MSAT: a new Matlab toolbox for the analysis and modelling of seismic anisotropy

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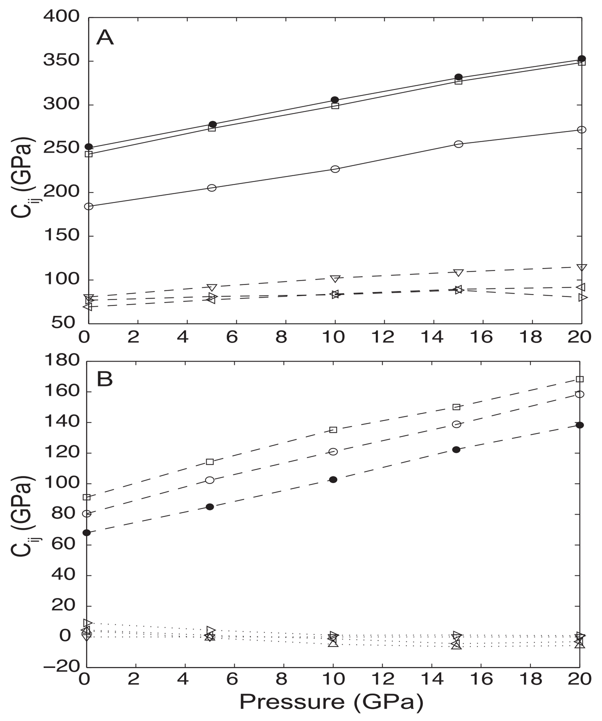
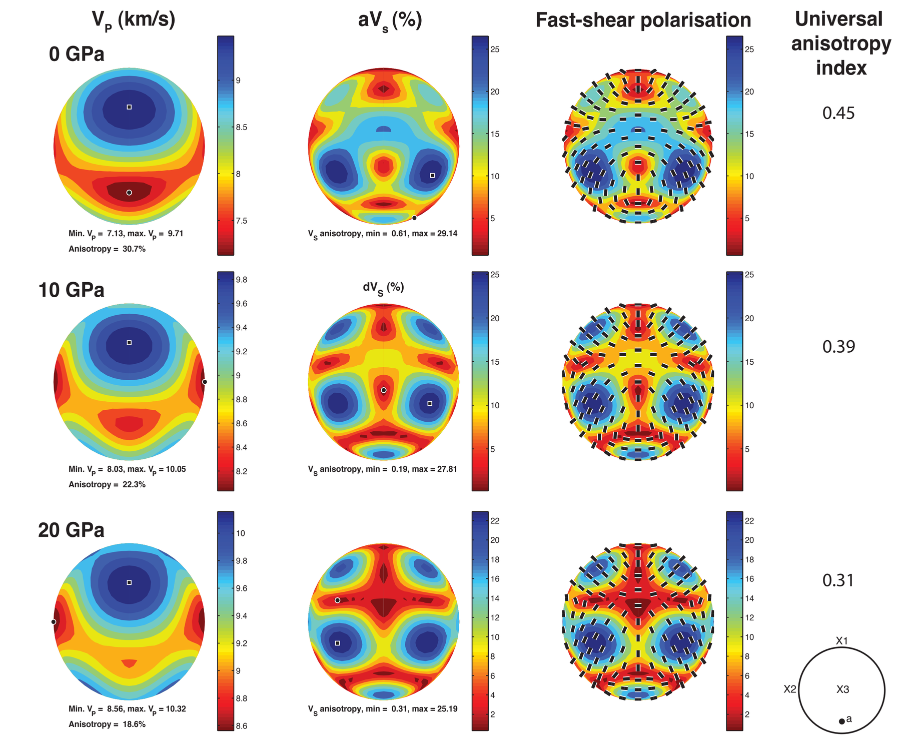
DI41A-2061

Example 1: Analysis of the effect of pressure on the elastic anisotropy of diopside

- By itself the elasticity tensor of a rock-forming mineral is of limited use, other measures of anisotropy are needed.
- We show the evolution of the elasticity of diopside with pressure, calculated using density functional theory [3].
- Anisotropy is analysed using MSAT in terms of seismic wave velocity and anisotropy indices.
- All measures of the total anisotropy of diopside decrease with increasing pressure.
- Shear wave splitting for a wave propagating normal to the shear plane developed in subducted oceanic crust is expected to more than double in the upper mantle pressure range.

