Supersymmetric Dark Matter as the Source of the WMAP Haze

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Introduction

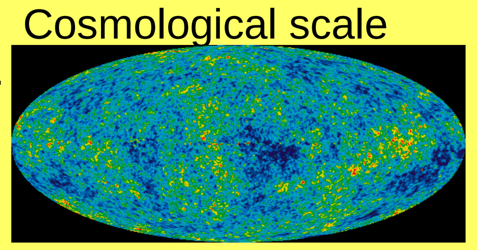
There is very compelling evidence indicating most of the matter in the universe is in the form of dark matter (DM). Among the many proposed DM candidates [1], the supersymmetric neutralino is one of the most widely studied particles [2]. The existence of DM could also account for other unexplained phenomena. Although the Wilkinson Microwave Anisotropy Probe (WMAP) has the primary mission of studying the Cosmic Microwave Background (CMB), within the inner 20 degrees from the Galactic Center it observes an anomalous excess emission referred to as the “WMAP Haze.”

Recently, the WMAP Haze has been interpreted as the synchrotron emission produced by decay products from DM annihilations [3, 4]. This project studies this possibility within the context of a simplified supersymmetric scenario known as the Constrained Minimal Supersymmetric Standard Model (CMSSM). We will study the regions of parameter space that provide a DM candidate with the properties required to produce the WMAP Haze.

(Sample of) Dark Matter Evidence

Cosmological scale

Fig. 1



The CMB (**Fig. 1**) helps to precisely determine that DM makes up ~22% of the universe, while only ~5% is regular baryonic matter [5].

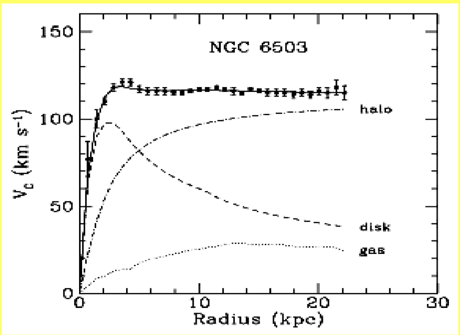
Galaxy cluster scale

Fig. 2

As light passes by clusters, Abell 2218 (**Fig. 2**) [6] for example, light is gravitationally lensed and a large discrepancy between the luminous matter and the mass is observed [7].

Galactic scale

Fig. 3



The rotational speed of galaxies tell us that there is DM distributed as a halo. This effect can be seen in **Fig. 3** for NGC 6503 [8].

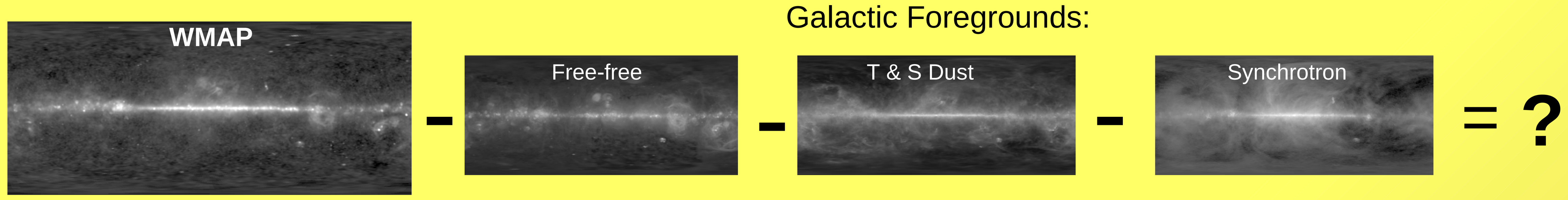
Supersymmetry

Supersymmetry [9] is a theory relating the two fundamental types of particles, fermions (spin ½) and bosons (integer spin). For each Standard Model particle it introduces a number of “superpartners” with different spin. The lightest supersymmetric particle (LSP), the neutralino, is is an excellent DM candidate. Unfortunately, the introduction of these new particles give the theory ~120 free parameters, which need to somehow be restricted to make supersymmetry a phenomenologically useful theory. The CMSSM assumes certain boundary conditions at the Grand Unification scale, reducing the number of free parameters to only five: $m_{1/2}$, m_0, A_0, tanβ, *sign*(μ).

