“Отчет в связи с переизбранием на должность с.н.с”

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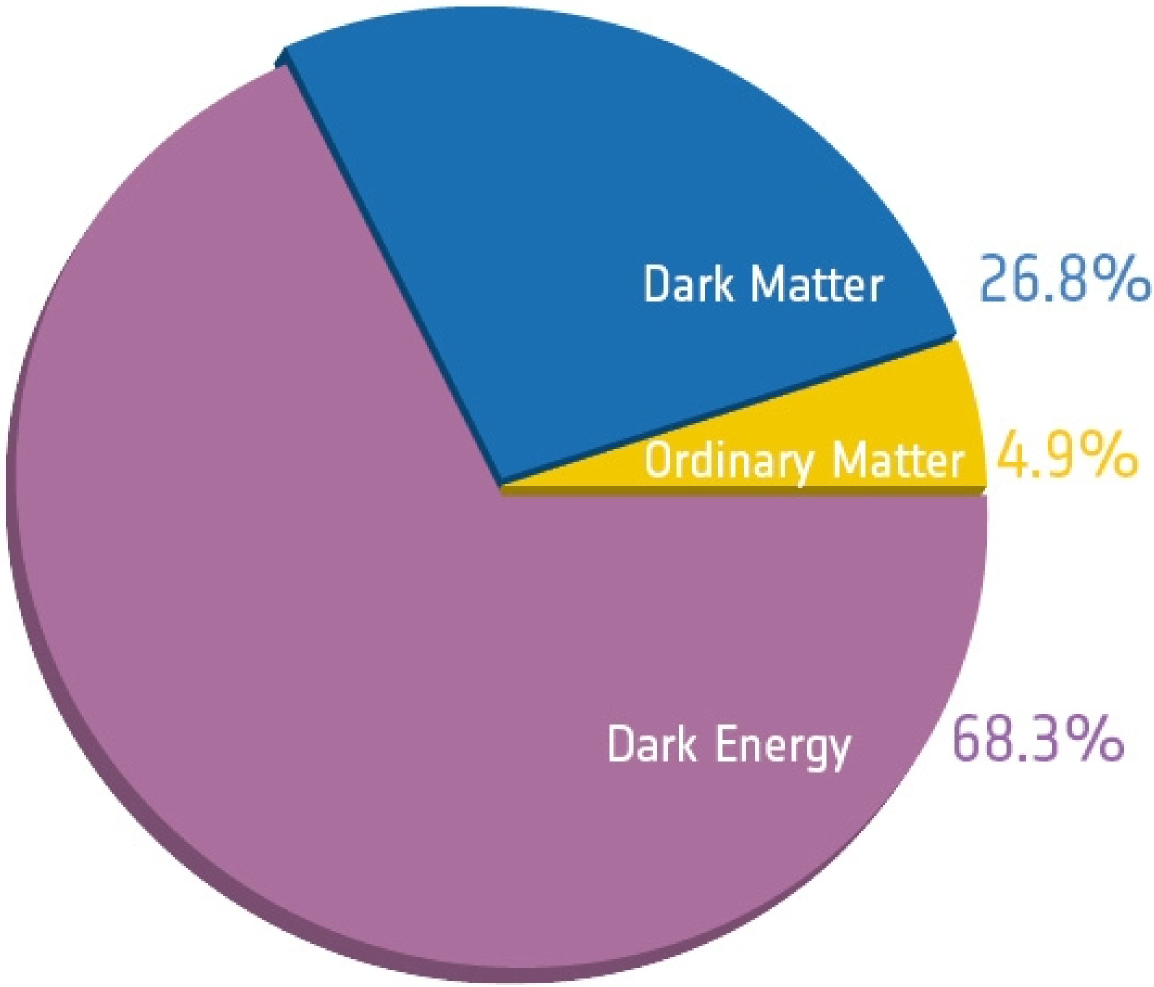
Микросеминар отдела релятивистской астрофизики 22 августа 2017 г.

Введение

- Направление работ 2012-2017
  - Первичные чёрные дыры
  - Галактические и внегалактические магнитные поля + UHECR
  - Гамма-астрономия
  - Разное
- Планы на 2017+
- Библиометрия

DM paradigm



95% of constituting stuff is acting only gravitationally (to our best present knowledge)

DM paradigm

- Let's follow the (C)DM path
- SM extension in a very broad mass range:
  - Axions and ALPs (10^{-9}-10^{-6} eV)
  - Sterile neutrinos (~keV)
  - Neutralinos, e.g. SUSY WIMPS (~GeV-TeV)
  - WIMPzillas (>~10^{12} GeV)
  - ...
  - More and more and more

OR

Primordial Black Holes

PBHs

- Perfect candidate:
  - Stable (if massive enough)
  - Cold
  - Very weakly interacting (i.e. **Dark**)

$$r_{bh} = \frac{2GM_{bh}}{c^2} = 3x10^{-8}\left(\frac{M_{bh}}{10^{20}g}\right)cm$$

e.g. Carr'06, Khlopov'10

Constraints from stellar evolution

- PBHs could be captured by a protostar
- Due to the dynamic friction, they could fall down to the central regions of the star
- After some compact object (WD or NS) would form, PBH would rapidly devour it
- Thus, observation of these objects could put some constraints on PBHs abundance.

F.Capela, MP & P.Tinyakov, 2013a (1209.6021,PRD 87 id. 023507)

Constraints from stellar evolution

- Star formation: GMC is fragmenting into denser clumps

  - $M_{GMC} = 5\text{x}10^5\ M_{sol}$ → $M_{PC} = 1$ Msol
  - $R_{GMC} = 20$ pc → $R_{PC} = 0.02$ pc
  - $\rho_{GMC} = 500$ см$^{-3}$ → $\rho_{PC} = 10^6$ см$^{-3}$

- Some fraction of DM would be gravitationally bound to a forming star. In case of the Maxwellian distribution this fraction could be estimated as:

$$dn = \bar{n}_{\rm DM} \left(\frac{3}{2\pi\bar{v}^2}\right)^{3/2} \exp\left\{\frac{-3v^2}{2\bar{v}^2}\right\} d^3v,$$

$$\rho_{\rm DM,bound} = \bar{\rho}_{\rm DM} \frac{4\pi}{3}\left(\frac{3|\phi_0|}{\pi\bar{v}^2}\right)^{3/2} = \bar{\rho}_{\rm DM} \frac{4\pi}{3}\left(\frac{6G\rho_0 R_0^2}{\bar{v}^2}\right)^{3/2}$$

F.Capela, MP & P.Tinyakov 2013a

Constraints from stellar evolution:AC

- Adiabatic contraction: DM is falling inside deepening potential well of the forming star
- $$I = \oint pdq = const$$
- Circular orbits, *L* conserved. ==> *rM(r)*=const
- This process would operate even when the collapse time scale is comparable to the free fall time
- However, there is no effective way for DM to lose its initial angular momentum, thus the final enhancement would be ~$r^{-3/2}$ for initially uniform cloud

$$\rho_{DM}(r) = \frac{1}{2}\rho_{DM,bound}\left(\frac{R_0}{r}\right)^{3/2}$$

Constraints from stellar evolution

- We need to look for regions with large abundance of slowly moving (small velocity dispersion) DM

- Old globular clusters of the galactic halo (?)
- Simulations show that they were formed at z=10-12 in rare density peaks and the initial DM density could reach 10 000 GeV/cm^3

$M_*/M_\odot$	ρ_{PSC}, GeV cm^{-3}	M_{bound}, g
1	2×10^1	4.4×10^{19}
2	5.2×10^1	2.5×10^{20}
3	9.2×10^1	7.2×10^{20}
4	1.4×10^2	1.5×10^{21}
5	1.9×10^2	2.6×10^{21}
6	2.4×10^2	4.2×10^{21}
7	3×10^2	6.2×10^{21}
8	3.6×10^2	8.7×10^{21}
10	5×10^2	1.6×10^{22}
12	6.4×10^2	2.4×10^{22}
15	8.7×10^2	4.3×10^{22}

TABLE II: Density of DM bound to the prestellar core, ρ_{PSC}, and the total mass M_{bound} of DM contained in a star right after its formation in a GC with the central DM density $\rho_{DM} \sim 10^4$ GeV cm^{-3} and velocity dispersion $\bar{v} = 7$ km s^{-1} for different star masses.

Constraints from stellar evolution:constraints

- If N_{BH}<1, no constraints arise

- If N_{BH}>1, then we could constrain PBH fraction

$$\frac{\Omega_{PBH}}{\Omega_{DM}} \leq \frac{1}{N_{BH}}$$

$$N_{BH} = M_{DM}(r_c)/m_{BH}$$

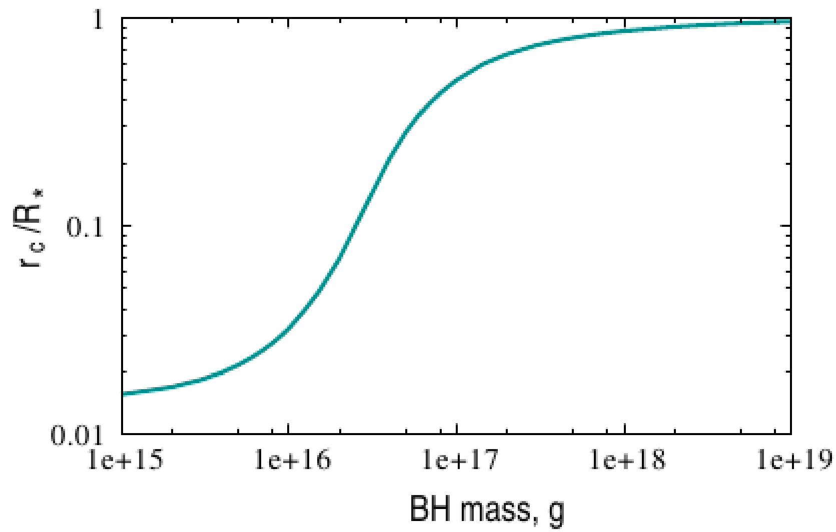


FIG. 2: The dependence of the size r_c of the collection region (the region from which the PBHs captured by the star at its formation have enough time to sink to within the radius of the future compact remnant, WD or NS) on the PBH mass, corresponding to the case of WD for $M_* = M_\odot$.

