Изучение асимметрии электронной плотности солнечной короны с помощью РСДБ

Даниил Аксим, Алексей Мельников,
Дмитрий Павлов, Сергей Курдубов

Институт прикладной астрономии Российской академии наук

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Exploring the Asymmetry of the Solar Corona Electron Density with Very Long Baseline Interferometry

Dan Aksim, Alexey Melnikov, Dmitry Pavlov, and Sergey Kurdubov

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Задержка сигнала

Показатель преломления для плазмы:

$$n_{\mathrm{gr}}(\mathbf{r},\omega) \approx 1 + \frac{N_{\mathrm{e}}(\mathbf{r})}{2\,N_{\mathrm{crit}}(\omega)} = 1 + \frac{e^2}{2\,m_{\mathrm{e}}\epsilon_0}\cdot\frac{N_{\mathrm{e}}(\mathbf{r})}{\omega^2},$$

где $N_{\mathrm{e}}(\mathbf{r})$ — электронная плотность, ω — частота сигнала.

Оптическая длина пути между $\mathbf{r}_a$ и $\mathbf{r}_b$:

$$\tau = \int_{\mathbf{r}_a}^{\mathbf{r}_b} n_{\mathrm{gr}}(s,\omega)\,\mathrm{d}s$$

Степенная модель

$$N_{\mathrm{e}}(r) = \frac{N_0}{r^{\alpha}},\ \alpha \approx 2$$

Невязки орбит космических аппаратов

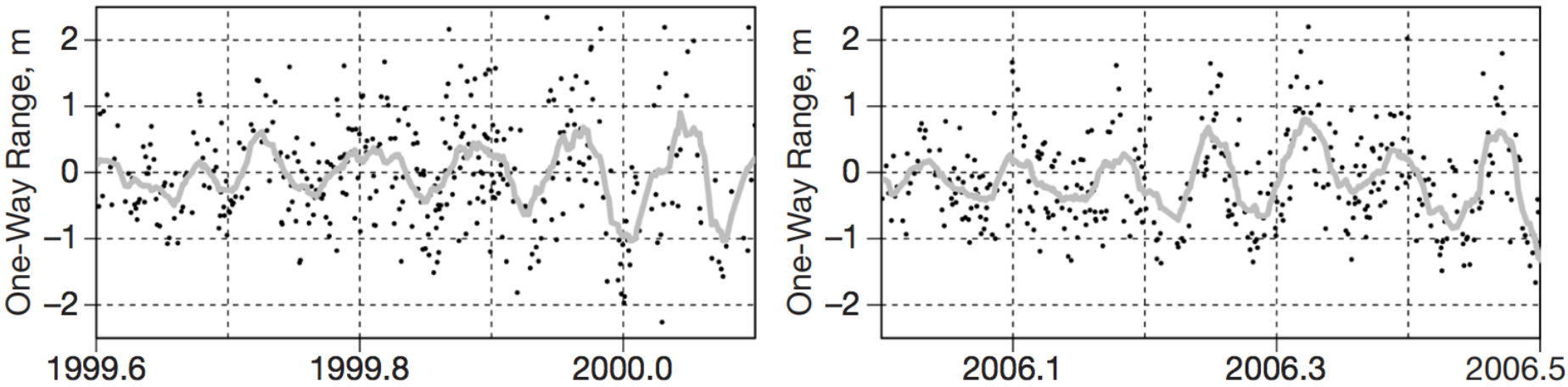


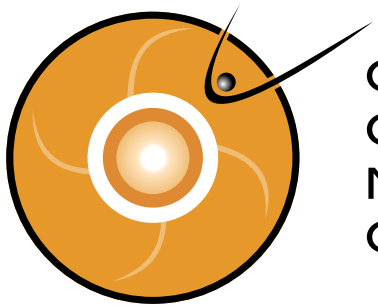
Figure 5. Range residuals, obtained with the new fit, near the 2001 and 2007 conjunctions. The left and right plots are based on MGS and ODY data, respectively. The gray lines correspond to a running average computed over a 10-day interval.

— Kuchynka et al. Station-Specific Errors in Mars Ranging Measurements. IPN Progress Report 42-190, 2012.