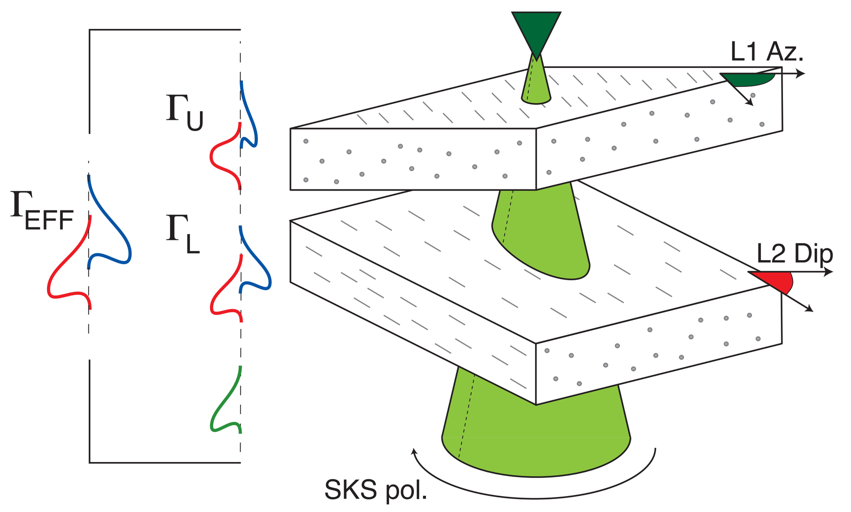


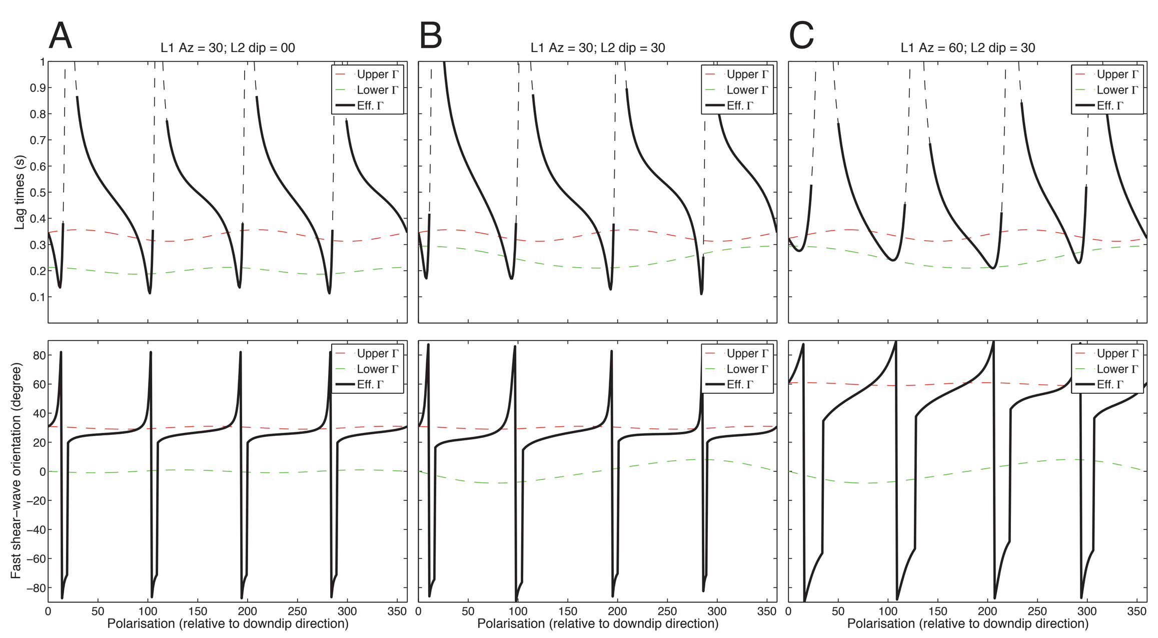
Above: Evolution of the individual longitudinal (A, solid lines – squares: C11, unfilled circles: C22, filled circles: C33), shear (A, dashed lines – right pointing triangle: C44, left pointing triangle: C55, downwards pointing triangle: C66) and off diagonal (B, dashed lines – squares: C12, unfilled circles: C13, filled circles: C23; B, dotted lines – right pointing triangle: C15, left pointing triangle: C25, downwards pointing triangle: C65, upwards pointing triangle: C43) elastic constants.



