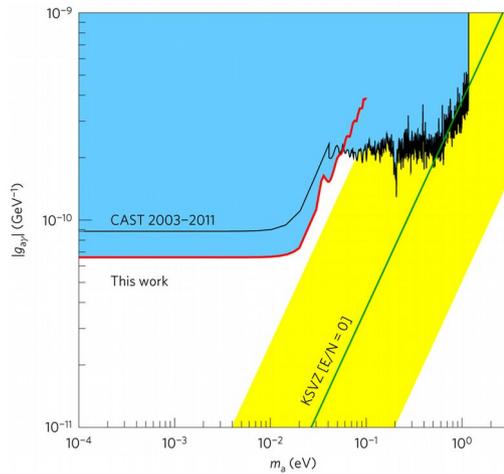
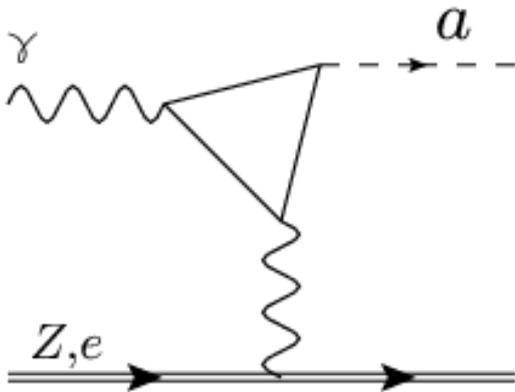


Аксион-фотонные осцилляции в магнитном поле Галактики

Спиридонов Андрей Николаевич
д. ф.-м. н. Рубцов Григорий Игоревич

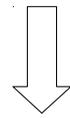
Кафедра физики частиц и космологии

Про аксион в картинках



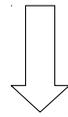
Уравнение эволюции

$$\mathcal{L} = \frac{1}{2}(\partial_\mu a \partial_\mu a - m^2 a^2) - \frac{a}{4M} F_{\mu\nu} \tilde{F}^{\mu\nu} - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$



$$\partial_\mu F^{\mu\nu} = J^\nu + \frac{1}{M} \tilde{F}^{\mu\nu} \partial_\mu a$$

$$(\square + m^2)a = -\frac{1}{4M} F_{\mu\nu} \tilde{F}^{\mu\nu}$$



$$\square \mathbf{A} = \frac{1}{M} \mathbf{B}_\perp \partial_t a$$

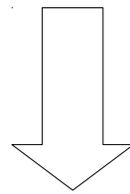
$$(\square + m^2)a = -\frac{1}{M} \mathbf{B}_\perp \cdot \partial_t \mathbf{A}$$

Численное решение

$$[\omega^2 + \partial_z^2 + \mathcal{M}] \begin{pmatrix} A_{\parallel} \\ A_{\perp} \\ a \end{pmatrix} = 0$$

$$\begin{aligned} \omega^2 + \partial_z^2 &= (\omega - i\partial_z)(\omega + i\partial_z) = \\ &= (\omega - i\partial_z)(\omega + k) \approx 2\omega(\omega - i\partial_z) \end{aligned} \quad \Downarrow$$

$$[\omega - i\partial_z + \mathcal{M}'] \begin{pmatrix} A_{\parallel} \\ A_{\perp} \\ a \end{pmatrix} = 0$$



$$\rho = \left| \begin{pmatrix} A_{\parallel} \\ A_{\perp} \\ a \end{pmatrix} \right\rangle \left\langle \begin{pmatrix} A_{\parallel} \\ A_{\perp} \\ a \end{pmatrix} \right|; \quad i \frac{\partial \rho}{\partial z} = [\widehat{\mathcal{M}}, \rho]$$

Параметры

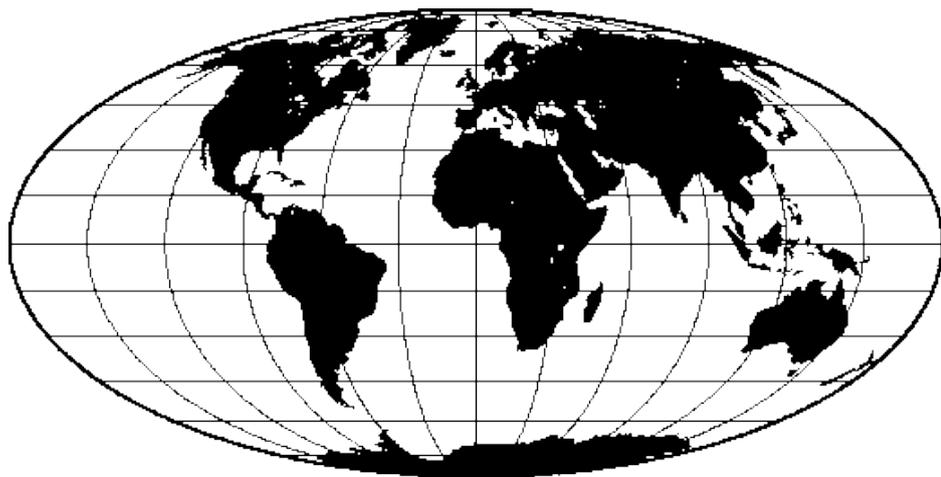
$$\rho_{init} = \begin{pmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 0 \end{pmatrix} \text{ or } \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\widehat{\mathcal{M}} = \begin{pmatrix} \omega(n-1) & 0 & \frac{B_i}{2M} \\ 0 & \omega(n-1) & \frac{B_i}{2M} \\ \frac{B_i}{2M} & \frac{B_i}{2M} & \frac{m^2}{2\omega} \end{pmatrix}$$

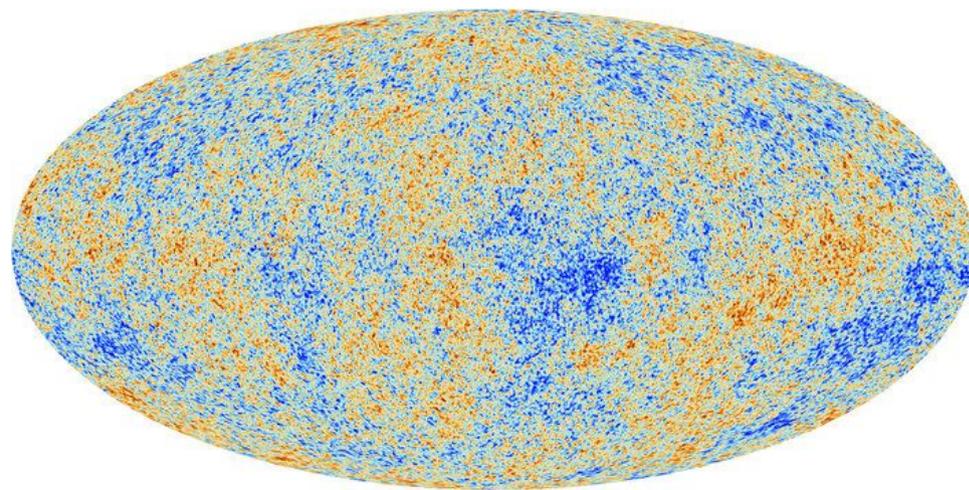
Выбранные параметры:

- $m = \{1e-8, 1e-7, 1e-6\}$ [эВ]
- $M = \{2e11, 4e11, 6e11\}$ [эВ]
- $\omega = \{1e11, 1e12\}$ [эВ]
- $n_e = 1e-4$ [см⁻³] (из литературы)
- Радиус галактики, исходя из моделей магнитного поля был выбран 20 кпк
- Солнечная система находится на расстоянии 8.5 кпк от центра галактики

Что такое проекция Моллвейда?

