Replicating DAMA/LIBRA's Annual Modulation

Sophia Hollick, Govinda Adhikari, and Reina Maruyama on behalf of the COSINE-100 Collaboration
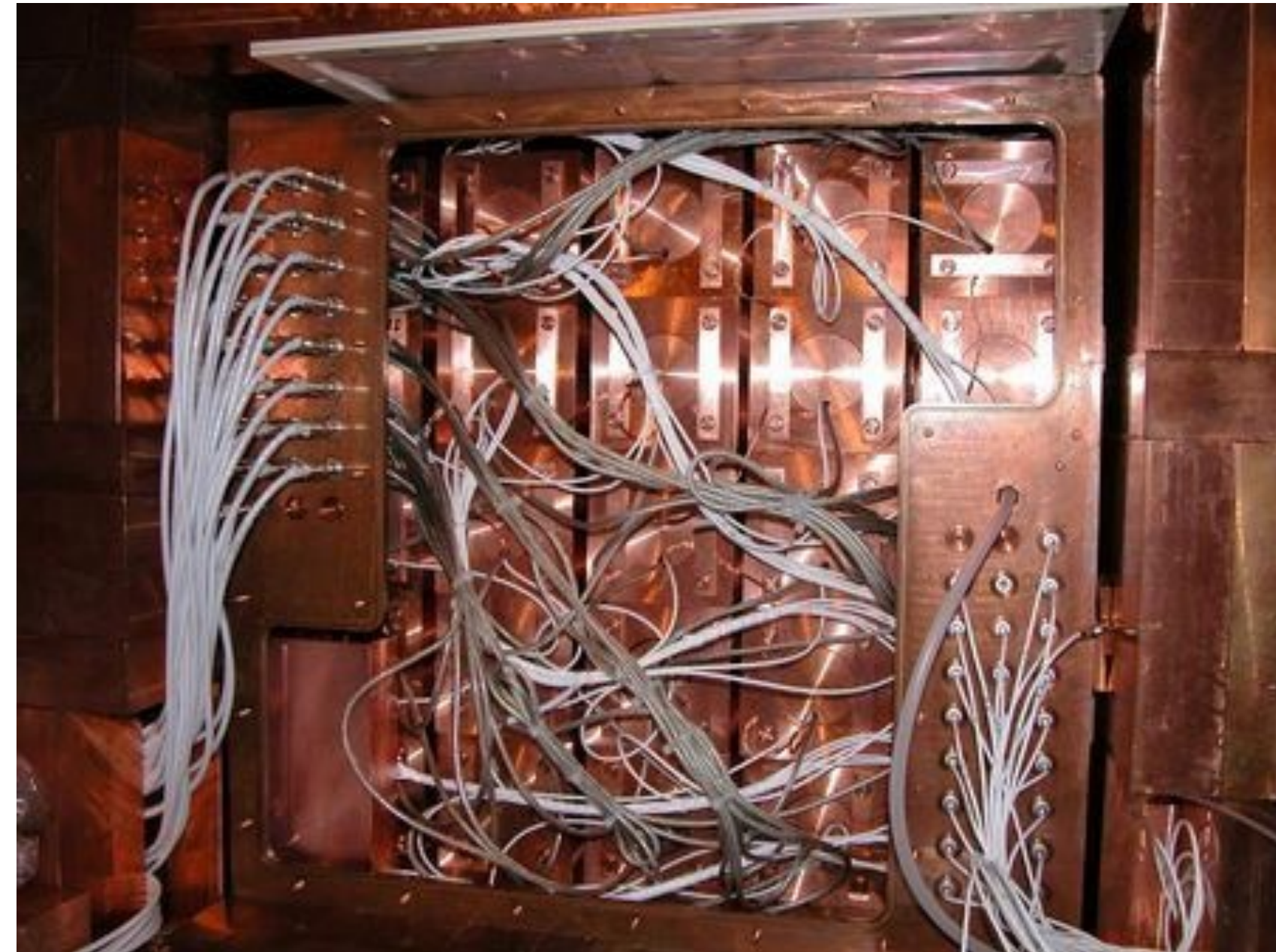*Yale University, Wright Laboratory*

