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L P I

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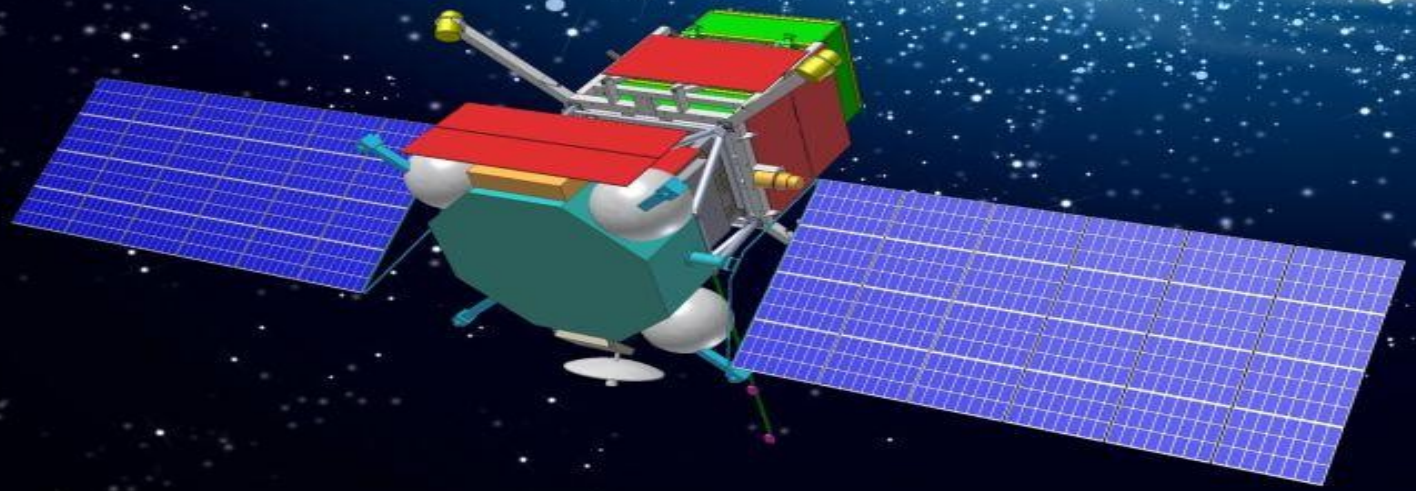
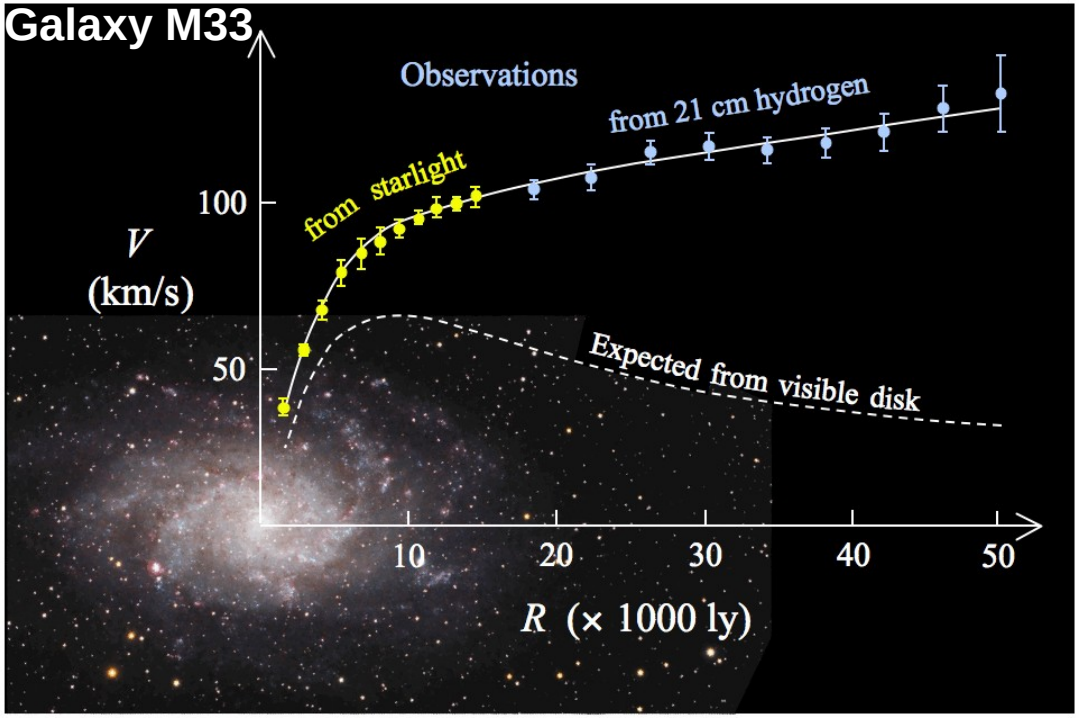
for the GAMMA-400 Collaboration