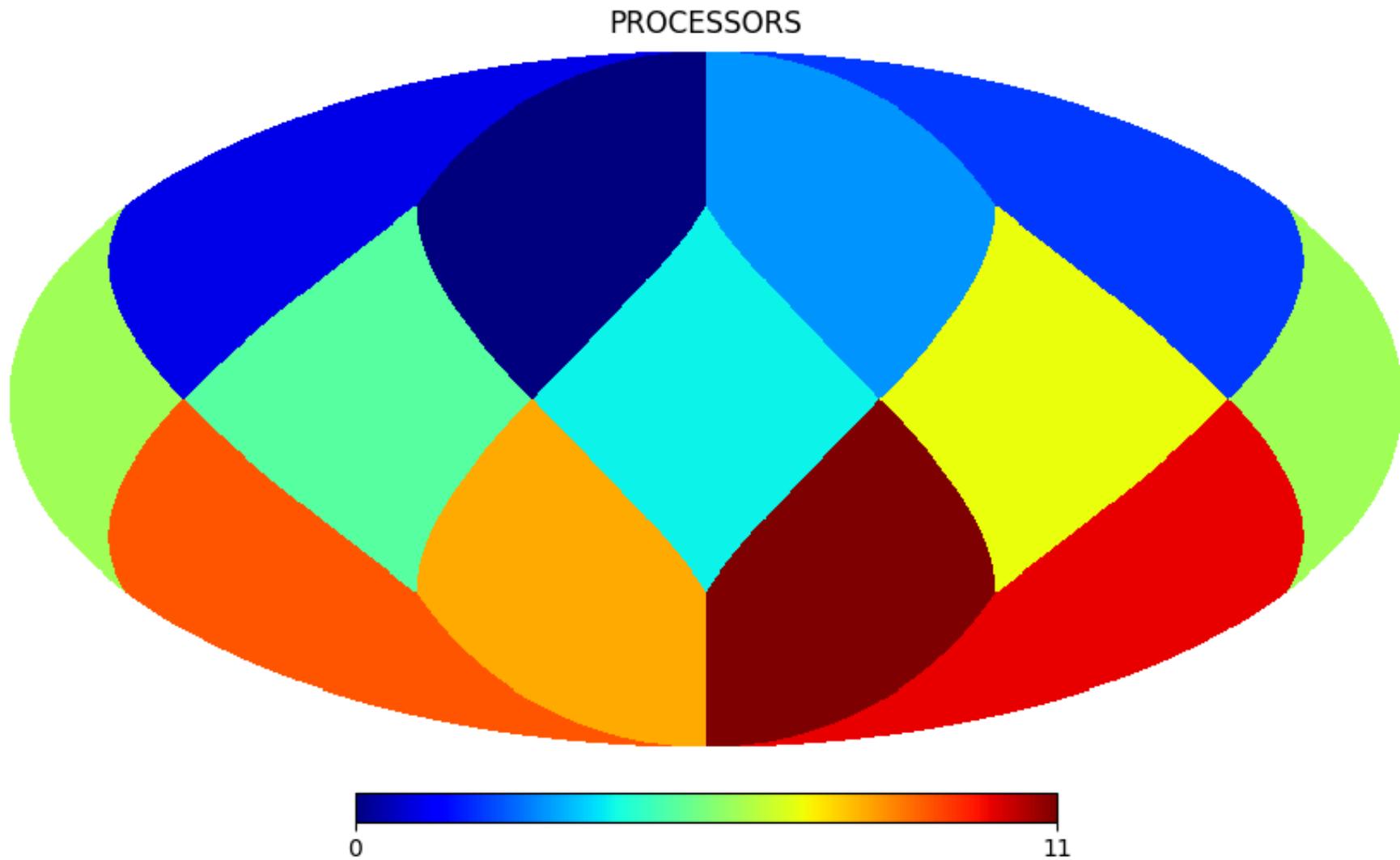


СНАРУЖИ

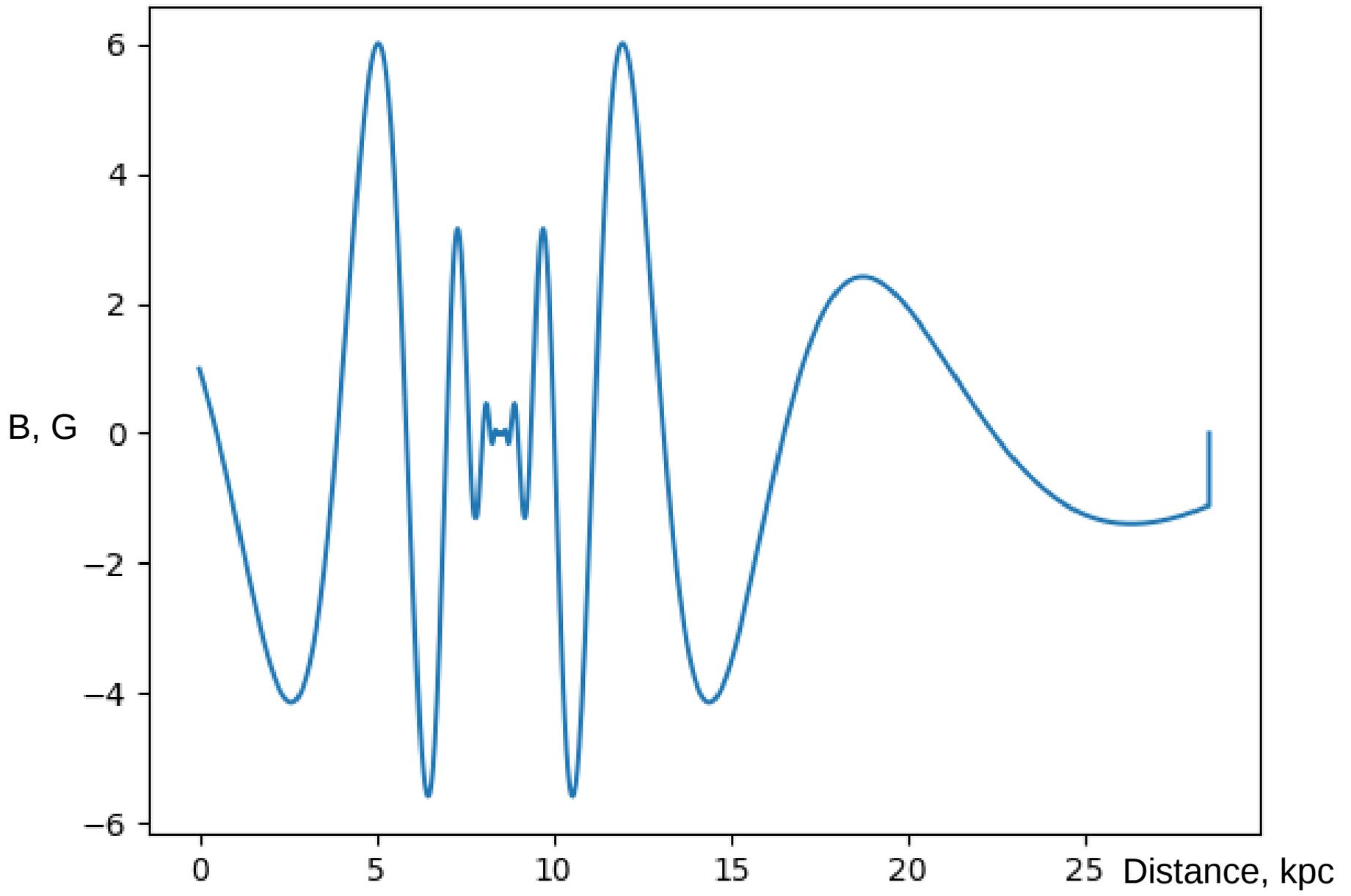


ИЗНУТРИ

