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Identifying Dark Matter Burners in the Galactic center

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Abstract. If the supermassive black hole (SMBH) at the center of our Galaxy grew adiabatically, then a dense "spike" of dark matter is expected to have formed around it. Assuming that dark matter is composed primarily of weakly interacting massive particles (WIMPs), a star orbiting close enough to the SMBH can capture WIMPs at an extremely high rate. The stellar luminosity due to annihilation of captured WIMPs in the stellar core may be comparable to or even exceed the luminosity of the star due to thermonuclear burning. The model thus predicts the existence of unusual stars, i.e. "WIMP burners", in the vicinity of an adiabatically grown SMBH. We find that the most efficient WIMP burners are stars with degenerate electron cores, e.g. white dwarfs (WD) or degenerate cores with envelopes. If found, such stars would provide evidence for the existence of particle dark matter and could possibly be used to establish its density profile. In our previous paper we computed the luminosity from WIMP burning for a range of dark matter spike density profiles, degenerate core masses, and distances from the SMBH. Here we compare our results with the observed stars closest to the Galactic center and find that they could be consistent with WIMP burners in the form of degenerate cores with envelopes. We also cross-check the WIMP burner hypothesis with the EGRET observed flux of gamma-rays from the Galactic center, which imposes a constraint on the dark matter spike density profile and annihilation cross-section. We find that the EGRET data is consistent with the WIMP burner hypothesis. New high precision measurements by GLAST will confirm or set stringent limits on a dark matter spike at the Galactic center, which will in turn support or set stringent limits on the existence of WIMP burners at the Galactic center.

Keywords: black hole physics, dark matter, elementary particles, stellar evolution, white dwarfs, infrared, gamma rays
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RESULTS

The highest density "free space" dark matter regions occur for dark matter particles captured within the gravitational potential of adiabatically grown SMBHs. Any star close enough to such a SMBH can capture a large number of WIMPs during a short period of time. Annihilation of captured WIMPs may lead to considerable energy release in stellar cores thus affecting the evolution and appearance of such stars. Such an idea has been first proposed in [1] and further developed in [2] who applied it to main-sequence stars. An order-of-magnitude estimate of the WIMP capture rates for stars of various masses and evolution stages [3] lead us to the conclusion that WDs, fully burned stars without their own energy supply, are the most promising candidates to look for. WIMP capture by WDs or degenerate cores with envelopes located in a high density dark matter region has been discussed in detail in [4].

A high WIMP concentration in the stellar interior may affect the evolution and appearance of a star. The effects of WIMPs can be numerous, here we list only a few. The additional source of energy from WIMP pair-annihilation may cause convective energy transport from the stellar interior when radiative transport is not effective enough. In turn, this may inflate the stellar radius. On the other hand, WIMPs themselves may provide energy transport and suppress convection in the stellar core; this would reduce the replenishment of the thermonuclear burning region with fresh fuel. The appearance of massive stars and the bare WDs should not change, however. The former are too luminous, $L_* \propto M_*^4$, while the energy transport in the latter is dominated by the degenerate electrons. Here we discuss observational features of DM burners, and GLAST's role in checking this hypothesis.

There several possible ways to identify the DM burners:

- The bare WDs burning DM should be hot, with luminosity maximum falling into the UV or X-ray band. The number of very hot WDs in the SDSS catalog [5] is small, just a handful out of 9316. This means that observation of a concentration of very hot WDs at the GC would be extremely unlikely unless they are "DM burners."
- Identification of DM burners may be possible by combining the data obtained by several experiments:
  - GLAST γ-ray measurements from the GC can be used to identify a putative DM spike at the SMBH, and also measure the annihilation flux from the spike. Identification of the DM spike requires a detection of a

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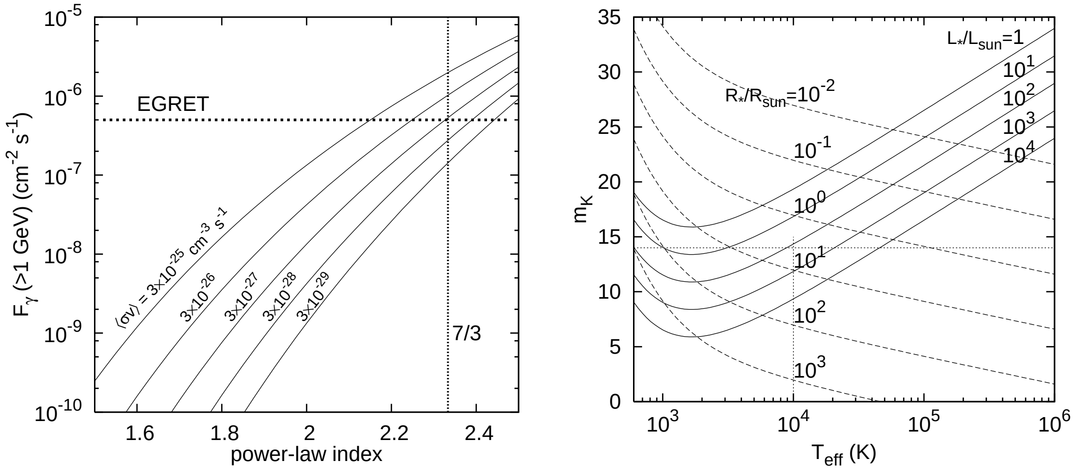

FIGURE 1. *Left:* γ-ray flux vs. the DM central spike power-law index. The lines are shown for a series of annihilation cross sections $\langle\sigma v\rangle$. *Right:* The visual K-band magnitude of DM burners at the GC without extinction vs. the effective surface temperature.

point source at the GC (i.e. not extended) centered on the SMBH (i.e. with no offset), and a source spectrum matching a WIMP of a particular mass, which agrees with the "universal" WIMP mass as determined by any other putative WIMP signals (i.e. from colliders, direct detection, other indirect detection).

– Direct measurement of the WIMP-nucleon scattering cross-section fixes the WIMP capture rate and thus the WIMP burner luminosity for a given degenerate core.
– Determination of stellar orbits would allow a calculation of the WIMP burning rate by a particular star and, therefore, the proportion of its luminosity which is coming from the WIMP burning.
– LHC measurements may provide information about the WIMP mass and interaction cross-sections.

Figure 1 (left) shows the DM annihilation γ-ray flux from the central spike vs. DM density power-law index assuming 10γ's above 1 GeV per annihilation and WIMP mass $m_\chi = 100$ GeV. The EGRET γ-ray flux from the GC $F_\gamma(>1\ \mathrm{GeV}) = 5\times10^{-7}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ [6].

Advances in near-IR instrumentation have made possible observations of stars in the inner parsec of the Galaxy [7, 8, 9]. The apparent K-band brightness of these stars is 14–17 mag while the extinction may be as large as 3.3 mag [10]. Assuming a central spike with index 7/3, the K-band brightness for bare Oxygen WDs with $T_{\mathrm{eff}} \sim 100,000$ K and $R_*/R_\odot \sim 0.01$ is about 22–23 mag not including extinction. A WIMP burning degenerate core with envelope may be cold enough to produce most of its emission in the IR band (Figure 1, right). For a given luminosity, the colder stars should necessarily have larger outer radii. A DM burner (w/envelope) with effective temperature $T_{\mathrm{eff}} < 10,000$ K and radius $> 5R_\odot$ could have visual K-band magnitude mag > 10 (without extinction) and be visible with the current techniques. The horizontal dotted line (mag = 14) show the dimmest stars currently observed in the GC.

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