WMAP Haze

Fig. 4

Galactic Foregrounds:



When the known galactic foregrounds—free-free emission from interactions of free electrons with ions; spinning and thermal dust; and synchrotron from supernova shock accelerated electrons—are subtracted from the full WMAP image (**Fig. 4**), a residual signal, called WMAP Haze, remains (**Fig. 5**) [10].

It has been shown that DM in the form of Weakly Interacting Massive Particles (WIMPs) could generate the observed emission [5]. When two WIMPs, neutralinos in this context, annihilate, some of the products eventually decay to electrons and positrons. As these relativistic charged particles travel, they will interact with the galactic magnetic field, thus emitting synchrotron radiation. The signal intensity and spectrum produced by WIMP annihilation can be calculated and used to constrain DM models.

The top frame of **Fig. 6** shows the neutralino annihilation cross section (in the low velocity limit) required to produce synchrotron emission of the same intensity observed for the WMAP Haze. The various lines represent different annihilation channels, plotted as a function of mass. In the bottom frame of **Fig. 6**, the ratio of synchrotron intensities produced in the 22 GHz and 33 GHz WMAP frequency bands gives us information about the spectrum of the Haze. Once again, the various dominant channels are plotted as a function of mass. The horizontal dashed lines are the (2σ) upper and lower limits of this ratio from measurements of the WMAP Haze [5]. With knowledge of these properties, we can proceed to compare neutralinos in the context of the CMSSM with the requirements of the Haze.