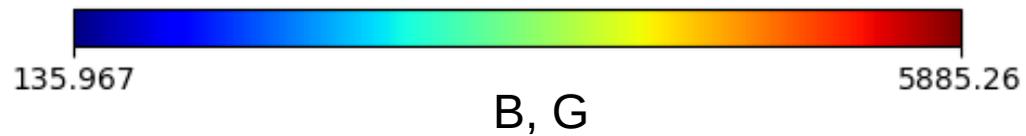
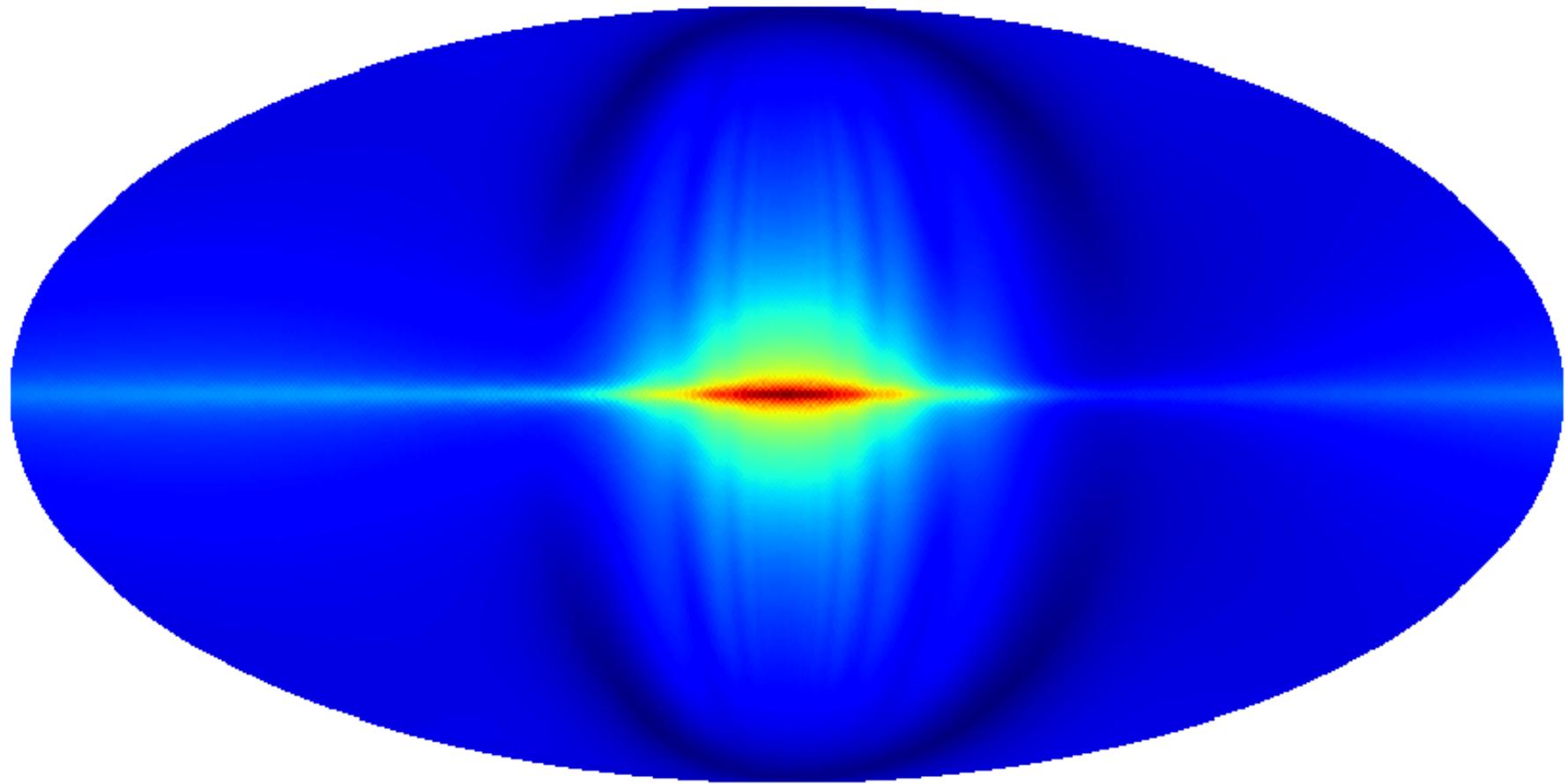
Область ответственности процессоров