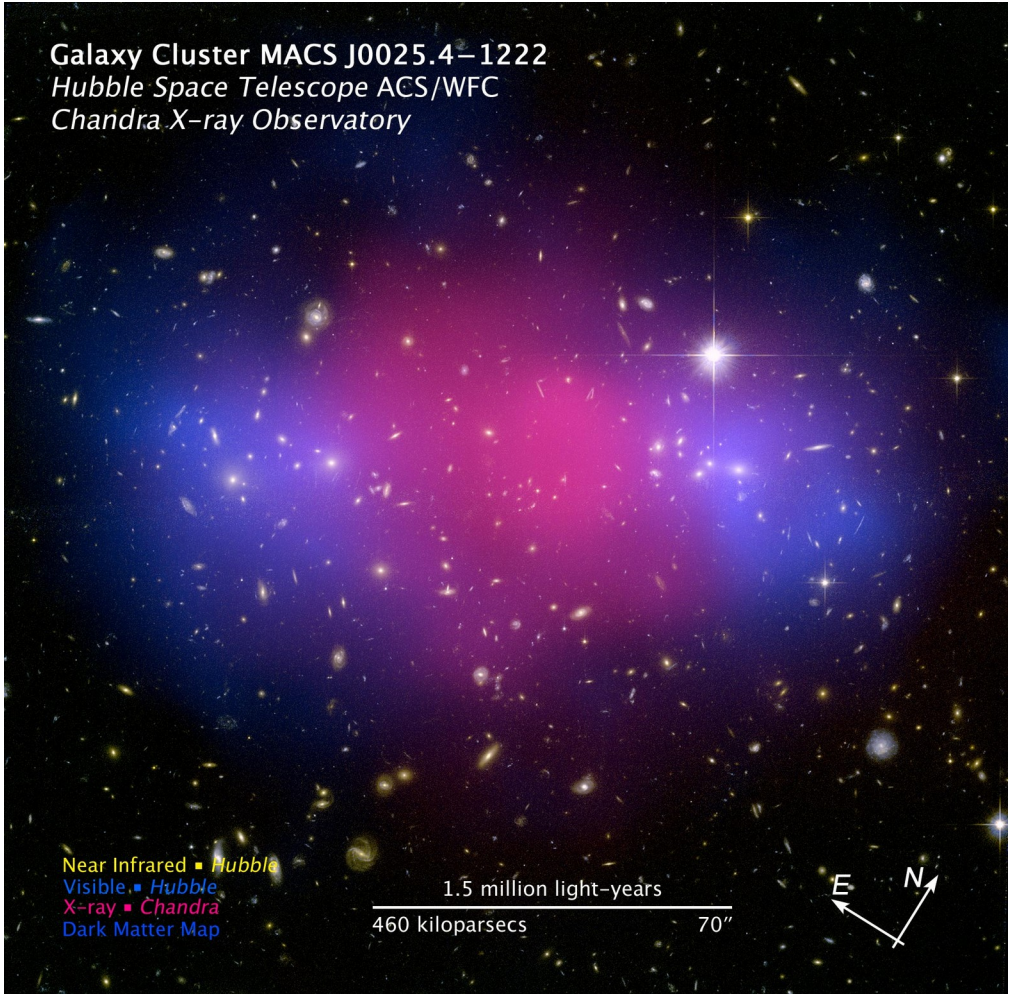
Dark matter searches by means of the GAMMA-400 gamma-ray telescope.



ICPPA-2020

DM was discovered ≈ 90 years ago, but its physical nature still remains puzzling..

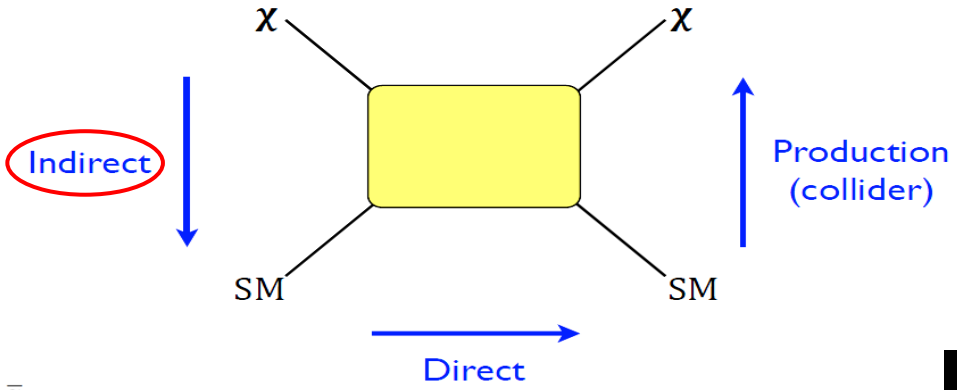




DM appears and organizes structures on all scales from dwarf galaxies to galaxy clusters.