Fig. 5

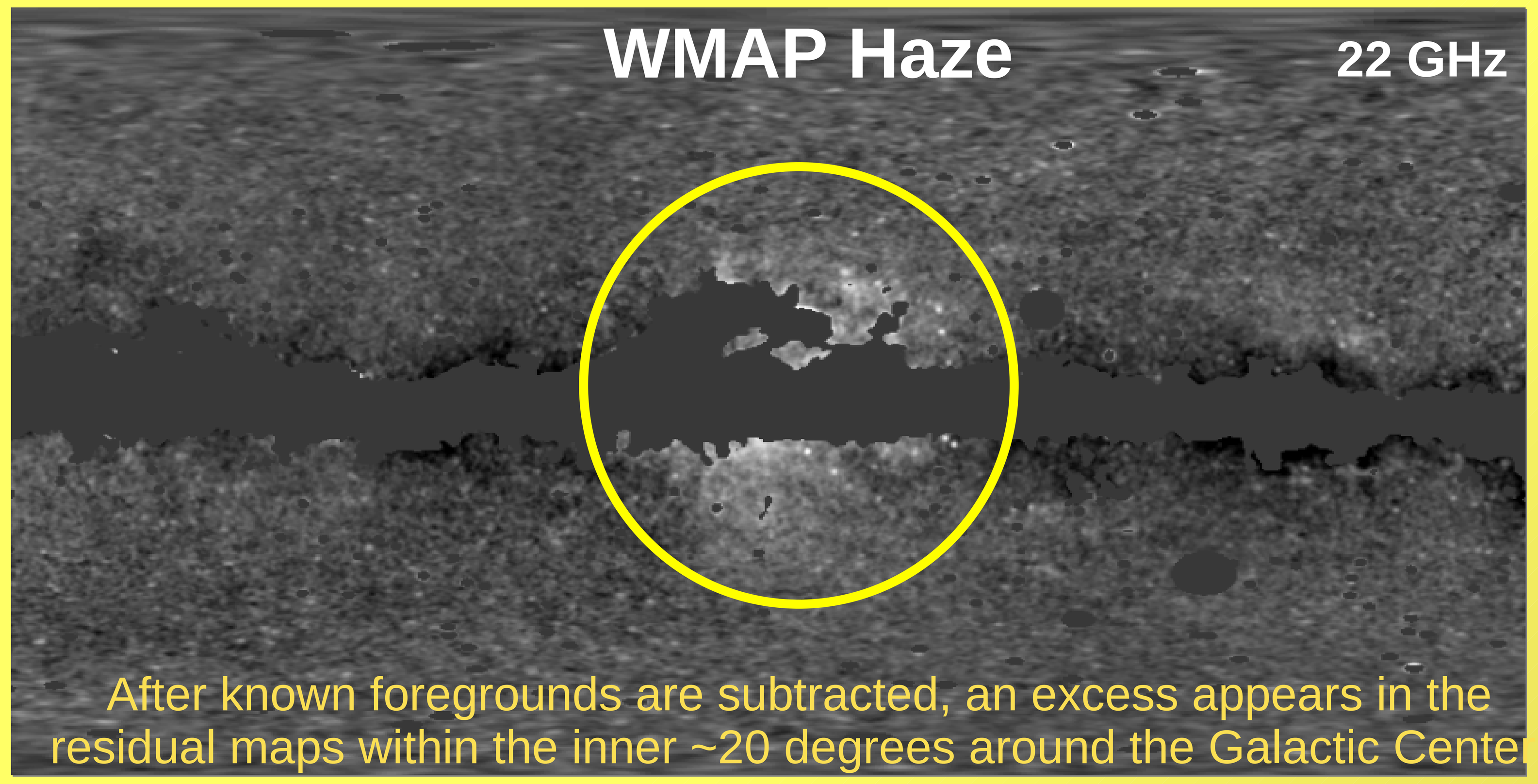
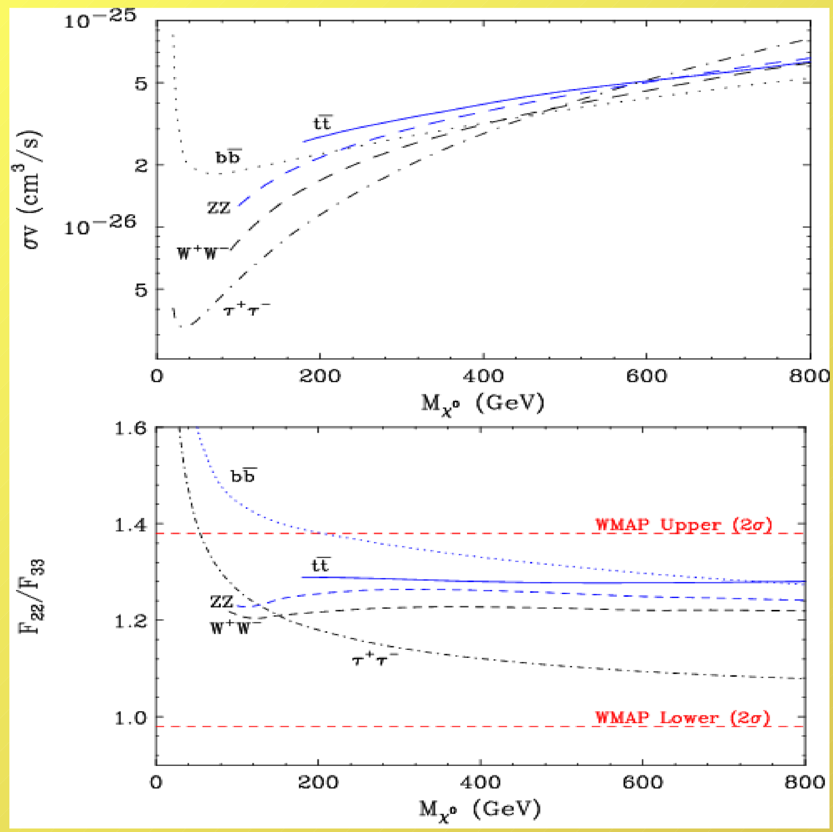


