What lies beyond Exo-Jupiters? A High Resolution study of q^1 Eridani

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Abstract

ALMA Band 6 (~1250µm) and 7 (~856 µm) observations of the >1Gyr F9V star q^1 Eri (HD 10647, HR 506) are presented, a system with a known ~2 au radial velocity planet (*Butler et al. 2006*) and debris disc. These resolve the broad, inclined debris disc, with a maximum brightness on both ansae at ~82au. The emission is asymmetric; the integrated flux is higher in the SW than the NE and the star is closer to the SW inner edge than the NE. HST data (*Stapelfeldt et al. 2007*) however have demonstrated that the scattered light is more radially extended in the NE direction. We modelled the disc, constraining its overall morphology and the origin of these disc asymmetries. We show that this is broadly consistent with a clump on the inner edge of the disc's SW ansa. The inner edge clump is shown to be consistent with perturbations from a planet having trapped planetesimals following a period of migration, or due to a recent massive collision. Further, we constrain the vertical aspect ratio as h~5%, and show that if this is due to dynamical interactions in the disc, then this requires perturbers in the belt with sizes ~0.5 R_{Pluto}, consistent with the lower limit we set on the maximum planetesimal size (>km-sized).

Observations: q^1 Eri's Disc is asymmetric

Continuum emission: significantly detected

Detailed exploration of the Band 7 image reveals the structure of this disc with a broad, inclined belt from ~23-161 au, with a peak brightness radius at ~82au consistent in all directions from the star. Further, it is found inside this radius, i.e., on the inner edge, that the **SW inner edge is closer to the star than the NE,** and that this **SW side of the disc has a higher integrated flux** than the NE. Given the resolved nature of the disc and due to its inclination, we were able to observationally estimate the vertical aspect ratio at the few per cent level.

CO J = 3-2 line emission: upper limit CO mass found

Spectro-spatial filtering (*Matrà et al. 2017)* of the CO J=3-2 line was performed to investigate if any CO gas is present. A **CO gas mass above $4 \times 10^{-6} M_{Earth}$ is ruled out**.

