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Dark Matter in the Center of the Milky Way and the Stars Burning It

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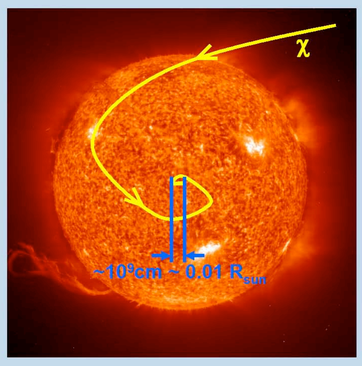
If the supermassive black hole (SMBH) at the center of our Galaxy grew adiabatically, then a dense "spike" of dark matter is expected to have formed around it. Assuming that dark matter is composed primarily of weakly interacting massive particles (WIMPs), we show that a star orbiting close enough to 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 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. We compute the luminosity from WIMP burning for a range of dark matter spike density profiles, degenerate core masses, and distances from the SMBH. We compare our results with the observed stars closest 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.

Basic idea

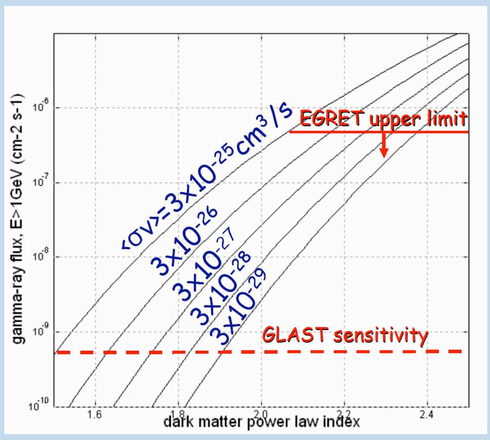
- Extremely high dark matter density possibly exists near the supermassive black hole at the Galactic center
- WIMP-nucleon scattering leads to gravitational capture and the accumulation of WIMPs stars
- WIMP pair annihilation creates a new energy source in stars, i.e. the "burning" of dark matter
- Dark matter "burners" may appear as red giants (Salati & Silk 1989)
- Degenerate electron cores at the Galactic center can "burn" dark matter quickly enough to be observable (Moskalenko & Wai 2006)



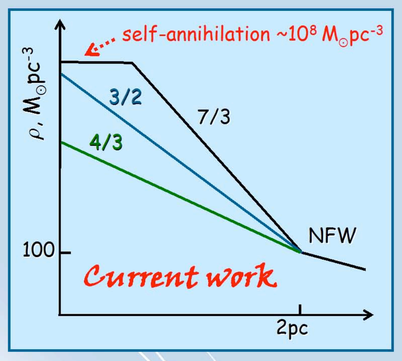
γ-ray flux vs DM spike power-law index

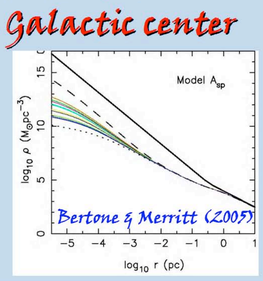
The DM annihilation γ-ray flux from the central spike vs DM matter density power-law index. The curves are shown for several values of the annihilation cross section <σv>.

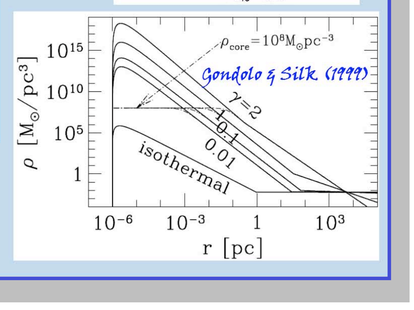
We also show the EGRET upper limit on gamma-ray flux from the Galactic center F(>1 GeV) = 5×10^{-7} cm^{-2} s^{-1} (Mayer-Hasselwander, et.al. 1998)



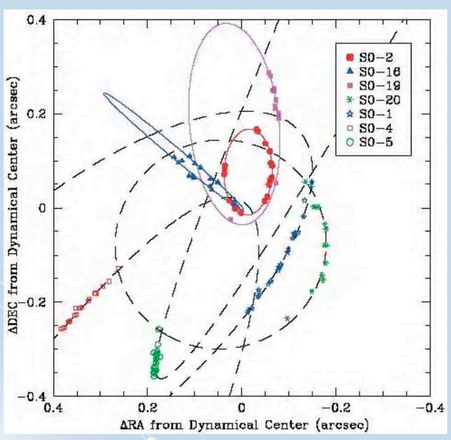
Computed dark matter densities near the supermassive black hole at the Galactic center







Galactic center stars in near-infrared (K-band)