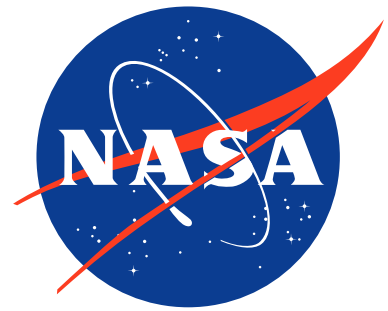
Предыдущие работы с РСДБ

Сессия	Дата	< 15°	Мин. элонг.	N_0 (10^{12} м$^{-3}$)
RD1106	2011/11/29	33	4.0°	0.0 ± 0.4
RD1107	2011/12/06	59	4.1°	1.7 ± 0.4
RD1201	2012/01/24	31	4.9°	3.3 ± 1.3
RD1202	2012/04/03	39	5.8°	0.9 ± 0.4
RD1203	2012/05/30	52	10.3°	2.2 ± 1.8
RD1204	2012/06/19	32	4.4°	1.2 ± 1.0
RD1205	2012/07/10	187	6.0°	0.5 ± 0.3
RD1206	2012/08/28	193	3.8°	0.3 ± 0.1
RD1207	2012/09/25	120	6.1°	0.6 ± 0.8
RD1208	2012/10/02	103	3.9°	1.5 ± 0.4
RD1209	2012/11/27	57	4.3°	0.1 ± 0.3
RD1210	2012/12/11	80	4.8°	2.5 ± 0.6
B. Soja et al. Probing the solar corona with VLBI. Nature Communications, 2014				0.57 ± 0.18

Community Coordinated Modeling Center

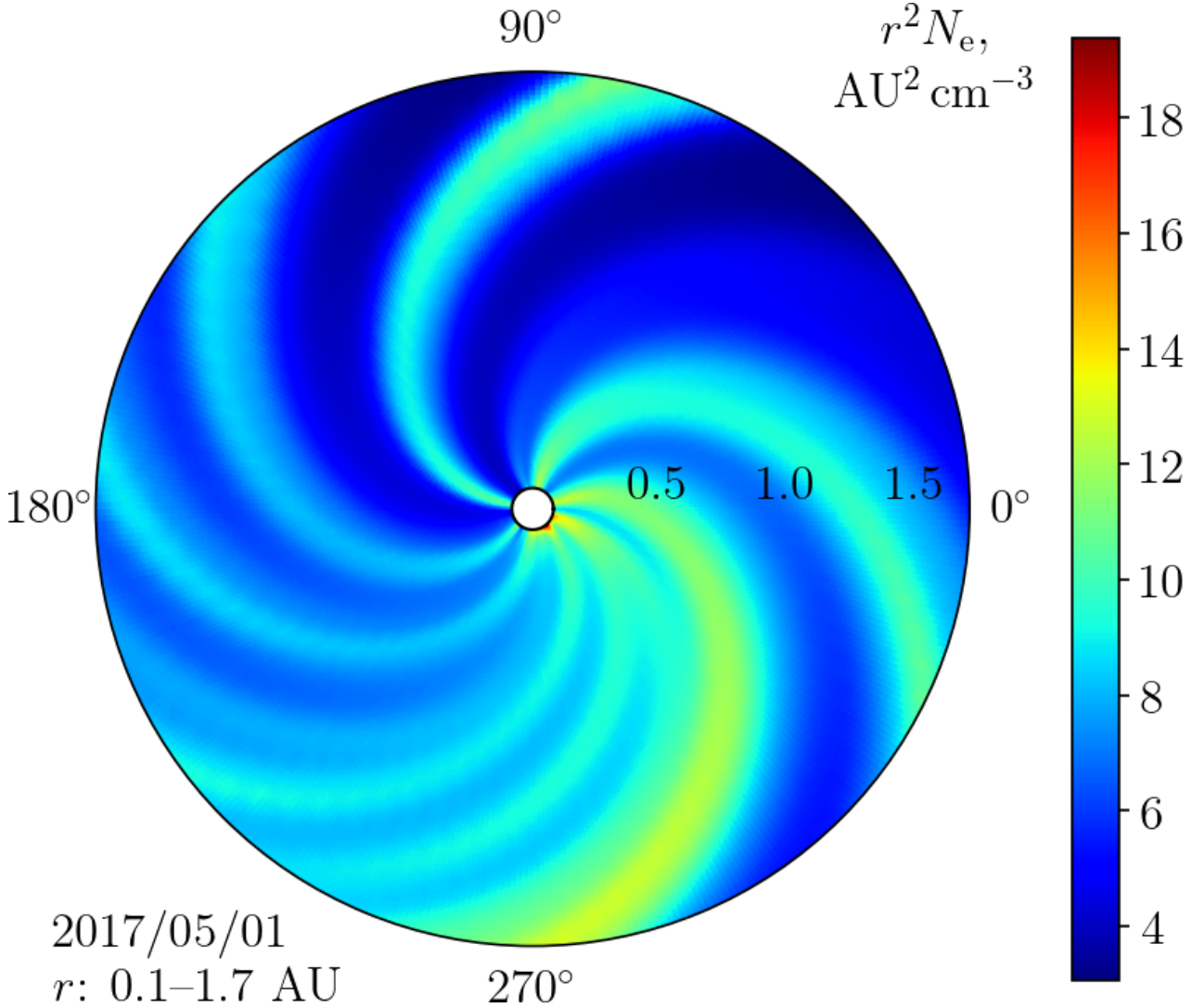


COMMUNITY
COORDINATED
MODELING
CENTER



https://ccmc.gsfc.nasa.gov/

Модель «ENLIL»