- More massive PBHs would sink faster but their number is much lower (we have fixed density of PBHs)

Constraints from stellar evolution: dynamic friction

- When a massive body is moving through a medium some drag force would emerge. Some density enhancement would be formed behind a moving body due to the effect of gravitational focussing. Thus this body would experience action of an additional attractive force, i.e. dynamical friction

$$\frac{\mathbf{f}}{m_{\rm BH}} = -\gamma(v)\mathbf{v}$$

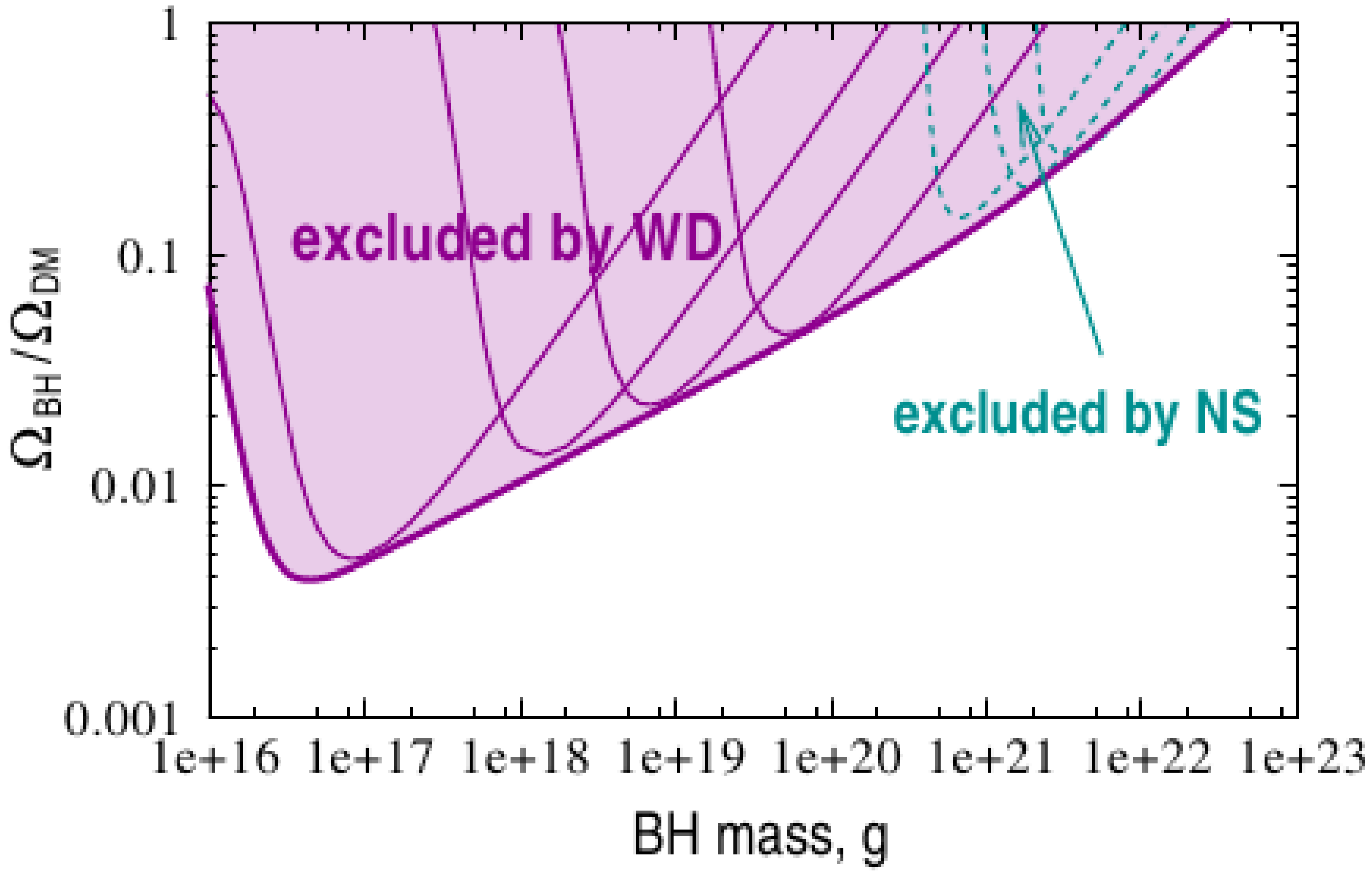
$$\gamma(v) = 4\pi G^2 \rho(r) m_{\rm BH} \ln(\Lambda) \frac{F(X)}{v^3},$$

$$F(X) = \mathrm{erf}(X) - 2X\exp(-X^2)/\sqrt{\pi},$$

$$X = v/(\sqrt{2}\sigma),$$

- Friction is more effective for **massive** bodies
- We are interested in the fraction of PBHs that would have spiralled down to the radius of future NS/WD in the star lifetime

Constraints from stellar evolution: constraints



Constraints from stellar evolution: revisited

- Previous estimates were based onto clear distinction: DM inside/outside a star always remains inside/outside
- Clearly insufficient—most of the orbits are radial
- Enhancement factor is ~2×10^3

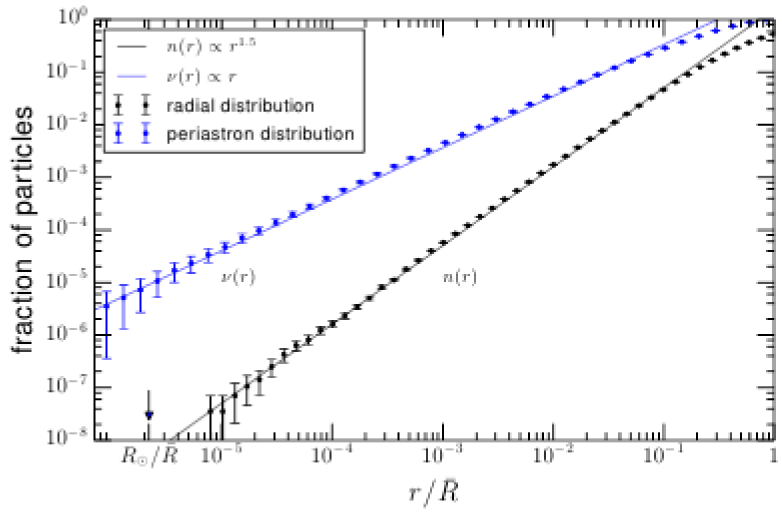
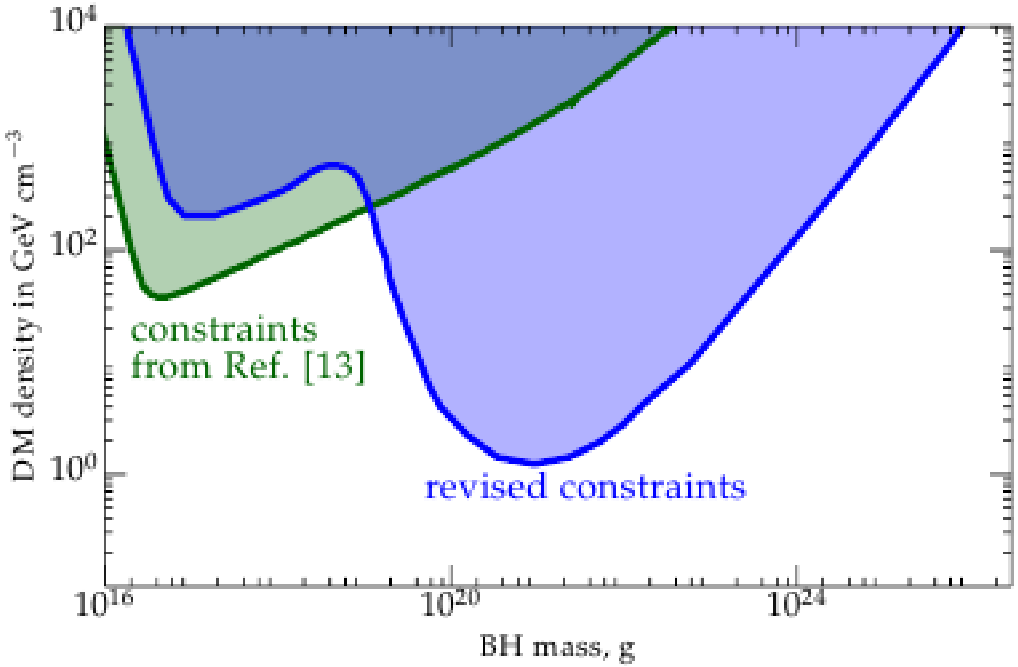


FIG. 1: *Lower curve:* The fraction of particles $n(r)$ that are found within radius r at the end of the adiabatic contraction. $\bar{R}$ is the initial radius of the prestellar core. *Upper curve:* The fraction of particles $\nu(r)$ whose orbits have the periastron smaller than r. Lines show the power laws $n(r) \propto r^{1.5}$ and $\nu(r) \propto r$. The errorbars represent statistical errors.

Constraints from stellar evolution: revisited

- Much more DM could be captured (depends on DM-nucleon interaction strength)
- Again, taking PBH:

$$t_{\rm capt} \simeq 2\tau\sqrt{\xi_0} \sim 2\times 10^8 \text{ yrs}\left(\frac{10^{22}\text{ g}}{m_{\rm BH}}\right) \qquad \tau = \frac{\pi R_*^{5/2} v^2}{4 G m_{\rm BH}\sqrt{GM}\ln\Lambda},$$



FC,MP&PT, PRD2014 (1403.7098)

FIG. 2: Constraints on the abundance of PBHs assuming the DM velocity dispersion of 7 km/s. The constraints derived in Ref. [13] are in green, while the revised ones are in blue.

PBH capture by NSs

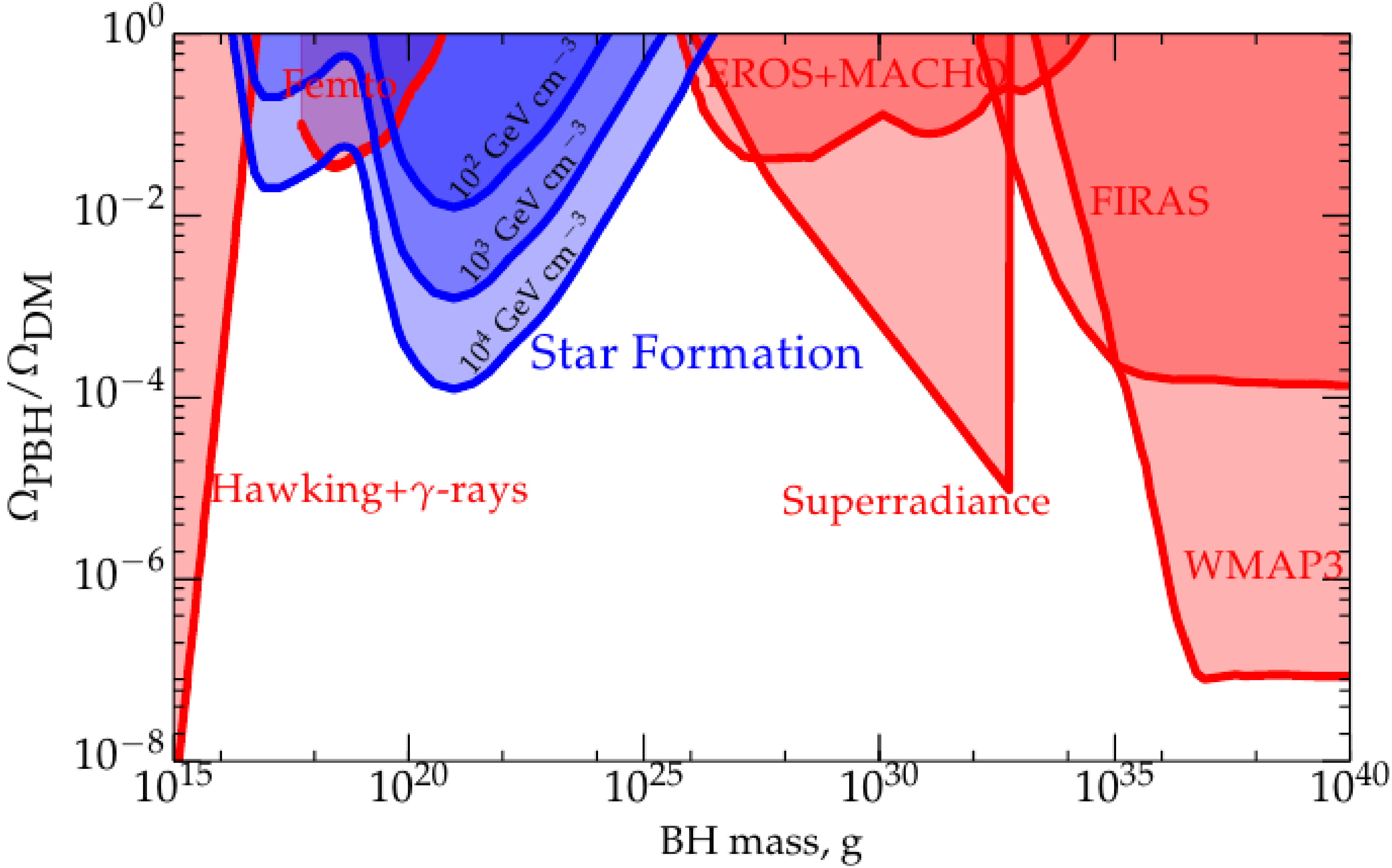
- Idea is quite similar – if a NS could capture a PBH, then the latter one would rapidly sink down to the centre of a NS and after that quickly destroy it.

