Mark Trodden Lecture Questions

Most questions (except Q8) already had first pass answering during the Q&A session. Original questions listed mostly without correction for grammar/spelling. Where a slide number was given it is shown.

Q1 [slide 11] What does it mean for a field to be dynamical?

Here I mean that they evolve in time and space, as opposed to a cosmological constant, which is a candidate for causing acceleration but which will do neither. As I discussed in the talk, sometimes dynamical dark energy is a new field in the theory, and other times it arises through a modification of gravity that gives rise to new fields., in the EFT way of describing things, we can remain agnostic as to the origin, but in either case it is a new degree of freedom that evolves in space and time.

Q2 [slide 11] Do the LIGO limits on gravity waves traveling at the speed of limit limit the parameter space for modifying GR?

Most certainly. See, for example, the discussion of the constraints on ghost-free scalar tensor theories (Horndeski theories) on slides 31 and 32.

Q3 [slide 11] Does the fact that the vector and scalar field components of the GR metric mean that they are not observable? Could they theoretically be observed indirectly?

No, these are just not propagating degrees of freedom in GR, and so they are not dynamical in the theory. However, if you modify GR, then some of these degrees of freedom can become dynamical. For example, in the f(R) theories, one frees up precisely one extra scalar degree of freedom that can be observable. In fact, it is so observable that solar system tests rule out large regions of parameter space in those theories.

Q4 [slide 17] What does analyticity of the S-matrix mean?

In quantum field theories, there are certain properties forced upon the theory by, for example, unitarity. Many of these constraints can be expressed as analytic properties of the scattering matrix, thought of as a complex function of its arguments. This can be particularly powerful as a way of constraining the structure of low energy EFTs by requiring that whatever is the UV completion of the theory be Lorentz invariant and unitary. In particular, by examining the low-energy S-matrix, quite a few of the ideas that use Vainshtein screening as a way to make a dark energy model consistent with solar system constraints require a choice that means that the UV theory cannot be Lorentz invariant and unitary. One might see this as a serious failing of these models, or one might think of it as a theoretical challenge to look for consistent UV completions that are not both Lorentz invariant and unitary.

Q5 [slide 20] What's a nonlinear completion?

Massive gravity as conceived by Fierz and Pauli was a Lagrangian for the graviton the was correct up to quadratic order (and hence has linear equations of motion). This is the same sense that if we take GR and expand the Einstein-Hilbert action around flat space we get at lowest order just a free massless graviton that obeys the wave equation.

The "nonlinear completion" of GR, in this language, is the full Einstein-Hilbert action, with all its nonlinearities. It was long thought that any attempt to provide such a "nonlinear completion: for massive gravity was doomed to have ghosts. The recent interest in massive gravity stems from the realization that there does, in fact, exist such a nonlinear form for the theory that is ghost-free.

Q6 [slide 29] What's the ISW effect?

This is the net (integrated) effect on CMB photons as they traverse potential wells that are evolving in time as structure forms in the expanding universe. You might find this useful:

http://background.uchicago.edu/~whu/physics/aux/isw.html

Q7 Could you please comment about the current consensus (or constraints) on mass varying neutrinos in relation to dark energy?

I'm afraid I'm not really up-to-date on this. Perhaps all I can say is that these models were/are interesting because they try to exploit the coincidence in scales between the neutrino mass differences and the energy scale of dark energy in order to address the coincidence problem of why dark energy has become important at this time in cosmic history.

Q8 How long has it been since the Vainshtein mechanism was first proposed?

Vainshtein's original paper was in 1972. It was an attempt to address an apparent peculiarity in the Fierz-Pauli theory known as the vdVZ discontinuity. In more recent times, it has been studied in DGP models, in ghost-free massive gravity, and in a range of scalar field models that exhibit some of the same interesting nonlinear phenomenology, such as the galileons.

You might find this interesting:

https://arxiv.org/pdf/1304.7240.pdf

Q9 [slide 15] Can you explain again the meaning of a "ghost"? Because I remember that the Faddeev-Popov ghosts have a standard kinetic term, so it's a bit confusing here. Please correct me if my memory is wrong. Thanks!

A ghost is a propagating degree of freedom in the theory with the wrong sign kinetic term. Fadeev-Popov ghosts are not actual degrees of freedom in non-Abelian gauge theories, but are an artifact used to implement the quantization procedure. Here I was talking about actual

degrees of freedom. They would have negative kinetic energy, and would render the theory unstable and unacceptable.