LOOKING FOR AXIONS WITH NEDM EXPERIMENT

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WE LOOK FOR OSCILLATIONS IN DATA OF ILL AND PSI NEUTRON EDM EXPERIMENTS TO SEARCH FOR ULTRA-LOW-MASS AXION DARK MATTER.

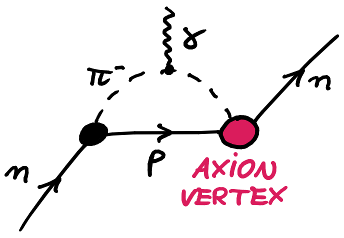
THEORETICAL MOTIVATION

AXION-LIKE PARTICLES TACKLE TWO PROBLEMS OF MODERN PHYSICS: THE STRONG CP PROBLEM OF QCD AND DARK MATTER. MOST SEARCHES FOCUS ON AXION COUPLING TO PHOTONS. RECENTLY, SEARCHING FOR GLUON COUPLING HAS BEEN PROPOSED:

MODEL-DEPENDENT PARAMETER ~ 1

$$\mathcal{L} = \frac{C_G}{f_a} \frac{g^2}{32\pi^2} a \, G^a_{\mu\nu} \tilde{G}^{a\mu\nu} + \ldots$$

AXION DECAY CONSTANT

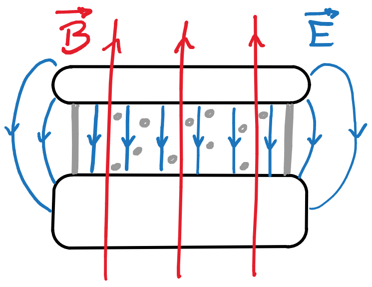


THIS COUPLING INDUCES AN OSCILLATING NEUTRON ELECTRIC DIPOLE MOMENT (EDM):

$$d_n(t) = 5.3 \cdot 10^{-22} C_G \frac{10^{-22}\,\mathrm{eV}}{m_a} \frac{10^{16}\,\mathrm{GeV}}{f_a} \cos(m_a t) \; e\cdot\mathrm{cm}$$

AXION MASS

NEUTRON EDM MEASUREMENT AT ILL & PSI



ULTRA-COLD NEUTRONS CANNOT PENETRATE CERTAIN MATERIALS. WE TRAP THEM BETWEEN TWO ELECTRODES IN A MAGNETIC FIELD. NEUTRONS HAVE ENERGY:

$$h\nu = -2\vec{S}\cdot(\mu\vec{B} + d_n\vec{E})$$

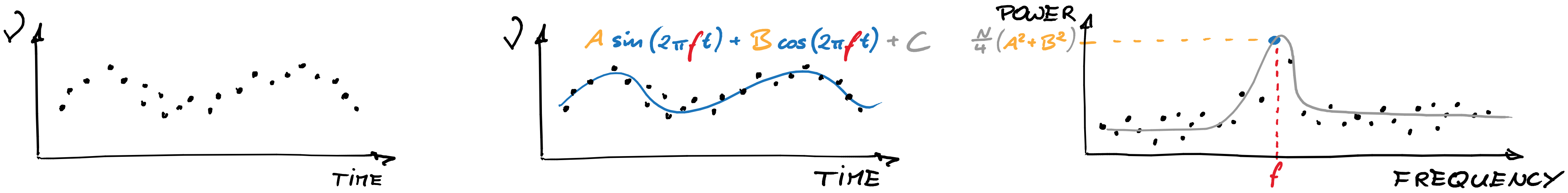
LARMOR PRECESSION FREQUENCY — MEASURED

MAGNETIC, ELECTRIC DIPOLE MOMENTS

STATIC NEUTRON EDM IS MEASURED BY LOOKING FOR A CHANGE IN ν WHEN THE $\vec{E}$ FIELD POLARITY IS REVERSED. OSCILLATING NEUTRON EDM WOULD CAUSE AN OSCILLATION IN THE MEASURED LARMOR PRECESSION FREQUENCY.

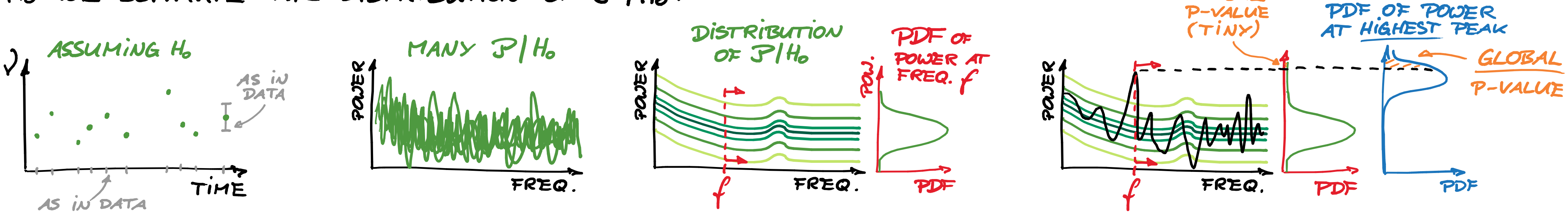
LEAST-SQUARES SPECTRAL ANALYSIS (LSSA)

TO QUANTIFY THE OSCILLATIONS WE USE LSSA. IN LSSA OSCILLATION POWER AT FREQUENCY f IS DETERMINED THROUGH AMPLITUDE OF THE BEST FIT SINE WITH FREQUENCY f TO THE TIME SERIES. THE PERIODOGRAM, $\mathcal{P}$, IS POWER EVALUATED FOR A RANGE OF FREQUENCIES.