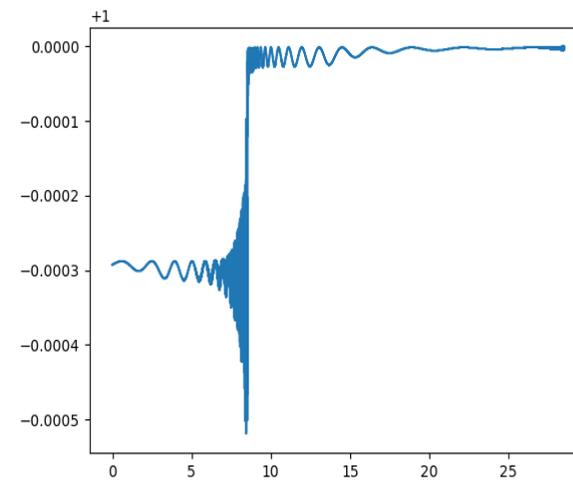
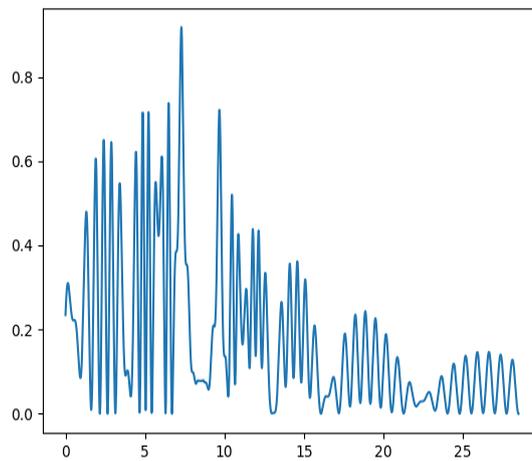
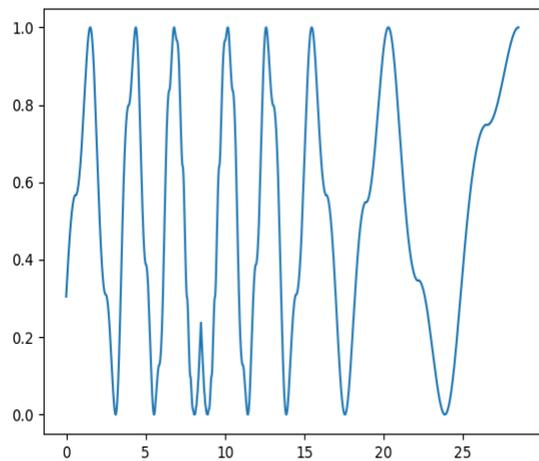
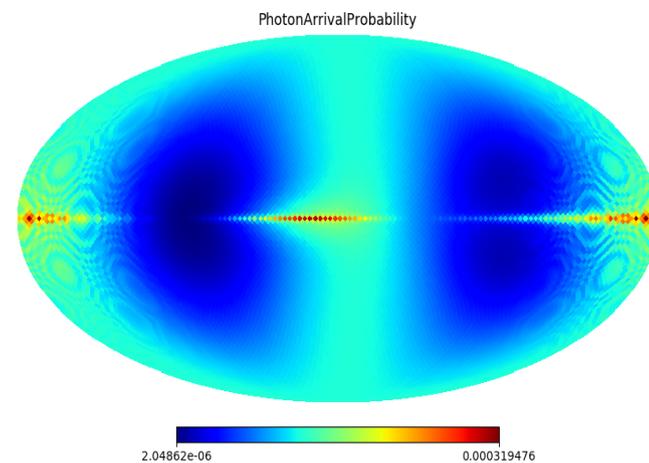
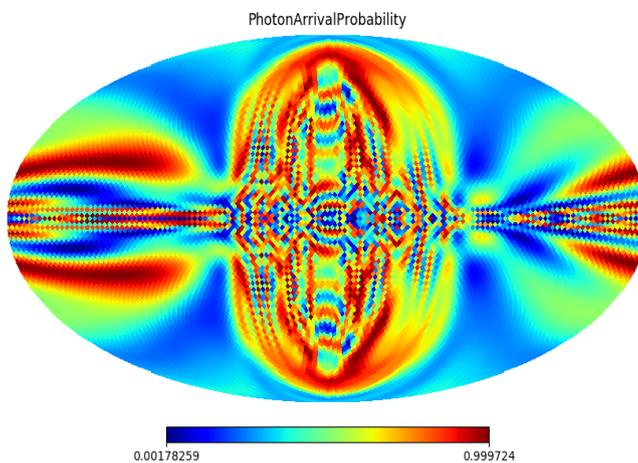
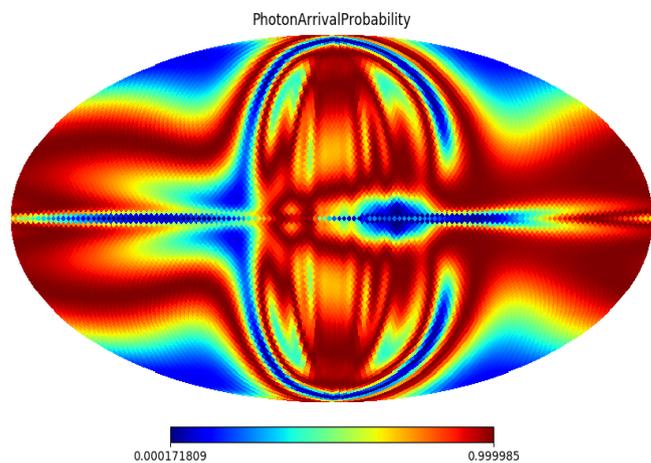
Harrari, Mollerach, Roulet 1999



