I. INTRODUCTION

The search for novel quantum states in low-dimensional antiferromagnets (AF) has triggered a significant activity in recent times. A remarkable amount of theoretical studies has concerned the phase diagram of antiferromagnets where long-range magnetic order is suppressed by enhanced quantum fluctuations. Such a scenario can be established when the magnetic lattice dimensionality and the spin value are reduced or when the disorder is increased, either by means of heterovalent substitutions or by spin dilution. Further enhancement of quantum fluctuations can occur when antiferromagnetic interactions are competing as, for instance, in frustrated two-dimensional $S = 1/2$ Heisenberg AF (2DQHAF) on a square-lattice, with nearest neighbour ($J_1$) and next-nearest neighbour ($J_2$) antiferromagnetic couplings of the same order of magnitude.

Recently, a prototype of frustrated 2DQHAF on a square-lattice has been discovered, the Li$_2$VOSiO$_4$. The analysis of the magnetic susceptibility, of the specific heat and of other quantities indicate that this compound is characterized by a ratio $J_2/J_1$ ranging from 1 to 4. The ground state is collinear, as theoretically expected, and the staggered magnetization reaches a value $\sim 0.6 \mu_B/3V^{44,1,15}$, consistent with the $J_2/J_1$ estimate. This value is remarkably close to the one of a non-frustrated 2DQHAF and, therefore, at first sight one could think that, as far as $J_2/J_1$ is not close to 0.5 and quantum fluctuations are not so strong, frustration does not affect sizeably the static magnetic properties of a 2DQHAF. In order to unravel the basic differences in the properties of frustrated and non-frustrated 2DQHAF it is tempting to compare also the behaviour of these systems when disorder is introduced, for example, by spin dilution. Spin dilution has been widely investigated in prototypes of non-frustrated 2DQHAF, as La$_2$Cu$_{1-x}$(Zn,Mg)$_x$O$_4$, and evidence for the validity of the simple dilution model with a renormalization of the spin stiffness and for the disappearance of long-range magnetic order at the classical percolation threshold has been given. At first, in a frustrated 2DQHAF on a square-lattice one would expect that the enhancement of quantum fluctuations leads to a suppression of the long-range order well below the percolation threshold. However, one should also consider that, owing to the next-nearest neighbours coupling, the percolation threshold extends to much larger doping levels with respect to non-frustrated antiferromagnets. Hence, it is not trivial to say a priori how the magnetic properties vary upon increasing the spin dilution.

In the following an experimental study of spin dilution effects in frustrated 2DQHAF on a square-lattice will be presented. In Li$_2$VOSiO$_4$ spin dilution can be achieved upon Ti$^{4+}$ ($S = 0$) for V$^{4+}$ ($S = 1/2$) substitution. It is found that spin dilution not only reduces the spin-stiffness by a factor $\sim (1 - x)^2$, but also causes the reduction of the effective ratio $J_2(x)/J_1(x)$. The analysis of the sublattice magnetization curves shows that, at variance with non-frustrated 2DQHAF, spin dilution affects the low-temperature staggered magnetization only to a minor extent. The $x$-dependence of the collinear ordering temperature and of other quantities will be discussed vis-à-vis with the trend observed for non-frustrated 2DQHAF. In the following section a description of the technical aspects involved in the sample preparation, magnetization, NMR and $\mu$SR measurements will be presented together with the experimental
data. Then the results will be discussed in the light of models which turned out to be valid for non-frustrated spin-diluted 2DQHAF. The final conclusions will be given in Sect.IV.

II. TECHNICAL ASPECTS AND EXPERIMENTAL RESULTS

A. Sample preparation and Magnetization measurements

Powder samples of Li$_2$V$_{1-x}$Ti$_x$OSiO$_4$ were prepared in a platinum crucible by solid state reaction starting from a stoichiometric mixture of Li$_2$SiO$_3$ (Aldrich, 99.5%), TiO$_2$ (Aldrich, 99.8%) and VO$_2$ at 830°C, under vacuum, for 24h. VO$_2$ was prepared from a stoichiometric mixture of V$_2$O$_5$ and V$_2$O$_3$ by heating in a vacuum-sealed quartz tube at 650°C for 24h. V$_2$O$_3$ itself was obtained by reducing V$_2$O$_5$ (99.9%, Aldrich Chem. Co) under hydrogen at 800°C. The sample purity was analyzed by means of X-ray powder diffraction and all peaks corresponded to the ones of Li$_2$VOSiO$_4$. The lattice parameters of each sample were refined using the program CELREF. The substitution of Ti for V leads to no significant variation of the cell parameters, which is consistent with the rather similar ionic radii of the two ions (r$_V$ = 0.55 Å and r$_{Ti}$ = 0.51 Å). Upon varying x from 0 to 0.15 the a axes varies from 6.3683(4) Å to 6.3678(6) Å while the c axes varies from 4.449(3) Å to 4.4502(4) Å. The homogeneity of Ti concentration in the different samples was verified by EDX (Energy Dispersive X-ray Analysis).

