Introduction: Given its abundance in the solar nebula, it is likely that water played a crucial role during the formation and differentiation of the terrestrial planets. Recent evidence from Ceres, a small proto-planet orbiting in the asteroid belt, confirmed that H$_2$O-rich planetary bodies existed during the early evolution of the Solar System [1,2]. Within accreting planetesimals chondritic water might have affected fundamental phenomena such as: i) formation of a proto-atmosphere by impact induced degassing [3], ii) protracted cooling of a magma ocean (>100 Ma) due to the blanketing effect of atmospheric steam, and iii) hydrogen transfer from deep mantle to the metallic core as FeH$_x$ that might have further facilitated core segregation [4,5]. Therefore, to resolve the planetary history of water is to glimpse back into the planet’s conception and understand its subsequent evolution.

The melting behaviour of an undegassed Martian mantle is investigated to explore the potential influence of water on the mode of early planetary differentiation. Mars is particularly interesting as it accreted from a chondritic mix richer in volatile elements than any other terrestrial planet [6], and because its size is equivalent to a proto-planet just before the giant impact stage [7], suggesting that Mars might have escaped the formation of a magma ocean that largely obliterates the evidence of early accretion and differentiation.

The water content of magmas from which Martian meteorites formed are our most direct constraints on the parameter. Estimates of water abundance in these partial melts of the Martian mantle range from as low as tenths of ppm to 2 wt. % [8,9]. However, the fact that except for a single Shergotty meteorite, these relatively young (<1.3 Ga) [10], and source-restricted stones from Martian Tharsis and Elysium provinces may not be representative of the bulk Martian mantle, is a reason to suspect a volatile-depleted mantle model [11].

Two fundamental questions exist. What is the water storage capacity of (deep) Martian mantle, and how efficient were H$_2$O sequestration and exsolution from the planet’s largest geochemical reservoir? We build upon previous experimental work that examined phase stability and wet melting relationships from 0.5 to 3 GPa [12] by performing water-saturated experiments on model Martian compositions [13] in excess of 3.6 GPa. Experimentally determined high-pressure hydrous phase relations will be presented and compared to the existing thermal models of planetary evolution [14].

Figure 1. Phase diagram of a primitive Martian mantle in a simplified MASH (MSH > 5.0 GPa) system modified after[12]. Water saturated phase relations above 3.0 GPa are estimated from terrestrial analogs. The hypothetical high-pressure solidi are taken from experimental work on the terrestrial peridotite of [15] (red), and projections of [16] (blue). Black circles are estimated total water contents bound in the Martian mantle calculated from phase proportions (excluding garnet), and water content in hydrous phases [12]. Empty circles mark the positions of supercritical endpoints determined by [16,17, and 18].

H$_2$O storage in Martian mantle: Experimental phase relations from terrestrial studies predict storage of significant amounts of water deep inside the planetary interior in the form of both hydrous Mg-silicates...
(talc, chlorite, antigorite) [19,20], and nominally anhydrous minerals (NAM) such as stishovite, garnet or the high-pressure olivine polymorphs such as wadsleyite (\(\gamma\)-Mg,Fe\(_2\))\(_2\)Si\(_2\)O\(_6\)) and ringwoodite (\(\gamma\)-Mg\(_2\)Si\(_2\)O\(_6\)) (Figure 1). A majority of the experimental work however, is based on simplified terrestrial mantle analog compositions [21], and little is known about the effects of iron, aluminum, chromium, phosphorous, and other minor elements which are both important constituents of the Martian mantle and may significantly influence phase equilibria. In terms of anhydrous phases, for example, apatite and spinel will be stabilized at higher pressures in Mars than on Earth, as a consequence of the higher P and Cr contents. The reduced, Fe\(^{2+}\)-enriched and Al-deficient mantle of Mars will be stabilized to higher pressures in Mars relative to those of wadsleyite, but it requires as much as 20 wt.% of H\(_2\)O to stabilize. [23] suggested that phase E may not coexist with this olivine polymorph in a water-undersaturated peridotite, whereas [24] observed phase E together with wadsleyite at 12 GPa and 1050°C. Together with the NAM, it is obvious that DHMS have a considerable potential for deep water burial inside planetary interiors. 

**Implications for deep wet melting:** Melting relations of dense hydrous silicates under vapor saturated conditions are poorly understood. In other words, the position of H\(_2\)O-saturated solidus relative to the stability fields of hydrous minerals has only been closely scrutinized at relatively low pressures below 4.0 GPa. [25] reassessed melting behavior of a primitive terrestrial peridotite (i.e. upper mantle) analog up to 3.2 GPa, while [12] investigated a Martian model mantle under similar conditions (green line in Fig. 1). Currently, nothing is known about the nearsolidus behavior in systems chemically equivalent to the Martian mantle at pressures above 3.0 GPa. The melting relations of dense hydrous silicates, and in turn the dominant phase regimes in deep mantle of early Mars, depend on where and to which extent the slope of the wet high-pressure solidus reverses in the Martian mantle analogs (red vs. blue lines in Fig. 1). Furthermore, the locus of the second critical endpoint will affect water speciation and the liquid composition at a given pressure, as well as solid-melt proportions. These relationships however, have important consequences for the fate of water during planetary accretion. Namely, as proto-Mars accretes, water stored in hydrous silicates is transferred into planetary interiors. 