- NSs in GCs are about 10 billion years old and we adopt high DM density ~10^3 GeV/cm^3

- Again we would employ the dynamic friction—if a PBH could lose enough energy to become bound (E_{tot}<0), all the subsequent fly-throughs would quickly (~several million years) would bring a PBH to the center

- Direct accretion is not as effective as a drag force (~ 25% contribution)

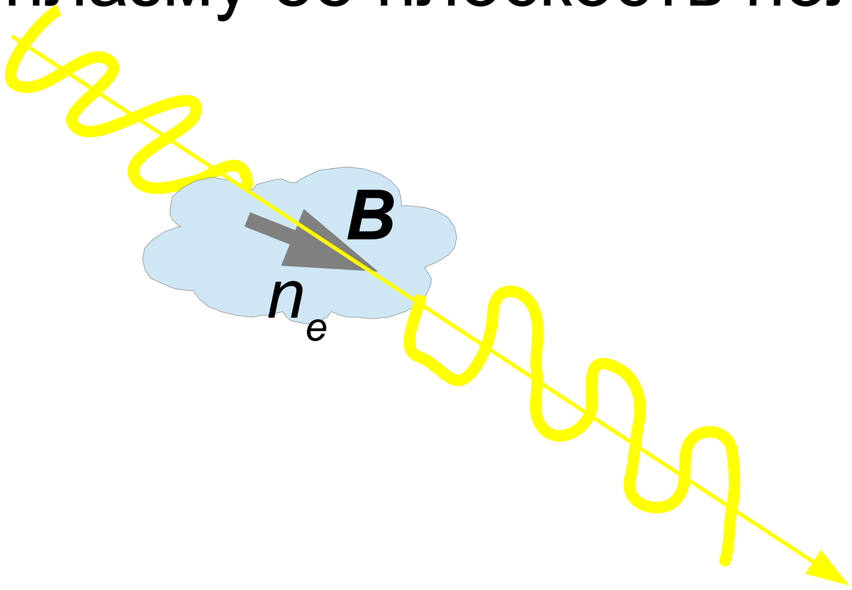
F. Capela, MP &P. Tinyakov 2013b (1301.4184,PRD 87 id. 123524)



PRD2013a,b; PRD2014

“Магнитное поле в Галактике и за её пределами. Распространение космических лучей сверхвысоких энергий.”

- Радионаблюдения (синхротрон, RM) являются основным средством исследования МП
- На самых больших масштабах (>Мпк) остаётся, в основном, RM
- При распространении ЭМ волны через намагниченную плазму её плоскость поляризации вращается



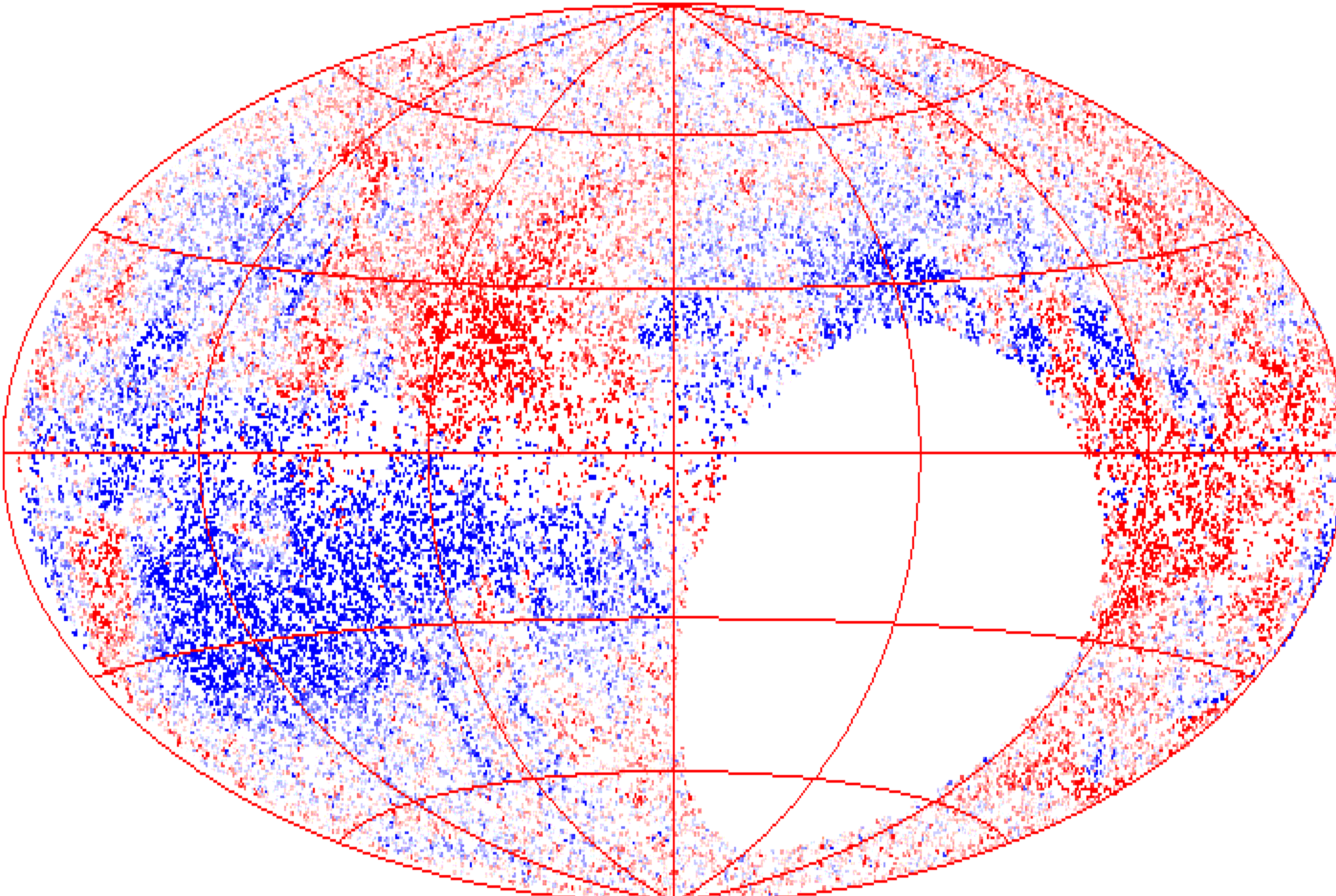
$$\Delta\psi = RM\,\lambda^2$$

$$RM = 0.81\int_0^D n_e B_{par}\,dl$$

Магнитные поля. Исходные данные.

- Исходные данные – каталог NVSS (NRAO VLA Sky Survey)
- 2 близких полосы по 42 МГц (1365 и 1435 Мгц)
- $\delta > -40^{\circ}$
- Всего 1.8 М источников
- Для небольшой доли источников удалось получить RM
- NVSS RM: всего 37 543 источника, ошибка ±11 рад $м^{-2}$
- Примерно 15-кратное увеличение числа источников, более равномерное покрытие

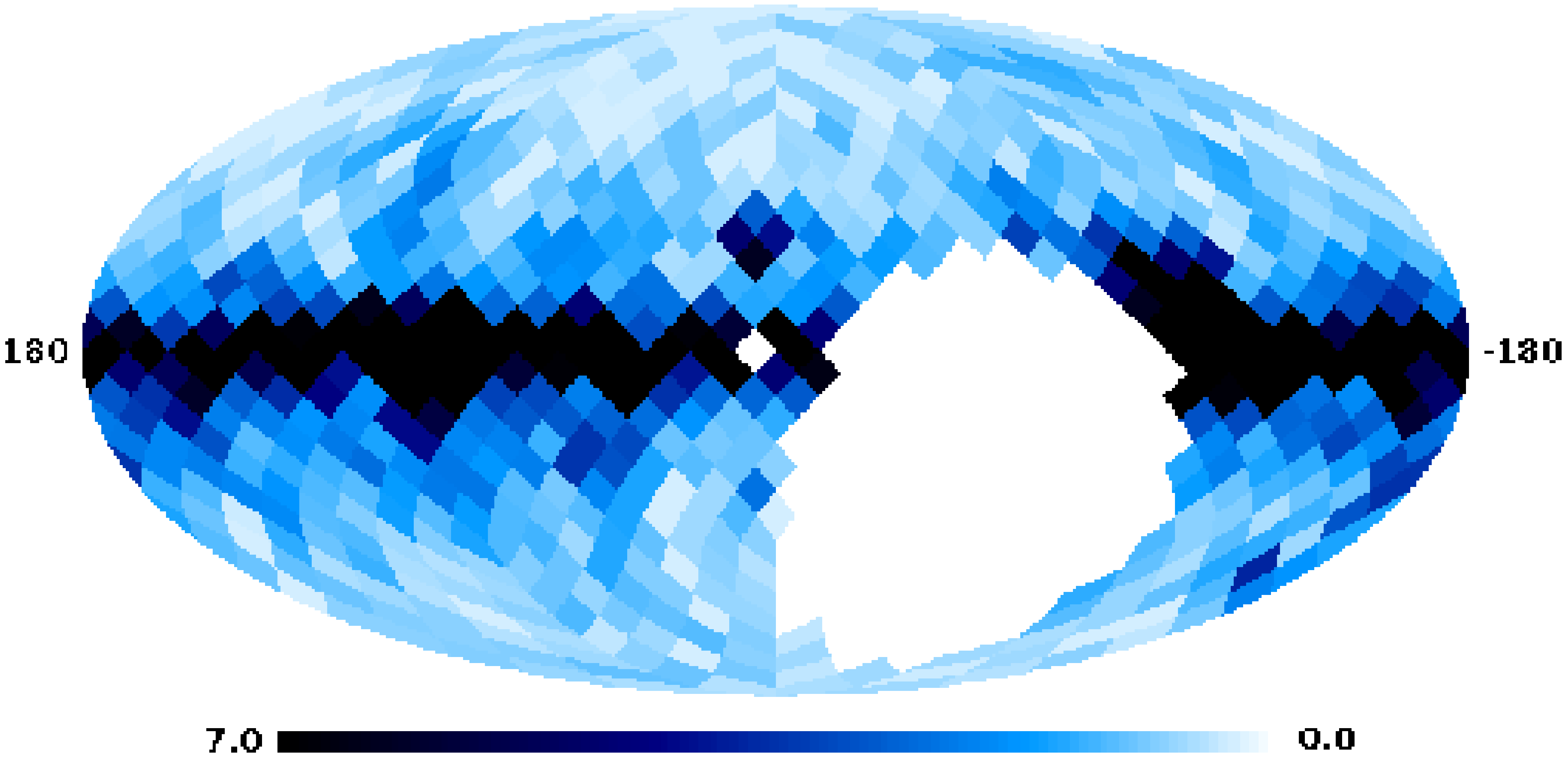
Магнитные поля. NVSS.