Wright Laboratory

Annual Modulation

- DAMA/LIBRA claims a dark matter WIMP annual modulation signal to 13σ
- COSINE-100 finds **no clear modulation**
  - Uses exponentially decaying background rates
- COSINE-100 **finds modulation to 7σ with DAMA analysis**
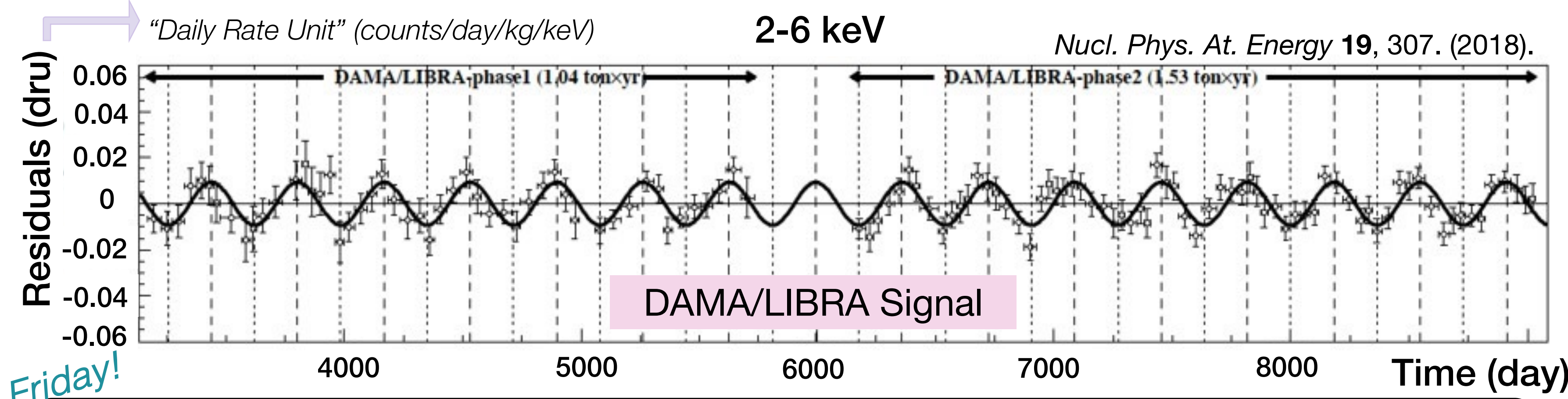 - Uses an annually averaged background subtraction

Nucl. Phys. At. Energy **19**, 307. (2018).