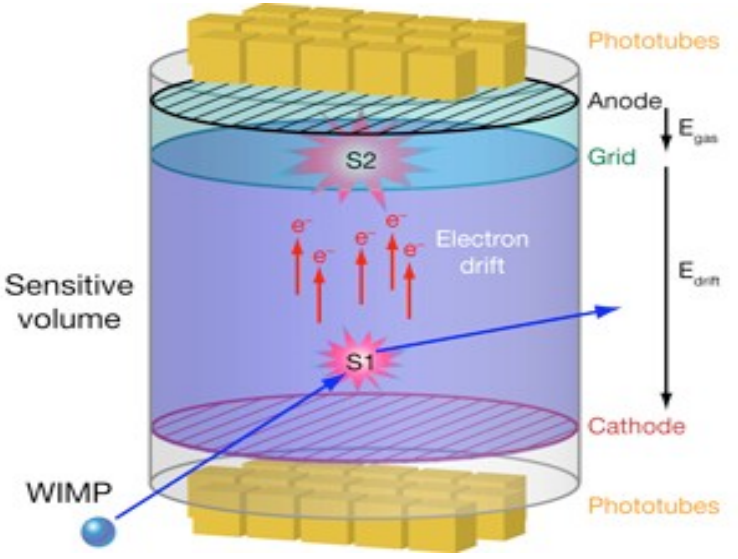
Big variety of candidates on the role of DM

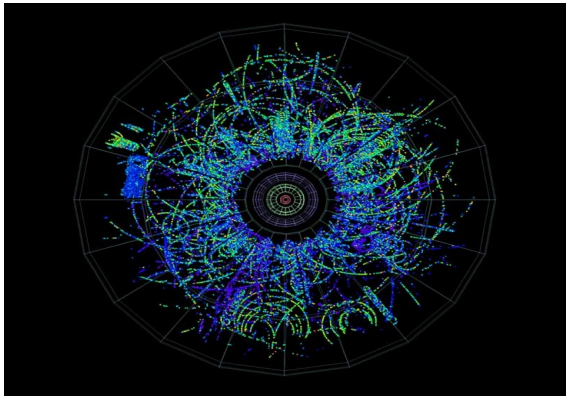
The key DM search strategies



$$\chi\chi \to e^+e^-,\ \mu^+\mu^-,\ \tau^+\tau^-,\ q\bar{q},$$
$$c\bar{c},\ b\bar{b},\ t\bar{t},\ \gamma\gamma,$$
$$W^+W^-,\ Z^0Z^0,\ hh,\ \nu_i\bar{\nu}_i\ \ldots$$

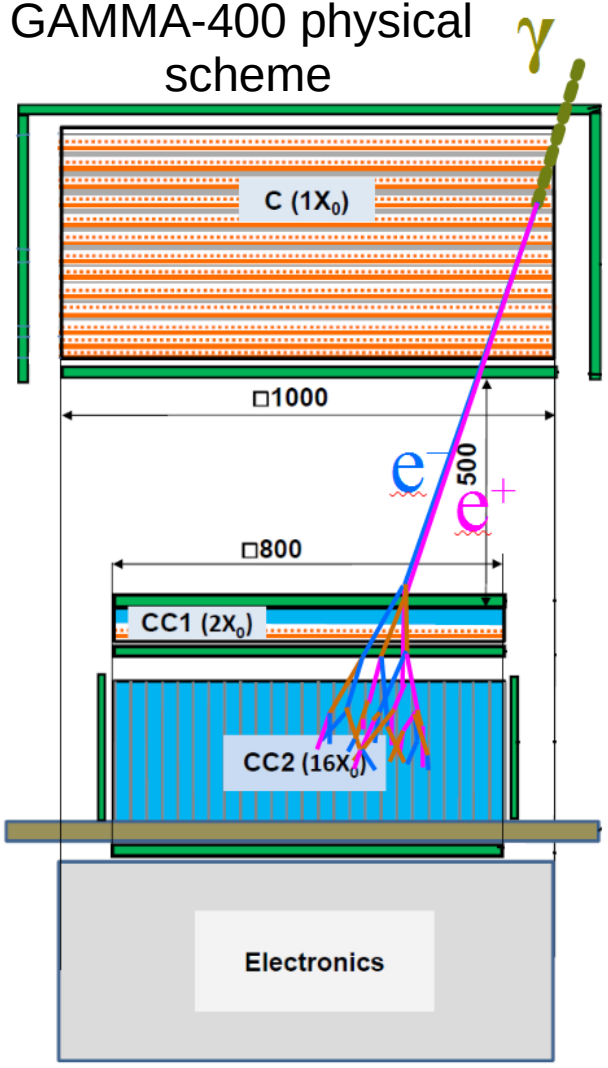
$$\chi\chi \to \tau^+\tau^- \to \pi^\pm + 2\pi^0 + \nu_\tau + \bar{\nu}_\tau \to$$
$$\mu^\pm + \nu_\mu + \bar{\nu}_\mu + 4\gamma + \nu_\tau + \bar{\nu}_\tau \to$$
$$e^\pm + 2\nu_\mu + 2\bar{\nu}_\mu + \nu_e + \bar{\nu}_e + 4\gamma + \nu_\tau + \bar{\nu}_\tau$$



