ➢ Comparison made with a **simplified** version of a BurST equilibrium

Similarities	Differences
Kinetic gradients	Aspect ratio (R/a=3.0)
Miller parameters	Electrostatic (β=0)
Magnetic geometry	No pressure gradient ($p'=0$)

- ➢ Qualitative agreement between two codes for linear growth rates at mid-radius
  - TGLF generally overestimates growth
- ➢ Quantify difference with following formula

$$\sigma_\gamma = \left[\frac{1}{N}\sum_{n=1}^{N}\frac{(\gamma^{GS2}-\gamma^{TGLF})^2}{(\gamma^{GS2})^2}\right]^{1/2}$$

- ➢ σ_γ = 58% for default settings
- ➢ Increasing number of basis functions from 4 to 8 reduces σ_γ = 45%
- ➢ Eigenfunctions qualitatively match at $k_y\rho_s$ where growth rates peak in ion/electron scales

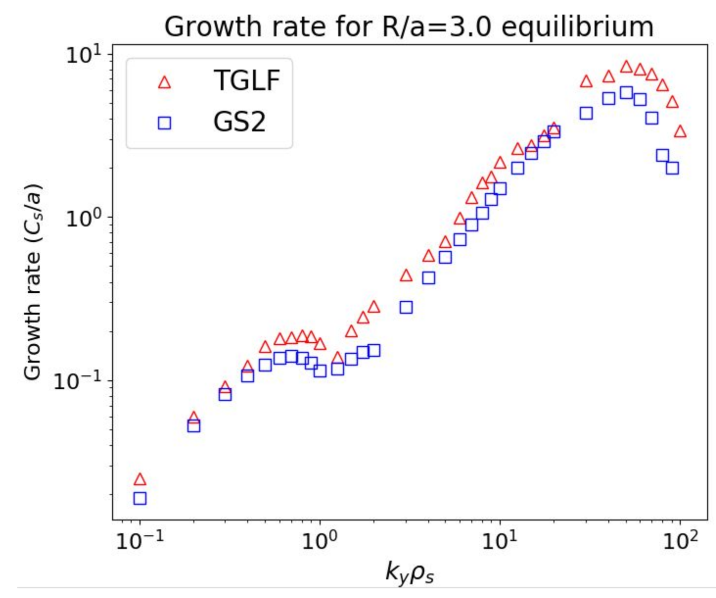
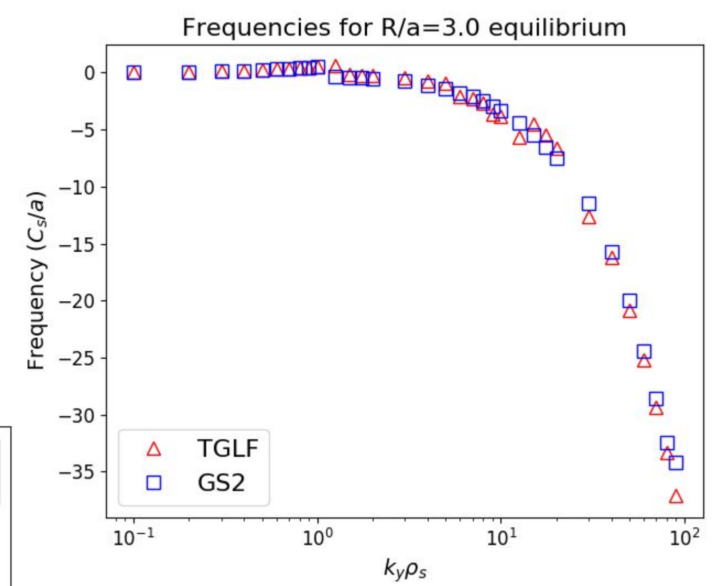


Figure 3: Comparison of linear growth rates (above) and the mode frequencies (below) predicted by GS2 and TGLF, using default settings in TGLF for a simplified geometry