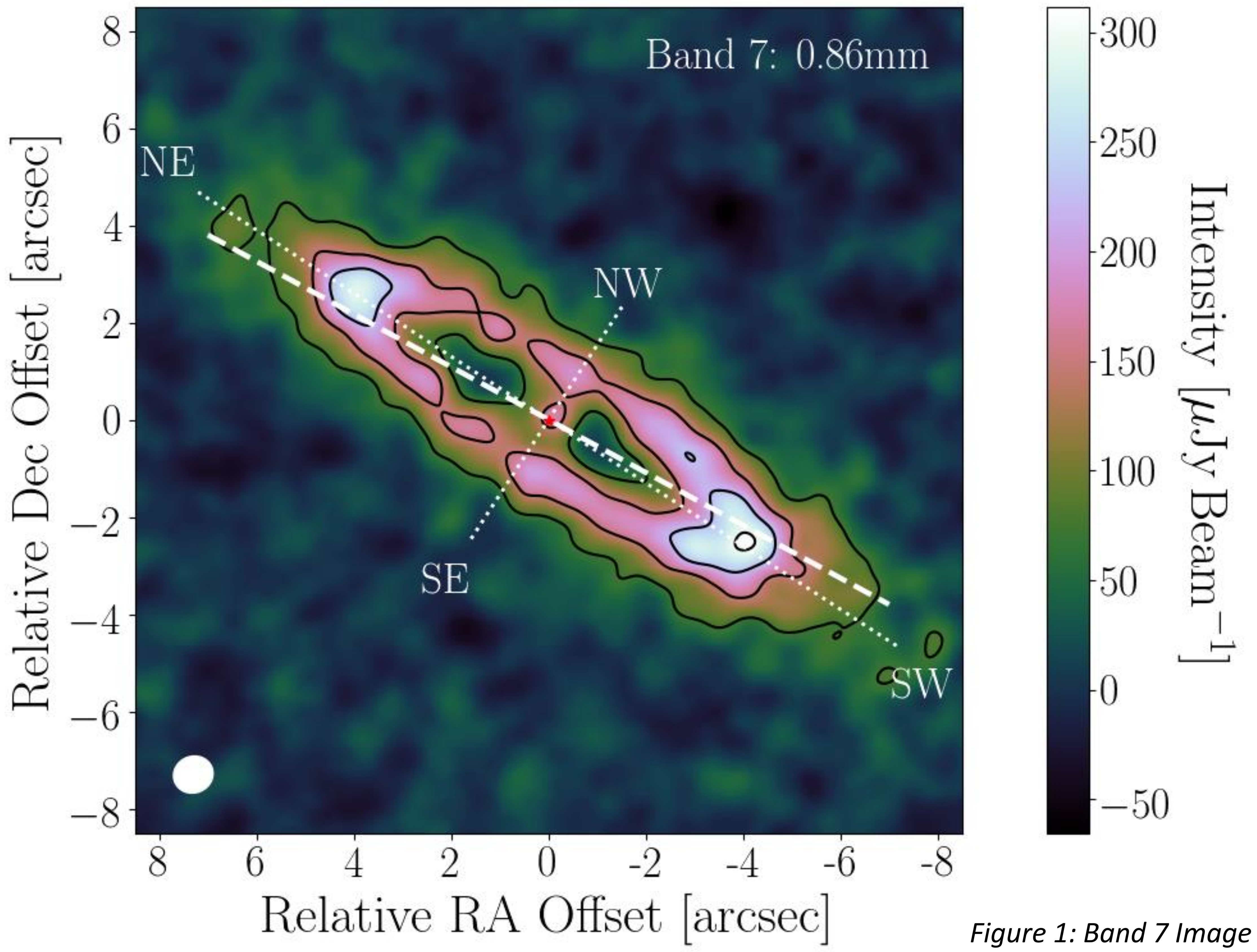


Figure 1: Band 7 Image

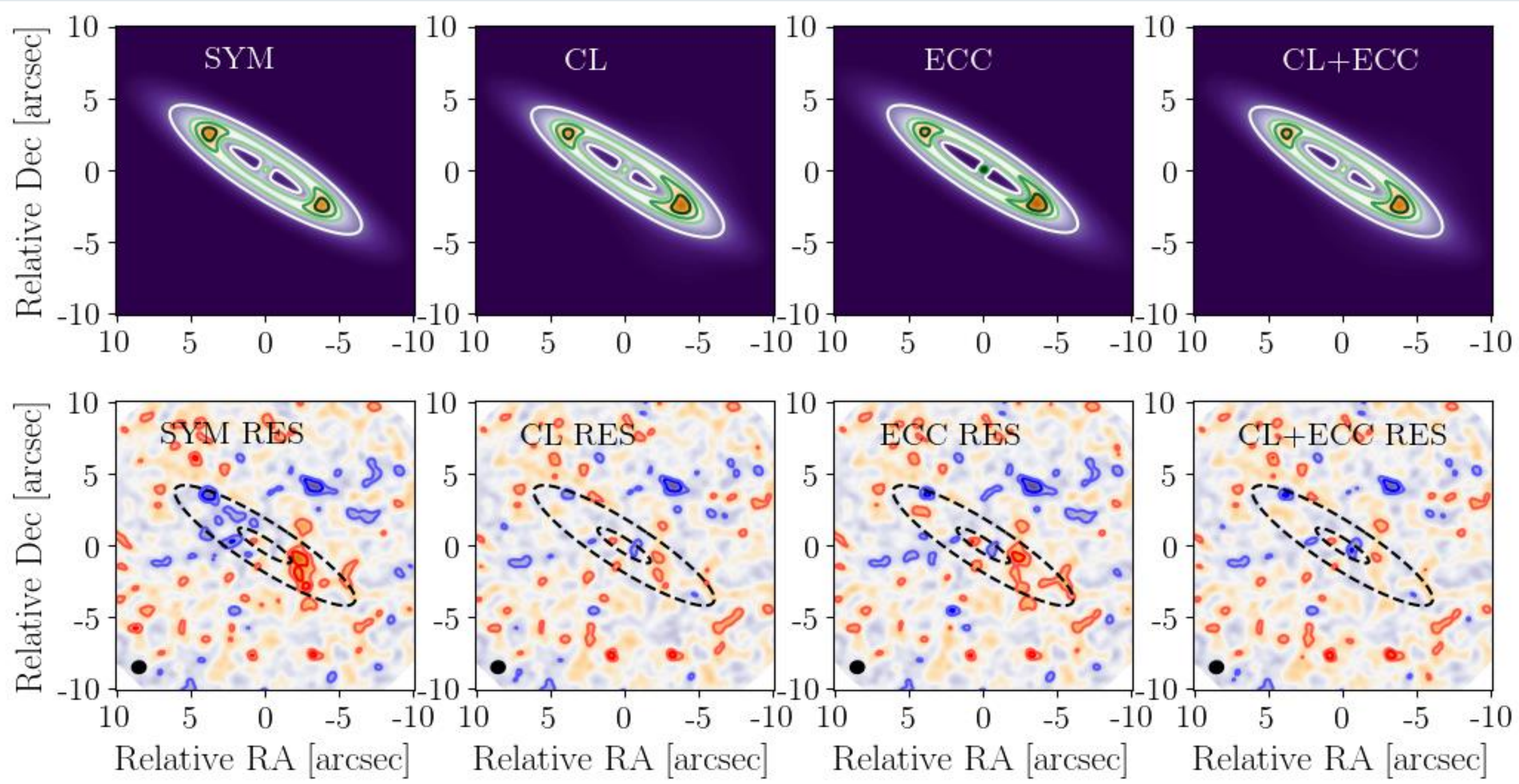


Figure 2: Models (top) & residual images (bottom)

Disc Modelling: A Clump in the South-West

Our observational analysis drives all scenarios considered in our sub-mm disc modelling, in which we consider a symmetric disc, an eccentric disc, and variants of these including a clump in the SW (see upper panel, Fig.2). We find the best fit to our data and our residual images is the symmetric disc with a clump ("**CL**"), given that this model:

- fits the inner edge offset asymmetry;
- fits the integrated flux asymmetry;
- results in no residuals >3σ coincident with the disc.

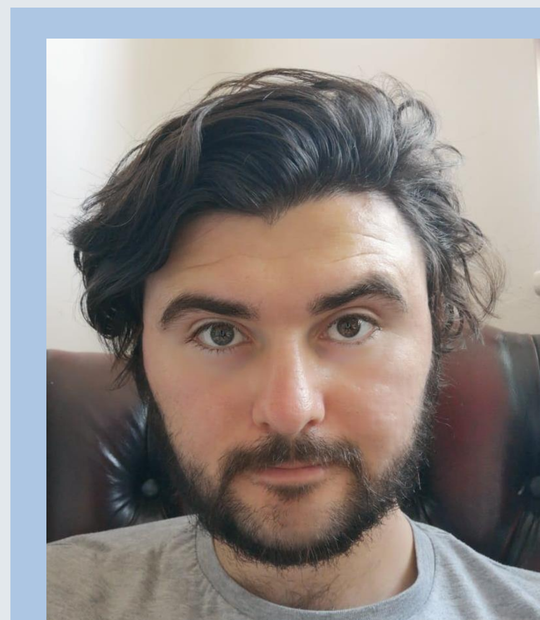
A recent collision or planet perturbations?

We explore two possibilities: that the **belt asymmetry is produced by either a large recent planetesimal collision, or via interactions with an internal planet**. Whilst neither can be ruled out, an outwardly migrating planet inside the disc could have trapped planetesimals in a 2:1 resonance in its migration. This could explain both the sub-mm clump in the SW, ***and*** the extended NE scattered light emission, i.e., as a result of planetesimal collisions producing both the sub-mm dust seen by ALMA, and the smaller grains seen by HST, which via radiation pressure could be blown onto eccentric orbits with periastra at the clump location.

Conclusions

1: q^1 Eri has been imaged by HST, and ALMA in Bands 6 and 7. Our combined analysis of this planetary system's data demonstrates that there is a broad, bright, inclined debris disk, with **significant asymmetric features**.

2: Modelling of the disc shows that these asymmetries can be explained by a **clump in the SW of the disc**, likely due to planetesimal collisions and/or planet-disc interactions. We detail this further in **Lovell+ 2021 (in prep)**.



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Other work: available here

References

Butler R. P., et al. 2006 ApJ, 646, 505 // Matrà L., et al. 2017 ApJ, 842, 9 // Stapelfeldt et al. 2007

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Please note that this work, J. B. Lovell, et al. 2021, is still in preparation. Consequently numerical values and analysis may differ from those presented here.