Распространение КЛСВЭ в Галактике

- Распространение КЛСВЭ в Галактике
  - Отклоняются МП
  - Регулярную компоненту теоретически можно учесть
  - Случайная компонента по амплитуде превосходит регулярную, чисто деструктивный эффект
  - Если КЛСВЭ сильно отклоняются в СГМП, то перспективы ухудшаются
  - Отклонения можно оценить из данных RM!
  - $\theta \sim \int B_{\perp} dl$, $RM \sim \int B_{||} n_e dl$
  - Разброс в данных RM даст оценку на отклонения в СГМП

Карта отклонений КЛСВЭ



MP, Tinyakov, Urban, MNRAS2013

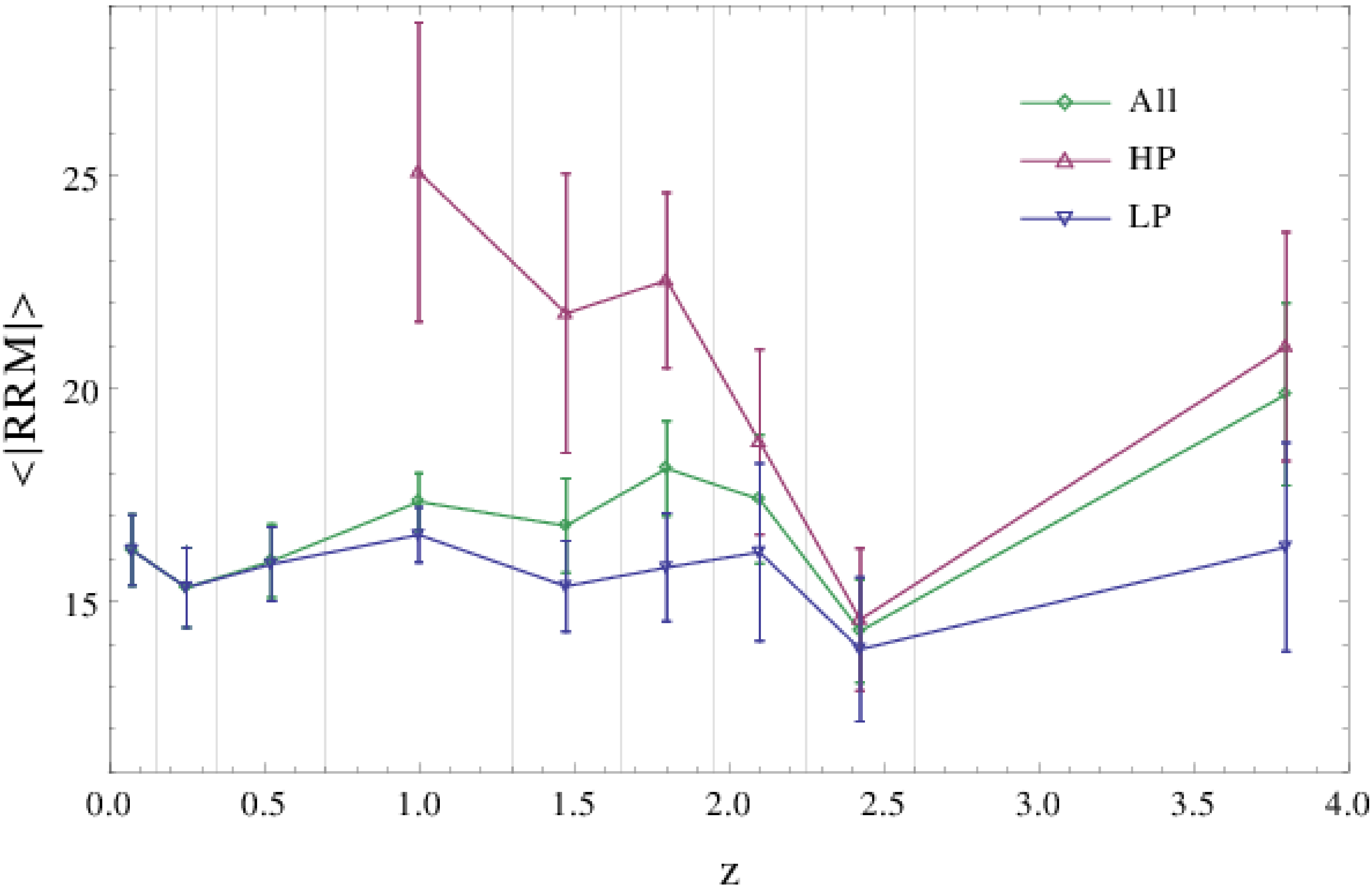
Эволюция RM(z)?

- Эволюция RM с *z*
  - Из RM NVSS 4002 источника с известным *z*
  - Можно уже попробовать изучить – пока противоречивые результаты
  - Изучалась эволюция *оценки* собственных RM – Rm_{in}:

$$RM_{in}=RM-RM_{gal}$$

  - Мотивация – зависимость собственных RM от свойств источника, прежде всего светимости
  - Порог L(1.4 Ггц) = $10^{27.8}$ Вт $Гц^{-1}$

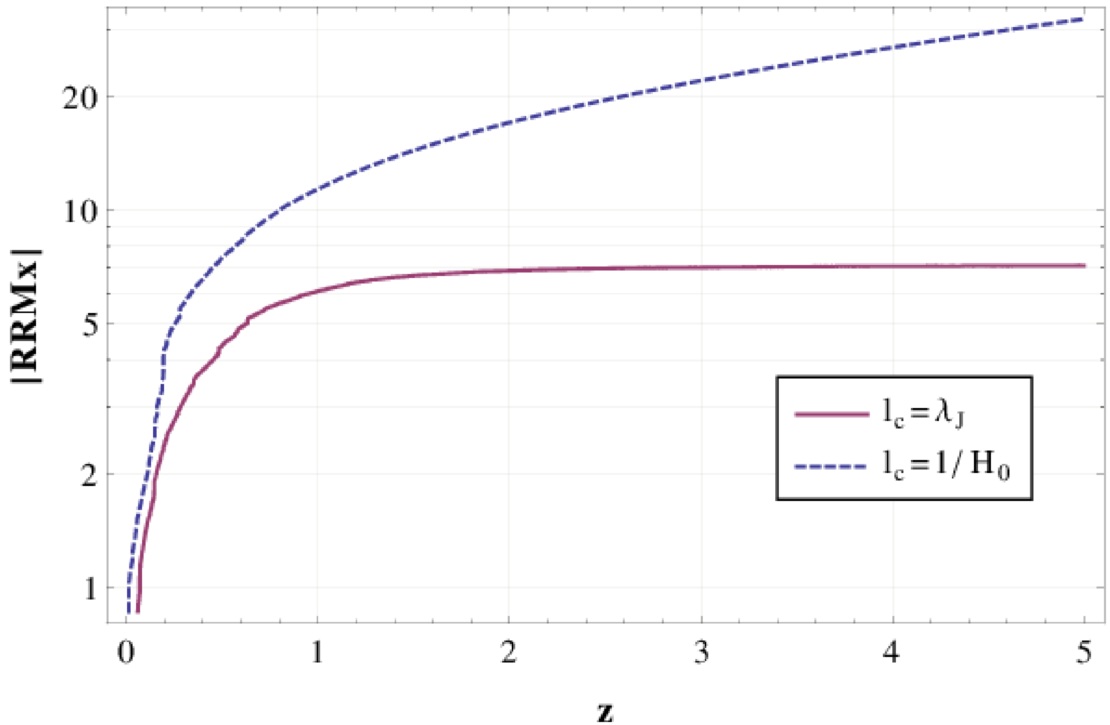
Эволюция RM(z)?



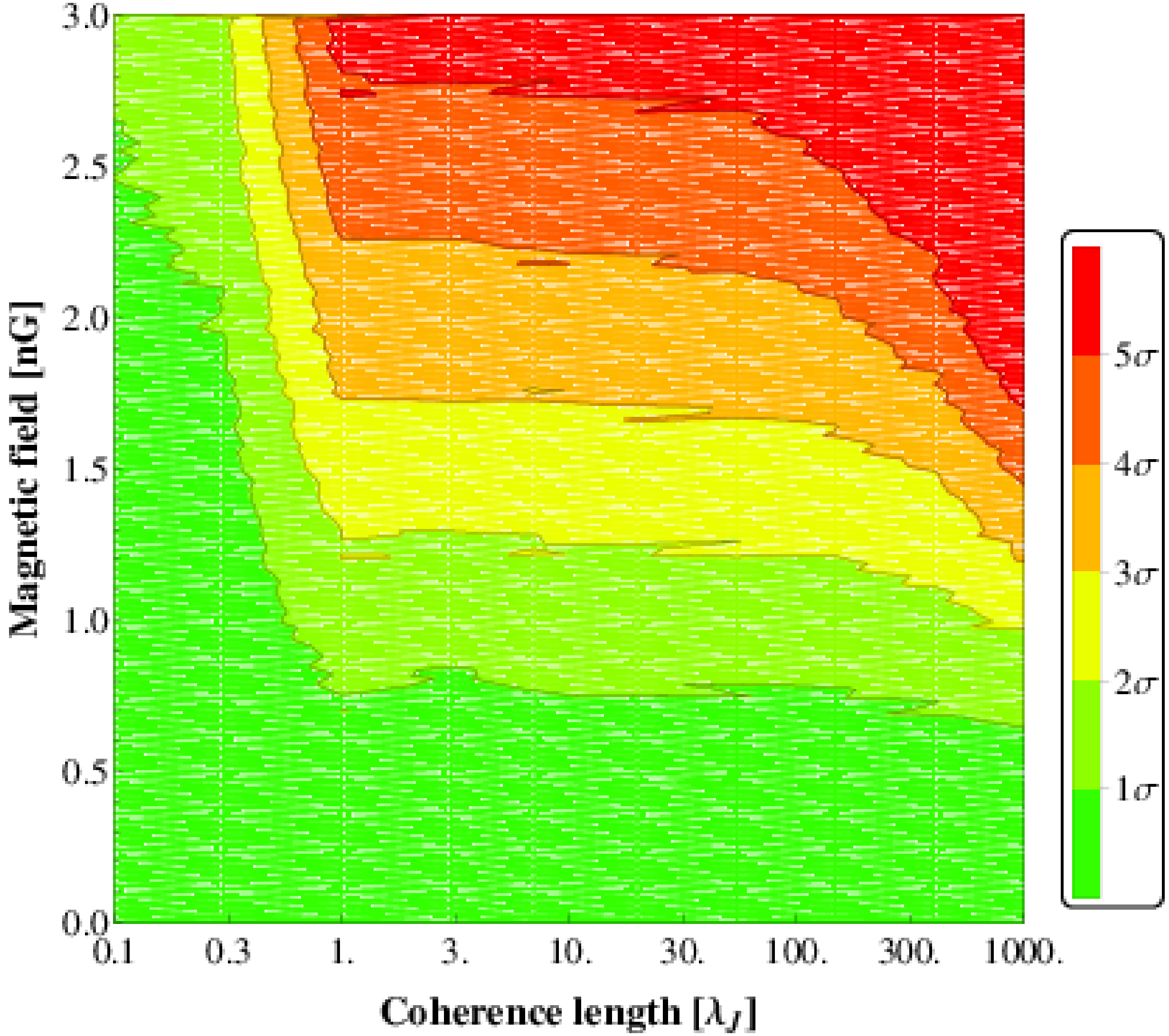
MP, Tinyakov, Urban, MNRAS2015

Внегалактичесие поля

- Ограничения на космологические поля
  - RM “слабых” источников не эволюционирует вплоть до *z*~5
  - Если бы были космологические поля заметной силы, то следовало бы ожидать какого-то роста с увеличением расстояния



Внегалактические поля



- Поля с длиной когерентности в 1 Мпк не могут быть сильнее 1.2 нГс (2σ), если же длина сравнима с горизонтом, то поля ограничиваются сверху величиной 0.5нГс

MP, Tinyakov, Urban, PRL, 2016

Гамма-астрономия

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY LETTERS

Mon. Not. R. Astron. Soc. **421,** L14–L18 (2012) doi:10.1111/j.1745-3933.2011.01197.x

Gamma-ray burst observations by *Fermi* Large Area Telescope revisited: new candidates found

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ABSTRACT

We search the *Fermi* Large Area Telescope (LAT) photon data base for an extended gamma-ray emission which could be associated with any of the 581 previously detected gamma-ray bursts (GRBs) visible to the *Fermi*-LAT. For this purpose, we compare the number of photons with energies $E > 100$ MeV and $E > 1$ GeV which arrived in the first 1500 s after the burst from the same region, to the expected background. We require that the expected number of false detections does not exceed 0.05 for the entire search and find the high-energy emission in 19 bursts, four of which (GRB 081009, GRB 090720B, GRB 100911 and GRB 100728A) were previously unreported. The first three are detected at energies above 100 MeV, while the last

Гамма-астрономия

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NUCLEI, PARTICLES, FIELDS, GRAVITATION, AND ASTROPHYSICS

Variable Gamma-Ray Sky at 1 GeV[1]

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Abstract—We search for the long-term variability of the gamma-ray sky in the energy range $E > 1$ GeV with 168 weeks of the gamma-ray telescope Fermi-LAT data. We perform a full sky blind search for regions with variable flux looking for deviations from uniformity. We bin the sky into 12288 pixels using the HEALPix package and use the Kolmogorov–Smirnov test to compare weekly photon counts in each pixel with the constant flux hypothesis. The weekly exposure of Fermi-LAT for each pixel is calculated with the Fermi-LAT tools. We consider flux variations in a pixel significant if the statistical probability of uniformity is less than 4×10^{-6}, which corresponds to 0.05 false detections in the whole set. We identified 117 variable sources, 27 of which have not been reported variable before. The sources with previously unidentified variability contain 25 active galactic nuclei (AGN) belonging to the blazar class (11 BL Lacs and 14 FSRQs), one AGN of an uncertain type, and one pulsar PSR J0633+1746 (Geminga).