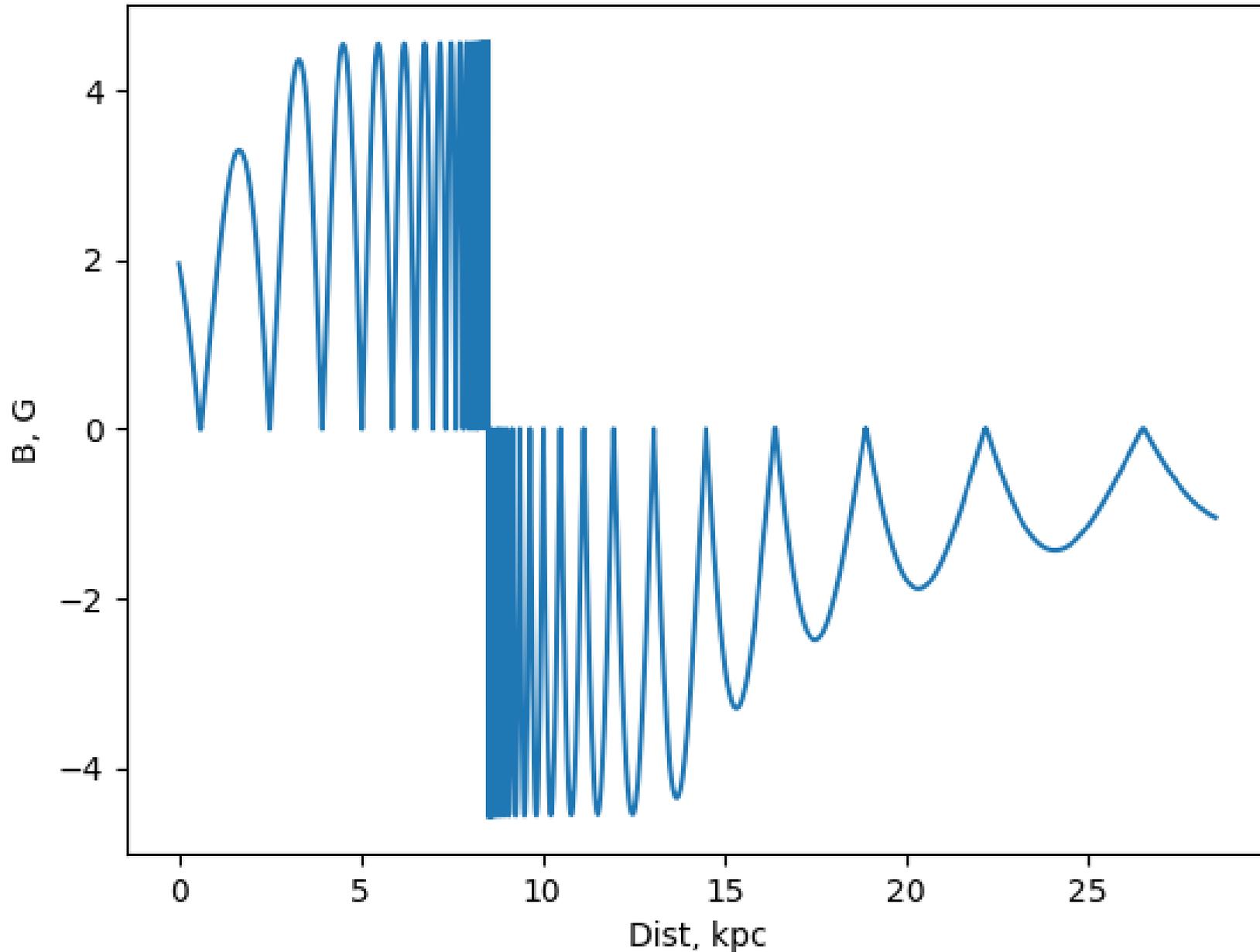
Harrari, Mollerach, Roulet 1999



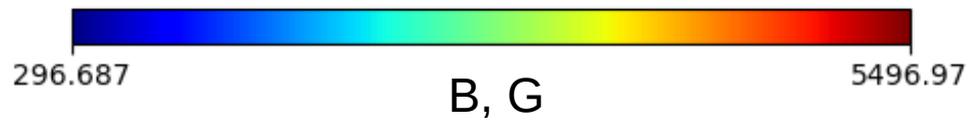
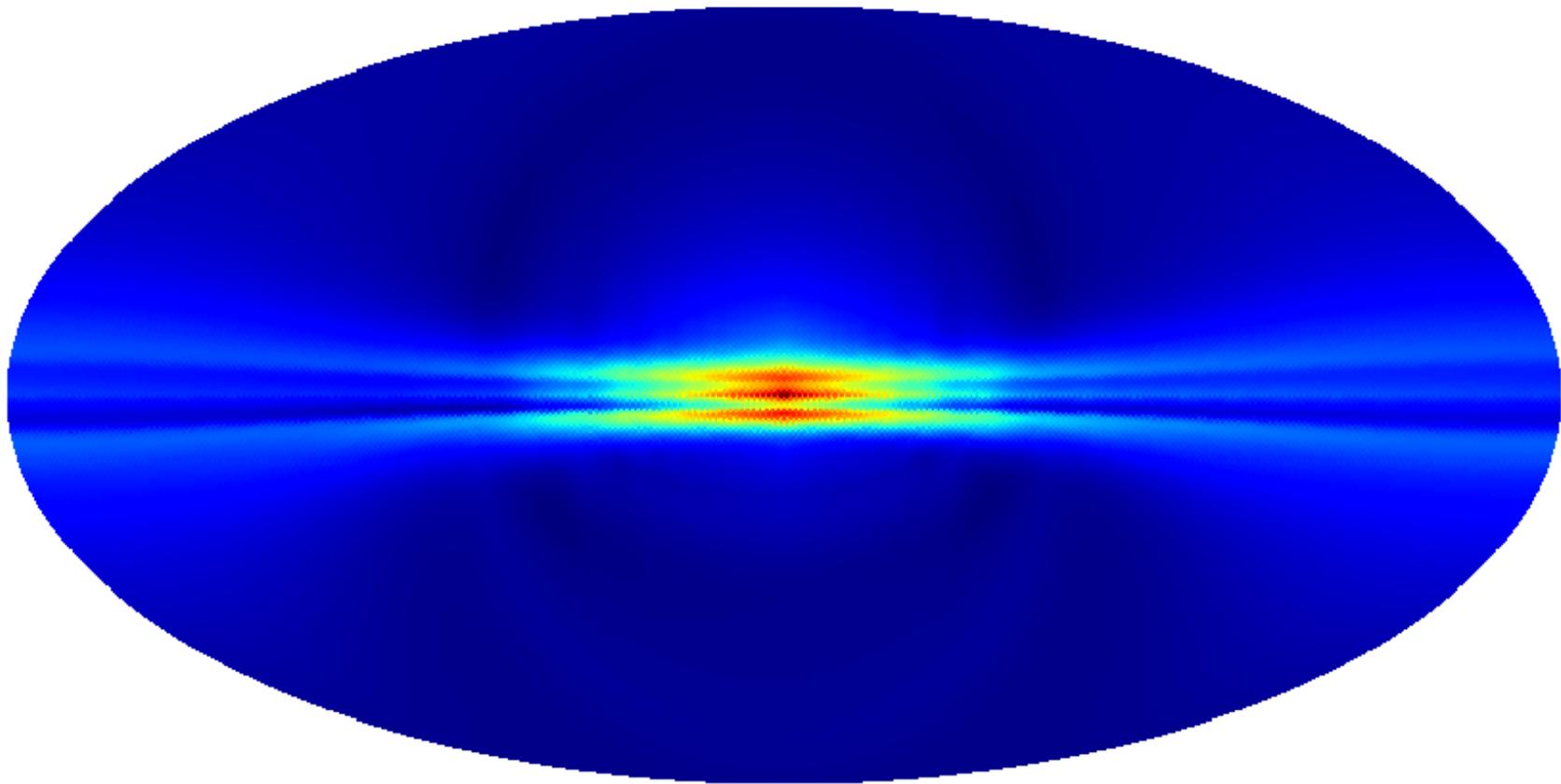
Harrari, Mollerach, Roulet 1999



