Introduction: The common marmoset (Callithrix jacchus) has a gray-to-white-matter volume ratio close to that of humans, making it an ideal nonhuman primate for visualizing, in vivo and noninvasively, myelinated structures [1]. Thus, the marmoset has been increasingly studied with MRI. To date, there have been no studies of the soft tissue contrast in marmoset brain using $T_2^*$ and phase contrast.

Materials and Methods: In vivo brain images of anesthetized marmosets were acquired on a 7T/30cm MRI scanner (Bruker-Biospin) using a custom-built birdcage transmission coil and a phased-array receiver coil. Two sequences were performed: three-dimensional (3D), high-resolution, $T_1$-weighted magnetization-prepared rapidly acquired gradient echo (MPRAGE) with isotropic voxel size = 150 μm$^3$, and 3D multi-gradient-echo (MGRE) with isotropic voxel size = 300 μm$^3$, 32 echoes spaced 1.71 ms apart. In one monkey, the MGRE sequence was repeated in 2D mode with higher in-plane resolution (150 μm$^2$), thicker slices (600 μm) and a different orientation (coronal). $T_2^*$ maps were obtained by a mono-exponential fit over all the echoes. Phase maps were obtained by correcting for phase wrap and by performing a linear fit of the phase variation in the temporal domain. The generated frequency maps were then high-pass filtered by applying a Gaussian filter and subtracting the original frequency maps. Regions of interest (ROIs) were drawn manually in both white matter (WM) and grey matter (GM). Mean and standard deviation (mean ± SD) were calculated in each ROI for both $T_2^*$ relaxation time and frequency values. In addition, an ex vivo 3D high-resolution (150μm$^3$ isotropic) DTI experiment was performed on one fixed brain using the same magnet.

Results/Discussion: Typical $T_2^*$ values in WM (corpus callosum = 22.4 ± 3.8 ms) and GM (cortical GM = 33.4 ± 4.6 ms and deep GM = 36.5 ± 6.9 ms) are close to those reported in human brain at same field strength [2]. Although WM appears homogeneous on $T_1$-weighted images (Figs 1A, 1E), the posterior WM shows a strikingly heterogeneous pattern on $T_2^*$ images (Figs 1B, 1F). Indeed, the internal part of posterior WM has significantly elevated values ($T_2^*$ = 34.2 ± 6.2 ms) as compared to the edges ($T_2^*$ = 24.4 ± 3.2 ms) interfacing with cortical GM. Such a pattern is also observed on phase images (Figs 1C, 1G) where there is a significant negative frequency shift (up to -3.3 Hz) between the internal part and the edges of the posterior WM. Similar to human brain [3], GM shows a slightly positive frequency shift relative to water (+ 0.3 ± 0.7 Hz). To explain the origin of the observed $T_2^*$ and phase contrasts, different sources can be potentially considered, including fiber orientation relative to the main field [4-5]. As illustrated by the color-encoded FA maps (Fig 1D, 1H), the white matter of marmoset brain has a highly structured fiber architecture, especially in the posterior WM areas. Local tissue composition and microstructure are also other possible sources of contrast [6-7]. Indeed, $T_2^*$ is highly sensitive to the degree of myelination, which typically varies across the cortical GM of marmoset brain (Figs 2A, 2B), especially in the medial temporal (MT) area [8]. Note that gross specimen tissue (Fig 2C) also shows a heterogeneous pattern in the posterior WM, which may suggest the presence of other chemical species (potentially magnetic).

Conclusions: $T_2^*$ and phase contrast were investigated in marmoset brain. A striking heterogeneous pattern, potentially related to fiber orientation, was observed in posterior WM areas. The marmoset brain is therefore an interesting system in which to study the mechanisms of $T_2^*$ and phase contrast.