\[ I(J^P_C) = 0.1(1-\cdots) \]

### γ MASS

For a review of the photon mass, see BYRNE 77.

<table>
<thead>
<tr>
<th>VALUE (eV)</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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<tbody>
<tr>
<td>&lt; 6 \times 10^{-17}</td>
<td></td>
<td>RYUTOV 97</td>
<td>MHD of solar wind</td>
<td></td>
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<tr>
<td>&lt; 1.4 \times 10^{-7}</td>
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<td>ACCIOLY 04</td>
<td>Dispersion of GHz radio waves by sun</td>
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<tr>
<td>&lt; 7 \times 10^{-19}</td>
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<td>LUO 03</td>
<td>Modulation torsion balance</td>
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<tr>
<td>&lt; 1 \times 10^{-17}</td>
<td></td>
<td>LAKES 98</td>
<td>Torque on toroid balance</td>
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<tr>
<td>&lt; 9 \times 10^{-16}</td>
<td>90</td>
<td>FISCHBACH 94</td>
<td>Earth magnetic field</td>
<td></td>
</tr>
<tr>
<td>&lt; (4.73 \pm 0.45) \times 10^{-12}</td>
<td></td>
<td>CHERNIKOV 92</td>
<td>Ampere-law null test</td>
<td></td>
</tr>
<tr>
<td>&lt; (9.0 \pm 8.1) \times 10^{-10}</td>
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<td>RYAN 85</td>
<td>Coulomb-law null test</td>
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<tr>
<td>&lt; 3 \times 10^{-27}</td>
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<td>CHIBISOV 76</td>
<td>Galactic magnetic field</td>
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<tr>
<td>&lt; 6 \times 10^{-16}</td>
<td>99.7</td>
<td>DAVIS 75</td>
<td>Jupiter magnetic field</td>
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<td>&lt; 7.3 \times 10^{-16}</td>
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<td>HOLLWEG 74</td>
<td>Alfvén waves</td>
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<tr>
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<td>FRANKEN 71</td>
<td>Low freq. res. cir.</td>
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<tr>
<td>&lt; 1 \times 10^{-14}</td>
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<td>WILLIAMS 71</td>
<td>Tests Gauss law</td>
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<td>&lt; 2.3 \times 10^{-15}</td>
<td></td>
<td>GOLDBACHER 68</td>
<td>Satellite data</td>
<td></td>
</tr>
<tr>
<td>&lt; 6 \times 10^{-15}</td>
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<td>PATEL 65</td>
<td>Satellite data</td>
<td></td>
</tr>
<tr>
<td>&lt; 6 \times 10^{-15}</td>
<td></td>
<td>GINTSBURG 64</td>
<td>Satellite data</td>
<td></td>
</tr>
</tbody>
</table>

1 RYUTOV 97 uses a magnetohydrodynamics argument concerning survival of the Sun’s field to the radius of the Earth’s orbit. “To reconcile observations to theory, one has to reduce [the photon mass] by approximately an order of magnitude compared with DAVIS 75.

2 LUO 03 determine a limit on \( \mu^2 \mathbf{A} < 1.1 \times 10^{-11} \) T m/m\(^2\) (with \( \mu^{-1}\)—characteristic length for photon mass; \( \mathbf{A} \) = ambient vector potential) — similar to the LAKES 98 technique. Unlike LAKES 98 who used static, the authors used dynamic torsion balance. Assuming \( \mathbf{A} \) to be \( 10^{12} \) T m, they obtain \( \mu < 1.2 \times 10^{-51} \) g, equivalent to \( 6.7 \times 10^{-19} \) eV. The rotating modified Cavendish balance removes dependence on the direction of \( \mathbf{A} \). GOLDBACHER 03 argue that because plasma current effects are neglected, the LUO 03 limit does not provide the best available limit on \( \mu^2 \mathbf{A} \) nor a reliable limit at all on \( \mu \). The reason is that the \( \mathbf{A} \) associated with cluster magnetic fields could become arbitrarily small in plasma voids, whose existence would be compatible with present knowledge. LUO 03B reply that fields of distant clusters are not accurately mapped, but assert that a zero \( \mathbf{A} \) is unlikely given what we know about the magnetic field in our galaxy.

3 LAKES 98 reports limits on torque on a toroid Cavendish balance, obtaining a limit on \( \mu^2 \mathbf{A} < 2 \times 10^{-9} \) T m/m\(^2\) via the Maxwell-Proca equations, where \( \mu^{-1}\) is the characteristic length associated with the photon mass and \( \mathbf{A} \) is the ambient vector potential in the Lorentz gauge. Assuming \( \mathbf{A} \approx 1 \times 10^{12} \) T m due to cluster fields he obtains \( \mu^{-1} > 2 \times 10^{10} \) m, corresponding to \( \mu < 1 \times 10^{-17} \) eV. A more conservative limit, using \( \mathbf{A} \approx (1 \mu G) \times (600 \) pc\) based on the galactic field, is \( \mu^{-1} > 1 \times 10^9 \) m or \( \mu < 2 \times 10^{-16} \) eV.

4 FISCHBACH 94 report \( < 8 \times 10^{-16} \) with unknown CL. We report Bayesian CL used elsewhere in these Listings and described in the Statistics section.
5 CHERNIKOV 92 measures the photon mass at 1.24 K, following a theoretical suggestion that electromagnetic gauge invariance might break down at some low critical temperature. See the erratum for a correction, included here, to the published result.

6 RYAN 85 measures the photon mass at 1.36 K (see the footnote to CHERNIKOV 92).

7 CHIBISOV 76 depends in critical way on assumptions such as applicability of virial theorem. Some of the arguments given only in unpublished references.

8 See criticism questioning the validity of these results in GOLDHABER 71, PARK 71 and KROLL 71. See also review GOLDHABER 71B.

\[ \gamma \] CHARGE

<table>
<thead>
<tr>
<th>VALUE (e)</th>
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<td>&lt;5 \times 10^{-30}</td>
<td>9 RAFFELT 94 TOF</td>
<td>Pulsar $f_1 - f_2$</td>
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<tr>
<td>&lt;8.5 \times 10^{-17}</td>
<td>10 SEMERTZIDIS 03</td>
<td>Laser light deflection in B-field</td>
<td></td>
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<tr>
<td>&lt;2 \times 10^{-28}</td>
<td>11 COCCONI 92</td>
<td>VLBA radio telescope resolution</td>
<td></td>
</tr>
<tr>
<td>&lt;2 \times 10^{-32}</td>
<td>COCCONI 88 TOF</td>
<td>Pulsar $f_1 - f_2$ TOF</td>
<td></td>
</tr>
</tbody>
</table>

9 RAFFELT 94 notes that COCCONI 88 neglects the fact that the time delay due to dispersion by free electrons in the interstellar medium has the same photon energy dependence as due to bending of a charged photon in the magnetic field. His limit is based on the assumption that the entire observed dispersion is due to photon charge. It is a factor of 200 less stringent than the COCCONI 88 limit.

10 SEMERTZIDIS 03 reports the first laboratory limit on the photon charge in the last 30 years. Straightforward improvements in the apparatus could attain a sensitivity of 10^{-20} e.

11 See COCCONI 92 for less stringent limits in other frequency ranges. Also see RAFFELT 94 note.

\[ \gamma \] REFERENCES

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GINTSBURG 64 Sov. Astr. AJ7 536 M.A. Gintsburg (ASCI)