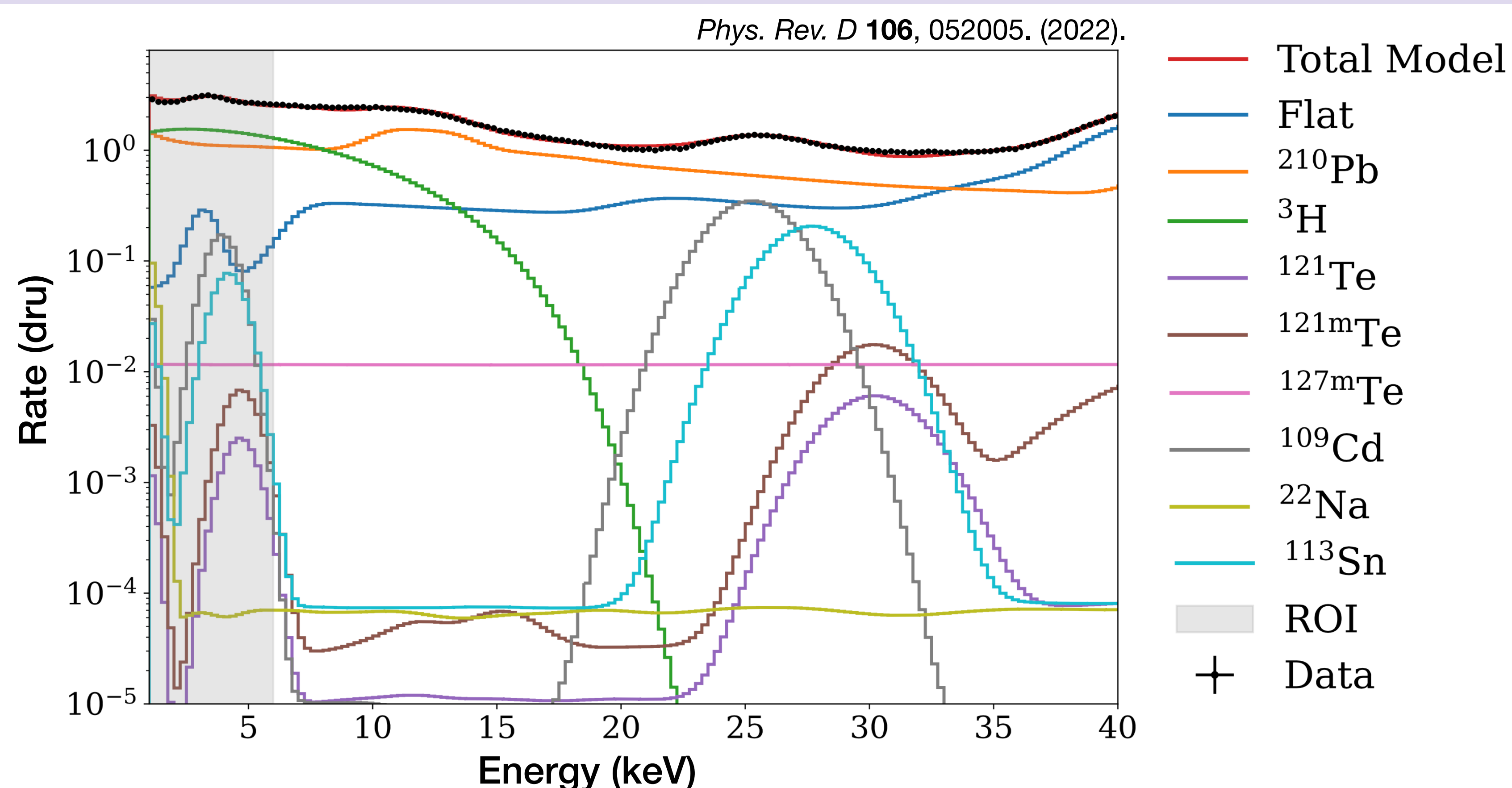*Nature (London)*, 564:83, (2018).

DAMA/LIBRA Experiment

COSINE-100 Experiment

"Daily Rate Unit" (counts/day/kg/keV)   **2-6 keV**   *Nucl. Phys. At. Energy* **19**, 307. (2018).

DAMA/LIBRA:phase1 (1.04 ton×yr)   DAMA/LIBRA-phase2 (1.53 ton×yr)

DAMA/LIBRA Signal

Residuals (dru) / Time (day)

Friday!