Гамма-астрономия: пузыри Ферми вокруг M31

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

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Evidence of *Fermi* bubbles around M31

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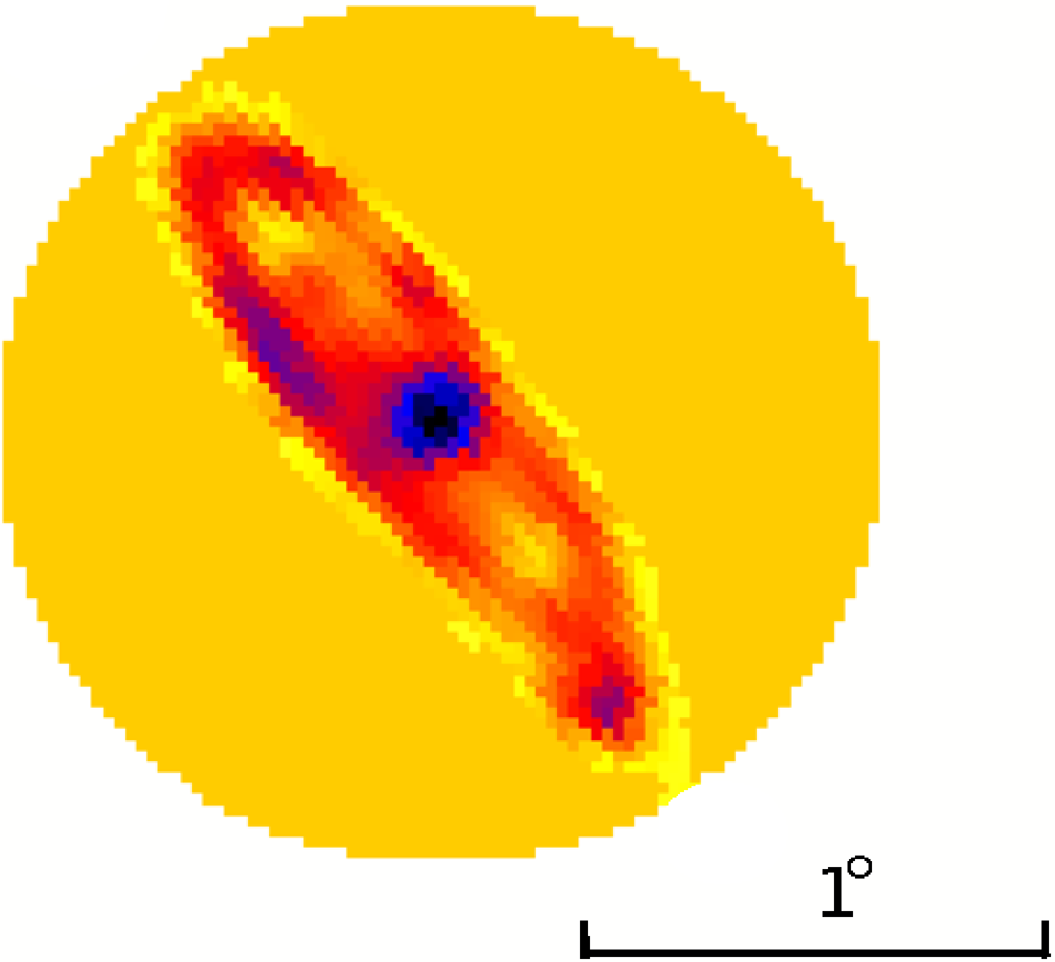
ABSTRACT

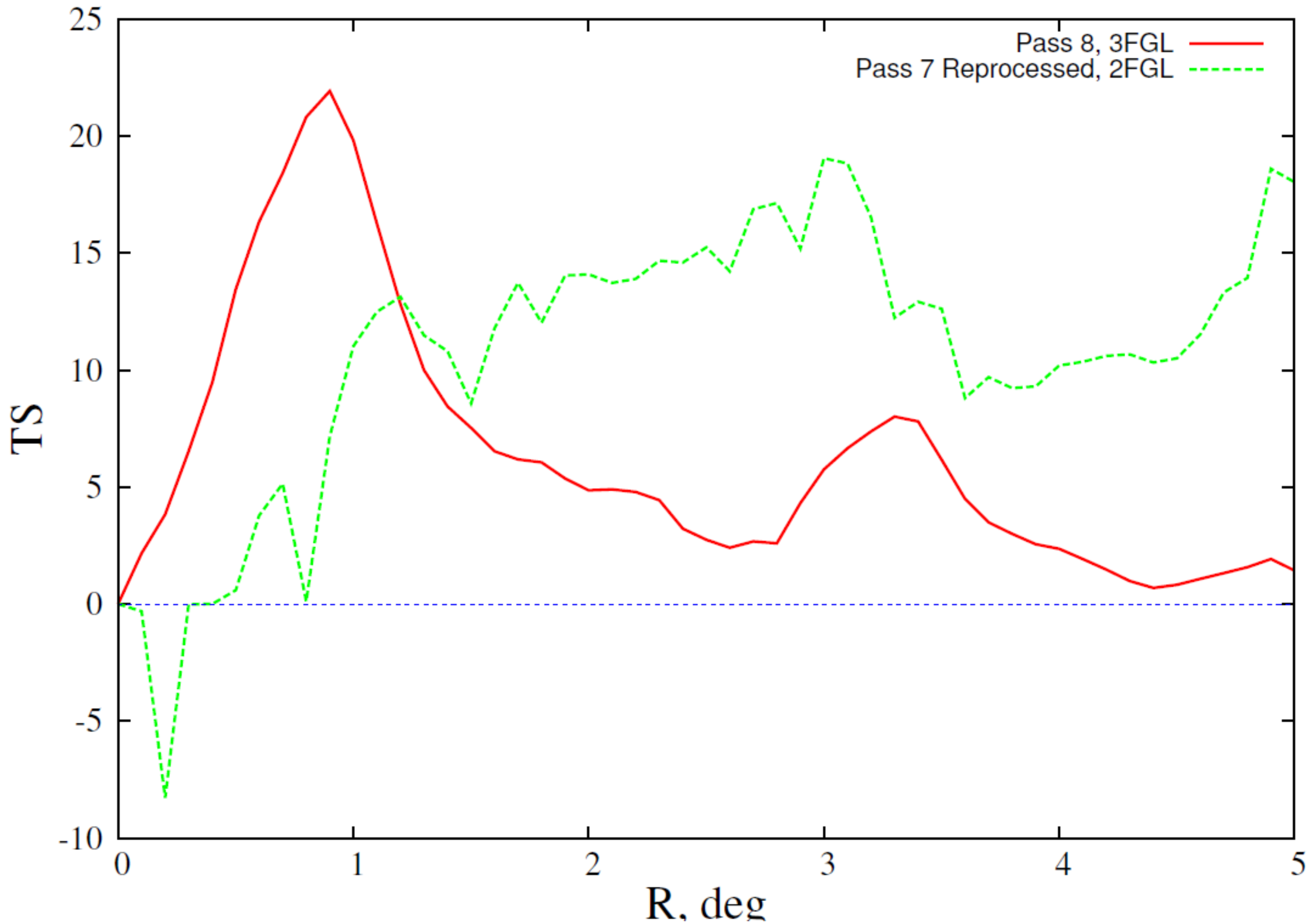
Gamma-ray haloes can exist around galaxies due to the interaction of escaping galactic cosmic rays with the surrounding gas. We have searched for such a halo around the nearby giant spiral Andromeda galaxy M31 using almost 7 yr of *Fermi* LAT data at energies above 300 MeV. The presence of a diffuse gamma-ray halo with total photon flux $2.6 \pm 0.6 \times 10^{-9}$ cm^{-2} s^{-1}, corresponding to a luminosity (0.3–100 GeV) of $(3.2 \pm 0.6) \times 10^{38}$ erg s^{-1} (for a distance of 780 kpc) was found at a 5.3σ confidence level. The halo form does not correspond to the extended baryonic H I disc of M31, as would be expected in hadronic production of gamma photons from cosmic ray interaction, nor it is spherically symmetric, as could be in the case of dark matter annihilation. The best-fitting halo template corresponds to two 6–7.5 kpc bubbles symmetrically located perpendicular to the M31 galactic disc, similar to the '*Fermi* bubbles' found around the Milky Way centre, which suggests the past activity of the central supermassive black hole or a star formation burst in M31.

Key words: cosmic rays – ISM: magnetic fields – galaxies: individual: M31 – gamma rays: galaxies.

