The Ultra-Broadband Receiver

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BEACON

- Goal of the grant is to carry out the most stringent tests of general relativity ever!

Objective: Testing general relativity with asymmetric binaries

- The effects on binary orbits we will be looking for are

  1. **Strong Equivalence Principle violations (wide orbits) - see Freire, Kramer & Wex 2012 (CQG, invited review, see arxiv:1205:3751)**

  2. **Dipolar gravitational wave emission (tight orbits) – See Freire et al. 2012, MNRAS, 423, 3328.**

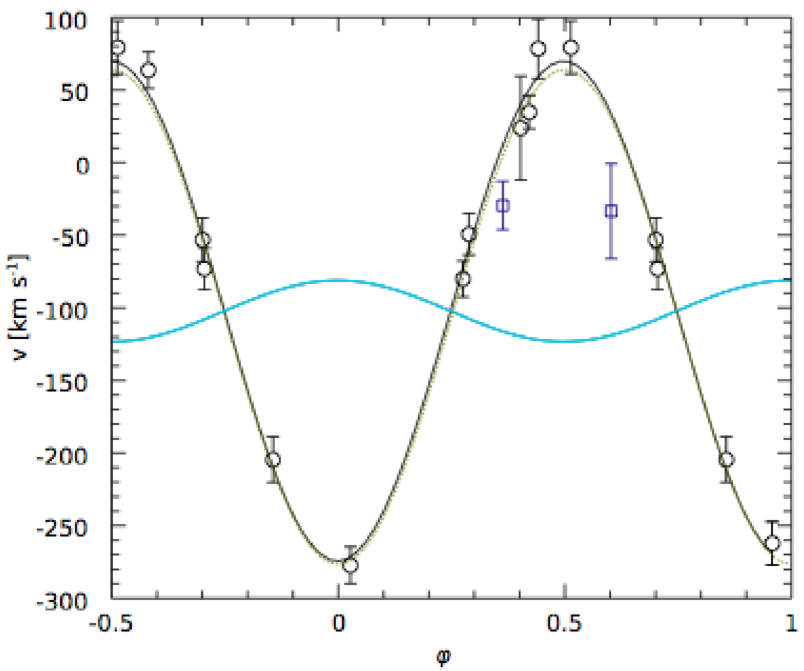
- These effects are predicted by many alternative theories to general relativity. **Detecting them would falsify GR**!

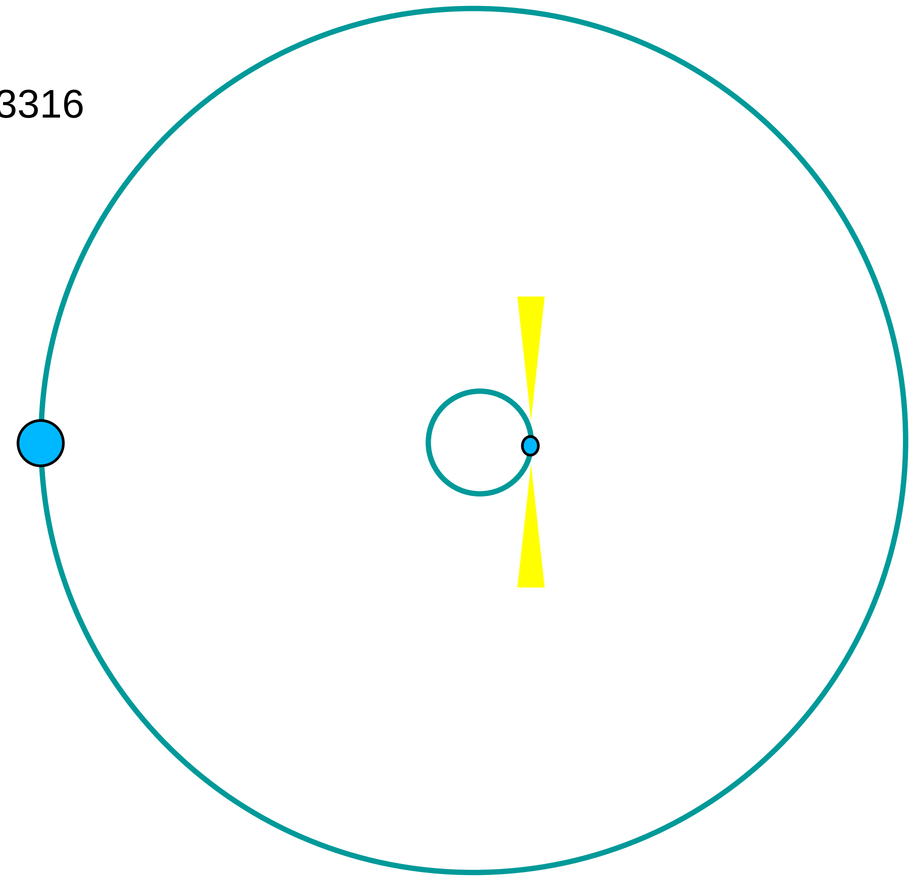
- Neither effect can be detected with the original binary pulsar (PSR B1913+16), or any double neutron star system: the reason is that the magnitude of these effects depends on **the difference** in the compactness between the two main components.

