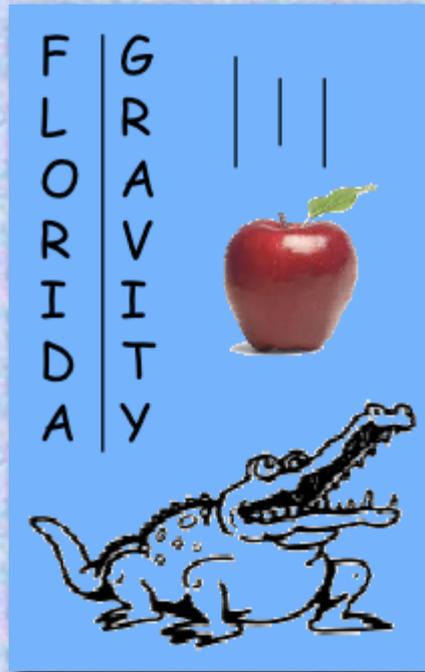


Testing GR: Then and Now



Clifford Will

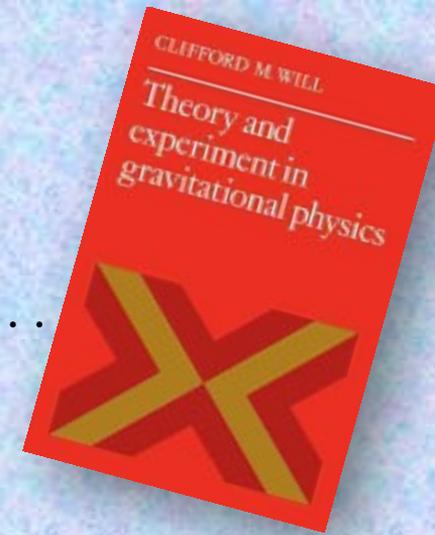
University of Florida, Gainesville

Institut d'Astrophysique de Paris

Physics and Astronomy at the Extreme, Nikhef, 14-17 Aug 2017

Then - 1981

Release of that blockbuster megahit . . .

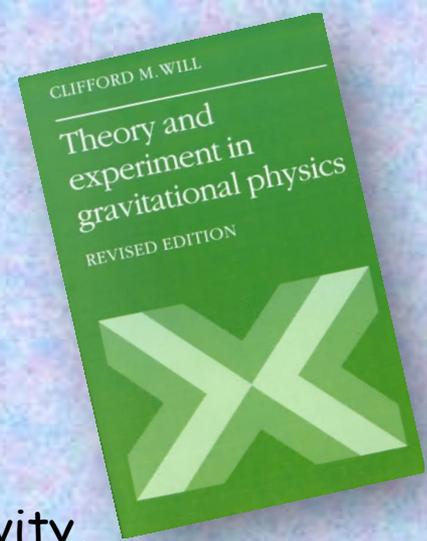


- ❑ Few alternative theories
 - ◆ Scalar-tensor, Rosen, Rastall, "straw-man" theories
 - ◆ Little contact with HE physics, quantum gravity, cosmology
 - ◆ PPN, $TE\mu$ framework
- ❑ Many experiments but narrow span
 - ◆ Solar-system - deflection, Mercury, Shapiro delay, LLR, preferred frame tests
 - ◆ EEP - redshift, Eötvös, Hughes-Drever
 - ◆ 1 binary pulsar
 - ◆ Cosmological tests - a joke
 - ◆ Astrophysical tests - you're kidding
 - ◆ GW tests - resonant bars ruled, no detections



Now - 2017

Coming soon to a Kindle near you . . .



- ❑ **Many** alternative theories
 - ◆ Scalar-tensor, T-V, T-V-S, Horava, Chern-Simons, massive gravity, Dilaton-Gauss-Bonnet, ...
 - ◆ **Much** contact with HE physics, quantum gravity, cosmology
 - ◆ PPN, SME, PPE, ...
- ❑ **Many** experiments, much broader and deeper span
 - ◆ Solar-system - precision, GPB, LAGEOS
 - ◆ EEP - WEP, LLI, LPI
 - ◆ Plenty of binary pulsars
 - ◆ Cosmological tests - getting serious
 - ◆ Astrophysical tests - data, models, ideas; SgrA*, EHT, Xrays
 - ◆ GW tests - finally!



Future: Gravitational-wave tests

Alternative theories are very complicated

- ◆ how to produce nPN waveforms
- ◆ compact body effects (sensitivities, black holes)
- ◆ different wave speeds
- ◆ numerical implementations

The problem of dipole radiation and compact binaries

- ◆ to get quadrupole formula equivalent, need EOM & dipole moment to 1PN order
- ◆ To get 2PN equivalent, need EOM & dipole to 3PN order!
- ◆ scalar-tensor to 2PN (Mirshekari, Will, Lang, Heffernan, Bernard)
- ◆ Einstein-Aether to QPN (Foster, Barausse et al) (binary pulsars only)

How much theoretical investment is appropriate?



Future: questions and challenges

To test GR in the strong-field, GW and cosmological regimes:

- ❑ How necessary are foils?
- ❑ How useful are the current alternatives in this role?
- ❑ How useful are parametrized approaches?
 - ◆ too phenomenological, lack theoretical clarity
 - ◆ too situational (eg circular inspiral parametrizations)
 - ◆ some predictions are environment-dependent (screening, chameleon, preferred frames)
- ❑ Can fundamental tests be done or must it be case by case?
- ❑ What does a measurement contra GR mean?
- ❑ How to confirm a violation of GR?

Testing GR in this new era will be much harder than in the 'old' days!



What role for the... the

SCIENCE

Gravitational Waves Detected, Confirming Einstein's Theory



Dennis Overbye
OUT THERE FEB. 11, 2016



"Einstein"

W

...even politicians



Nation

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Wednesday, 17 February 2016 | MYT 10:32 PM

M'sian woman in team that proved Einstein's gravitational waves theory

BY MICHELLE TAM CALIFORNIA | U.S. & WORLD

Los Angeles Times

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Einstein's theory confirmed again: Scientists detect gravitational waves for second time



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What role for testing GR in the 3G science case?

GW are pure Einstein, so that should be exploited
"Einstein was right" excites the general public, maybe even politicians

Other science case arguments don't excite me:

failure of GR in quantum regime

Looking for hints of quantum gravity in *GW* is not serious
impossible to explain

Testing our fundamental theories is what physicists do
i.e. give us billions for more of the same

Einstein could be wrong

Really? It has passed every test so far. Why not accept it and move on
the Gravity Probe B problem

Current alternatives are hardly compelling, are very complicated