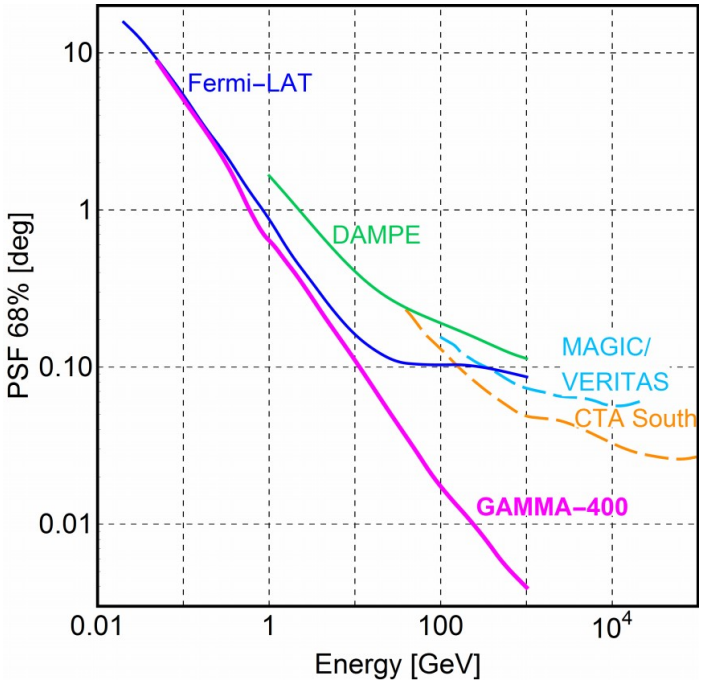


Indirect searches: gamma-ray band is the most promising

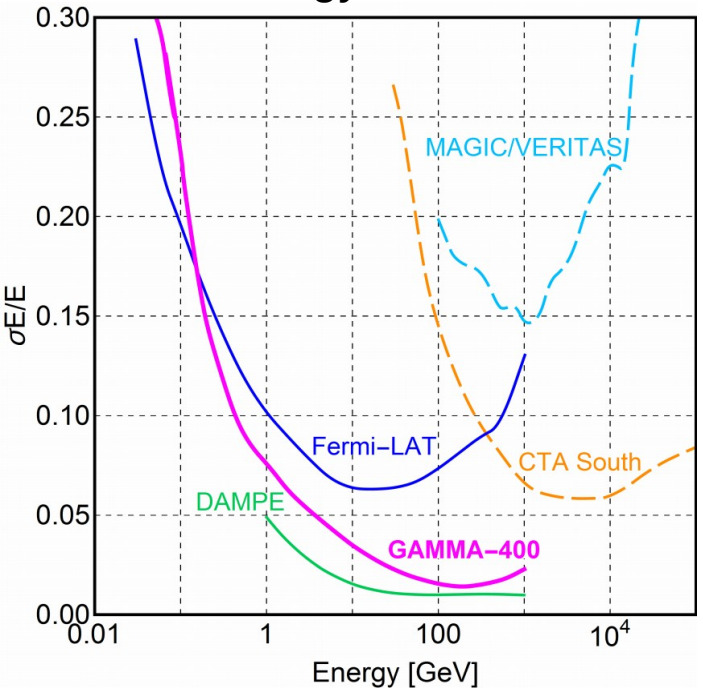
GAMMA-400 physical scheme



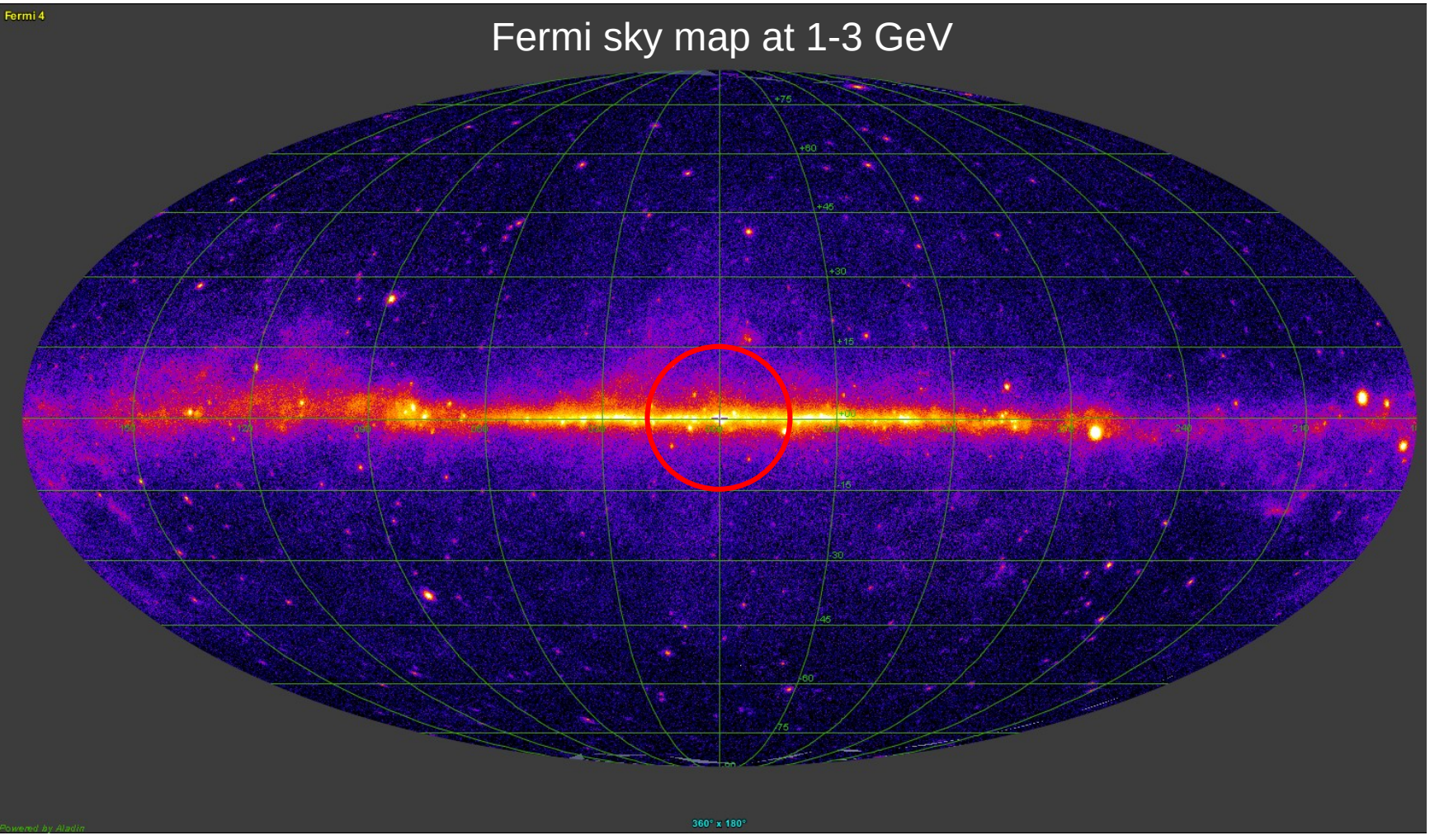
Angular resolution



Energy resolution



Search for the narrow spectral lines due to DM annihilation or decay in the Galactic center



We plan to observe the Galactic center during 2-4 years **continuously**. The DM signal will be searched inside the disk with 10°-15° radius around GC, which is the optimal region of interest for the steep DM density profiles like Einasto.

Search for the narrow spectral lines due to DM annihilation or decay in the Galactic center – basic equations

Annihilation: $\chi\chi \to \gamma\gamma$. Decay: $\chi \to \gamma\nu$, or $\chi \to \gamma Z$, $\chi \to \gamma\gamma$..

$n = n_b + n_{sig} + n_s$ - the observed number of photons inside the relevant energy bin.

$\mu = \mu_b + \mu_{sig} + n_s$ - the average anticipated number of photons in the bin.