Magnetization measurements on Li$_2$V$_{1-x}$Ti$_x$OSiO$_4$ powders were performed using a Quantum Design XPMS-XL7 SQUID magnetometer. The temperature dependence of the susceptibility, defined as $\chi = M/H$ is shown in Fig. 1. One observes a high-temperature Curie-Weiss behaviour, a low-temperature maximum indicating the onset of antiferromagnetic correlations and a small kink in the 2-3 K range signaling a phase transition to a collinear ground-state. In the more doped sample, with 20% of Ti, a low-temperature upturn is noticed. This upturn is typical of diluted 2DQHAF and originates from the correlated response of the spins around the S = 0 impurity. Above 20 K the data can be conveniently fitted according to

$$\chi = \frac{C}{T + \Theta} + \chi_{VV},$$

where C is Curie constant, $\Theta$ the Curie-Weiss temperature and $\chi_{VV} = 4 \times 10^{-4}$ emu/mole the T-independent Van-Vleck susceptibility. The x-dependence of the Curie-Weiss temperature is shown in Fig. 2, together with the x-dependence of the temperature $T^m_x$ at which $\chi$ displays a maximum and of the transition temperature $T_c$ to the collinear phase. This latter quantity was estimated from the peak in the derivative $dT^m_x/dT$. One notices basically a monotonic decrease of all three quantities with increasing dilution, as expected.
B. NMR measurements

$^7$Li and $^{29}$Si NMR measurements have been carried out using standard radiofrequency pulse sequences. In particular, the nuclear spin-lattice relaxation rate $1/T_1$ was estimated from the recovery of the nuclear magnetization after a saturating pulse sequence. Since in the powder sample at low-$T$ $^7$Li NMR line broadens due to the paramagnetic shift anisotropy, only a partial irradiation of the central and satellite lines is achieved. This causes a departure of the recovery law from a single exponential and hence at low temperature, below about 3 K, it is more appropriate to fit the recovery of the nuclear magnetization with a stretched exponential form, namely $M(\tau) = M(\infty) \cdot (1 - e^{x p(-\tau/T_1^\beta)})$. The exponent $\beta$ decreased down to $\beta \simeq 0.7$ for $T \simeq 1.3$ K. On the other hand, the recovery law for $^{29}$Si was a single exponential over all the explored $T$-range. The temperature dependence of $^7$Li and $^{29}$Si $1/T_1$ derived from the fit of the recovery laws following the aforementioned procedure are shown in Figs. 3 and 4, respectively. One notices that while $^7$Li $1/T_1$ displays a peak at $T_c$, which broadens upon increasing $x$, $^{29}$Si $1/T_1$ doesn’t show any peak and the relaxation rate is found to decrease on cooling.

C. µSR measurements

µSR measurements were performed on the EMU instrument at the ISIS pulsed muon facility, using 29 MeV/c spin-polarized muons.

$\text{Li}_2\text{V}_{1-x}\text{Ti}_x\text{OSiO}_4$ powders were pressed on a silver sample-holder, whose background contribution to the muon asymmetry was determined from the slowly decaying oscillating signal in a 100 Gauss transverse magnetic field, below $T_c$. In fact, below $T_c$ the external magnetic field sums up with the randomly oriented internal field $H_{int}$ and gives rise to a fast damping of the oscillating signal due to the muons stopping in the sample. The background was estimated $A_{\text{back}} \simeq 0.071$ for $x = 0.05$ and $A_{\text{back}} = 0.0475$ for $x = 0.11$. These values were kept fixed for all the subsequent fits.