LOOKING FOR AN OSCILLATION

AS THE STATISTICAL TEST WE COMPARE THE PERIODOGRAM OF THE ν TIME SERIES WITH ITS DISTRIBUTION GIVEN THE NULL HYPOTHESIS, H_0 – „THE TIME SERIES IS NOISE". BY GENERATING MANY TIME SERIES UNDER H_0 WE ESTIMATE THE DISTRIBUTION OF $\mathcal{P}|H_0$.



THE BEST SIGNAL CANDIDATE IS THE PEAK IN THE DATA PERIODOGRAM RISING HIGHEST ABOVE THE $\mathcal{P}|H_0$ DISTRIBUTION. HOW HIGH ABOVE IT RISES DETERMINES THE LOCAL P-VALUE. THE LOCAL P-VALUE IS ALWAYS SMALL, E.G. ~ 1/100 WHEN 100 FREQUENCIES ARE CONSIDERED. THE CORRECTED, GLOBAL P-VALUE IS:

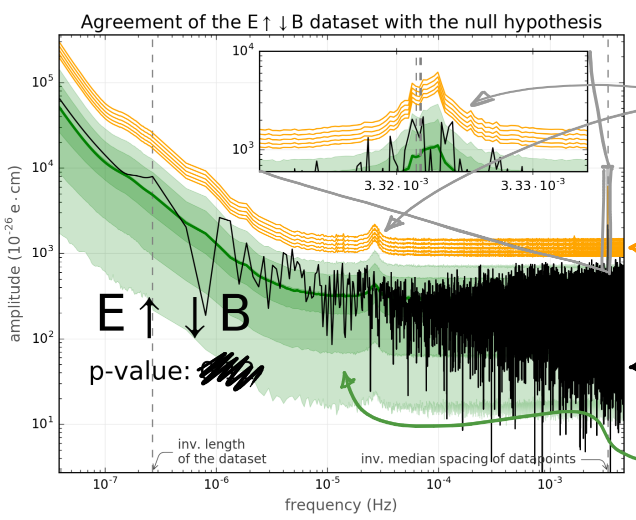
$$p_G = 1 - (1 - p_L)^N$$

NUMBER OF FREQUENCIES

FOR EXAMPLE WITH N=100 P-VALUES

LOCAL:	0.01	10^{-4}
GLOBAL:	0.63	0.01

A SUBSET OF THE ANALYSIS



EXPECTED RISE IN POWER DUE TO THE TIME-STRUCTURE OF THE DATA TAKING

THRESHOLDS FOR GLOBAL P-VALUES 1-, ..., 5-SIGMA

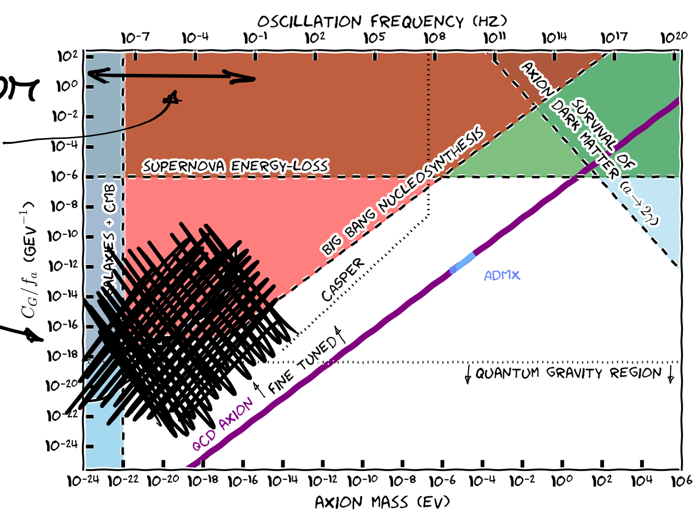
PERIODOGRAM OF A SUBSET OF PSI DATA

$\mathcal{P}|H_0$ DISTRIBUTION

FIRST EXPERIMENTAL SEARCH

WE COVER PERIODS FROM MINUTES TO YEARS

TO BE PUBLISHED SOON!



FURTHER READING: Y.V. STADNIK, V.V. FLAMBAUM, PHYS. REV. D **89**, 043522 (2014)
D.J.E. MARSH, PHYS. REP. **643**, 1 (2016)

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