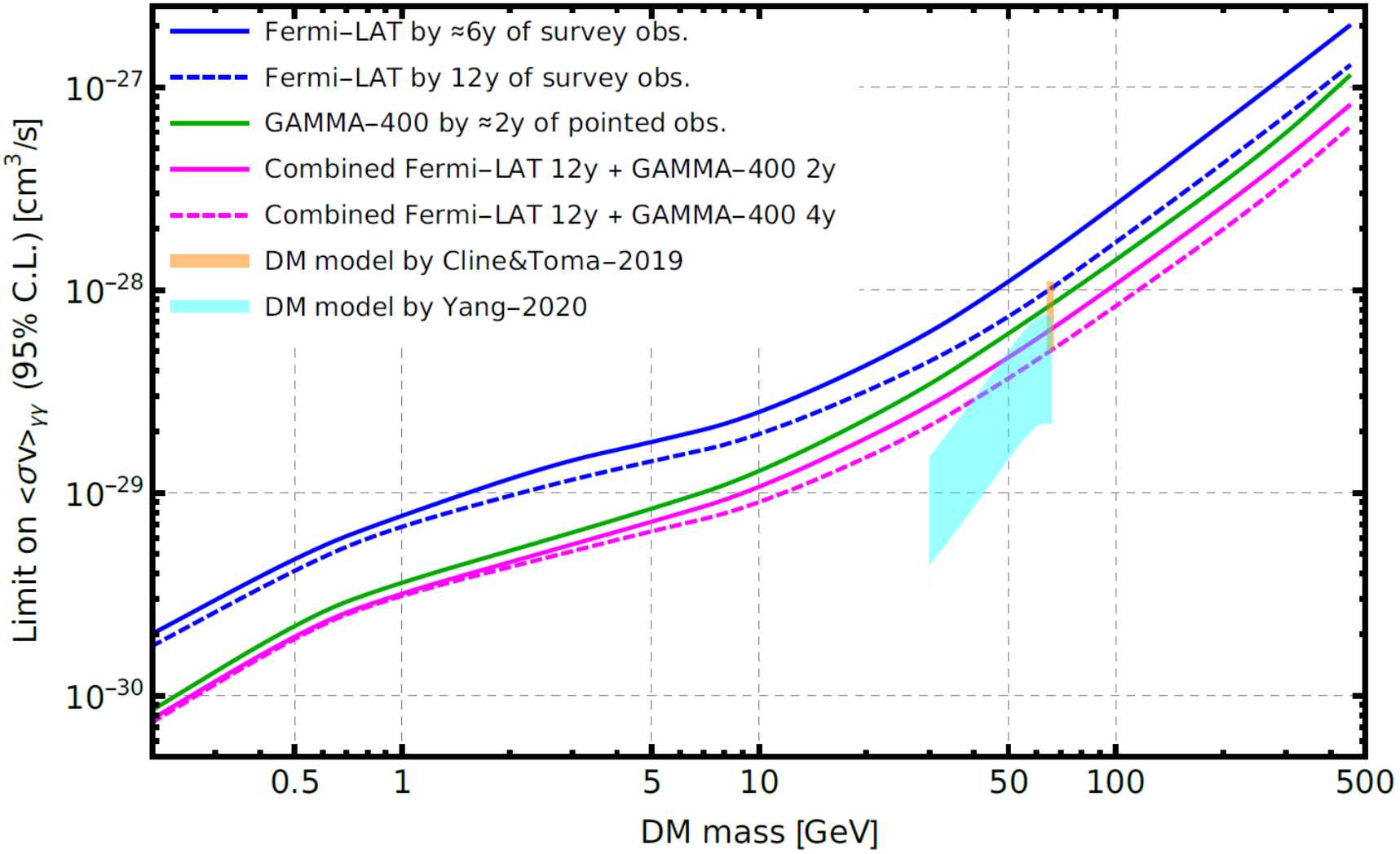
$$L\left(\mu_{sig}\left(\begin{matrix}\langle\sigma v\rangle_{\gamma\gamma}\\ \tau_{\gamma\nu}\end{matrix}, m_\chi\right), n_s | n, \mu_b\right) \propto P_s(n_s, \mu_b) \times P(\mu|n) = \frac{1}{\sqrt{2\pi}\sigma_s}\exp\left(-\frac{n_s^2}{2\sigma_s^2}\right) \times \frac{\mu^n}{n!}e^{-\mu}$$

- the likelihood function

$$\mu_b(m_\chi) = \int_{m_\chi - k(m_\chi)\sigma_E(m_\chi)}^{m_\chi + k(m_\chi)\sigma_E(m_\chi)} dE' \int dE f_b(E) \frac{1}{\sqrt{2\pi}\sigma_E(E)} \exp\left(-\frac{(E-E')^2}{2\sigma_E^2(E)}\right)\varepsilon(E)$$

- the mean number of background photons (annihilation case) from the diffuse Galactic emission (gas), isotropic (extragalactic) emission and point sources.