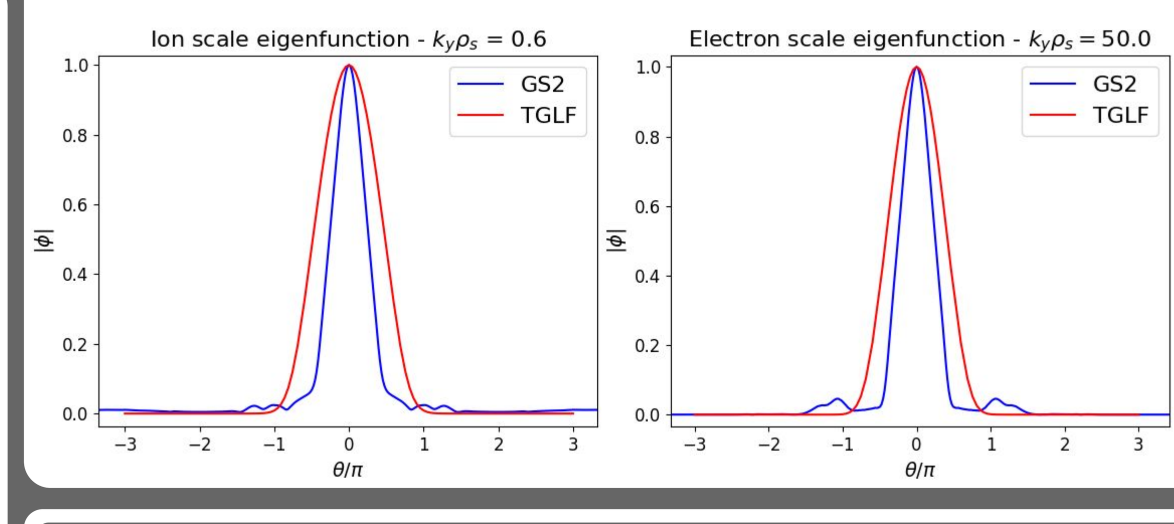


Figure 4: Comparison of eigenfunctions in ballooning space for the $k_y\rho_s$=0.6 (left) and for $k_y\rho_s$=50 (right) for TGLF and GS2

4. Reduce aspect ratio

- ➢ Model a shaped ST device, R/a=1.9 - electrostatic and no pressure gradient
- ➢ TGLF fitting parameter θ_{trap} sets boundary between Landau resonant and Landau averaging trapped particles -> guesses $k_{||}$ as $\theta_{trap} \propto 1/k_{||}$
- ➢ θ_{trap} will impact trapped particle drive
  - Fitted to DIII-D like equilibria -> θ_{trap} set to 0.7
  - BurST has larger trapped particle fraction so it must be re-examined
- ➢ Look at σ_γ in 3 regions -> best results at θ_{trap} = 0.4

		4 basis θ_{trap}=0.7	8 basis θ_{trap}=0.7	8 basis θ_{trap}=0.6	8 basis θ_{trap}=0.5	8 basis θ_{trap}=0.4	8 basis θ_{trap}=0.3
$k_y\rho_s \lesssim 1$	σ_γ^{low}	56%	60%	44%	32%	30%	40%
$1 \lesssim k_y\rho_s \lesssim 10$	σ_γ^{mid}	86%	58%	48%	29%	12%	58%
$k_y\rho_s \gtrsim 10$	σ_γ^{high}	80%	50%	36%	43%	38%	48%
	$\boldsymbol{\sigma_\gamma^{total}}$	**77%**	**55%**	**43%**	**36%**	**29%**	**50%**

Table 2: Showing difference in growth rates for several different TGLF settings for an electrostatic BurST equilibrium. Colours correspond to $\sigma_\gamma > 50\%$, $30\% < \sigma_\gamma < 50\%$, $\sigma_\gamma < 30\%$