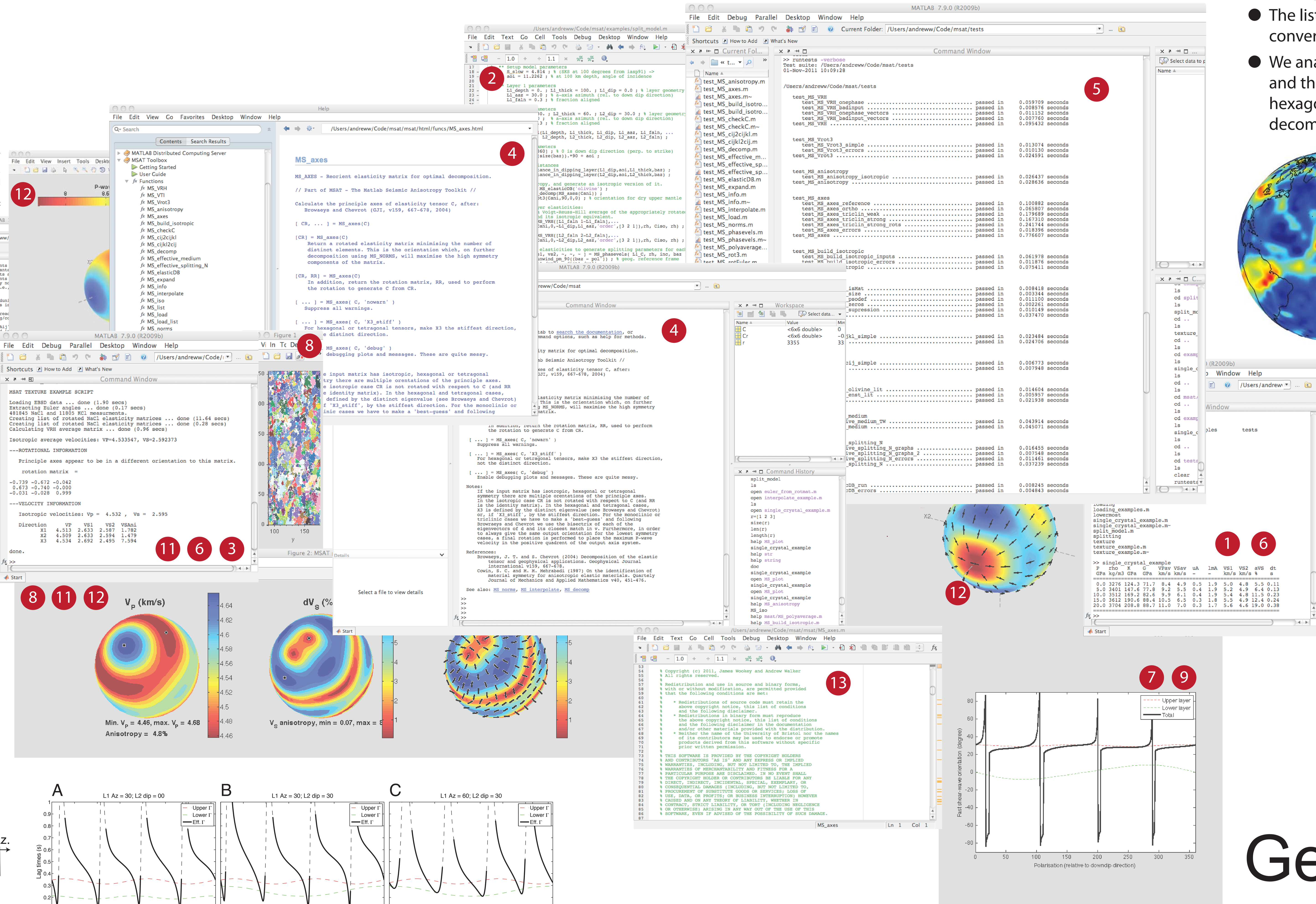
Example 3: Effective shear-wave splitting parameters for dipping layers

- MSAT can calculate shear-wave splitting parameters from elasticity tensors and ray-paths.
- We show how the SKS shear-wave splitting caused by the interaction of two layers, one of which is dipping.
- The model setup consists of two anisotropic layers defined by an anisotropic strength, orientation and dip.
- We calculate the effective splitting parameters as a function of backazimuth using the approximation of Silver and Savage [6].
- A conclusion from this analysis is that the effect on lag time and fast shear-wave polarisation direction of having two layers is more important than the dip in the lower layer.





