511 keV Annihilation Emission from the Galactic Center and the Past Higher Activity of the GC Black Hole

Tomonori TOTANI (Kyoto Univ.)

Abstract:
The origin of 511 keV emission from the Galactic Center (GC) direction is still an intriguing mystery in astrophysics. In 2006 I proposed a new scenario that positrons are produced in the accretion flow onto the supermassive black hole (SMBH) at GC, in the framework of the standard theoretical accretion model of GC (TT 2006, PASJ, 58, 965). For sufficient amount of positron production, an accretion rate that is higher than now by a factor of $\sim 10^3$ is required during the past $\sim 10^7$ yr, but I argued that this is indeed favored from several observational evidences. Since then, recently an interesting discovery of large bipolar gamma-ray bubble has been reported by Fermi (the Fermi bubble). This new discovery gives a further support to the case of higher activity of GC BH in the past. Here I summarize arguments for the past higher activity, and the scenario for the 511 keV line emission. See TT 2006 for more details.

1. The 511 keV line emission from GC

- positron production rate ~ 1.5×10^{43} s^{-1}
- the large bulge-disk ratio excludes most scenarios based on young massive stars, supernovae, etc.
- type Ia SNe: the SN rate not sufficient.
- GC SMBH gives a natural explanation for the large B/D ratio

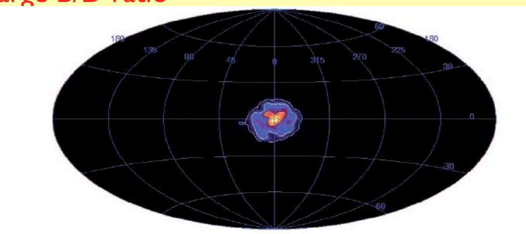


Fig. 4. Richardson-Lucy image of 511 keV gamma-ray line emission (iteration 17). Contour levels indicate intensity levels of 10^{-2}, 10 and 10^{-4} ph cm^{-2} s^{-1} sr^{-1} (from the centre outwards).

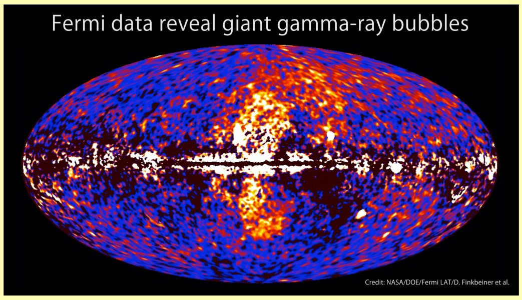
511 keV emission from GC direction (Knodlseder+'05)

2. Accretion flow to GC BH and positron production

- accretion rate to GC BH is much lower than the Eddington rate → radiatively inefficient accretion flow (RIAF)
- RIAF-based models of GC BH matches the observed luminosities in wide wavelength range (e.g., Yuan+'04)
- positrons produced in RIAF, and injected into interstellar medium (ISM) by outflow naturally expected for RIAF (TT '06)
- However, a factor of $\sim 10^3$ enhancement of accretion rate is required than the current rate, for a time scale of $\sim 10^7$ yr (annihilation time scale in ISM), to explain the observed annihilation rate
- Is it feasible!? The answer is actually YES!

3. Past higher activity of GC BH?

- evidence for outflow from GC on scale of ~100 pc from radio, mid-IR, and X-ray obs. (Bland-Hawthorn+'03)
- evidence for outflow on ~ kpc originally argued by Sofue from radio observations (Sofue '00)
- this is confirmed by recent detection of the Fermi bubble (Su+'10)
- X-ray reflection nebula: evidence for $\sim 10^5$ times higher L_X ~300 yrs ago than the current GC (Koyama +'96) (note: L_X scales as $(\text{accretion rate})^2$ in RIAF)



Fermi bubble (Su+'10)

4. Why GC BH is so dim now?

- GC BH seems interacting with a nearby supernova remnant, Sgr A East (Maeda+'02).
- The accretion flow may have been destructed by the fast moving shell of Sgr A East ~300 yrs ago
- The past enhanced accretion rate is not particularly high compared with typical galaxies like our Galaxy
  - in other words, current rate is extremely small!

5. Comparison with another scenario of 511 keV emission using GC BH:

- Cheng+'06 proposed another scenario of the positron production from GC BH
  - Occasionally stars are captured by BH, disrupted, and jet from BH accelerates cosmic rays, then produces positrons by proton-proton (pp) collisions
  - positrons produced by pp should have high energy of ~70 MeV, which should produce too much continuum gamma-rays than observed, by in-flight annihilation before slowing down in ISM (Beacom+'05)
  - rate of stellar captures on BH, and efficiency of jet and cosmic-ray production are highly uncertain