By means of zero field (ZF) muon spin relaxation mea-
measurements it is possible to extract the temperature dependence of the order parameter below $T_c$, as previously done for the pure LiVOSiO$_4$. Below $T_c$, superposed to an almost constant background, one observes a precessional signal at frequency $\omega_\mu = \gamma_\mu H_{int}$ (Fig. 5), with $\gamma_\mu$ the muon gyromagnetic ratio and $H_{int}$ the local magnetic field at the muon generated by the collinear order. In a powder about 2/3 of the total signal oscillates while about 1/3 of the muons are in a longitudinal field configuration. Hence, one can write for the decay of the muon asymmetry

$$A(t) = A_T \cdot \cos(\gamma_\mu H_{int} t + \phi_0) \cdot \exp(-\sigma t)$$
$$+ A_L \cdot \exp(-\lambda t) + A_{back}$$

with $A_T$ the asymmetry of the oscillating component and $A_L$ the one of the longitudinal component. The ratio $A_T/A_L$ deviates from 2 and is T-dependent since at a pulsed muon source the amplitude of the oscillating part is progressively filtered out as the precessional frequency increases. The reduction in $A_T$ on cooling is actually slightly more pronounced than what one would expect, taking into account that at ISIS the width of the muon pulse is about 70 ns. This suggests that a small part (a fraction below 15%) of the initial asymmetry is lost due to fast relaxing muons. This observation is supported by preliminary experiments performed at PSI facility. There it was found that the asymmetry decay is characterized by a certain distribution of relaxation rates, typical of systems with impurities, and that a fraction of muons relax too fast to be detected at ISIS pulsed muon facility. In Fig. 4 the T-dependence of $H_{int}$ for $x = 0.05$ is reported and compared to the one for $x = 0.00$. One observes only a slight reduction of the saturation value of the local field at the muon and of $T_c$, while the temperature dependence is unaffected.

Above $T_c$ the decay of the muon is conveniently described by a nearly static Kubo-Toyabe function. As in the pure compound the decay of the muon polarization can be conveniently fit using Keren analytical approximation, which yields reliable results in the fast fluctuating limit, namely when $\tau_c \gamma_\mu \sqrt{\Delta h^2} \ll 1$, with $\tau_c$ the characteristic correlation time for the modulation of a magnetic field distribution of amplitude $\sqrt{\Delta h^2}$. At variance with LiVOSiO$_4$ in the Ti doped samples one finds that $\tau_c \gamma_\mu \sqrt{\Delta h^2} \simeq 1$. However, Keren approximation can still be used provided the fit is limited to a time $t \simeq \tau_c$. In fact, the data above $T_c$ were accurately fit up to $t = 6 \mu s$ with the function (Fig. 5)

$$A(t) = A(0) \exp(-\lambda t) P^K(H, \tau_c, \sqrt{\Delta h^2})$$

where the first term describes the spin-lattice relaxation driven by the fast fluctuations, while the second one is Keren analytical approximation of Kubo-Toyabe function. By fixing $\lambda$ from the high longitudinal field measurements above 900 Gauss and fitting $\mu$SR data at different magnetic fields, the T-dependence of $\tau_c$ was derived. It was found that $\tau_c$, at variance with the pure compound where it diverges on cooling, is $T$-independent and more than an order of magnitude larger (Fig. 7).
III. DISCUSSION

In the weak doping limit, when the so-called “dilution model” should hold, the spin Hamiltonian of a 2DQHAF with only n.n. interactions can be written in the form

\[ \mathcal{H} = J \sum_{i,j} p_i p_j \mathbf{S}_i \cdot \mathbf{S}_j = J(0) (1 - x)^2 \sum_{i,j} \mathbf{S}_i \cdot \mathbf{S}_j, \]

where the \( x = 0 \) Hamiltonian is modified simply by taking into account the probability \( p_i \) to find a spin at site \( i \). This leads to a simple renormalization of the characteristic energy scales and the spin stiffness becomes\(^{22}\)

\[ \rho_s(x) = \rho_s(0) (1 - x)^2. \]

One can try to extend this result to frustrated 2DQHAF on a square lattice by considering that also a second-nearest neighbour coupling is present. On qualitative grounds one would expect that, since both the probability to find a pair of nearest-neighbour spins and of next-nearest-neighbours scale as \( (1 - x)^2 \), either \( J_1 \) or \( J_2 \) are renormalized by the same factor and, hence, the effective degree of frustration \( J_2/J_1 \) is unaffected by dilution. Moreover, the spin-stiffness is expected to scale as \( (1 - x)^2 \) as for the non-frustrated system. It will be shown hereafter that although the spin-stiffness scales roughly as \( (1 - x)^2 \) the experimental data evidence a modification of the effective \( J_2/J_1 \) ratio upon increasing \( x \).

