

graviton

$$J = 2$$

graviton MASS

Van Dam and Veltman (VANDAM 70), Iwasaki (IWASAKI 70), and Zakharov (ZAKHAROV 70) almost simultaneously showed that "... there is a discrete difference between the theory with zero-mass and a theory with finite mass, no matter how small as compared to all external momenta." The resolution of this "vDVZ discontinuity" has to do with whether the linear approximation is valid. De Rham *et al.* (DE-RHAM 11) have shown that nonlinear effects not captured in their linear treatment can give rise to a screening mechanism, allowing for massive gravity theories. See also GOLDHABER 10 and DE-RHAM 17 and references therein. Experimental limits have been set based on a Yukawa potential or signal dispersion. h_0 is the Hubble constant in units of $100 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

The following conversions are useful: $1 \text{ eV} = 1.783 \times 10^{-33} \text{ g} = 1.957 \times 10^{-6} m_e$; $\lambda_C = (1.973 \times 10^{-7} \text{ m}) \times (1 \text{ eV}/m_g)$.

VALUE (eV)	DOCUMENT ID	TECN	COMMENT
<6 × 10⁻³²	¹ CHOUDHURY 04	YUKA	Weak gravitational lensing
• • • We do not use the following data for averages, fits, limits, etc. • • •			
<6.8 × 10 ⁻²³	BERNUS	19	YUKA Planetary ephemeris INPOP17b
<1.4 × 10 ⁻²⁹	² DESAI	18	YUKA Gal cluster Abell 1689
<5 × 10 ⁻³⁰	³ GUPTA	18	YUKA SPT-SZ
<3 × 10 ⁻³⁰	³ GUPTA	18	YUKA Planck all-sky SZ
<1.3 × 10 ⁻²⁹	³ GUPTA	18	YUKA redMaPPer SDSS-DR8
<6 × 10 ⁻³⁰	⁴ RANA	18	YUKA Weak lensing in massive clusters
<8 × 10 ⁻³⁰	⁵ RANA	18	YUKA SZ effect in massive clusters
<7 × 10 ⁻²³	⁶ ABBOTT	17	DISP Combined dispersion limit from three BH mergers
<1.2 × 10 ⁻²²	⁶ ABBOTT	16	DISP Combined dispersion limit from two BH mergers
<2.9 × 10 ⁻²¹	⁷ ZAKHAROV	16	YUKA S2 star orbit
<5 × 10 ⁻²³	⁸ BRITO	13	Spinning black holes bounds
<4 × 10 ⁻²⁵	⁹ BASKARAN	08	Graviton phase velocity fluctuations
<6 × 10 ⁻³²	¹⁰ GRUZINOV	05	YUKA Solar System observations
<9.0 × 10 ⁻³⁴	¹¹ GERSHTEIN	04	From Ω_{tot} value assuming RTG
>6 × 10 ⁻³⁴	¹² DVALI	03	Horizon scales
<8 × 10 ⁻²⁰	^{13,14} FINN	02	DISP Binary pulsar orbital period decrease
	^{14,15} DAMOUR	91	Binary pulsar PSR 1913+16
<7 × 10 ⁻²³	TALMADGE	88	YUKA Solar system planetary astrometric data
< 2 × 10 ⁻²⁹ h_0^{-1}	GOLDHABER	74	Rich clusters
<7 × 10 ⁻²⁸	HARE	73	Galaxy
<8 × 10 ⁴	HARE	73	2 γ decay

¹ CHOUDHURY 04 concludes from a study of weak-lensing data that masses heavier than about the inverse of 100 Mpc seem to be ruled out if the gravitation field has the Yukawa form.