Гамма-астрономия: пузыри Ферми вокруг M31

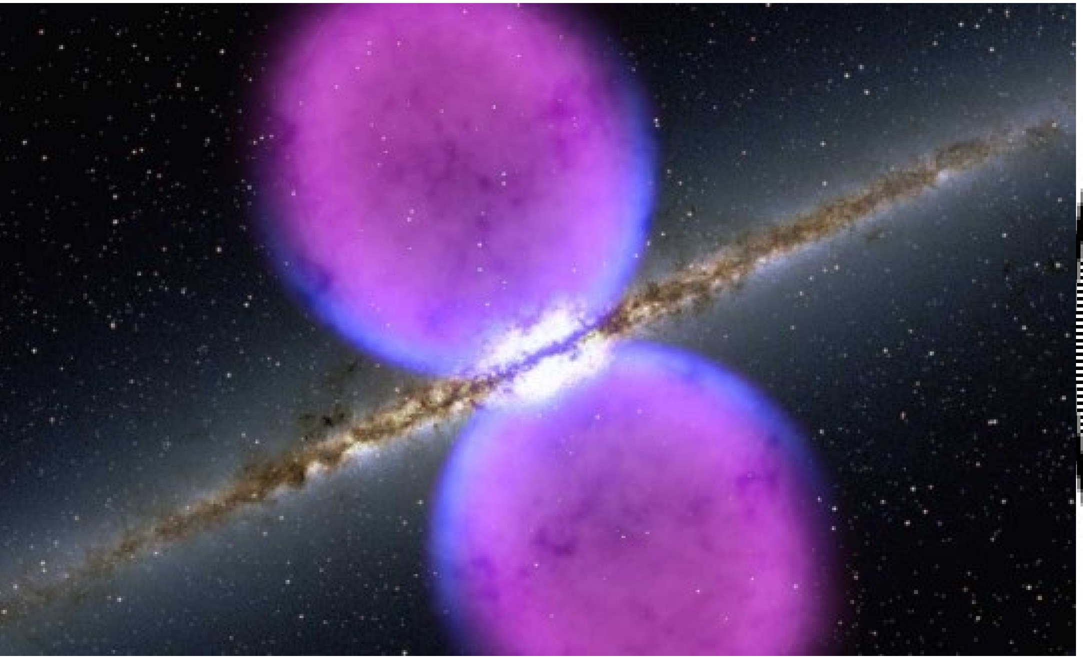


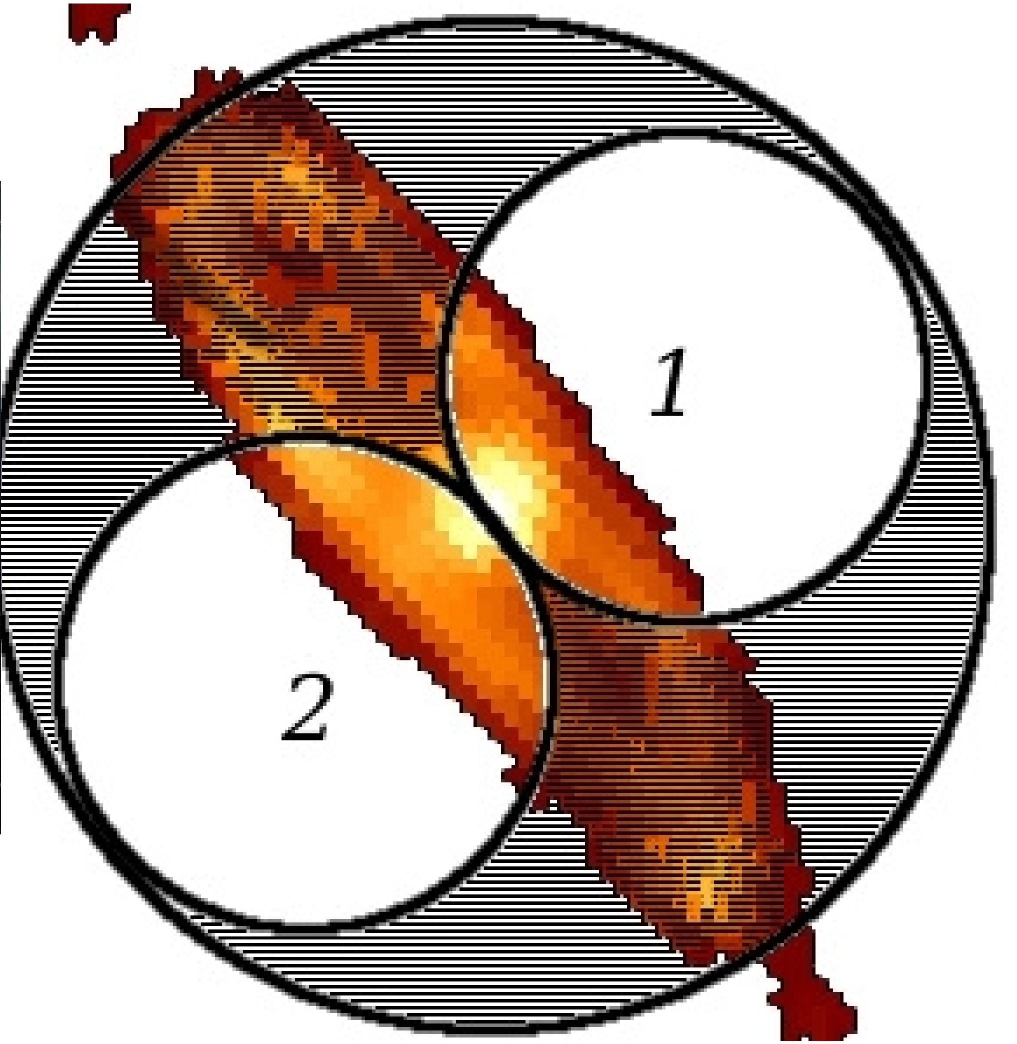
Гамма-астрономия: пузыри Ферми вокруг M31



- Best result for halo R_{halo}**=0.9 deg (12-15 kpc)**
- Statistical significance of halo detection is **~4.7σ**
- Halo spectrum with spectral index **p=2.3±0.1**
- **F_γ (0.3-100 GeV)=(3.2+/-1.0)×10^{-9} ph cm^{-2} s^{-1}**
- **L_γ (0.3-100 GeV)=(4+/-1.5)×10^{38} erg s^{-1}**

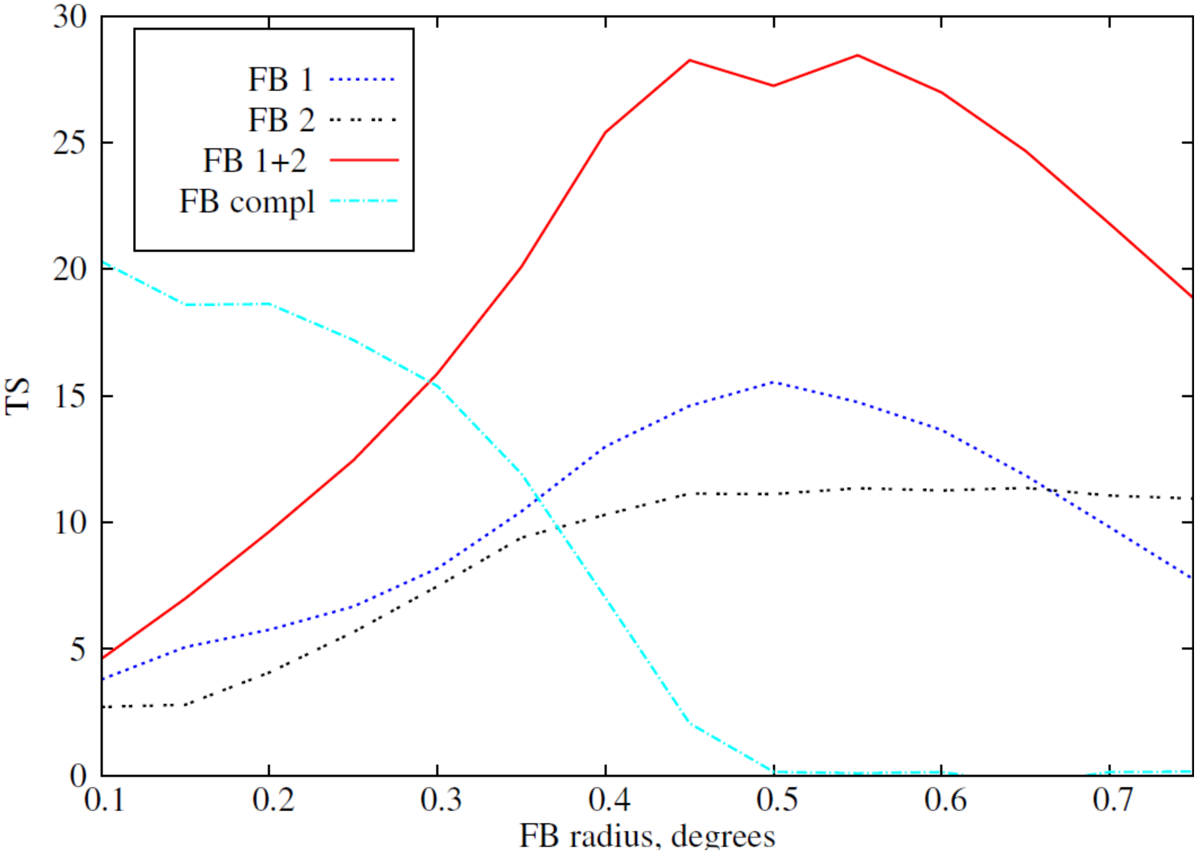
M31: Fermi-bubble like templates



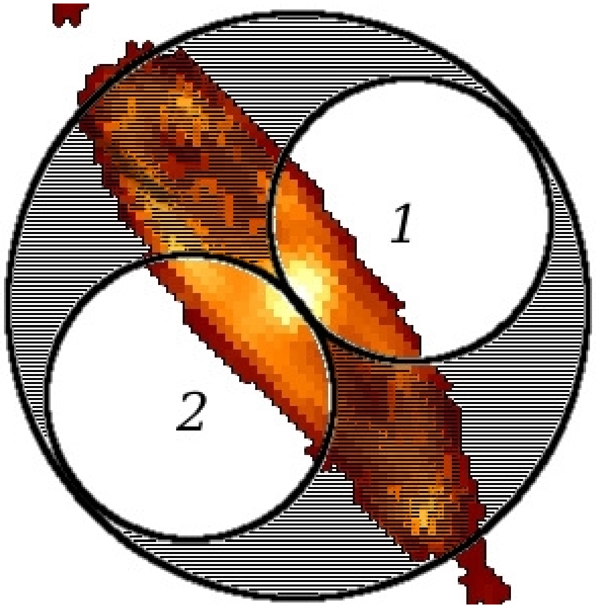


- Two spherical 0.9 deg lobes symmetrically placed around M31 centre
- Complementary region (shaded) for control

M31 Fermi-bubbles: results



model	TS	F_{300}, 10^{-9} (cm^{-2} s^{-1})	Γ
IRAS only	–	2.9 ± 0.4	2.4 ± 0.1
FB 1	14.6	1.4 ± 0.5	2.5 ± 0.3
FB 2	11.1	0.72 ± 0.35	2.0 ± 0.2
FB 1+2	28.2	2.6 ± 0.6	2.3 ± 0.1
FB_{compl}	2.0	1.1 ± 0.9	2.5 ± 0.4
$0.9°$ circle	22.0	3.2 ± 1.0	2.3 ± 0.1



- **TS=28.2**
- **F(0.3-100 GeV)= (2.6+/-0.6)x10^{-9}**
- **p=2.3+/- 0.1**
- **L=(3.2+/- 0.6)x 10^{38} erg/s**

Гамма-астрономия: WR+O двойные

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **457**, L99–L102 (2016) doi:10.1093/mnrasl/slv205