Preliminary information on the effects of spin-dilution can be obtained from the analysis of the doping dependence of the transition temperature \( T_c(x) \), which shows a different trend with respect to non-frustrated 2DQHAF. In Fig. 2 \( T_c(x) \), extracted either from susceptibility data or from the peak in \( ^7\)Li 1/T\( _1 \), is shown. The initial suppression rate of \( T_c \) with Ti doping \(-d T_c(x)/d x = C T_c(0)\), is not characterized by a \( C \) value close to the one theoretically predicted and experimentally found for non-frustrated 2DQHAF, namely \( C \approx 3.2^{22}\). In fact, in \( \text{Li}_2V_{1-x}\text{Ti}_x\text{OSiO}_4 \) \( T_c(x) \) is rather well described by the expression \( T_c(x) = T_c(0)(1 - 2x) \) (see Fig. 2), namely by \( C \approx 2 \). This difference can be explained by resorting to the mean-field expression for \( T_c(x) \)^{15}

\[ k_B T_c(x) = J_\perp (1 - x)^2 \xi(x, T_c)^2 \left( \frac{M(x)}{M(0)} \right)^2 \]

where \( M(x) \) is the \( T = 0 \) staggered magnetization, \( \xi(x, T) \sim \exp(2\pi \rho_s(x)/T) \) the in-plane correlation length in lattice units and \( J_\perp \) the inter-layer coupling, which is reduced by a factor \( (1 - x)^2 \) accounting for the probability to find two coupled spins in adjacent layers.

From this expression it is evident that the reduction of the staggered magnetization induced by dilution contributes to the reduction of \( T_c(x) \). However, at variance with non-frustrated compounds, in which a spin dilution of 5% was found to reduce the zero temperature magnetization already by about 9\%\(^{13}\), in \( \text{Li}_2V_{1-x}\text{Ti}_x\text{OSiO}_4 \) the same amount of doping reduces it only by 1% (see Fig. 6). This explains why in \( \text{Li}_2V_{1-x}\text{Ti}_x\text{OSiO}_4 \) the effect of doping on \( T_c(x) \) is less pronounced. Moreover, it is observed that if in Eq.\(^4\) one neglects the reduction of the staggered magnetization with doping and one considers that \( \rho_s(x) \sim \rho_s(0)(1 - x)^2 \), one finds an initial suppression of \( T_c(x) \) characterized by a coefficient \( C = 2 \), exactly the one experimentally observed for \( \text{Li}_2V_{1-x}\text{Ti}_x\text{OSiO}_4 \).

In the lower part of Fig. 2 the \( x \)-dependence of the spin-stiffness, estimated from Eq.\(^5\) using the experimental values for \( T_c(x) \) and neglecting the reduction with \( x \) of the staggered magnetization, is reported. It is observed that the spin-stiffness is reduced by a factor \( \approx (1 - x)^2 \) by spin dilution. A more accurate estimate of \( \rho_s(x) \) can be done taking into account the decrease of \( M(x)/M(0) \) in Eq.\(^5\), derived from the reduction of the local field at the muon for \( T \to 0 \) (Fig. 6). One finds that \( \rho_s(x)/\rho_s(0) \approx 1 - 1.5x \). Hence one concludes that the reduction of the spin-stiffness with \( x \) is close to but not exactly the one that one would obtain by rescaling \( J_1 \) and \( J_2 \) by exactly the same factor \( (1 - x)^2 \).

In this respect it is interesting to analyze the effect of Ti-doping on the effective ratio between the competing exchange couplings. A first evidence that \( J_2(x)/J_1(x) \) is not \( x \)-independent comes from the analysis of the susceptibility data (see Fig. 2). The ratio between \( T_m^{\text{m}} \) and the Curie-Weiss temperature \( \Theta \) is a measure of the degree of frustration\(^{22}\). In fact, while for \( J_2 = 0 \) this ratio is close to unity, on increasing \( J_2 \) it diminishes, reaching a minimum for \( J_2/J_1 = 0.5 \) and then increases again\(^{22}\).

In \( \text{Li}_2V_{1-x}\text{Ti}_x\text{OSiO}_4 \) this ratio is found to slightly decrease with \( x \) from \( T_m^{\text{m}}/\Theta = 0.57 \pm 0.02 \) for \( x = 0 \) to \( T_m^{\text{m}}/\Theta = 0.48 \pm 0.04 \) for \( x = 0.11 \). In principle it is difficult to extract precise values of \( J_2/J_1 \) from the above ratios, however, if one considers that for small changes \( J_2/J_1 \) varies linearly with \( T_m^{\text{m}}/\Theta \), the observed modifications imply a reduction in \( J_2/J_1 \) by 15-20\% for \( x = 0.11 \).