- 2 DESAI 18 limit based on dynamical mass models of galaxy cluster Abell 1689.
- 3 GUPTA 18 obtains graviton mass limits using stacked clusters from 3 disparate surveys.
- 4 RANA 18 limit, 68% CL, obtained using weak lensing mass profiles out to the radius at which the cluster density falls to 200 times the critical density of the Universe. Limit is based on the fractional change between Newtonian and Yukawa accelerations for the 50 most massive galaxy clusters in the Local Cluster Substructure Survey. Limits for other CL's and other density cuts are also given.
- 5 RANA 18 limit, 68% CL, obtained using mass measurements via the SZ effect out to the radius at which the cluster density falls to 500 times the critical density of the Universe for 182 optically confirmed galaxy clusters in an Altacama Cosmology Telescope survey. Limits for other CL's and other density cuts are also given.
- 6 ABBOTT 16 and ABBOTT 17 assumed a dispersion relation for gravitational waves modified relative to GR.
- 7 ZAKHAROV 16 constrains range of Yukawa gravity interaction from S2 star orbit about black hole at Galactic center. The limit is $< 2.9 \times 10^{-21}$ eV for $\delta = 100$.
- 8 BRITO 13 explore massive graviton (spin-2) fluctuations around rotating black holes.
- 9 BASKARAN 08 consider fluctuations in pulsar timing due to photon interactions ("surfing") with background gravitational waves.
- 10 GRUZINOV 05 uses the DGP model (DVALI 00) showing that non-perturbative effects restore continuity with Einstein's equations as the graviton mass approaches 0, then bases his limit on Solar System observations.
- 11 GERSHTEIN 04 use non-Einstein field relativistic theory of gravity (RTG), with a massive graviton, to obtain the 95% CL mass limit implied by the value of $\Omega_{tot} = 1.02 \pm 0.02$ current at the time of publication.
- 12 DVALI 03 suggest scale of horizon distance via DGP model (DVALI 00). For a horizon distance of 3×10^{26} m (about age of Universe/c; GOLDHABER 10) this graviton mass limit is implied.
- 13 FINN 02 analyze the orbital decay rates of PSR B1913+16 and PSR B1534+12 with a possible graviton mass as a parameter. The combined frequentist mass limit is at 90%CL.
- 14 As of 2014, limits on dP/dt are now about 0.1% (see T. Damour, "Experimental tests of gravitational theory," in this *Review*).
- 15 DAMOUR 91 is an analysis of the orbital period change in binary pulsar PSR 1913+16, and confirms the general relativity prediction to 0.8%. "The theoretical importance of the [rate of orbital period decay] measurement has long been recognized as a direct confirmation that the gravitational interaction propagates with velocity c (which is the immediate cause of the appearance of a damping force in the binary pulsar system) and thereby as a test of the existence of gravitational radiation and of its quadrupolar nature." TAYLOR 93 adds that orbital parameter studies now agree with general relativity to 0.5%, and set limits on the level of scalar contribution in the context of a family of tensor [spin 2]-biscalar theories.

graviton REFERENCES

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DESAI	18	PL B778 325	S. Desai	(HYDER)
GUPTA	18	ANP 399 85	S. Gupta, S. Desai	
RANA	18	PL B781 220	A. Rana <i>et al.</i>	(DELHI)
ABBOTT	17	PRL 118 221101	B.P. Abbot <i>et al.</i>	(LIGO and Virgo Collabs.)
DE-RHAM	17	RMP 89 025004	C. de Rham <i>et al.</i>	
ABBOTT	16	PRL 116 061102	B.P. Abbott <i>et al.</i>	(LIGO and Virgo Collabs.)
ZAKHAROV	16	JCAP 1605 045	A.F. Zakharov <i>et al.</i>	
BRITO	13	PR D88 023514	R. Brito, V. Cardoso, P. Pani	(LISB, MISS, HSCA+)
DE-RHAM	11	PRL 106 231101	C. de Rham, G. Gabadadze, A.J. Tolley	
GOLDHABER	10	RMP 82 939	A.S. Goldhaber, M.M. Nieto	(STON, LANL)
BASKARAN	08	PR D78 044018	D. Baskaran <i>et al.</i>	
GRUZINOV	05	NAST 10 311	A. Gruzinov	(NYU)
CHOUDHURY	04	ASP 21 559	S.R. Choudhury <i>et al.</i>	(DELPH, MELB)
GERSHTEIN	04	PAN 67 1596	S.S. Gershtein <i>et al.</i>	(SERP)
		Translated from YAF 67 1618.		

DVALI	03	PR D68 024012	G.R. Dvali, A. Grizinov, M. Zaldarriaga	(NYU)
FINN	02	PR D65 044022	L.S. Finn, P.J. Sutton	
DVALI	00	PL B485 208	G.R. Dvali, G. Gabadadze, M. Porrati	(NYU)
TAYLOR	93	NAT 355 132	J.N. Taylor <i>et al.</i>	(PRIN, ARCBO, BURE+) J
DAMOUR	91	APJ 366 501	T. Damour, J.H. Taylor	(BURE, MEUD, PRIN)
TALMADGE	88	PRL 61 1159	C. Talmadge <i>et al.</i>	(JPL)
GOLDHABER	74	PR D9 1119	A.S. Goldhaber, M.M. Nieto	(LANL, STON)
HARE	73	CJP 51 431	M.G. Hare	(SASK)
IWASAKI	70	PR D2 2255	Y. Iwasaki	
VANDAM	70	NP B22 397	H. van Dam, M. Veltman	(UTRE)
ZAKHAROV	70	JETPL 12 312	V.I. Zakharov <i>et al.</i>	