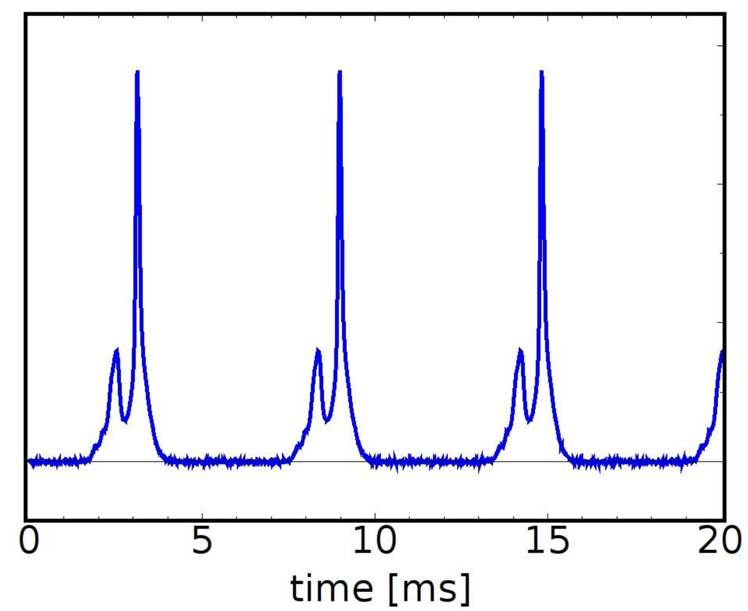
- **Therefore, we need pulsar – white dwarf systems, for which this difference is very large!**

Optical observations are very important!

From: Antoniadis et al., 2012, MNRAS, 423, 3316





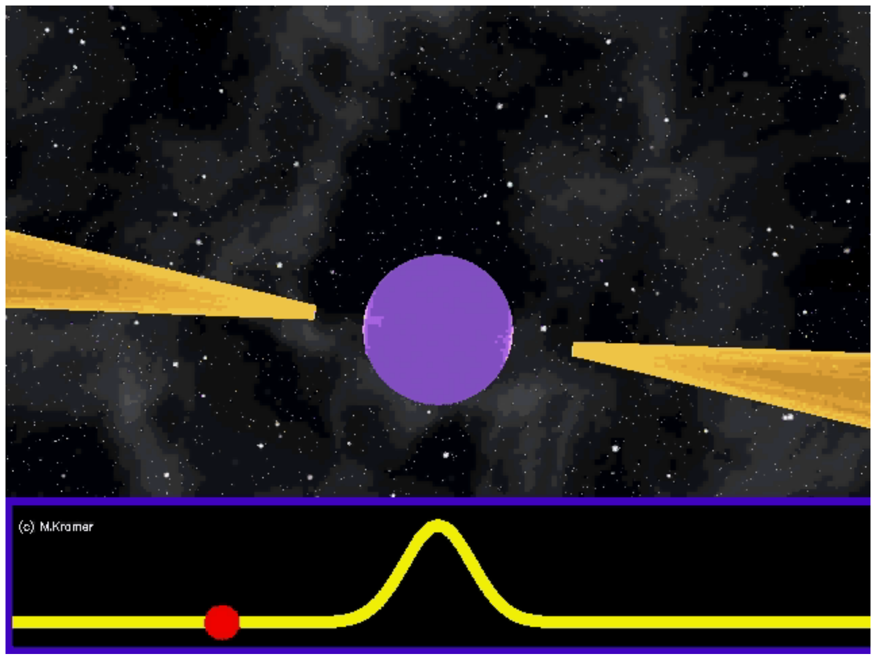


- Optical observations provide masses and systemic velocities..