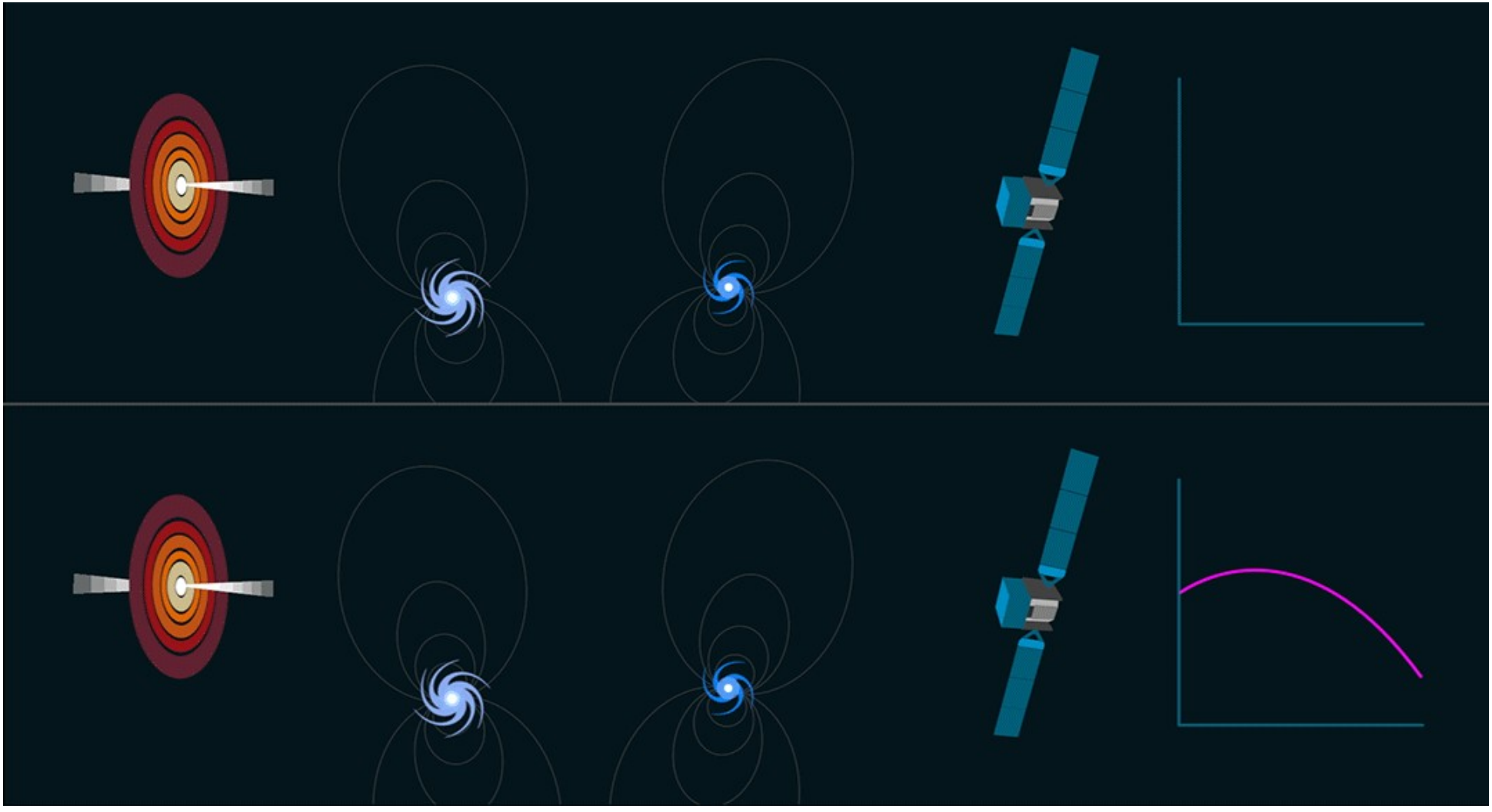
GAMMA-400 sensitivity to DM diphoton annihilation cross section



The sensitivity gains by GAMMA-400 with respect to Fermi-LAT in the case of optimistic systematics

	2 years of obs. by GAMMA-400 alone	Joint: 2 years by GAMMA-400 + 12 years by Fermi-LAT	Joint: 4 years by GAMMA-400 + 12 years by Fermi-LAT
Annihilation case	1.1-2.1	1.6-2.3	2.0-2.4
Decay case (less gains due to limited sky coverage)			1.1-2.6

Axionlike particle (ALP) searches



ALP searches by observations of a nearby supernova and bright pulsars

$$\frac{dN_a}{dE} = C_a \left(\frac{g_{a\gamma}}{\mathrm{GeV}^{-1}}\right)^2 \left(\frac{E}{E_a}\right)^{\beta_a} \exp\left(-\frac{(\beta_a+1)E}{E_a}\right)$$

- hypothesized ALP luminosity of supernova, peaks at 60-70 MeV, lasts ~10s.