Fig. 6



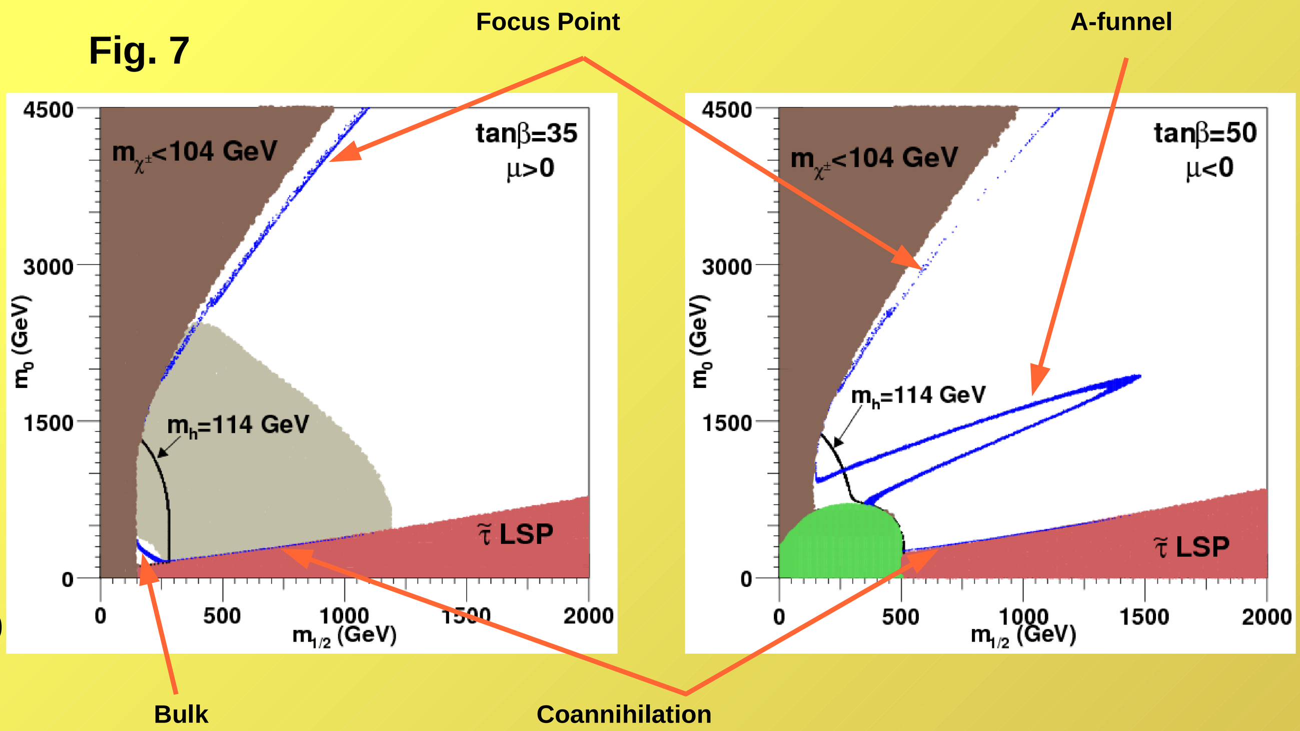
Constrained Minimal Supersymmetric Standard Model Analysis

To study the CMSSM, we fix a value for A_0, tanβ, and sign(μ), and scan through the m_0-$m_{1/2}$ plane. The two universal masses, m_0 and $m_{1/2}$, determine the masses of the supersymmetric particles, and thus are the most important for our phenomenological purposes.

Fig. 7 shows the supersymmetric parameter space. The most important region to notice is filled in blue, where the models predict the correct amount of DM.

(Done for μ>0, tanβ 3,10,35,50 and μ<0, tanβ 35,50)

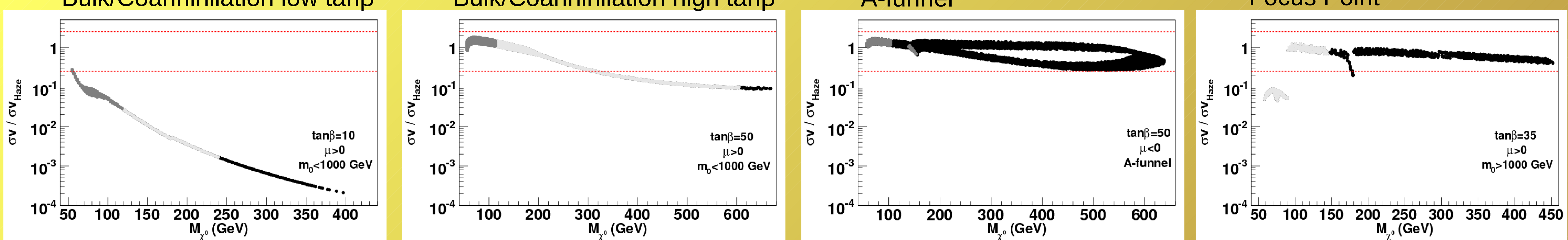
Fig. 7



The models in the regions of correct DM abundance are compared (**Fig. 8**) with the values given in **Fig. 6**. Models within the red lines are able to satisfy the properties of the Haze. The labeled features in **Fig. 7** and their phenomenology can be summarized as follows:

- Focus Point: Neutralino mixing is different, large couplings enable efficient annihilation. Satisfies requirements of the Haze.
- A-funnel: Resonance allows efficient annihilation. Satisfies requirements of the Haze.
- Bulk: Contains many light superpartners, enabling efficient annihilation. Consistent with the Haze at high tanβ values.
- Stau-coannihilation: Coannihilation permits correct DM abundance. Does not produce enough synchrotron intensity to account for the Haze.