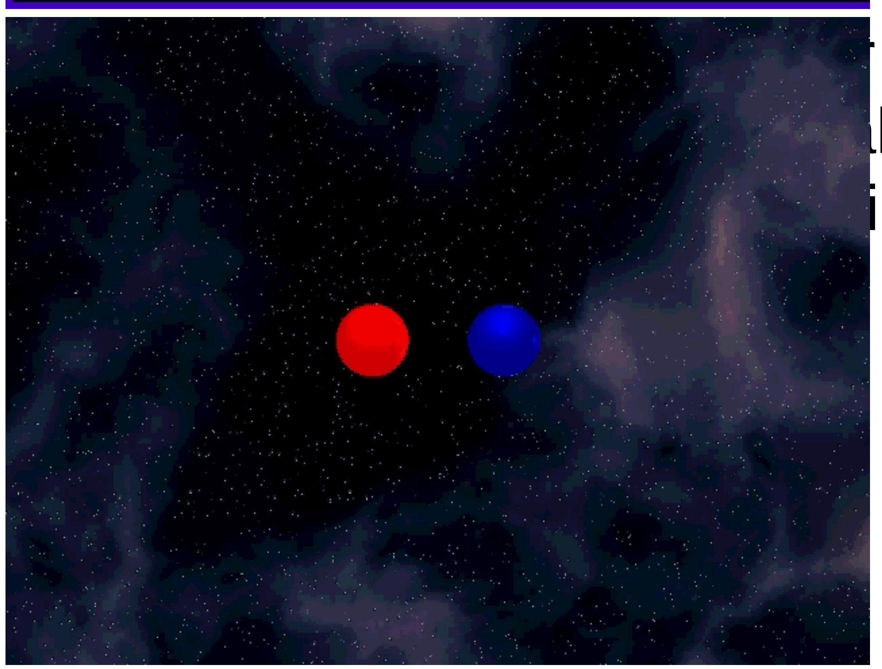
- This allows new tests of general relativity from timing!

What for? Pulsar timing!

We want to perform clean and simple experiment:



Pulsar timing: Measure pulsar motion by timing arrival of radio pulsars at telescope.



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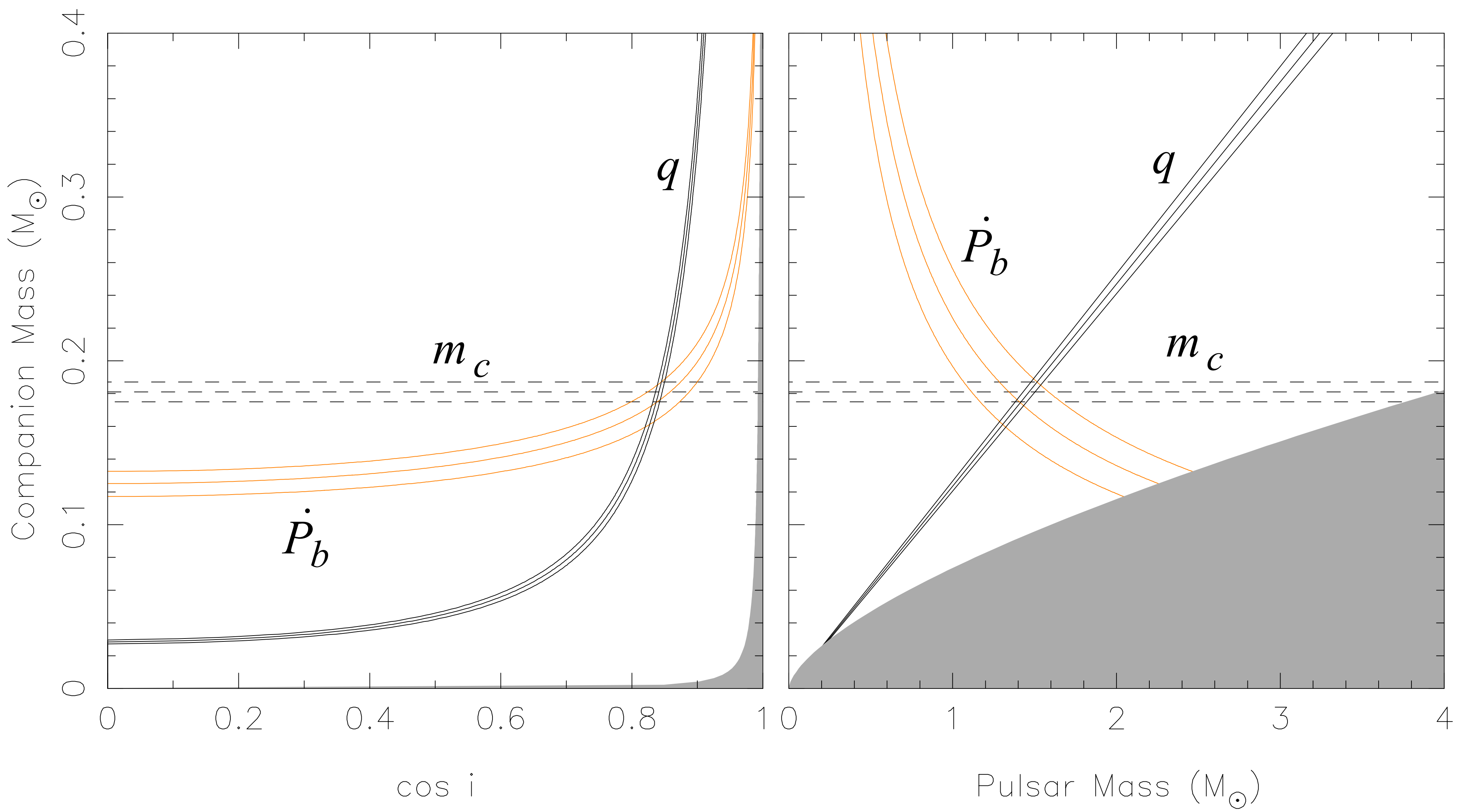
Different theories predict different orbital dynamics for these systems!