Dark Matter Direct Detection Searches with COSINE Experiment Resolving DAMA   *Govinda Adhikari Reina Maruyama*
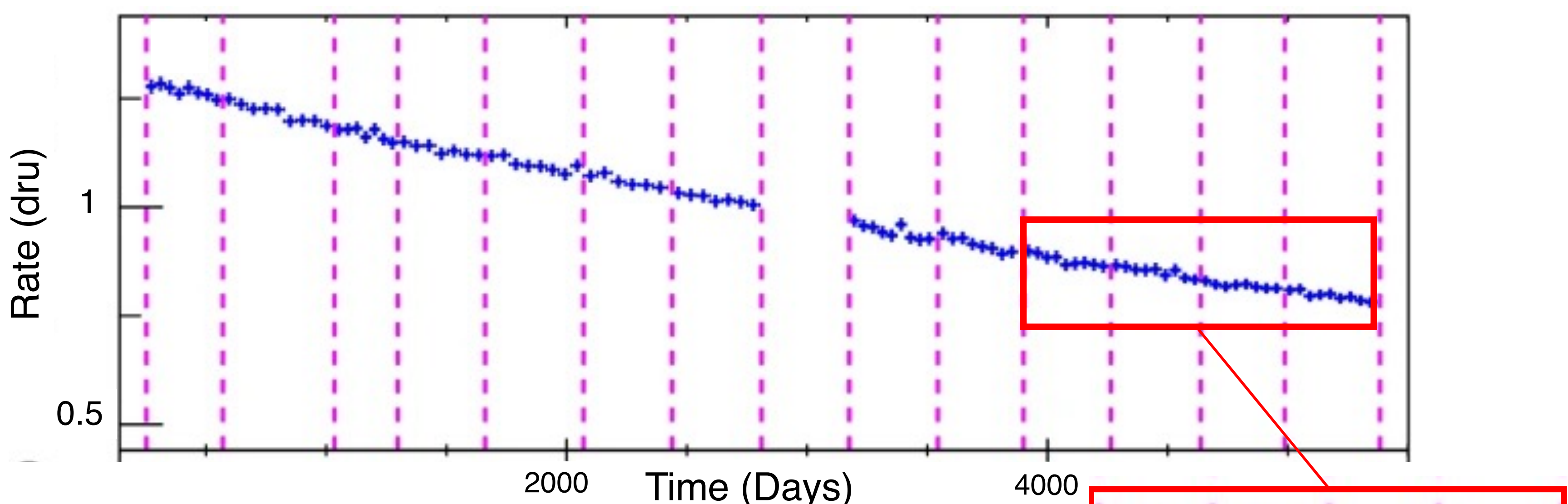PAB- 1-425, UCLA   11:15 – 11:45

Background Rates

- Undeniable time-dependent background exists in COSINE-100's detector
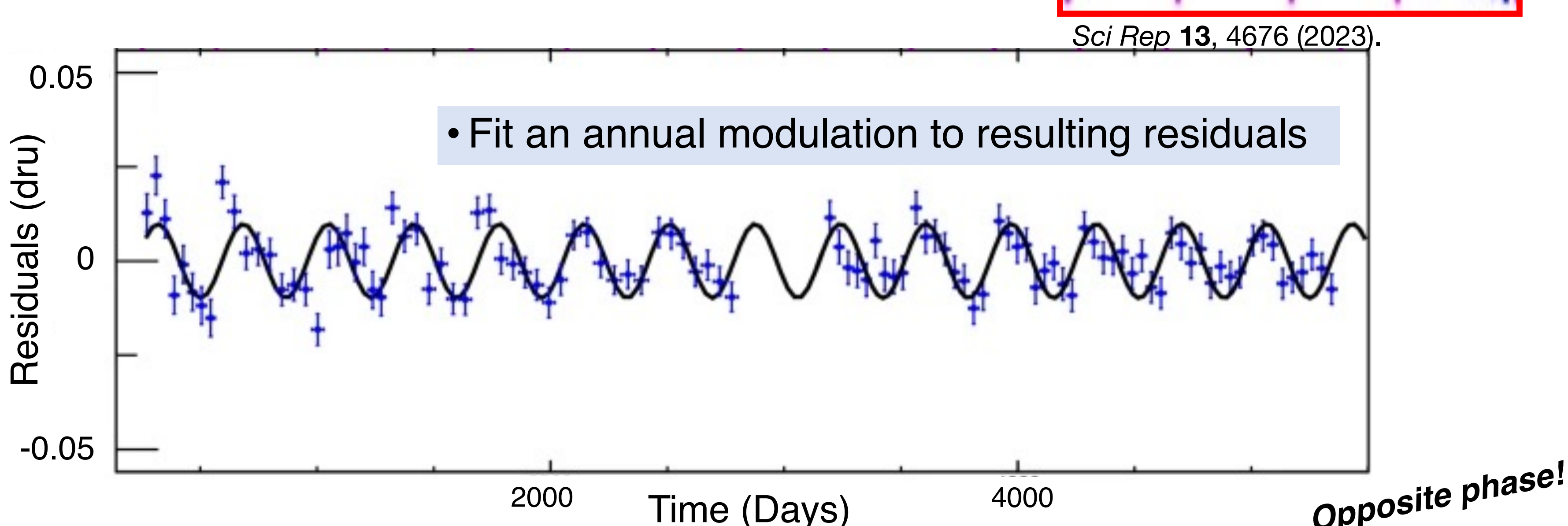 - Modelled from 8 major contributing radioisotopes in NaI(Tl)