Сессии AUA020 и AOV022

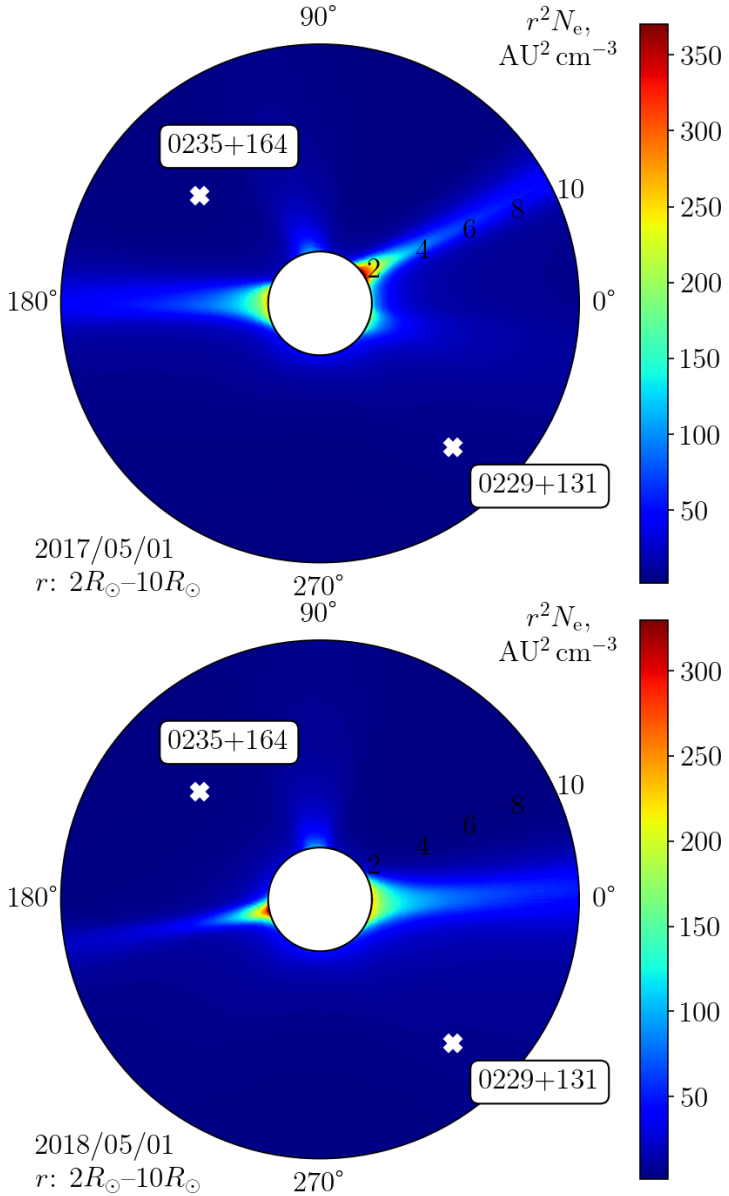
AUA020 — 1 мая 2017 г.

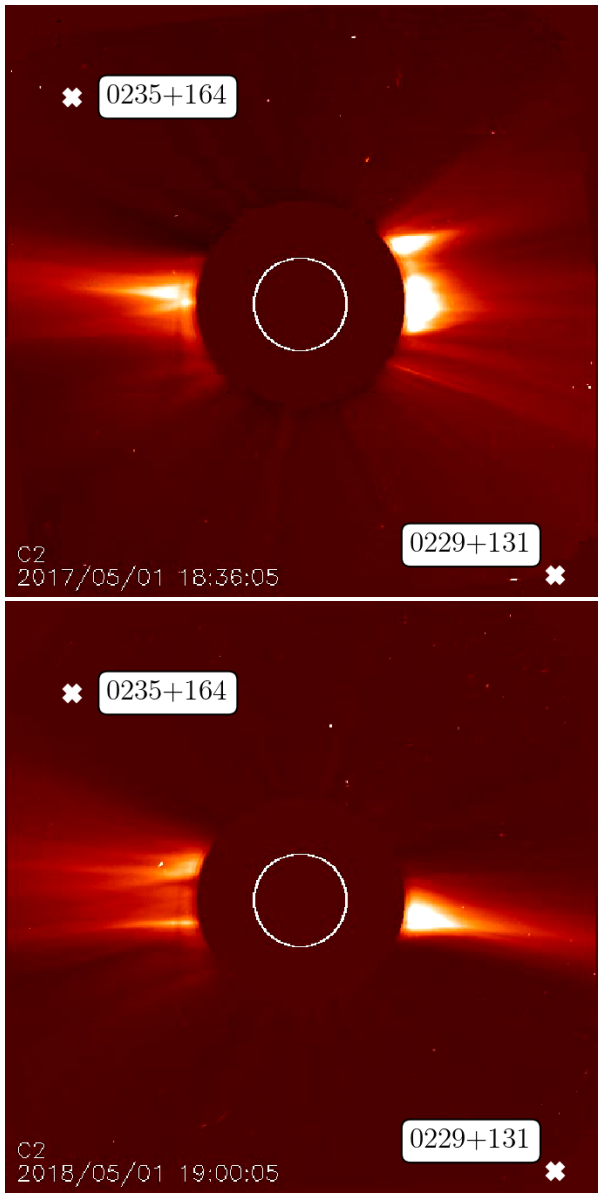
- 0235+164 (1.2°–1.5°) — 452 наблюдения
- 0229+131 (2.2°–2.7°) — 577 наблюдений