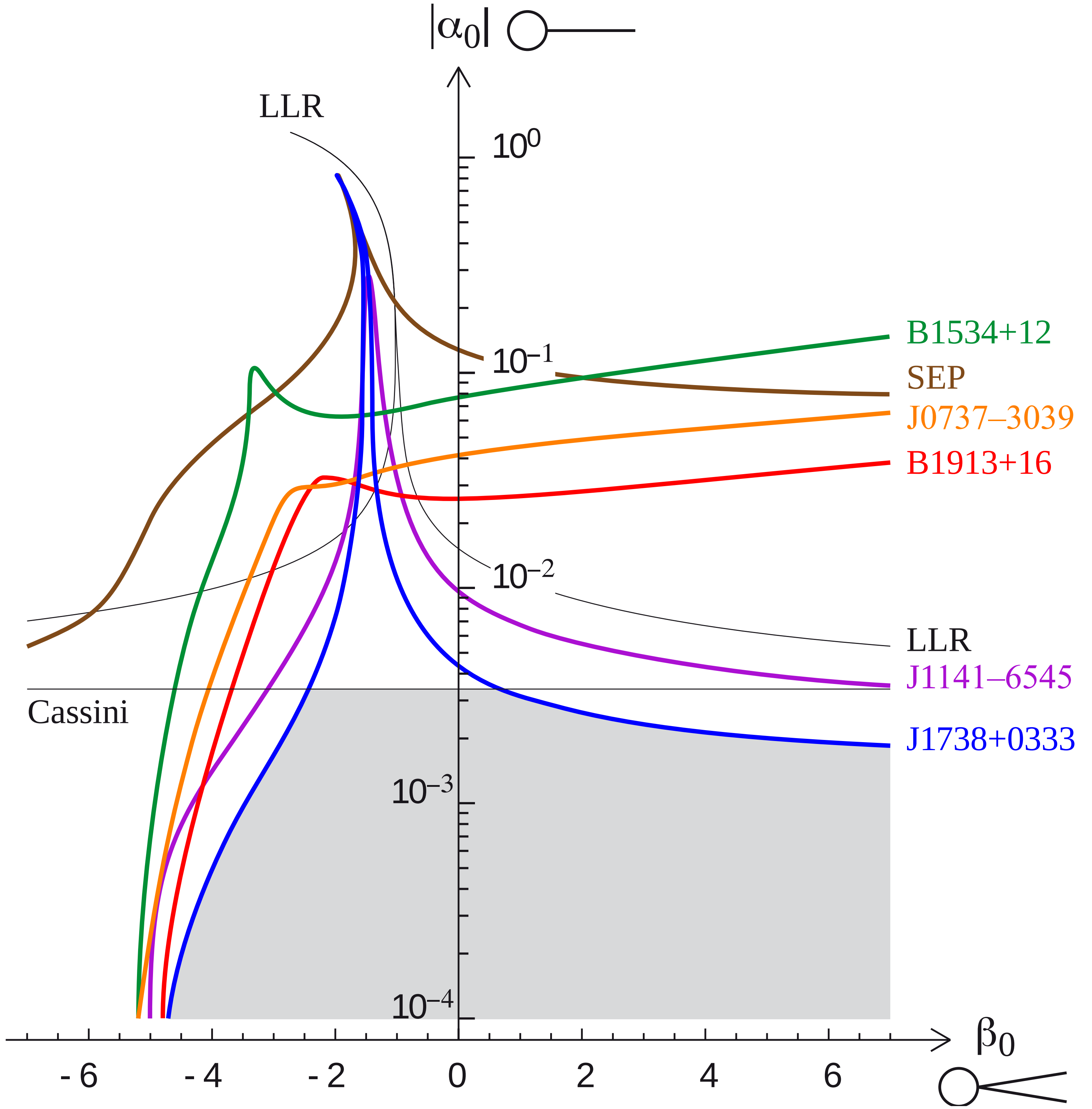
Binary pulsars: ~200 out of the total of ~2000 known pulsars have binary companions. Pulsar’s momevent probes space-time around companion star!