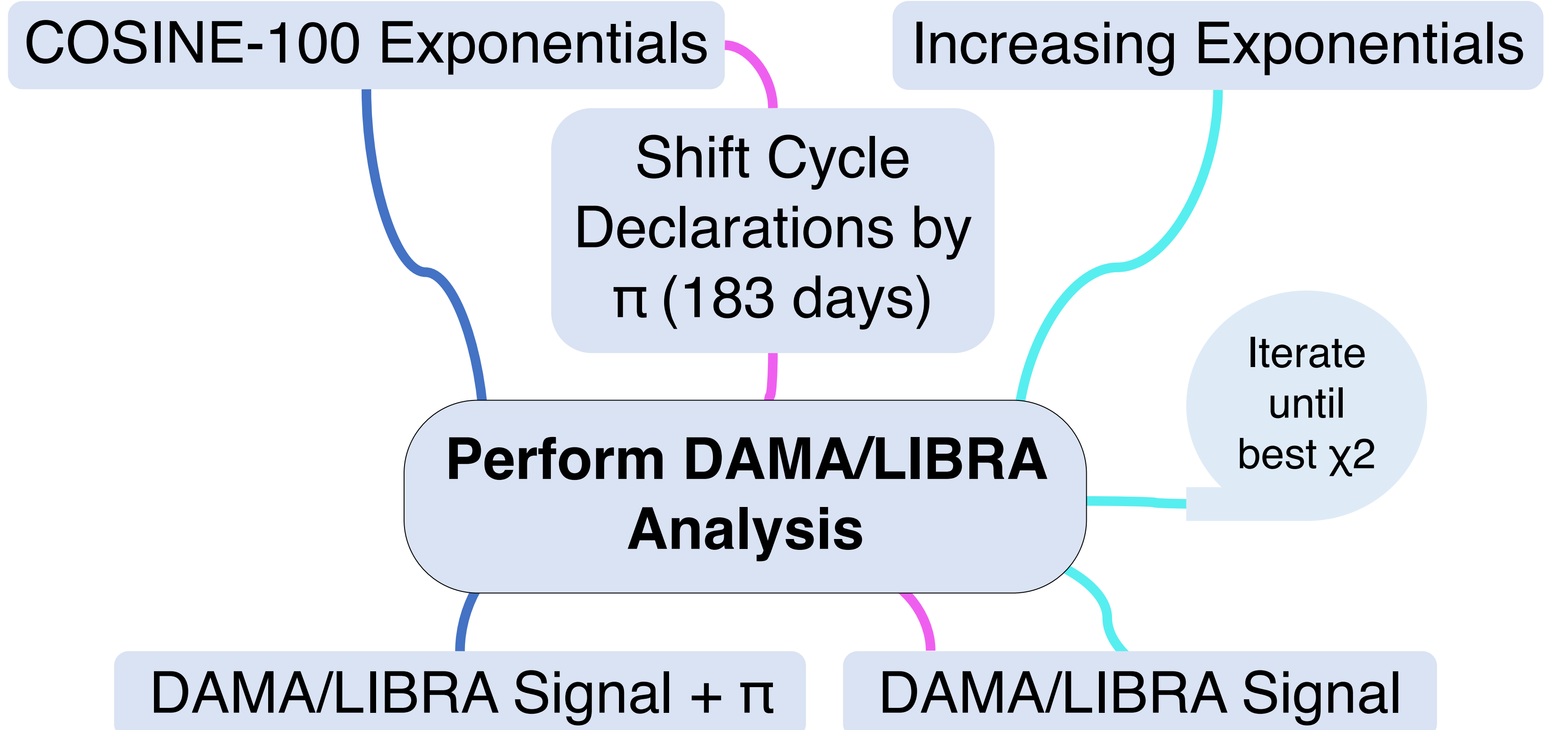*Phys. Rev. D* **106**, 052005. (2022).