AOV022 — 1 мая 2018 г.

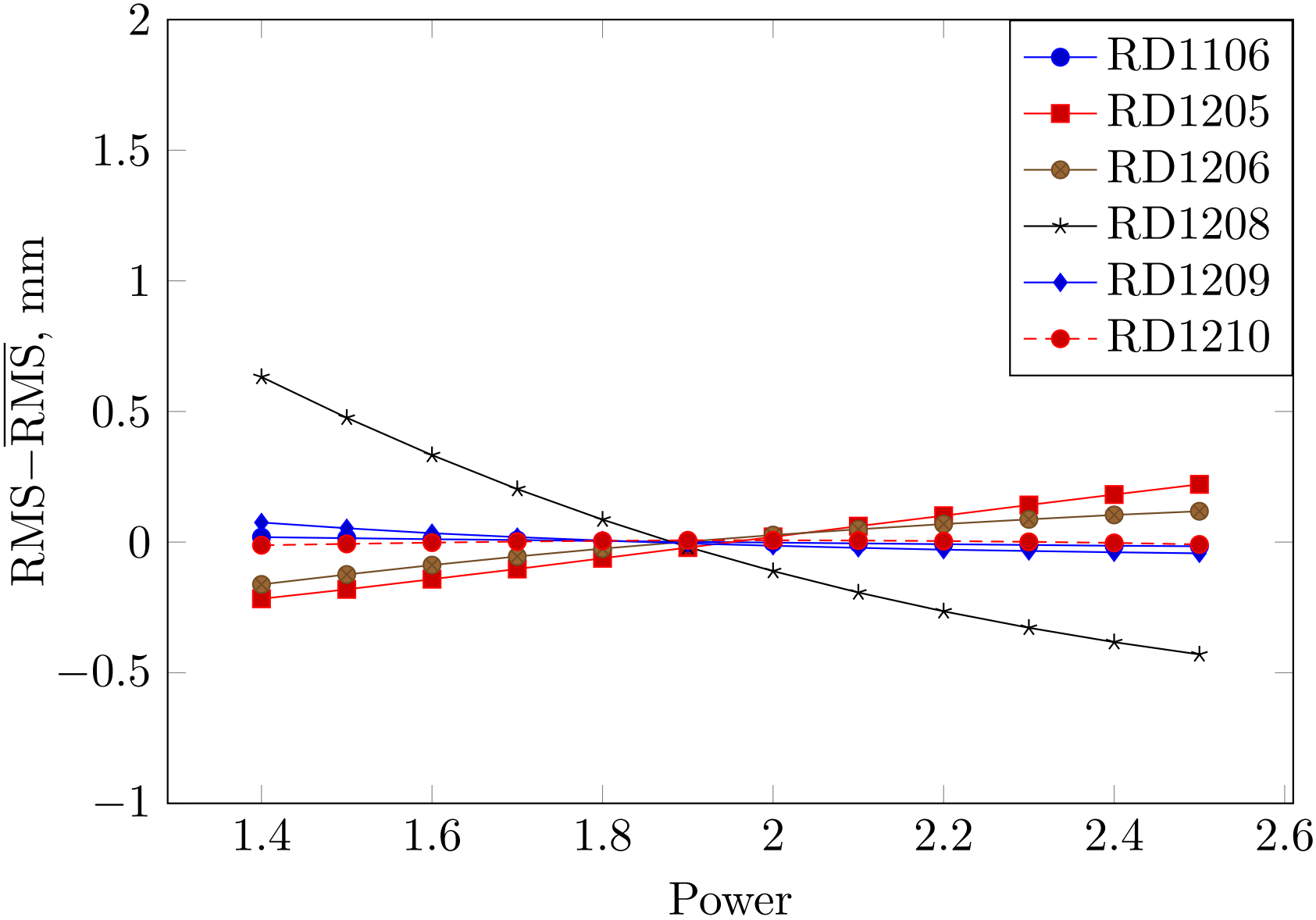
- 0235+164 (1.3°–1.6°) — 1013 наблюдений
- 0229+131 (2.0°–2.3°) — 2416 наблюдений