Also the analysis of the temperature dependence of the nuclear spin-lattice relaxation rate \( 1/T_1 \) suggests that the effective ratio \( J_2/J_1 \) is affected by spin-dilution. \( 1/T_1 \) can be written in terms of the components of the dynamical structure factor \( S(\mathbf{q}, \omega) \) at the nuclear Larmor frequency \( \omega_L \) as

\[ \frac{1}{T_1} = \frac{\gamma^2}{2N} \sum_\mathbf{q} |A_\mathbf{q}|^2 S(\mathbf{q}, \omega_L) \]

where \( \gamma \) is the nuclear gyromagnetic ratio and \( |A_\mathbf{q}|^2 \) is the form factor, which describes the hyperfine coupling of the spin excitations at wavevector \( \mathbf{q} \) with the nuclei.

In non-frustrated two-dimensional \( S = 1/2 \) antiferromagnets it was pointed out that the in-plane correlation length can be conveniently derived from the nuclear spin-lattice relaxation rate\(^{23}\). In fact, by applying scaling arguments for the amplitude and frequency of the collective spin excitations at wavevector \( \mathbf{q} \), one can write the NMR relaxation rate in terms of the correlation length \( \xi \)
The data are compared with theoretical calculations, for different values of $J_2/J_1$, made in the framework of pure-quantum self-consistent harmonic approximation. The vertical dotted line indicates the transition to the collinear phase.

\[
\frac{1}{T_1} = C \varepsilon \xi^{z+2} \frac{\beta^2 \sqrt{2\pi}}{\omega_E} \left( \frac{1}{4\pi^2} \right) \int_{BZ} dq |A_q|^2 \frac{(1 + q^2 \xi^2)^2}{(1 + q^2 \xi^2)}
\]

where $C = \gamma^2 S(S+1)/3$, $z$ is the dynamical scaling exponent (for $J_2/J_1 = 0$ $z \approx 0.32$), $\varepsilon$ is a coefficient accounting for the reduction of the amplitude of spin excitations due to quantum fluctuations, $\omega_E \sim \sqrt{J_1 + J_2} k_B / \hbar$ is the Heisenberg frequency, describing the uncorrelated spin fluctuation for $T \to \infty$ and $\beta$ is a normalization factor which preserves the spin sum rule. The form factors have been calculated on the basis of the hyperfine constants determined for the pure Li$_2$VOSiO$_4$.

Once $z$ is defined a one-to-one relationship between $T_1$ and $\xi$ is established, and one can determine $\xi$ from $^7$Li NMR relaxation data in Li$_2$VOSiO$_4$ reported both in the assumptions that $z = 1$ or that $z = 2$.

One observes that, above the crossover from 2D to 3D yielding the divergence of $1/T_1$ at $T_c$, $\xi$ data derived for $z = 1$ are in rather good agreement with the theoretical calculations for $J_2/J_1 = 1$. Larger ratios of $J_2/J_1$ and a dynamical scaling exponent $z = 2$ do not appear to be consistent with the experimental findings. This suggests that the same scaling laws used for pure 2DQHA could still be valid in the presence of frustration. For $z = 1$ and $T \ll J_1 + J_2$, if the form factor is weakly $q$-dependent as for $^7$Li in Li$_2$VOSiO$_4$, one has that

\[
\frac{1}{T_1} \sim \xi \sim \exp \left( 2\pi \rho_s(x)/T \right).
\]

Then, if $J_1$ and $J_2$ are reduced to the same extent by dilution and $\rho_s(x) = \rho_s(0) \cdot (1-x)^2$, the $T$-dependence of $1/T_1$ data should be $x$ independent once the temperature is rescaled to $T/(1-x)^2$. In fact, in diluted non-frustrated 2DQHAF as La$_2$Cu$_{1-x}$Zn$_x$O$_3$, such a scaling does occur (see Fig. 9). On the other hand, in the diluted frustrated 2DQHAF Li$_2$V$_{1-x}$Ti$_x$SiO$_4$, such scaling does not seem to be accurate any longer, suggesting that also the effective ratio $J_2/J_1$ is changing. In fact, one has to observe that while the spin hamiltonian for a diluted non-frustrated 2DQHAF on a square-lattice can still be mapped onto the same hamiltonian, provided the exchange coupling is renormalized, the spin hamiltonian for the frustrated 2DQHAF on a square lattice can no longer be mapped onto the same hamiltonian as dilution in the $J_2 - J_1$ model yields the appearance of triangular spin configurations.