General Relativity still passes our tests

For each constraint on the masses, the corresponding curves (calculated using a gravity theory in the case of the orbital decay) must meet on a mass-mass diagram. For 1738+0333, GR passes the test with flying colors!



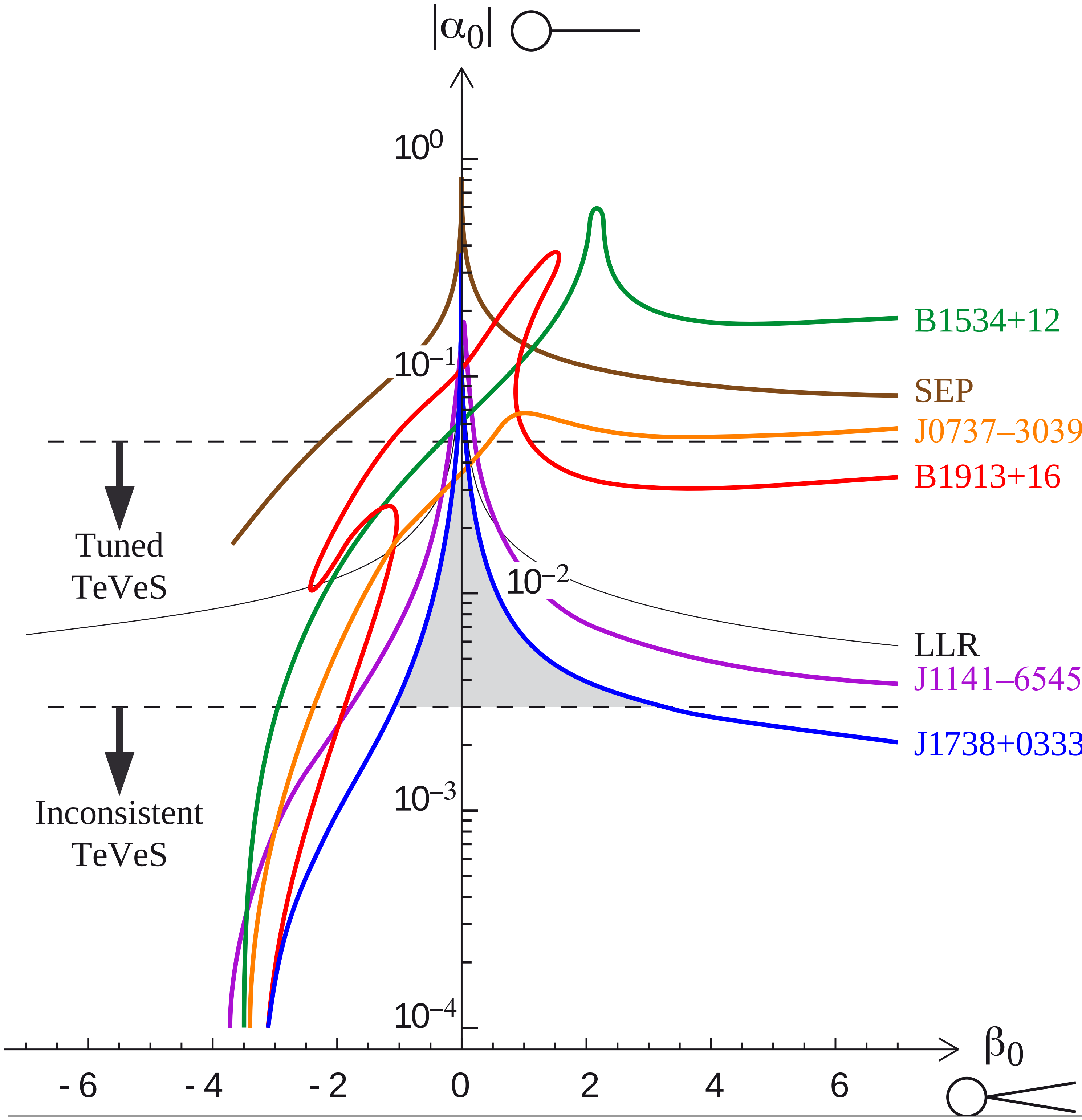
We already have the most constraining binary pulsar tests ever!