Legend:
- Total Model
- Flat
- ^{210}Pb
- ^{3}H
- ^{121}Te
- ^{121m}Te
- ^{127m}Te
- ^{109}Cd
- ^{22}Na
- ^{113}Sn
- ROI
- + Data

Rate (dru) / Energy (keV)

DAMA/LIBRA's Analysis

- Simulate DL experiment with COSINE-100 backgrounds
  - Slice into DAMA declared annual cycles

Rate (dru) / Time (Days)

- Average the rates for each cycle and subtract their points

Sci Rep **13**, 4676 (2023).

- Fit an annual modulation to resulting residuals

Residuals (dru) / Time (Days)

Opposite phase!

Investigating DAMA Phase Dependence

COSINE-100 Exponentials → Shift Cycle Declarations by π (183 days) ← Increasing Exponentials

Perform DAMA/LIBRA Analysis

Iterate until best χ2
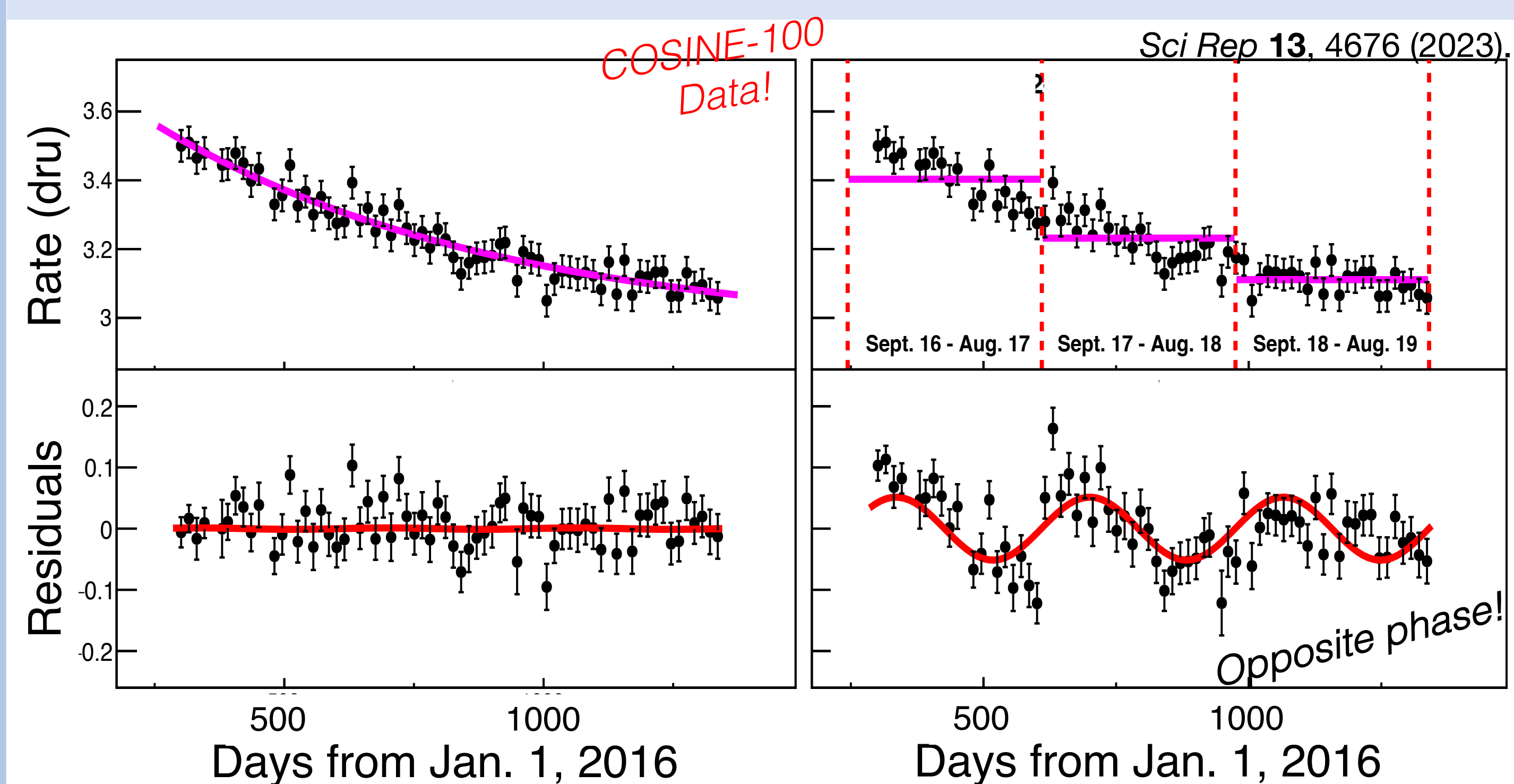
DAMA/LIBRA Signal + π   DAMA/LIBRA Signal