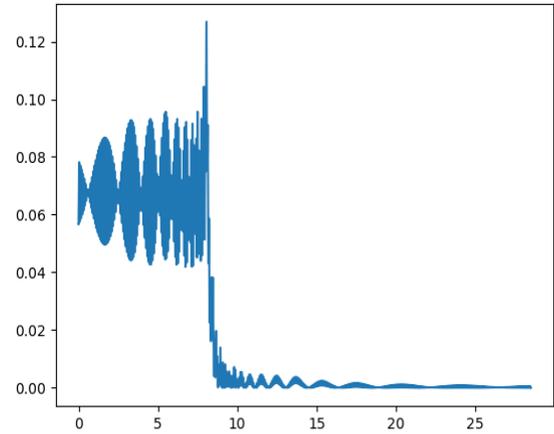
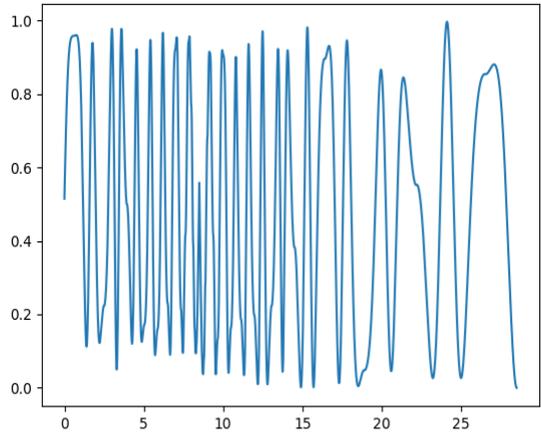
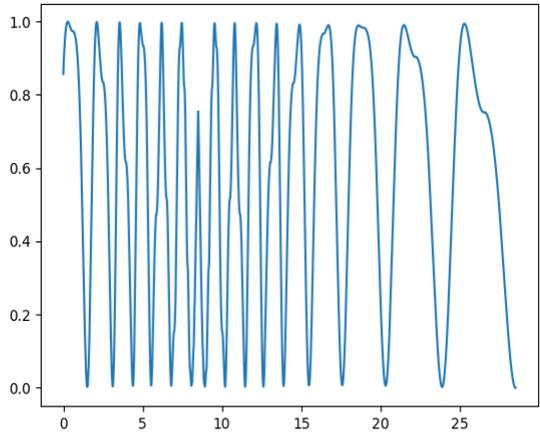
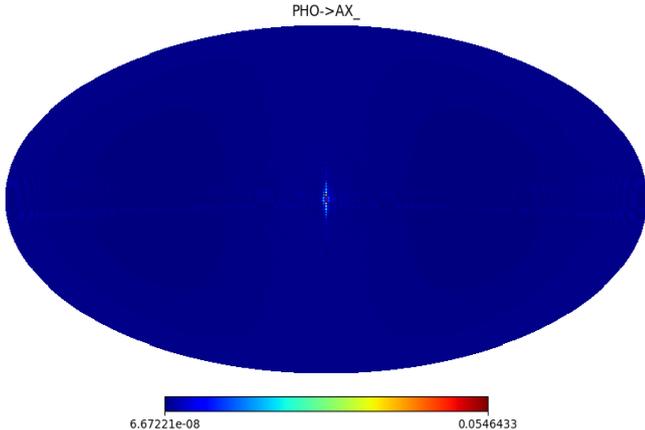
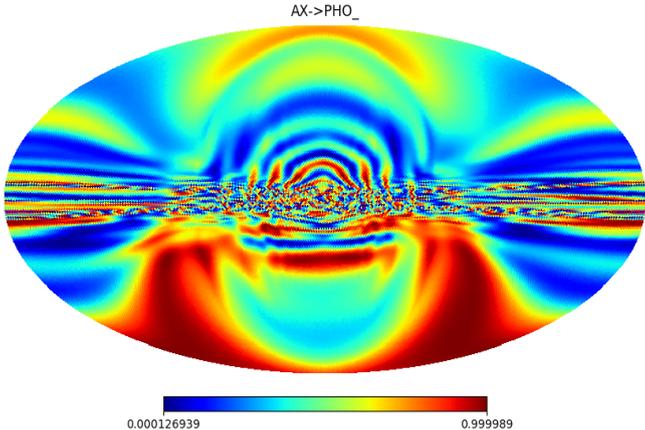
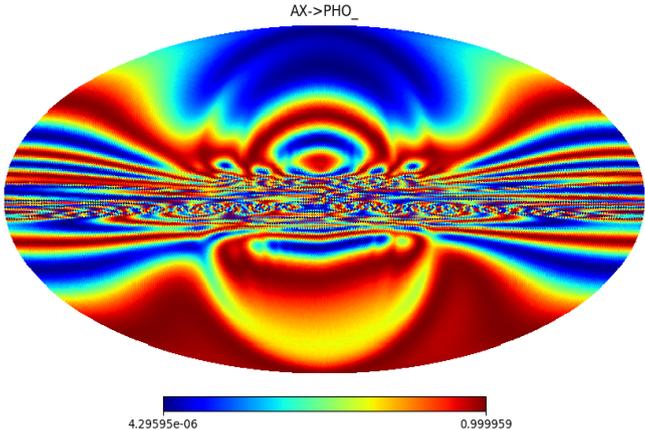
Pshirkov, Tinyakov, Kronberg 2011



