

# SR $\mu$ CT in comparative anatomy and biomechanics of amphibian skulls

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Amphibians comprise caecilians (174 species), salamanders (571 species), and frogs (5602 species; all species numbers from [1]). Amphibians are highly diverse in their habitats (e.g. aquatic, subterrestrial, terrestrial, aboreal), their life-cycles (biphasic vs. direct development), their reproductive modes (oviparity vs. viviparity), and their feeding strategies (suction feeding, biting, tongue protraction, filter feeding) [2]. By comparing the anatomy of different amphibian species and by studying the constraints that functional demands put on anatomy, it is possible to reveal the mechanisms that led to today's diversity.

Recently,  $\mu$ CT imaging has become an important technique for comparative studies on invertebrate [3] and vertebrate [4] anatomy. Synchrotron x-ray radiation based  $\mu$ CT (SR $\mu$ CT) imaging has been shown to result in highest quality of the datasets [5], especially for the visualization of soft-tissues. Here, we present the results of SR $\mu$ CT imaging of larval and adult amphibian skulls, which is part of our ongoing research on the development and biomechanics of amphibian head structures.

SR $\mu$ CT imaging was performed at beamlines BW2 and W2 in 2007 and 2008. So far, the SR $\mu$ CT datasets of 10 caecilian specimens (4 species), 3 salamanders (3 species), and 1 frog tadpole are available for analysis. Specimens that were CT scanned at BW2 are usually larvae and juveniles; radiation energy was in-between 9 keV and 19 keV. At W2 we scanned adult individuals at 20 keV to 30 keV. Voxelsizes of the reconstructed volumes range from 1.9  $\mu$ m to 9.2  $\mu$ m.

All datasets show an outstanding detail of hard and soft tissues (Fig. 1, 2). Single muscle fibres, nerves, and connective tissues can be identified in the SR $\mu$ CT datasets. The high detail of the SR $\mu$ CT data made it possible to develop a semi-automatic algorithm to extract muscle fibre angles from the volume datasets. For adult caecilians, those muscle fibre angles were used in a biomechanical model that contributed to our understanding of caecilian jaw mechanics [6] and led to an animation of caecilian jaw movements (Fig. 1).



Figure 1: Animation of caecilian jaw movements (specimen ZMH A08981; GKSS ID: zim03). This animation is based on a biomechanical model that was developed from measurements within the SR $\mu$ CT data.

The  $\mu$ CT data was used for the comparison of amphibian anatomy in different species (Fig. 2). Although there is a high diversity in cranial anatomy between the three amphibian groups, it is possible to identify homologous structures, especially for the head musculature, in all amphibian species studied so far by SR $\mu$ CT imaging. Thus, it will be possible for the first time to conclude on the set of cranial muscles that were present in the most recent common ancestor of amphibians. In a second step, it will be possible to trace the changes within cranial musculature from the ancestral amphibians to highly derived species over evolutionary time and to discuss those evolutionary transformations in a functional context.

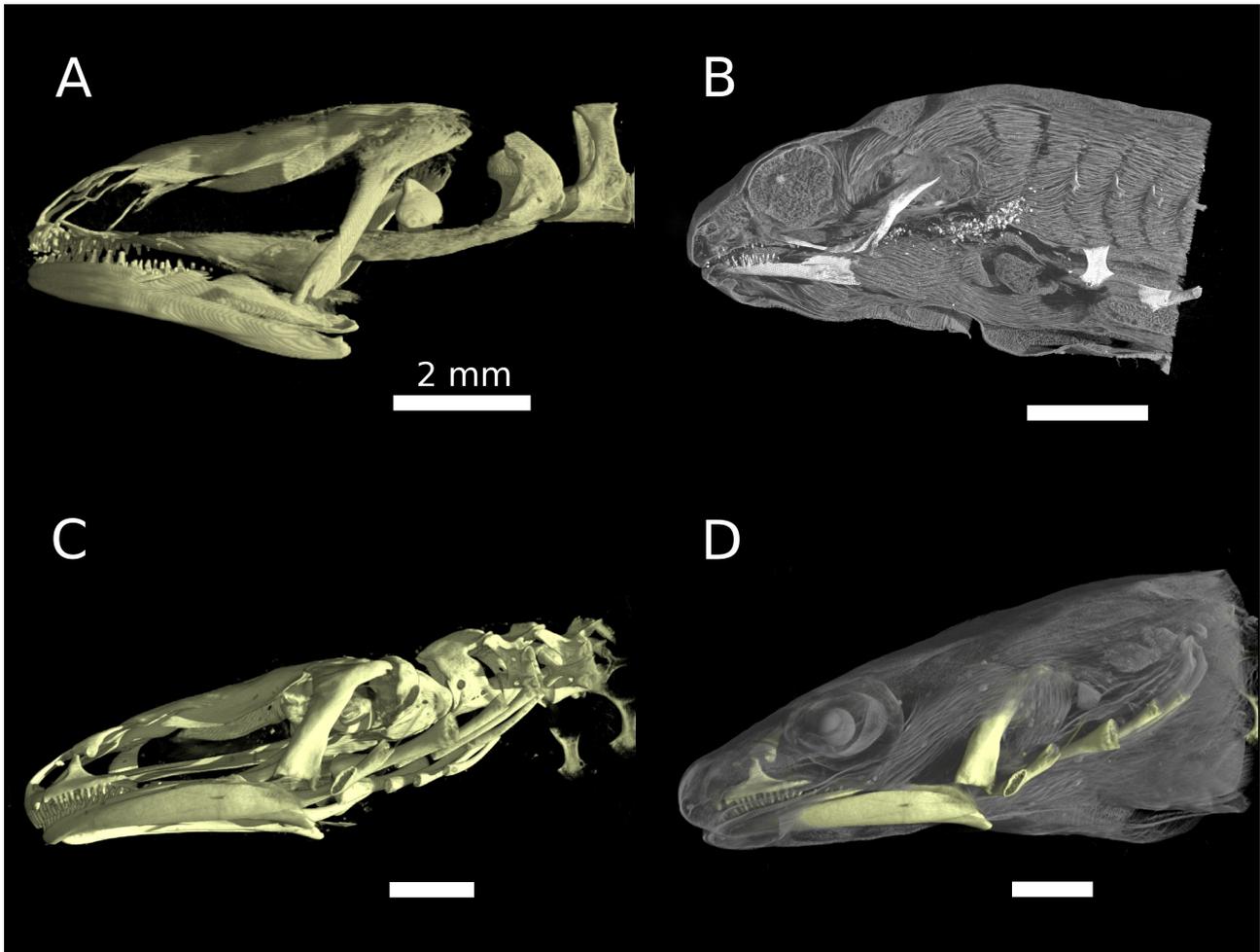


Figure 2:  $\mu$ CT images of salamander heads in lateral views. Left hand side: hard tissues only. Right hand side: hard and soft tissues rendered. SR $\mu$ CT at DORIS III beamlines BW2 and W2 results in highest detail of the CT datasets and thus is valuable for comparative anatomical studies. A: Larval specimen of *Andrias japonicus* (specimen KUHE 38459; GKSS-ID: zim13). B: Larval specimen of *Onychodactylus japonicus* (KUHE38445; zim14). C, D: Larval specimen of *Dicamptodon ensatus* (ZMH A10055; zim15).

## References

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