- Alternative theories of gravity predict much larger orbital decay in a system containing a neutron star and a white dwarf.

- Because of this, PSR J1738+0333 *already represents the best constraint on alternative theories of gravity*! For Tensor-Scalar theories of Gravity, current limits are derived from it and Cassini.

… most constraining binary pulsar tests ever!



- Tensor-Vector-Scalar (TeVeS) theories can also be constrained, but in this case PSR J1738+0333 is not enough.
- Improvements in the timing precision of the double pulsar (PSR J0737−3039) will be essential to constrain regions near linear coupling.
- Depending on the quality of these improvements, **TeVeS might become an inconsistent theory**.

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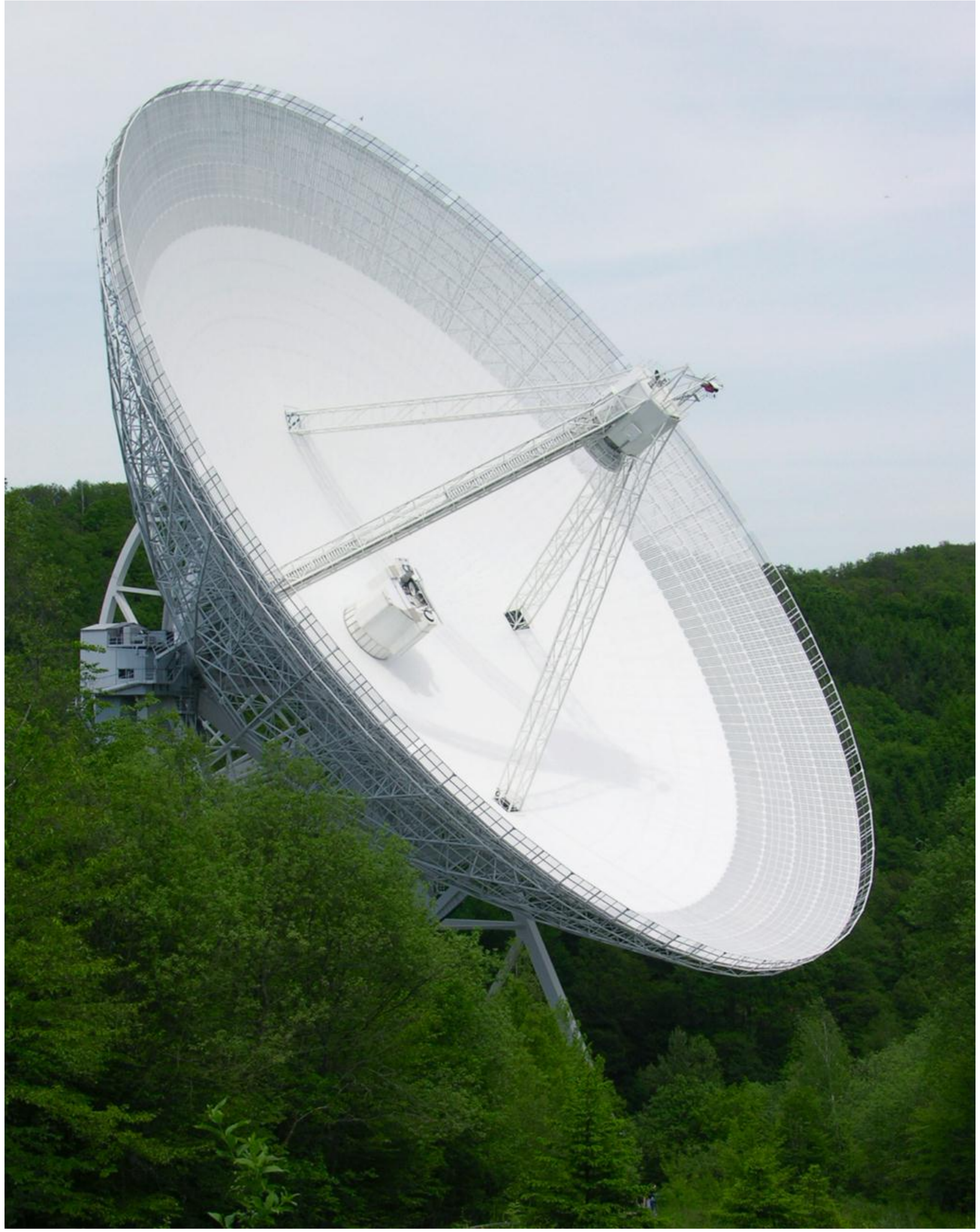
- Project funded in 2011 by ERC Consolidator Grant n. 279702.