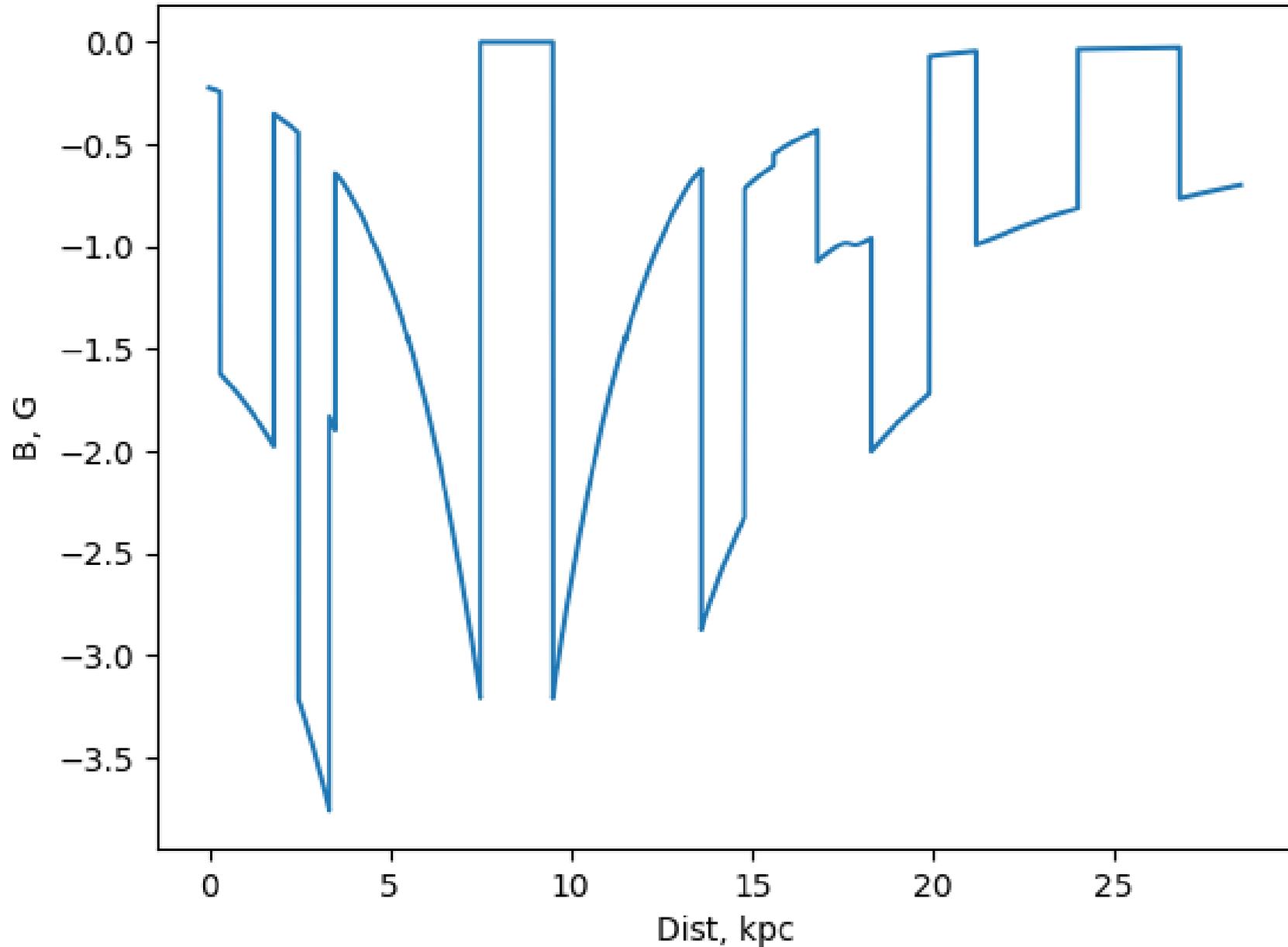
Pshirkov, Tinyakov, Kronberg 2011



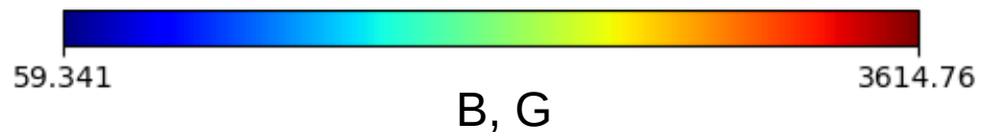
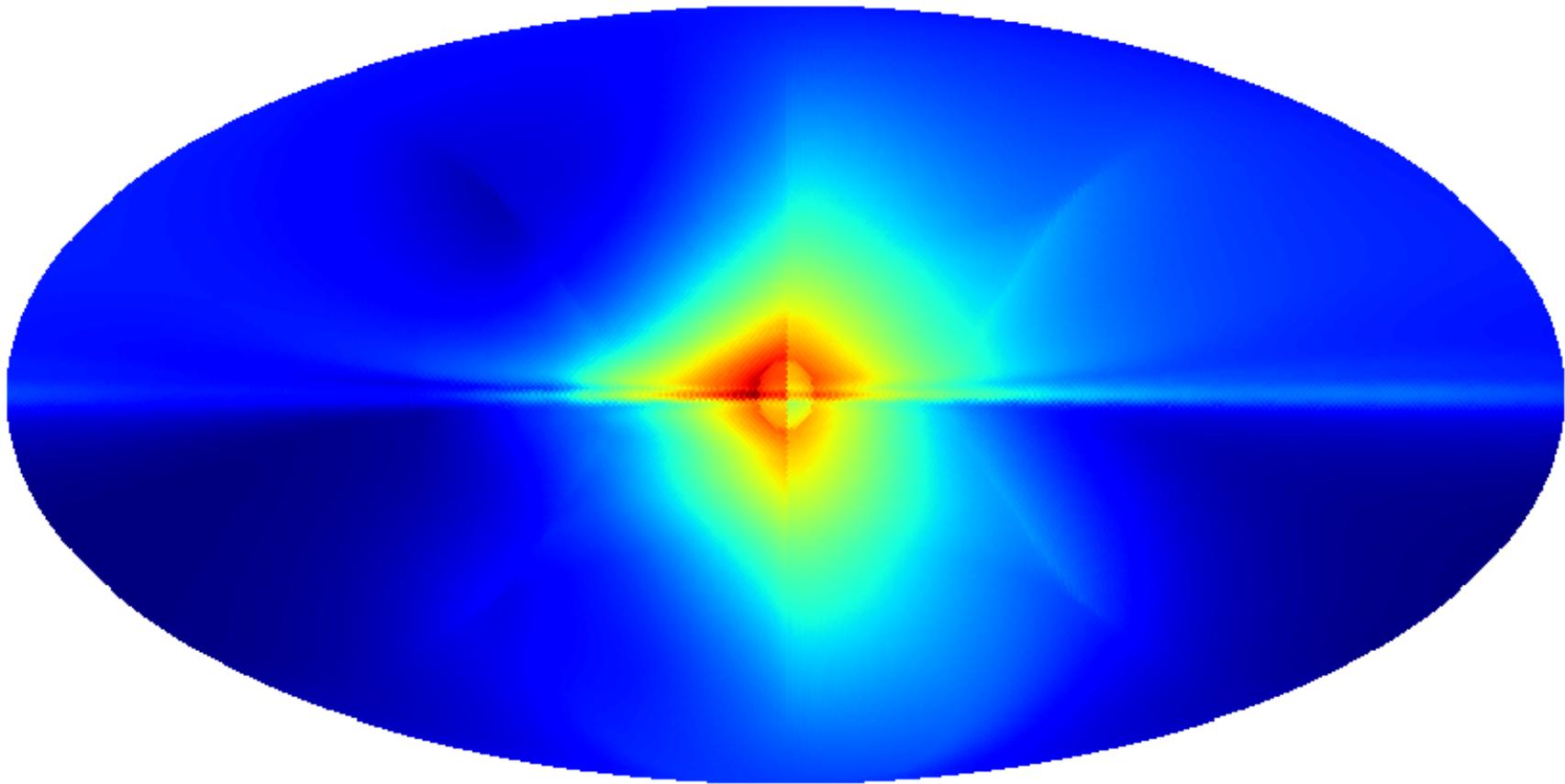
Pshirkov, Tinyakov, Kronberg 2011