The *Fermi*-LAT view of the colliding wind binaries

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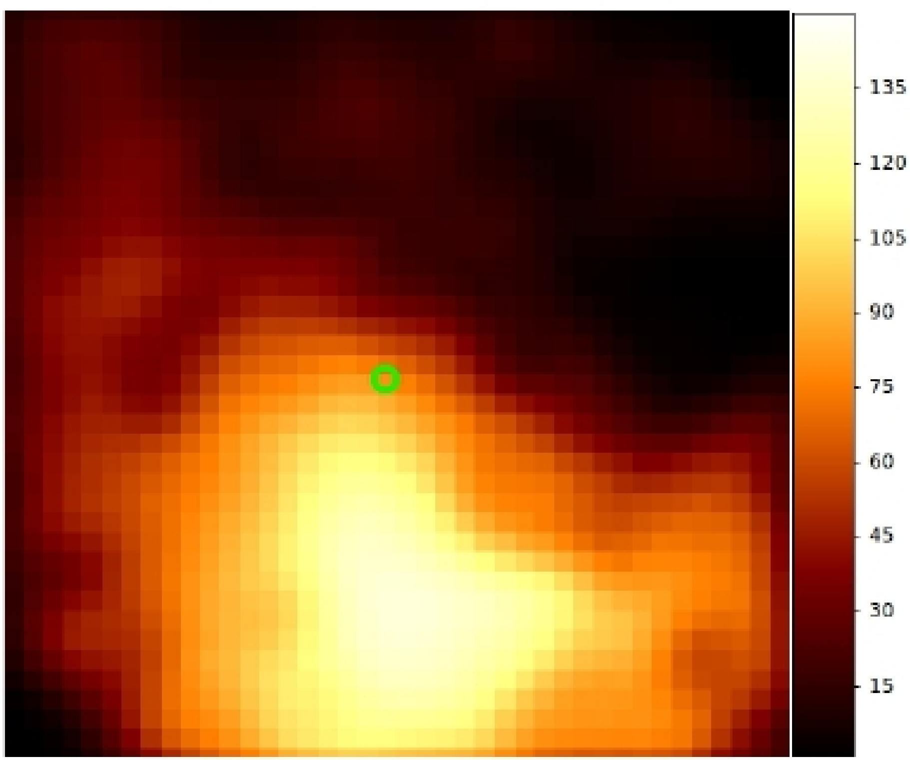
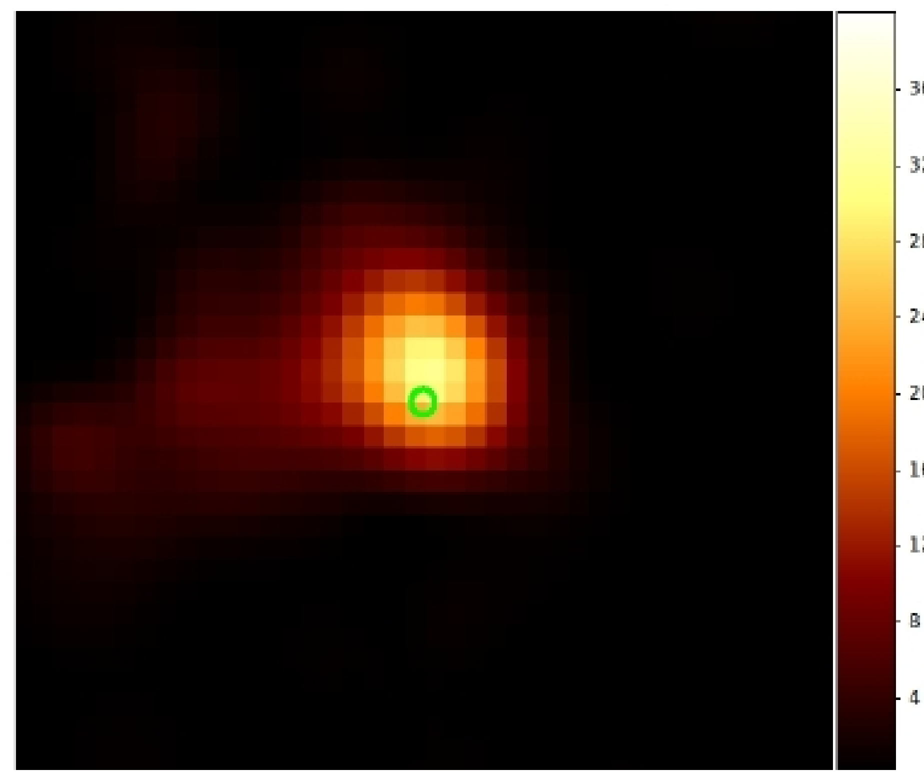
Гамма-астрономия: WR+O двойные

- Источники очень близко к гал. плоскости – могут быть просто артефактами фона

- Карта *TS* 2°x2° с центром на источниках



WR 147 (и другие)



WR 11

WR 11 (γ Vel)

- Ближайшая система на расстоянии *d*=340 пк
- Тесная система: *a*~1.2 au, *P*=78.53 сут, *e*=0.32

Parameter	unit	WC8	O7.5
Mass, M	$M_\odot$	9.0	29.0
Mass-loss rate, $\dot{M}$	10^{-7} $M_\odot$ yr^{-1}	80	1.8 (1)
Terminal wind velocity, v^∞	$km\ s^{-1}$	1450	2500 (1)
Luminosity, L	10^5 $L_\odot$	1.7	2.8

References: If not otherwise specified, all values are taken from (North et al. 2007); (1) (De Marco & Schmutz 1999).

$$P_W = 5.8 \times 10^{36} \text{ эрг с}^{-1}$$

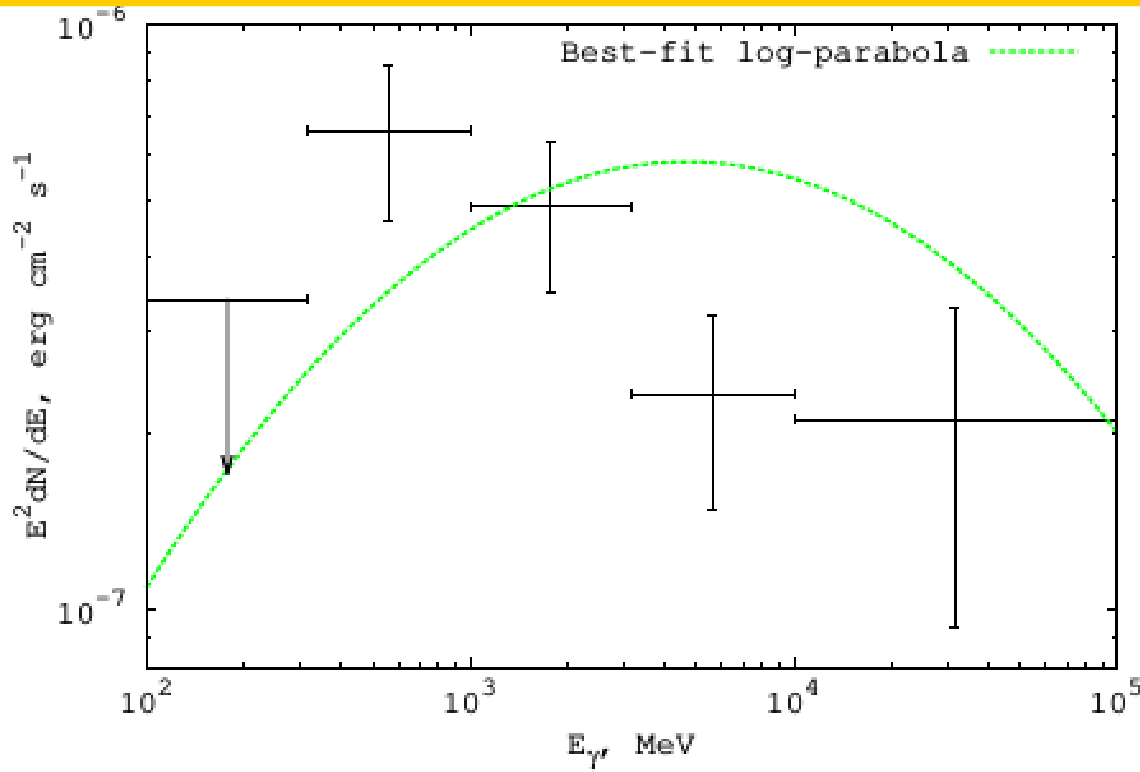
$$\eta = 0.04$$

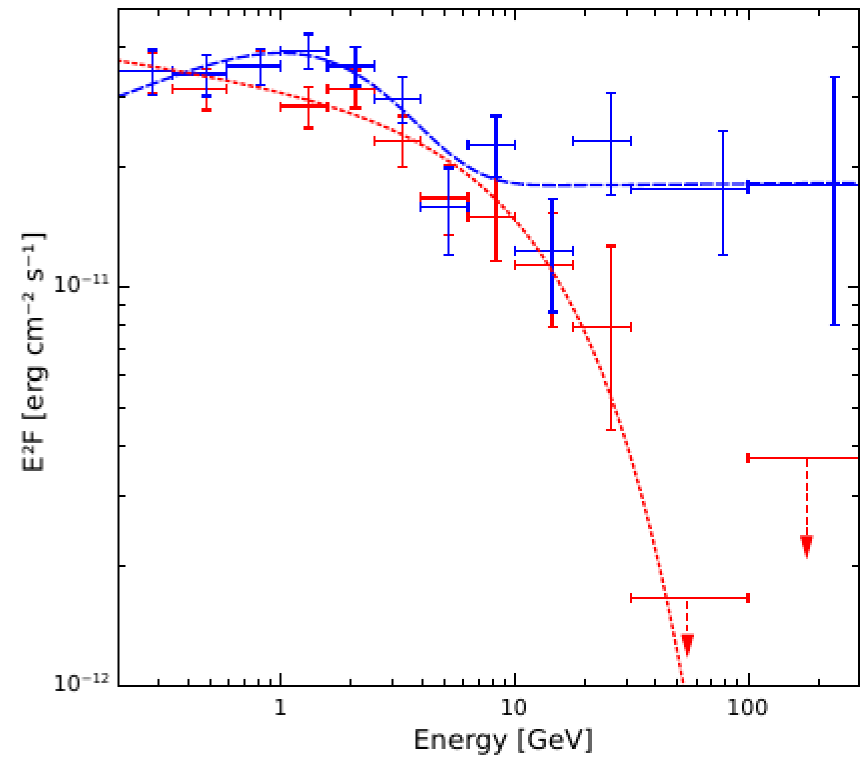
$$P_{CWZ} = 2.3 \times 10^{35} \text{ эрг с}^{-1}$$

WR 11 (γ Vel)

- TS_{PL}=37.7 (6.1σ)
- Спектр лучше описывается более сложными моделями (TS_{LP}=41.5, TS_{BPL}=44.3)
- Всё равно недостаточно, есть жёсткий хвост на E>10 ГэВ, нужно добавлять вторую компоненту

WR 11 (γ Vel)





Reitberger et al, 2015

- Спектр похож на η Car в эпоху периастра.

- $a_{\eta\ Car}$ ~ 15 au, но e=0.9 и d_{min}=1.5 au, что сравнимо с расстояниями в WR11

WR 11 (γ Vel)

- F_γ=(1.8±0.6)x10^{-9} см$^{-2}$с$^{-1}$
- F_E=(2.7±0.5)x10^{-12} эрг/(см^2 с)
- L_γ = (3.7±0.7)x10^{31} эрг/с
- $L_\gamma = 6\text{x}10^{-6}\,P_W = 2\text{x}10^{-4}\,P_{CWZ}$

Гамма-астрономия: гало у пульсаров

PHYSICAL REVIEW D **94,** 063004 (2016)

Constraining the production of cosmic rays by pulsars

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(Received 7 June 2016; published 13 September 2016)

One of the possible sources of hadronic cosmic rays (CRs) are newborn pulsars. If this is indeed the case, they should feature diffusive gamma-ray halos produced by interactions of CRs with interstellar gas. In this paper we try to identify extended gamma-ray emission around young pulsars, making use of the 7-year Fermi-LAT data. For this purpose we select and analyze a set of eight pulsars that are most likely to possess detectable gamma-ray halos. We find extended emission that might be interpreted as a gamma-ray halo only in the case of PSR J0007 + 7303. Its luminosity accords with the total energy of injected cosmic rays $\sim 10^{50}$ erg, although other interpretations of this source are possible. Irrespectively of the nature of this source, we put bounds on the luminosity of gamma-ray halos which suggest that pulsars' contribution to the overall energy budget of galactic CRs is subdominant in the GeV–TeV range.

DOI: 10.1103/PhysRevD.94.063004

Гамма-астрономия: 511 keV

PHYSICAL REVIEW D **94,** 103002 (2016)

Positron excess in the center of the Milky Way from short-lived β^+ emitting isotopes

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Observations of the INTEGRAL satellite revealed the presence of yet unexplained excess in the central region of the Galaxy at energies around 511 keV. These gamma rays are produced in the process of positron annihilation; the needed rate is around 10^{42} s^{-1}. In this short paper it is shown that β^+ -emitting isotopes that are formed in interactions of subrelativistic cosmic rays with light nuclei (CNONe) can account for a considerable fraction—up to several tens of percent—of e^+ production rate in the central region.

Разное

International Journal of Modern Physics D
Vol. 25, No. 14 (2016) 1650103 (6 pages)

DOI: 10.1142/S0218271816501030

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Prospects for strangelet detection with large-scale cosmic ray observatories

M. S. Pshirkov

International Journal of Modern Physics D
Vol. 26 (2017) 1750068 (5 pages)

DOI: 10.1142/S0218271817500687

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May axion clusters be sources of fast radio bursts?