Сессии AUA020 и AOV022

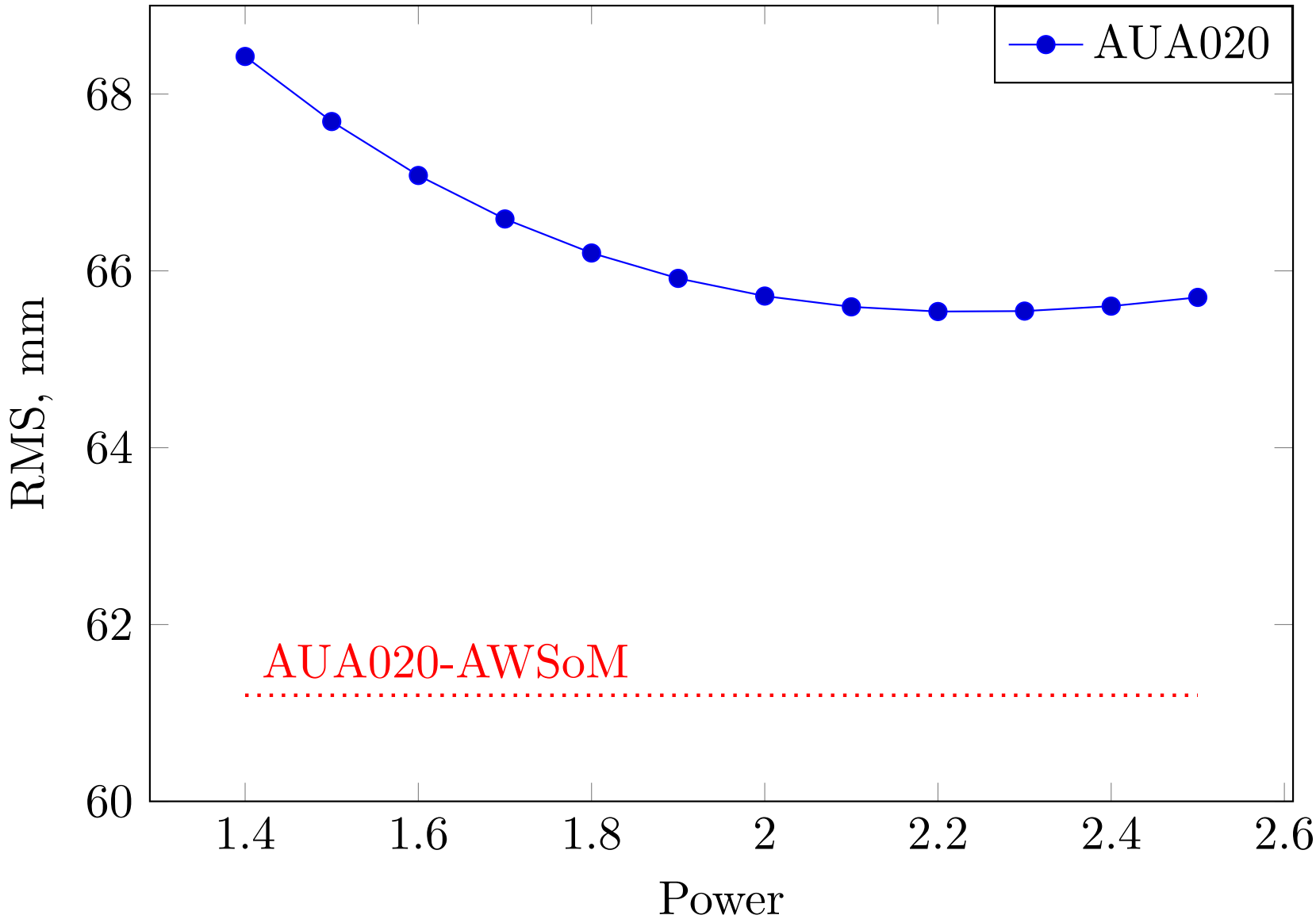




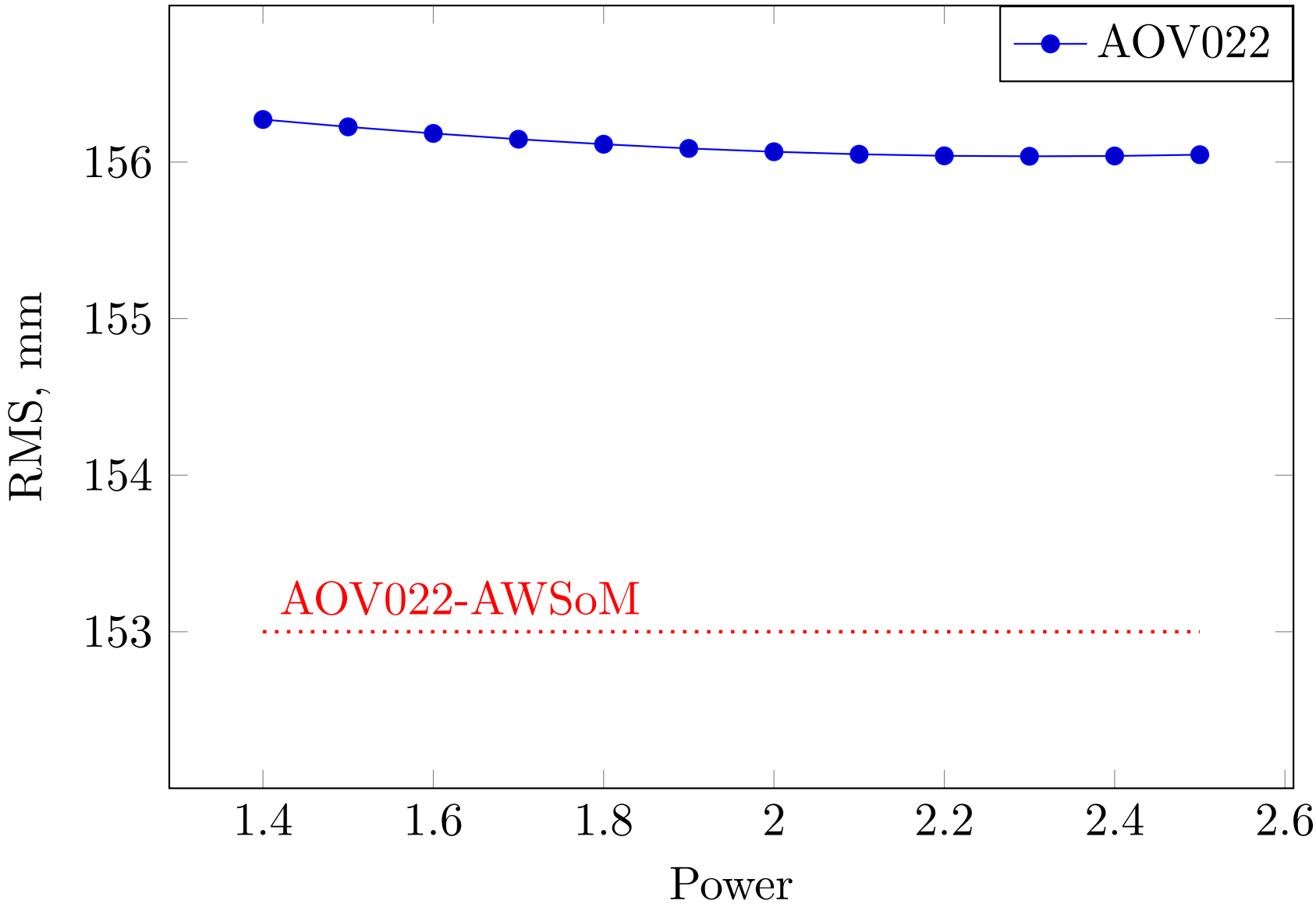
Невязки R&D-сессий



Невязки AUA020



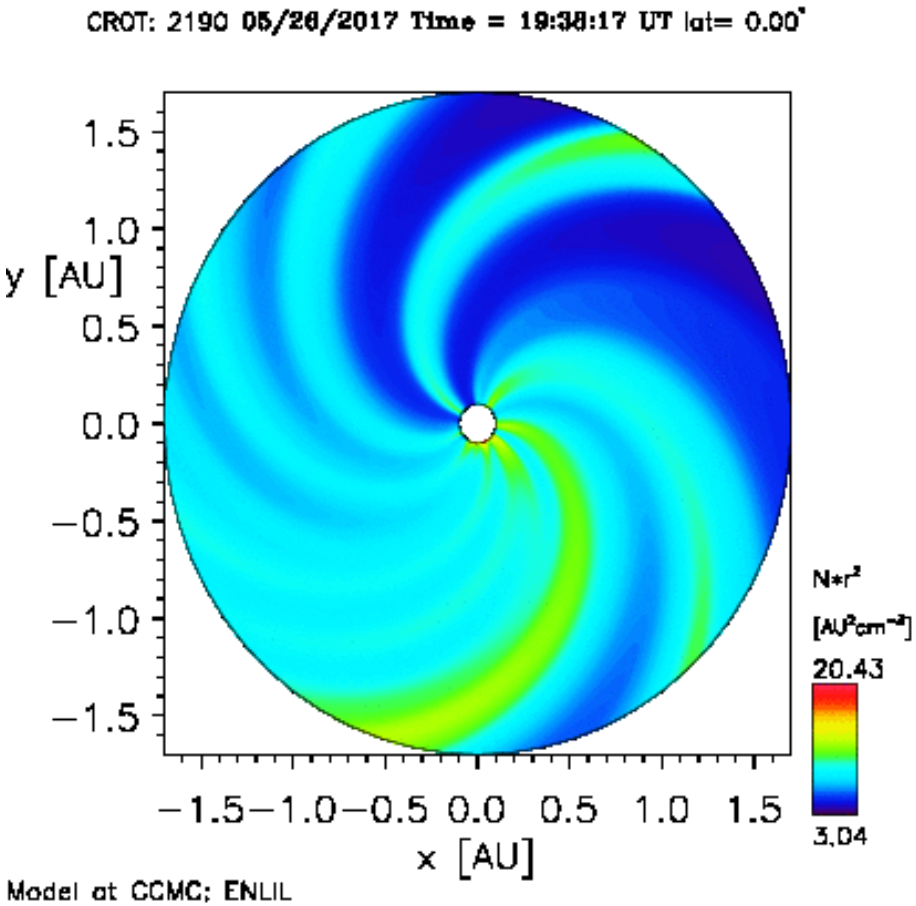
Невязки AOV022

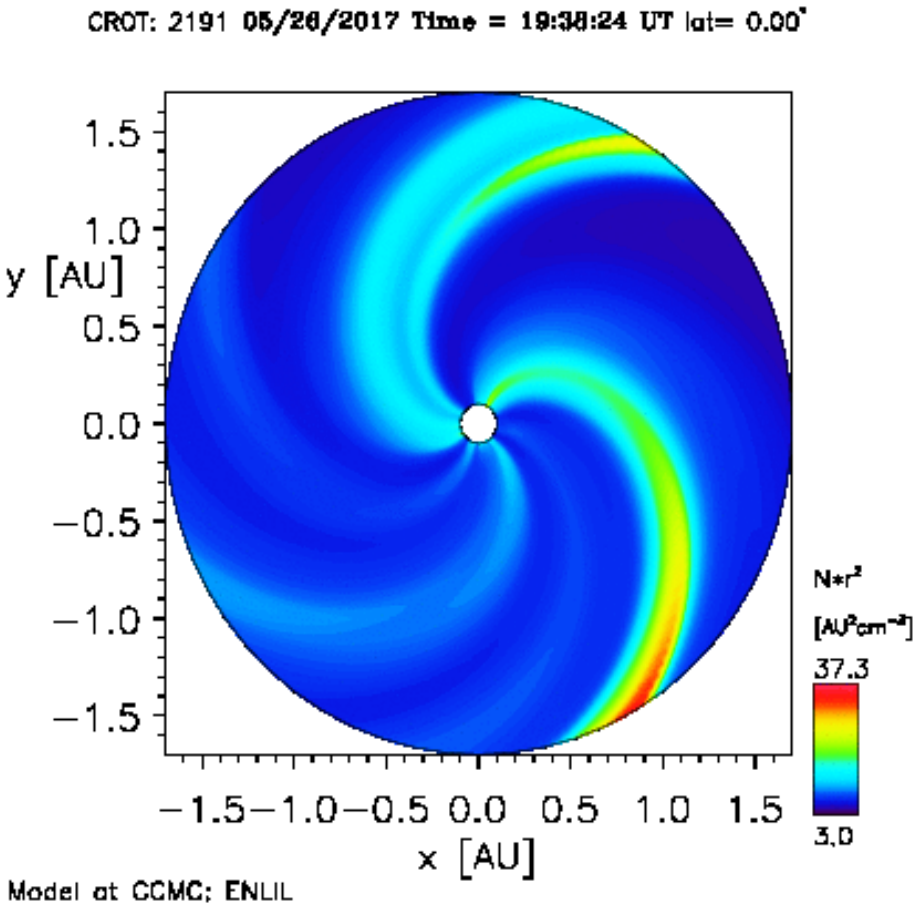


Результаты