DAMA/LIBRA's Analysis on COSINE-100 Data

- Clear modulation in single-hit events
  - $S_m = (-0.044 \pm 0.006)$ dru at 7σ, but opposite phase
- No modulation in multiple-hit events
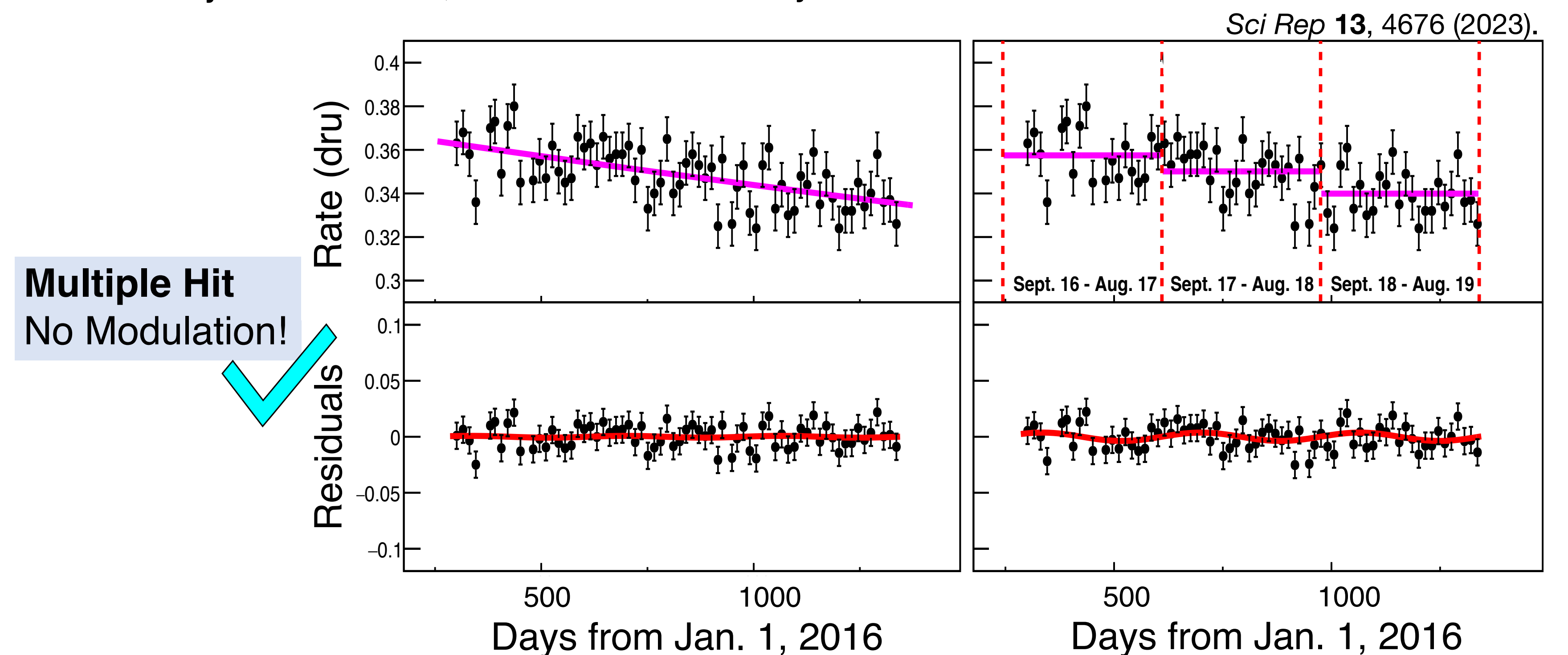 - Matches DAMA's S_m (0.00030 ± 0.00032) dru
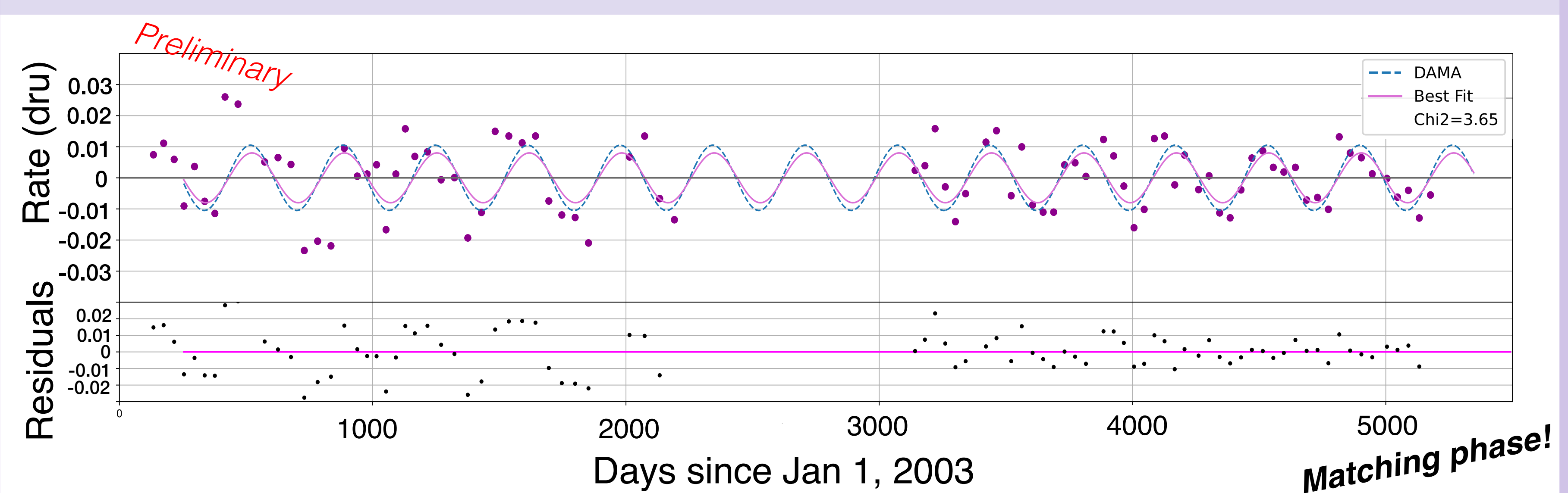
Scan for our paper!

COSINE-100 Data!   *Sci Rep* **13**, 4676 (2023).

Sept. 16 - Aug. 17   Sept. 17 - Aug. 18   Sept. 18 - Aug. 19

Rate (dru) / Residuals / Days from Jan. 1, 2016

Opposite phase!

7σ!

Single Hit Modulation!

Multiple Hit No Modulation!

Sci Rep **13**, 4676 (2023).

Sept. 16 - Aug. 17   Sept. 17 - Aug. 18   Sept. 18 - Aug. 19

Rate (dru) / Residuals / Days from Jan. 1, 2016

π Shifted Cycle Declarations

Using the simulated data, cycle times are shifted by π (183 days), the fitted modulation phase shifts by π, resulting in DAMA's phase.

Preliminary

Legend: DAMA / Best Fit / Chi2=3.65

Rate (dru) / Residuals / Days since Jan 1, 2003

Matching phase!

Conclusions

An induced modulation is possible using DAMA's analysis methods and shows phase dependence for time-dependent backgrounds by:

- shifting cycles times for annual average background subtraction
- modeling exponentially increasing/decreasing background rates

DAMA's analysis is only valid for time-independent backgrounds.

Yale