- This is to be achieved using the pulsar timing technique.

- It has a strong experimental component, with two main pieces of new Hardware: the ultra broadband receiver and associated broadband coherent dedispersion back-ends.

What do we need to do?



- To differentiate between GR and alternatives, ***we must improve pulsar timing precision***!
- *Limitations*:
  - *telescope sensitivity*
  - *effects of the interstellar medium*.
- Solution:
  - ***ultra-broad-band receiver*** (0.6 - 3 GHz),
  - ***Beyond state-of-the-art spectrometer***

Other impacts in pulsar science.

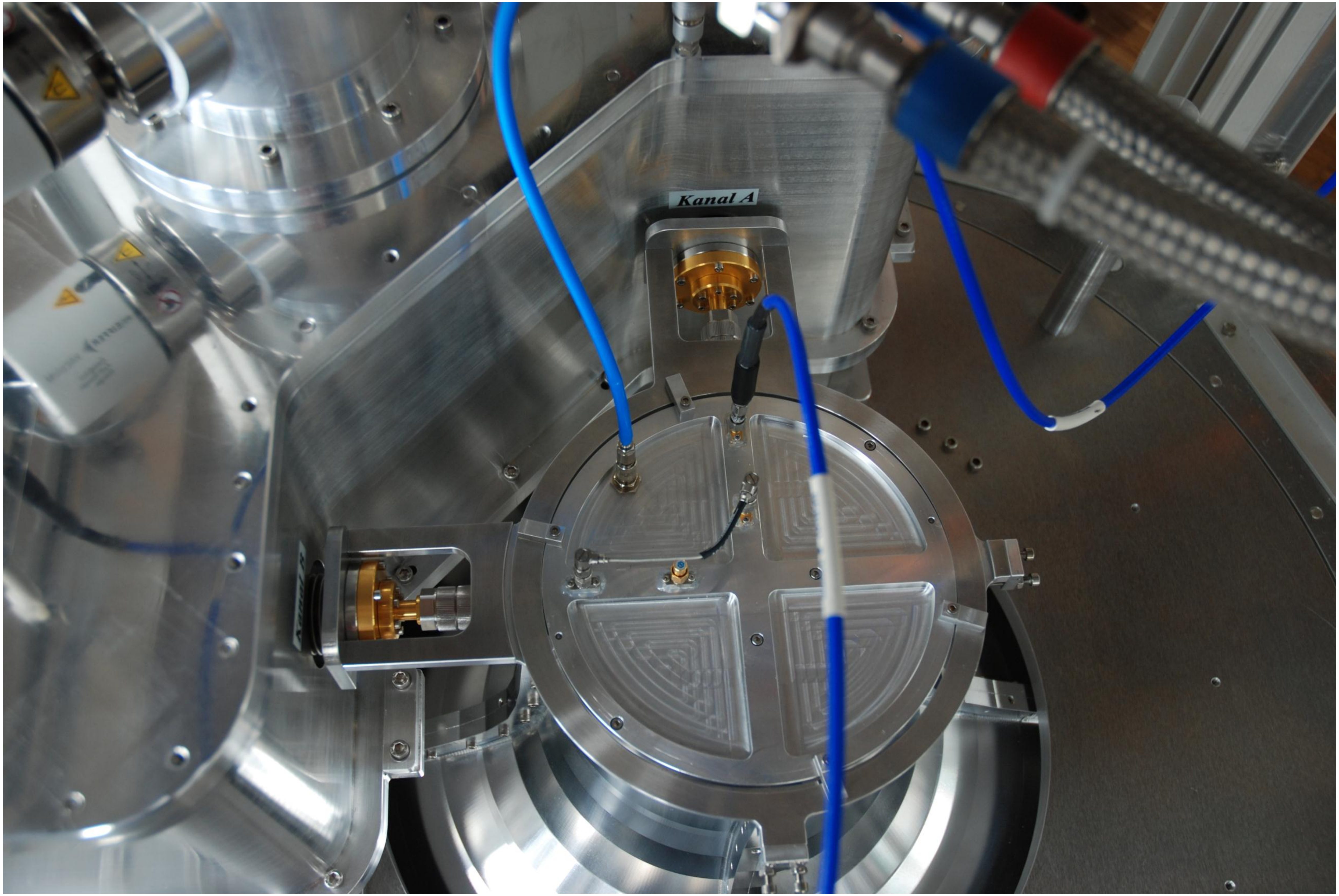
- Timing system will contribute *to direct detection of very low-frequency gravitational waves (now being attempted with MSP timing)*.
- Better mass determinations *will* rule out equations of state for super-dense matter, and many others.
- Unprecedented studies of pulsar emission mechanisms and the ISM!