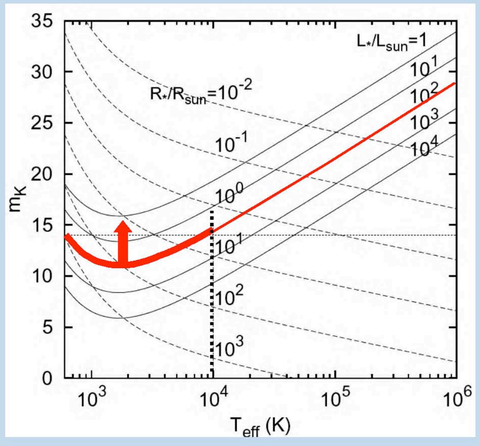


Ghez et al. 2005

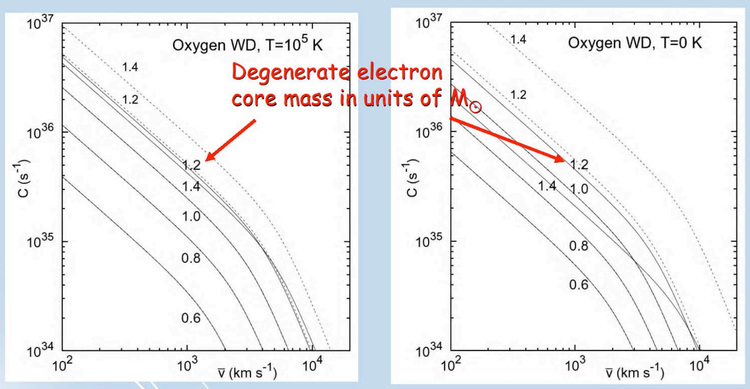
K-band magnitude vs. effective temperature

K-band magnitude m_K vs effective temperature T_{eff} without extinction.

A degenerate core with H or He envelope can be brighter than 14 mag if T_{eff} = 600-10000K and R>5 $R_\odot$.



WIMP capture rate vs velocity dispersion



Solid lines are for the capture rate taking into account the geometrical limit; dotted lines without the geometrical limit

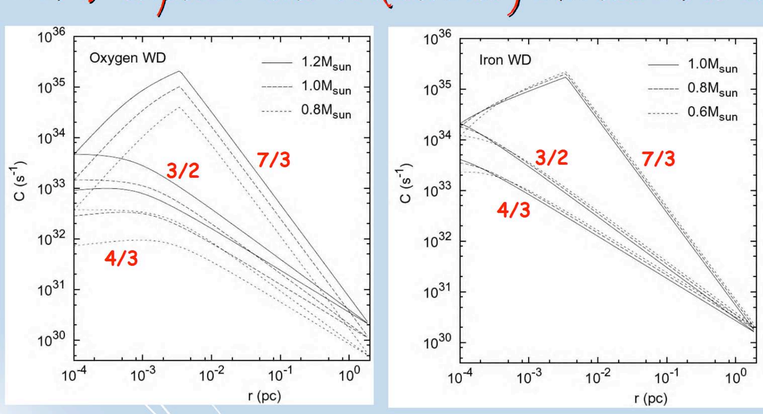
The "paradox of youth" for Sgr A* stars (e.g. Ghez, et.al. 2005)

- K-band measurements of Sgr A* stars indicate that they are hot (m_K=14-17 mag, extinction ~3.3 mag)
  - ★ imply that they are young stars (O9) or old stars (K5)
- Difficult to see how they could have formed in situ:
  - ★ given the lack / low density of gas
  - ★ extreme gravitational forces near the supermassive BH
- Difficult to see how they could have efficiently migrated in given the short time since birth
- Conventional hypotheses discussed are:
  - ★ "old stars masquerading as young" or
  - ★ "hot dwarfs - stripped cores of red giants"

Experimental inputs

- Spin-independent scattering limits
  - ★ CDMS II: $\sigma_{SI}<10^{-43}$cm^2
- Spin-dependent scattering limits
  - ★ SuperK: $\sigma_{SD}<10^{-38}$cm^2 (NOT used in calculations)
- Annihilation cross-section estimate (actual value not important for results!)
  - ★ $<\sigma v>\sim3\times10^{-26}$cm^{3}s^{-1}
- Recent infrared (K-band) observations of Galactic center stars
- EGRET upper limit on gamma-ray flux at the Galactic center

WIMP capture rate vs distance from the SMBH



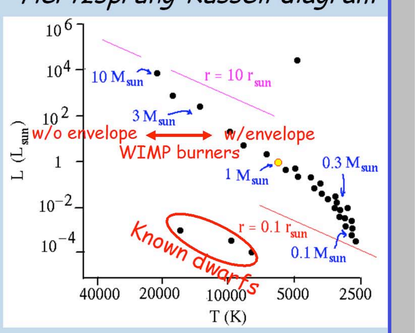
Capture rate vs distance from the central BH for Oxygen (left) and Iron (right) white dwarfs of T_{eff}=100000 K. Numbers (7/3, 3/2, 4/3) show power-law indices for the central spike profile.

The degenerate core WIMP burner hypothesis

- Stars with degenerate electron cores are everywhere!

  Some just happen to fall into the high density dark matter region near the black hole where they appear as WIMP burners
- Compact structure: more stable against extreme gravitational conditions near the supermassive black hole
- What are the spectral or other signatures?

Hertzsprung-Russell diagram



Summary

- If the supermassive black hole at the Galactic center has a dark matter spike with a profile ~7/3, unusual stars - "WIMP burners" - may be observed in the K-band (m_K<14 mag)
- If found, a luminosity distribution of dark matter burners near Sgr A* would trace the dark matter distribution
- Another consequence of the dark matter spike is a gamma-ray WIMP annihilation flux above 1 GeV coincident with Sgr A*; this prediction is consistent with EGRET measurements
- GLAST should be able to provide crucial measurements of the Galactic center gamma-ray source and thereby confirm or set stringent limits on this scenario

References

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- Salati & Silk 1989, ApJ 338, 24
- Mayer-Hasselwander et al. 1998, Astron.Astrophys. 335, 161