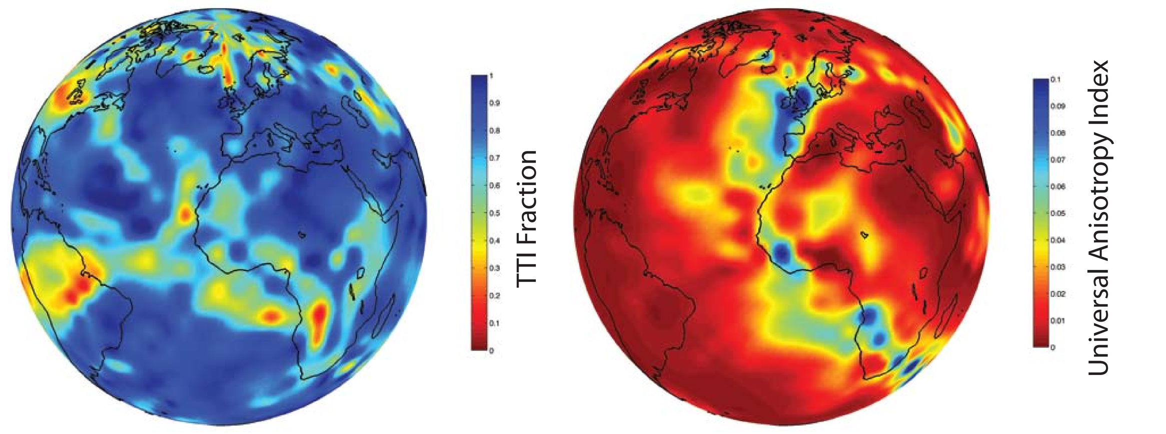
Studies of seismic anisotropy rarely end with measurements of shear-wave splitting -- instead an explanation of the physical origin of the anisotropy is sought in order to yield useful geological or geophysical information. We describe a new Matlab toolbox designed to aid the modelling needed for this interpretative step of the analysis of seismic anisotropy. Provision of key building blocks for modelling in this modern integrated development environment allows the rapid development and prototyping of explanations for measured anisotropy. The Matlab graphical environment also permits plotting of key anisotropic parameters. Furthermore, this work complements the SplitLab toolbox [1] used for measuring shear wave splitting and the MTEX toolbox [2] used for the analysis of textures in rocks.



References: [1] Wüstefeld et al. (2008) Comp. & Geosci. 34:515-528. http://www.gm.univ-montp2.fr/splitting/. [2] Bachmann et al. (2010) Solid State Phenomena 160:63-68 http://mtex.googlecode.com/. [3] Walker (in press) PEPI doi:10.1016/j.pepi.2011.10.002. [4] Walker et al. (2011) Geochem. Geophys. Geosyst. 12:Q10006. [5] Browaeys and Chevrot (2004) Geophys. J. Int. 159:667-678. [6] Silver and Savage (1994) Geophys. J. Int. 119:949-963

Example 2: Anisotropy of polycrystalline post-perovskite in D″

- Single crystal elasticity (see example 1) gives the maximum intrinsic anisotropy of a rock which is only observed if all grains are fully aligned.
- MSAT includes functions to use the results of the simulation (e.g. from the VPSC approach) or measurement (e.g. from EBSD with integration to the MTEX toolbox) to calculate the effective anisotropy of a polycrystalline sample.
- We show how the results of modelling of the deformation of the lowermost mantle [4] can be analysed in terms of the style of deformation generated anisotropy.
    - The list of crystal orientations extracted from VPSC modelling is converted into an estimate of the bulk elasticity.
    - We analyse the bulk elasticity in terms of magnitude of anisotropy and the degree to which the bulk anisotropy can be explained by hexagonal symmetry, where the elasticity tensor has been decomposed using an orthogonal projection based method [5].



Features

1. Extract summary parameters describing anisotropy
2. Easy to use API
3. Principal axis decomposition, symmetry determination
4. Documentation embedded in Matlab help system
5. Fully automated test suite
6. Calculation of seismic phase velocities
7. Multi-layer shear wave splitting analysis
8. Integration with MTEX
9. Effective media calculation
10. Load and save many data formats
11. Built in database of elastic properties
12. Display seismic anisotropy in 2D or 3D
13. Free to use and remix (three-clause BSD licence)

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