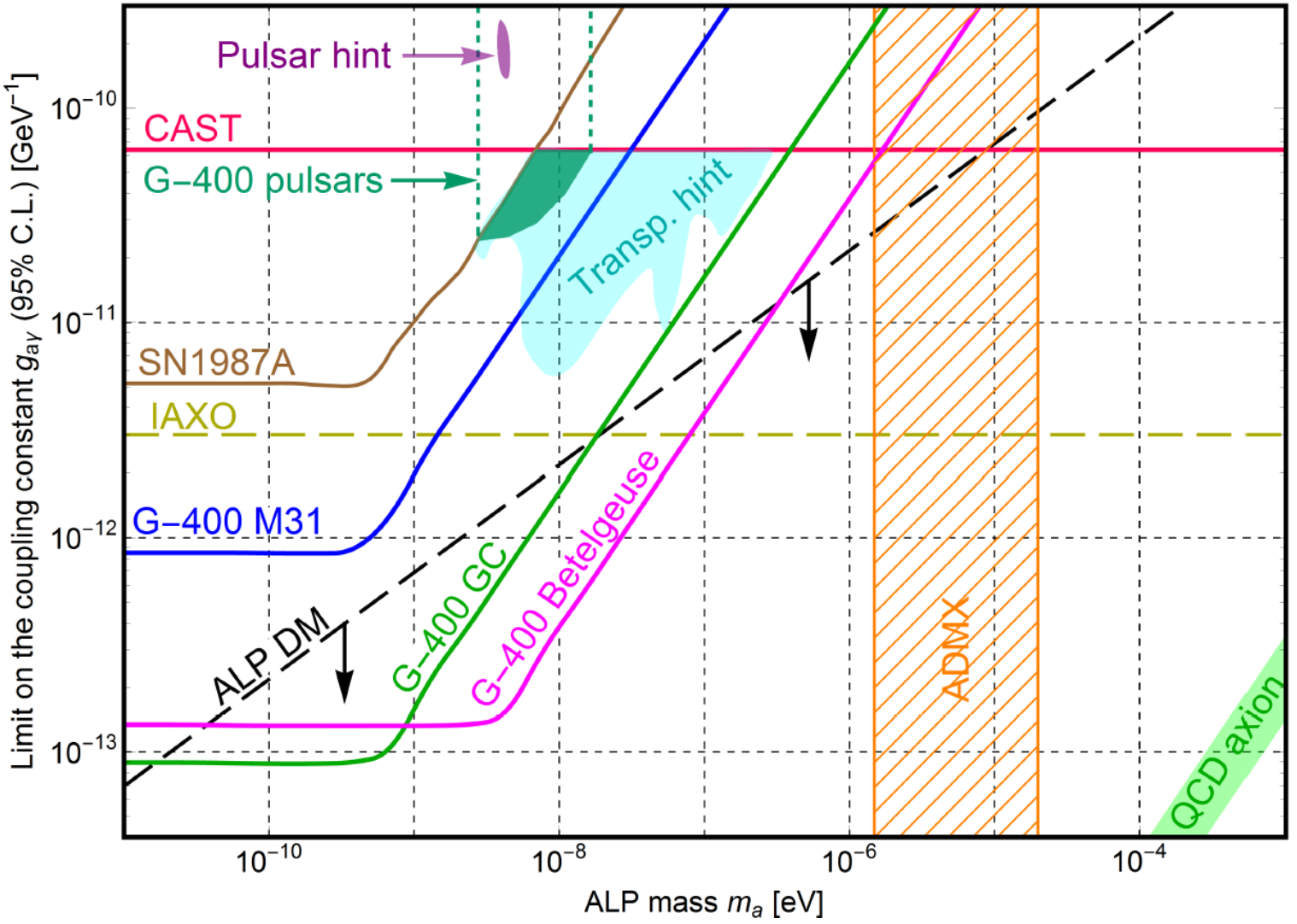
$$P_{a\leftrightarrow\gamma}(E, m_a, g_{a\gamma}, \vec{r}_{SN}) = \frac{1}{1+(E_c/E)^2} \sin^2\left(\frac{g_{a\gamma} B_\perp d}{2}\sqrt{1+\left(\frac{E_c}{E}\right)^2}\right),$$

$$E_c \simeq 2.5 \frac{|m_a^2 - \omega_{pl}^2|}{\mathrm{neV}^2}\left(\frac{\mu\mathrm{G}}{B_\perp}\right)\left(\frac{10^{-11}\ \mathrm{GeV}^{-1}}{g_{a\gamma}}\right)\ \mathrm{GeV}$$

- ALP-photon conversion probability in the uniform magnetic field

However, the SN explosion in Milky Way or M 31 is indeed a rare event - the chance to catch it by GAMMA-400 is ≈ 10%. But pulsars are indeed available.

GAMMA-400 sensitivity to ALP parameters



Conclusions

- GAMMA-400 is expected to bring a significant contribution in the field of DM indirect searches – particularly along the following directions.
- The deep pointed observations of the Galactic center and joint data analysis from both telescopes (GAMMA-400 + Fermi-LAT) may yield the sensitivity gain by factor of ≈ 2 to the diphoton annihilation cross section for the wide range of DM particle masses 0.2-500 GeV in the optimistic case scenario.
- A lucky event of an observation of the Galactic supernova explosion (e.g. Betelgeuse) will be a VERY sensitive probe for ALP parameters: the ALP-photon coupling constant values down to $g_{a\gamma} \approx 10^{-13}$ GeV^{-1} for $m_a \leq 1$ neV can be tested.
- Observations of the bright Galactic pulsars will confirm or refute the ALP signal hint identified in the Fermi-LAT data with $g_{a\gamma} \approx 2 \cdot 10^{-10}$ GeV^{-1} and $m_a \approx 4$ neV.
- Other targets are possible: annihilating WIMPs in globular clusters and dwarf MW satellites, ALPs in NGC 1275 and others.
- More details can be seen in our paper *ArXiv:2005.09032* (accepted for publication in JCAP).
- Project website - *http://gamma400.lebedev.ru/*