After having presented these arguments suggesting a variation of the effective ratio $J_2(x)/J_1(x)$ and a negligible reduction of $M(x)$, the effect of spin vacancies on the distortion initially observed in undoped frustrated systems will be discussed. As pointed out in the introduction, Li$_2$VOSiO$_4$ is characterized by $J_2/J_1 > 0.8$ and hence by a two-fold degenerate collinear ground-state, with a magnetic wave vector which can be either $\mathbf{Q} = (0, \pi/a, 0)$ or $\mathbf{Q} = (\pi/a, 0, 0)$. At low-$T$, after an Ising transition, the spin system will eventually collapse in either one of the two collinear ground-states. Now, in a real system a finite spin-lattice coupling exists and for $J_2/J_1 > 0.8$ it would favour a tetragonal to orthorhombic

![FIG. 8: Correlation length $\xi$ extracted from $^7$Li NMR relaxation 1/T$_1$ in Li$_2$VOSiO$_4$ by inverting Eq. 7 in the text, in the assumptions that $z = 1$ or that $z = 2$. The data are compared with theoretical calculations, for different values of $J_2/J_1$, made in the framework of pure-quantum self-consistent harmonic approximation. The vertical dotted line indicates the transition to the collinear phase.](image1)

![FIG. 9: Comparison of $^{63}$Cu 1/T$_1$ in La$_2$Cu$_{1-x}$Zn$_x$O$_3$ and $^7$Li 1/T$_1$ in Li$_2$V$_{1-x}$OTi$_x$SiO$_4$ as a function of the scaled temperature $T/(1-x)^2$.](image2)

In fact, the behaviour of $^{29}\text{Si}$ NMR spectra and $1/T_1$ observed in some $\text{Li}_2\text{VOSiO}_4$ samples is consistent with such a distortion. $^{29}\text{Si}$ form factor $|A_{q2}|^2$ is peaked at $(q_x=\pi/a, q_y=\pi/a)$ and vanishes at the critical wavevector $Q=(0,\pi/a)$ or $Q=(\pi/a, 0)$. Hence, on approaching $T_c$, as the spectral weight shifts to the critical wavevector of the envisaged collinear order, $1/T_1$ should decrease and no peak observed. However, in the pure $\text{Li}_2\text{VOSiO}_4$ a peak in $1/T_1$ was observed suggesting that a distortion modifying $^{29}\text{Si}$ form factor takes place. In Ti-doped samples (Fig. 4) no peak in $^{29}\text{Si}$ $1/T_1$ is observed at $T_c$, pointing out that Ti impurities tend to hinder this distortion.

Finally, we point out that above $T_c$ Ti doping also hinders the very-low-frequency dynamics evidenced by $\mu$SR measurements in $\text{Li}_2\text{VOSiO}_4$ (Fig. 4). These dynamics were associated with the motion of domain walls separating regions were correlations with $Q=0, 0$ develop before the lattice distortion removes their degeneracy. Although a clear explanation of such a phenomenon goes beyond the aim of the present work, the observation of a $T$-independent much longer correlation time measured by $\mu$SR suggests that Ti impurities might pin the motions of domain walls.

IV. CONCLUSIONS

In conclusion, a thorough investigation of a spin diluted frustrated 2DQHAF system by means of NMR, $\mu$SR and susceptibility measurements has been presented. It has been shown that the decrease of the magnetic ordering temperature is consistent with a reduction of the spin-stiffness by a factor $\sim (1-x)^2$ and with a minor effect of spin dilution on the sublattice magnetization. The analysis of the magnetic susceptibility and of the nuclear spin-lattice relaxation rate shows that the effective ratio $J_2(x)/J_1(x)$ decreases with $x$, namely that the two coupling constants are not renormalized in the same way by dilution. This would actually mean that the spin Hamiltonian of a frustrated 2DQHAF on a square-lattice cannot be mapped onto the same square-lattice Hamiltonian after spin dilution has occurred. Finally it was shown that the low frequency dynamics observed in pure $\text{Li}_2\text{VOSiO}_4$ by means of $\mu$SR measurements disappears in $\text{Li}_2\text{V}_{1-x}\text{Ti}_x\text{OSiO}_4$. Moreover the absence of a peak in $^{29}\text{Si}$ NMR relaxation rate at the transition indicates that the distortion induced by frustration might be hindered by doping.

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