M. S. Pshirkov

Разное

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **462,** L16–L20 (2016) doi:10.1093/mnrasl/slw118
Advance Access publication 2016 June 16

Fast radio bursts counterparts in the scenario of supergiant pulses

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ABSTRACT

We discuss identification of possible counterparts and persistent sources related to fast radio bursts (FRBs) in the framework of the model of supergiant pulses from young neutron stars with large spin-down luminosities. In particular, we demonstrate that at least some of the sources of FRBs can be observed as ultraluminous X-ray sources (ULXs). At the moment no ULXs are known to be coincident with localization areas of FRBs. We searched for a correlation of FRB positions with galaxies in the 2MASS Redshift survey catalogue. Our analysis produced statistically insignificant overabundance (p-value $\approx$ 4 per cent) of galaxies in error boxes of FRBs. In the very near future with even modestly increased statistics of FRBs and with the help of dedicated X-ray observations and all-sky X-ray surveys it will be possible to decisively prove or falsify the supergiant pulses model.

Key words: pulsars: general – X-rays: binaries.

Планы

- Транзиенты в гамма-, рентгеновском и радио диапазонах
- FRB
- UHECR (Telescope Array)

Библиометрия (NASA ADS)

- Число статей за 5 лет: 17 (38)
- Число статей полное: 30 (51)
- Цитирование статей, вышедших за последние 5 лет: 172 (938)
- Полное цитирование: 449 (1215)
- H: 11(19)

СПАСИБО!

Запасник

PBH capture by NSs

$$\mathbf{f}_{\rm dyn} = -4\pi G^2 m_{\rm BH}^2 \rho \ln\Lambda \frac{\mathbf{v}}{v^3}$$

$$E_{\rm loss} = \frac{3Gm_{\rm BH}^2 \ln\Lambda}{R}$$

- During every subsequent passage, the PBH would lose the same amount of energy and gradually its orbit would shrink

$$\dot{\xi} = -\frac{1}{\tau}\frac{\xi^{3/2}}{\xi - 1}; \qquad \tau = \frac{\pi M R^{3/2}}{3m_{\rm BH}\sqrt{GM}\ln\Lambda} \simeq 6.1\times 10^5{\rm s}\left(\frac{m_{\rm BH}}{10^{22}{\rm g}}\right)^{-1}$$

$$t_{\rm loss} \simeq 1.8\times 10^3{\rm yr}\left(\frac{m_{\rm BH}}{10^{22}{\rm g}}\right)^{-3/2}$$

- Evolution time scale is comparable with the Universe age for PBHs with masses $3\text{x}10^{17}$ g

PBH capture by NSs

$$E_{\rm loss} = \frac{3Gm_{\rm BH}^2 \ln\Lambda}{R}$$

- Only PBHs with asymptotic energy less than E_{loss} could be captured
- Rate would be determined by the distribution parameters
- Maxwellian:

$$F_0 = 2\sqrt{6\pi}\frac{\rho_{\rm DM}}{m_{\rm BH}}\frac{GMR}{\bar{v}}\left(1-\exp\left(-\frac{3E_{\rm loss}}{m_{\rm BH}\bar{v}^2}\right)\right)$$

↓

$$F_0 = 6\sqrt{6\pi}\frac{\rho_{\rm DM}}{m_{\rm BH}}\frac{GMR}{\bar{v}^3}\frac{E_{\rm loss}}{m_{\rm BH}}$$

PBH capture by NSs

- Coulomb logarithm value is crucial for the DF effect to play any role

$$\ln\Lambda = \ln\frac{b_{max}}{G_N M_{BH}} \approx \ln\frac{M_{star}}{M_{BH}}$$

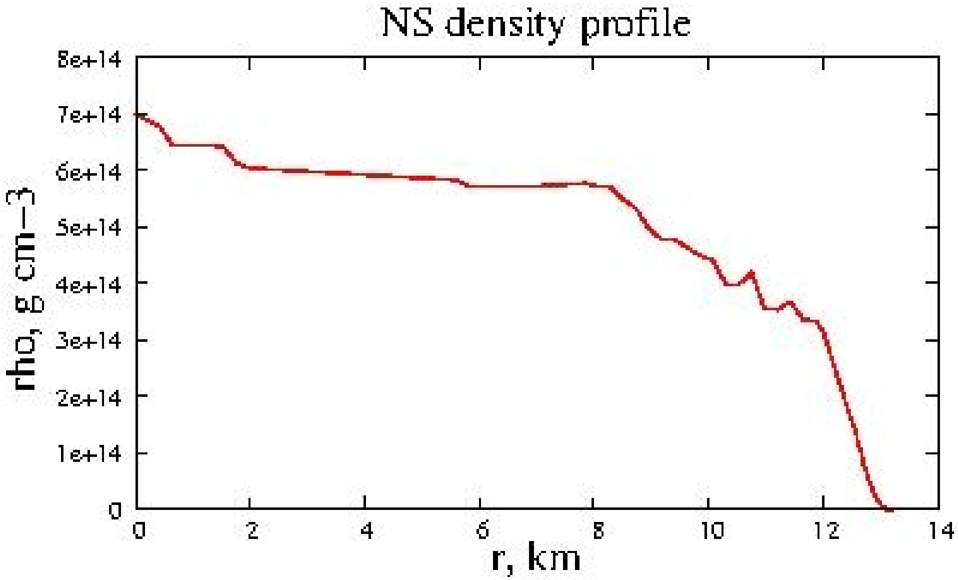
- Usual star: $\ln\Lambda \sim 30$

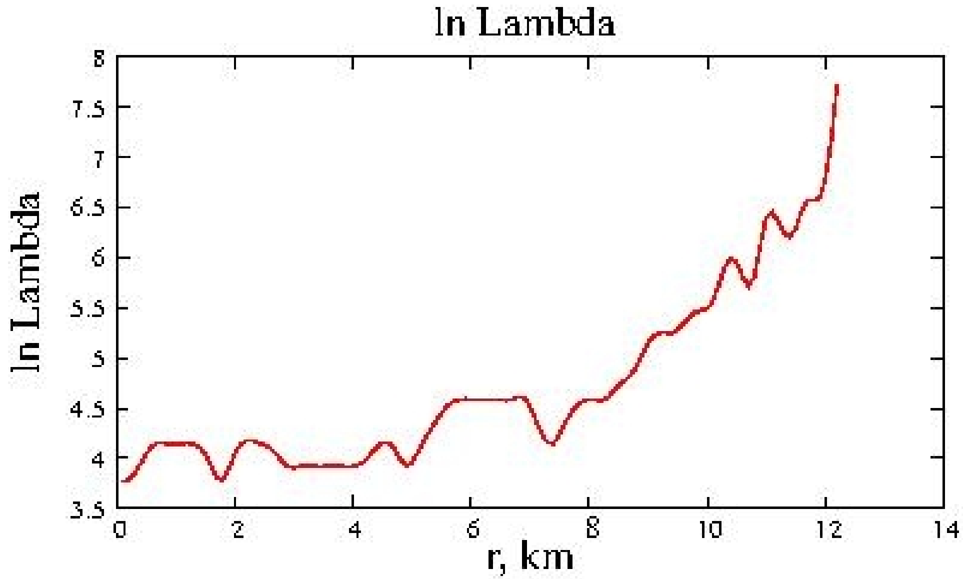
- When we are dealing with NS (degenerate matter) it's not so simple now—$b_{max} << R_{star}$. Impact parameter should be small enough in order to transfer more than Fermi momentum to the particles constituting NS

$$k_F(r) = \left(3\pi^2\frac{\rho(r)}{m_n}\right)^{1/3}$$

PBH capture by NSs

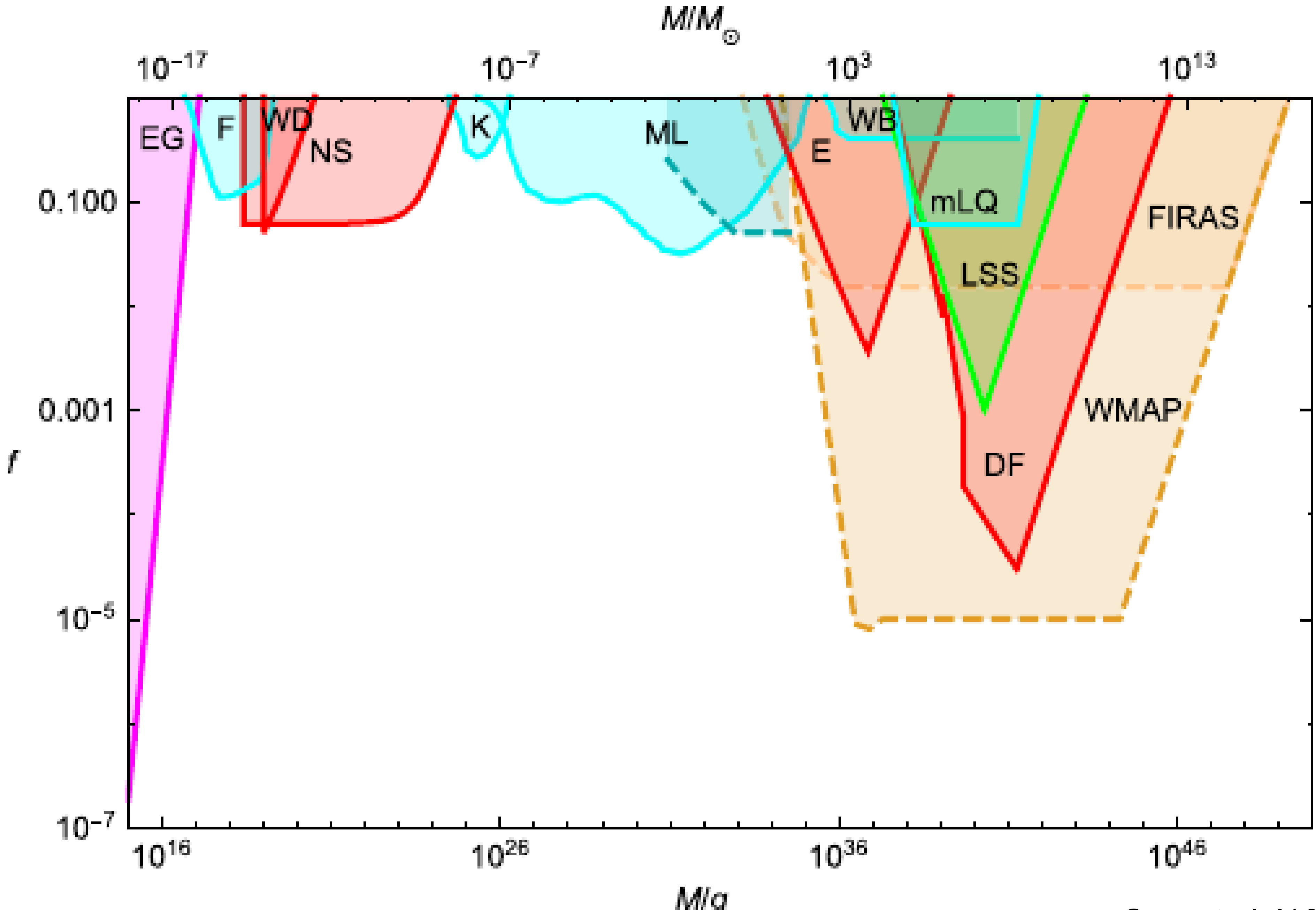
- We used Belvedere et al' 12 model but results proved to be rather robust and model-independent





- Taking into account drag due to the direct accretion we finally got that in the degenerate case the effect is weaker in k=4.5 times.

Наблюдательные ограничения (2/2)



Carr et al '16

ИСТИНА

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доктор физико-математических наук с 2016 года

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- Мои отобранные статьи
- Конкурсы
- Достижения
- Последние добавленные мной результаты
- Экспорт публикаций в BibTeX
- Мои возможные дубликаты
- Мои потерянные статьи
- Инструкция по работе с системой

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