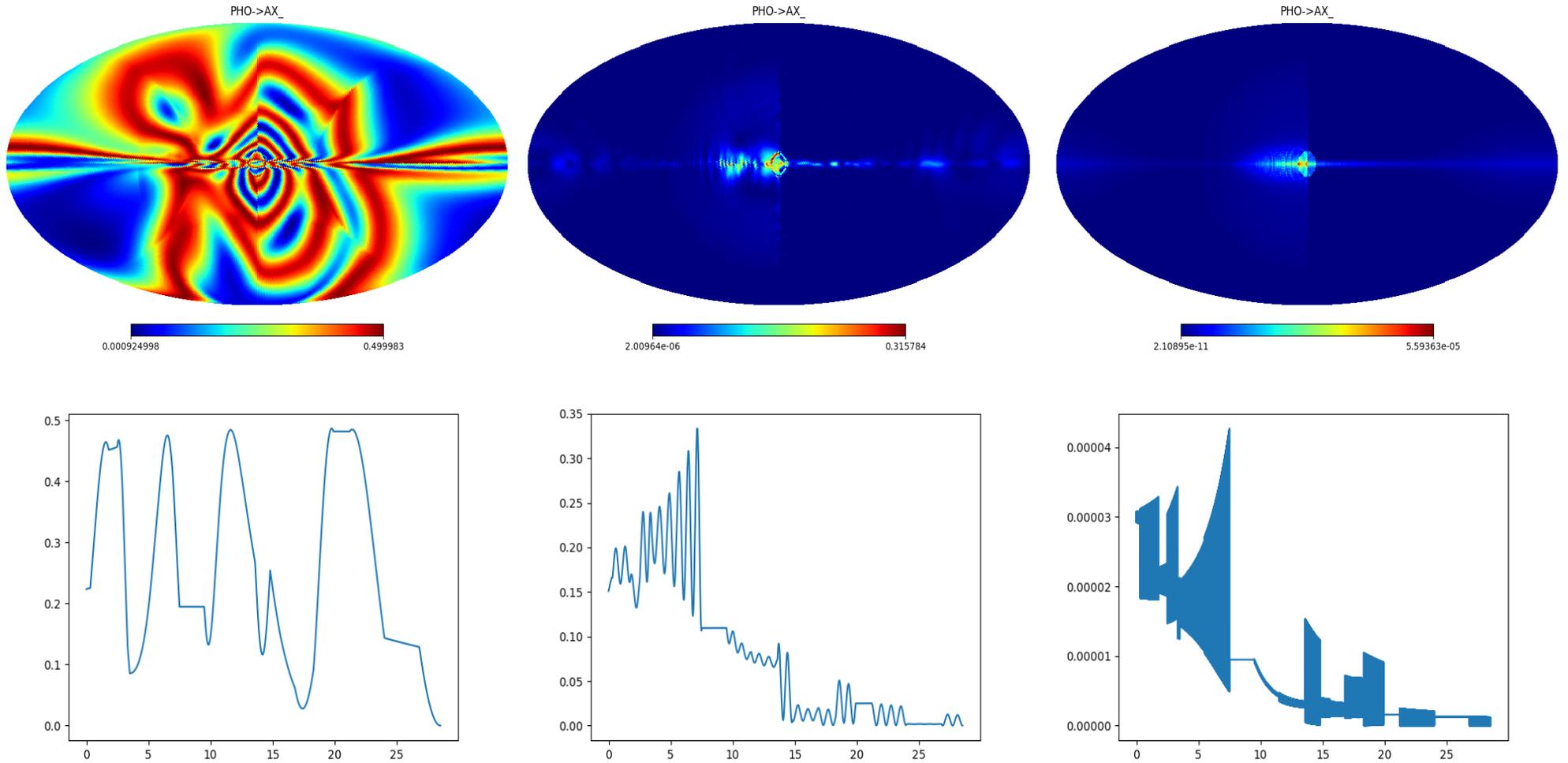
Farrar, Jansson 2012



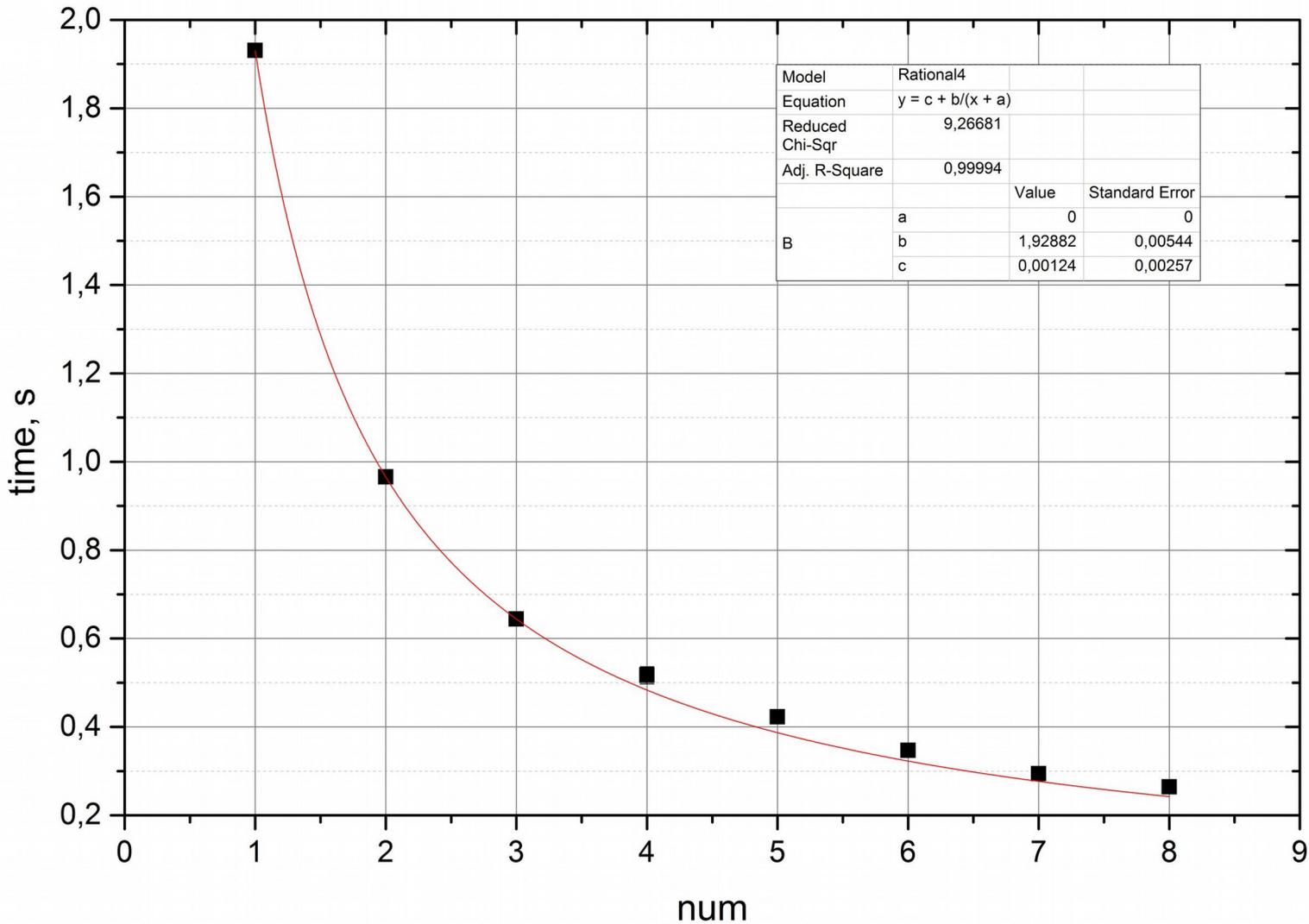
Farrar, Jansson 2012



Farrar, Jansson 2012



Время работы в зависимости от числа процессоров



Результаты



OPEN MPI



Использованная в докладе литература

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