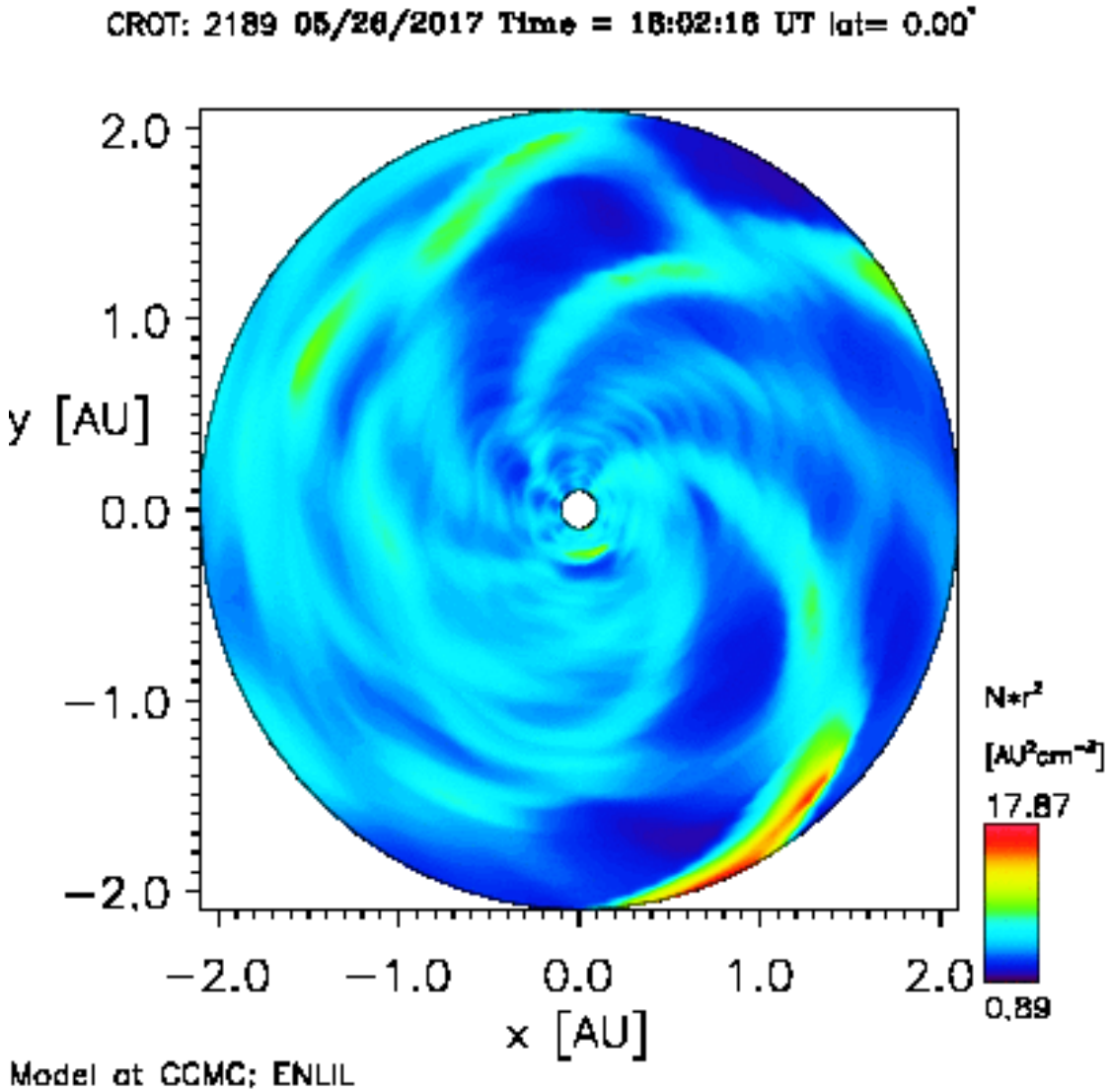
Session	Outliers	α	Soja et al.	Power law		AWSoM	
			N_0 (10^{12} m^{-3})	N_0 (10^{12} m^{-3})	RMS (m)	A	RMS (m)
RD1106	114	2	0.0 ± 0.4	0.10 ± 0.47	0.0485	-1.43 ± 1.28	0.0476
RD1205	214	2	0.5 ± 0.3	1.08 ± 0.21	0.0211	0.21 ± 0.12	0.0223
RD1206	98	2	0.3 ± 0.1	0.34 ± 0.15	0.0288	...	...
RD1208	56	2	1.5 ± 0.4	0.86 ± 0.20	0.0315	...	...
RD1209	234	2	0.1 ± 0.3	0.48 ± 0.25	0.0497	...	...
RD1210	51	2	2.5 ± 0.6	0.00 ± 0.68	0.0482	0.93 ± 0.80	0.0478
AUA020	155	2.2	0.61 ± 0.05	0.57 ± 0.01	0.0655	0.96 ± 0.02	0.0612
AOV022	1203	2	0.44 ± 0.005	0.43 ± 0.02	0.15607	0.84 ± 0.04	0.1530
		2.3	...	0.60 ± 0.03	0.15604		

Разрывы в данных ENLIL





ENLIL с ежедневными магнитограммами



Текст статьи

https://iopscience.iop.org/article/10.3847/1538-4357/ab499a

https://arxiv.org/abs/1910.10529