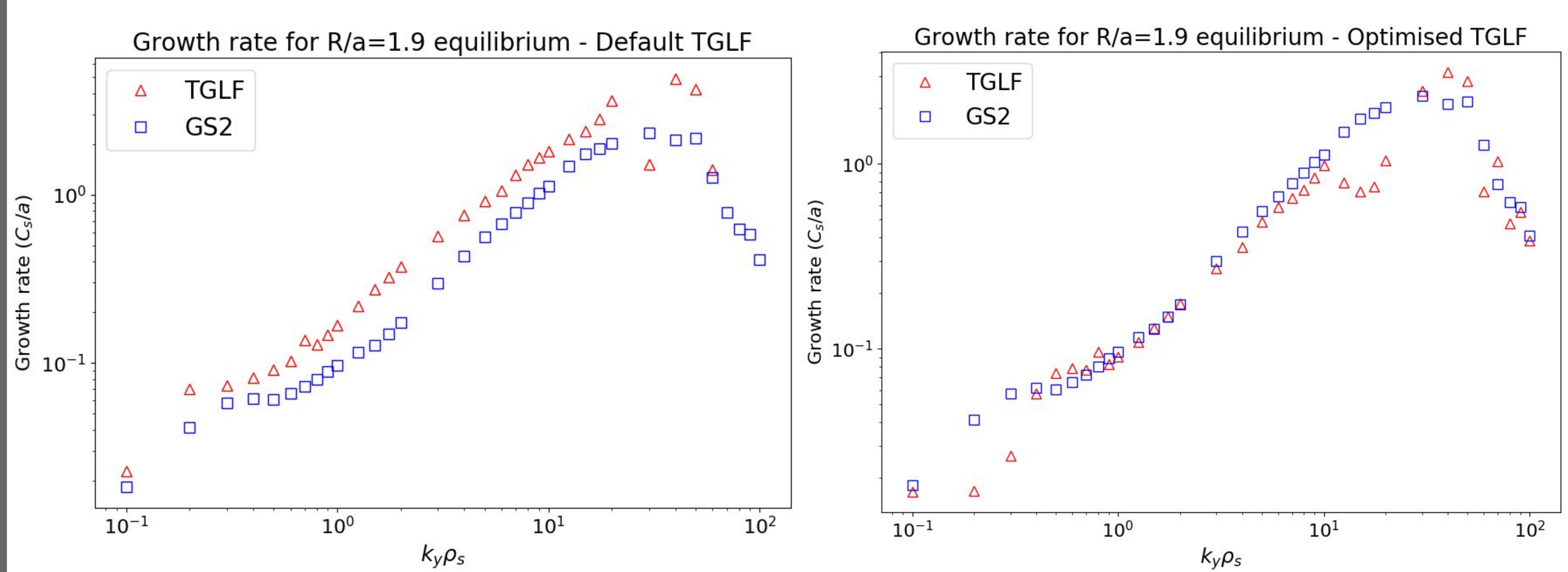


Figure 5: Comparison of linear growth rates predicted by GS2 and TGLF, using default settings (left) and 8 basis functions with θ_{trap}=0.4 (right) in TGLF for an electrostatic BurST

5. Summary

- ➢ Shaped R/a=3.0 aspect ratio plasma -> qualitative agreement between TGLF and GS2 in the electrostatic limit
  - Growth rates/frequencies match reasonably well but the growth rates were generally overestimated in TGLF
  - Increasing number of basis functions from 4 to 8 improves the agreement for the simplified geometry cases
  - More basis functions results in a longer runtime -> balance must be found
- ➢ For the R/a=1.9 device reducing θ_{trap} from 0.7 -> 0.4 resulted in a better agreement
  - Need to optimise for a range of flux surfaces to find appropriate settings
  - Look at iteratively setting θ_{trap} using the $k_{||}$ calculated for the eigenmode
- ➢ High k_y modes have the highest discrepancy -> need to minimise this
- ➢ Future work will be to further optimise TGLF for equilibria with high β and p' as this will have significant impacts on the eigenmodes
- ➢ Using the optimised parameters JINTRAC will be used to analysed the performance of BurST

References

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EUROfusion

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