Fig. 8



Detection Prospects

Direct Detection

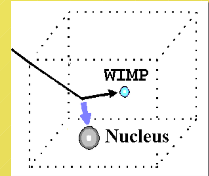
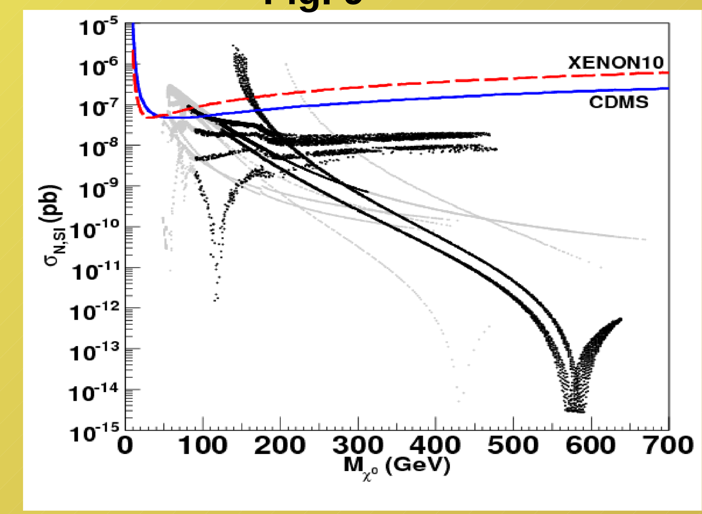


Fig. 9



It is possible for WIMPs to elastically scatter off nuclei. **Fig. 9** shows the direct detection prospects for models with the correct DM abundance. Points in black satisfy the properties required by the Haze, while gray points do not. The two lines drawn represent the current experimental limits [11, 12].

Neutrino Detection

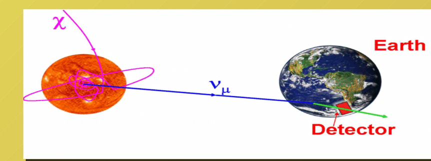
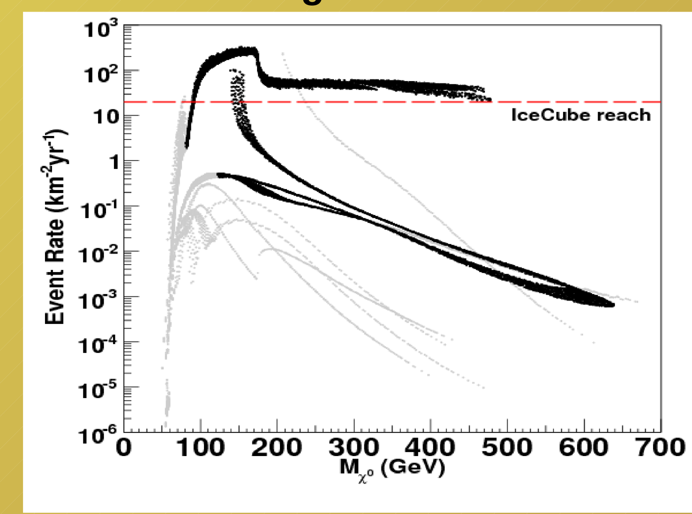


Fig. 10



Neutralinos in the core of the sun can annihilate and create neutrinos which escape towards the earth, where they are potentially observable [13]. **Fig. 10** shows the neutrino detection prospects for models with the correct DM abundance. Points in black satisfy the properties required by the Haze, while gray points do not. The line drawn represents the reach of next generation high- energy neutrino telescopes [14].

Conclusions

It has previously been shown that the anomalous emission from the inner Milky Way, known as the WMAP Haze, can be generated by a WIMP. In this paper we have studied the possibility that annihilating neutralinos are the source of this signal. Confining our study to the Constrained Minimal Supersymmetric Standard Model (CMSSM), we find that a large fraction of the phenomenologically viable parameter space naturally leads to an annihilation cross section and spectrum of annihilation products consistent with the observed properties of the WMAP Haze. In particular, the focus point, A-funnel and bulk regions of the CMSSM are each well suited for generating this anomalous signal. In contrast, the stau coannihilation region does not satisfy the properties required to account for the Haze. If the WMAP Haze is in fact generated by annihilating neutralinos, then the prospects for direct and indirect detection are promising.

For more information:

This poster is based on:

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