UBB – record construction time!

Construction started around September 2011. Here is how it looked like in Jan. 19 2012!

2012 April 19

2012 June 24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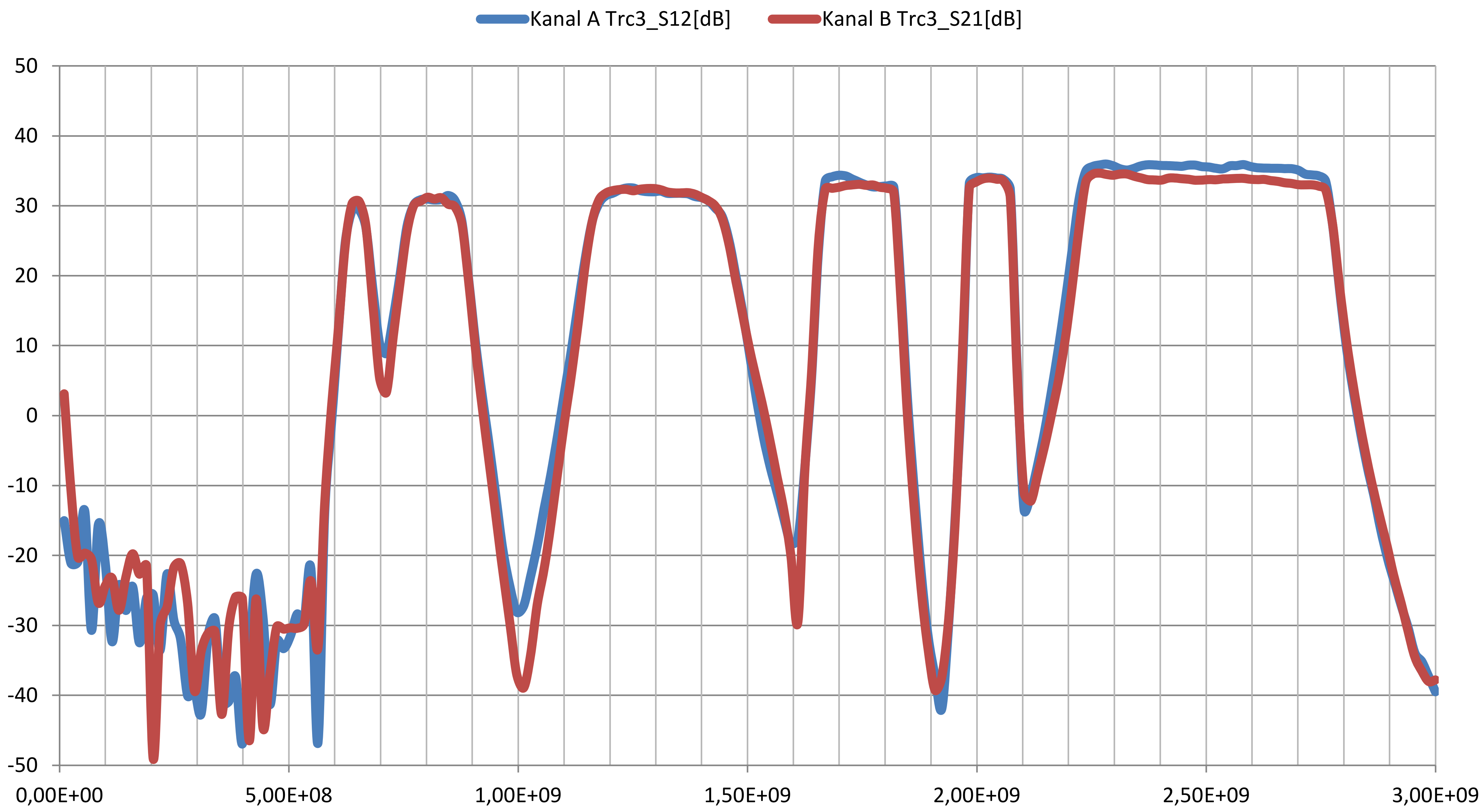
Sensitivity…

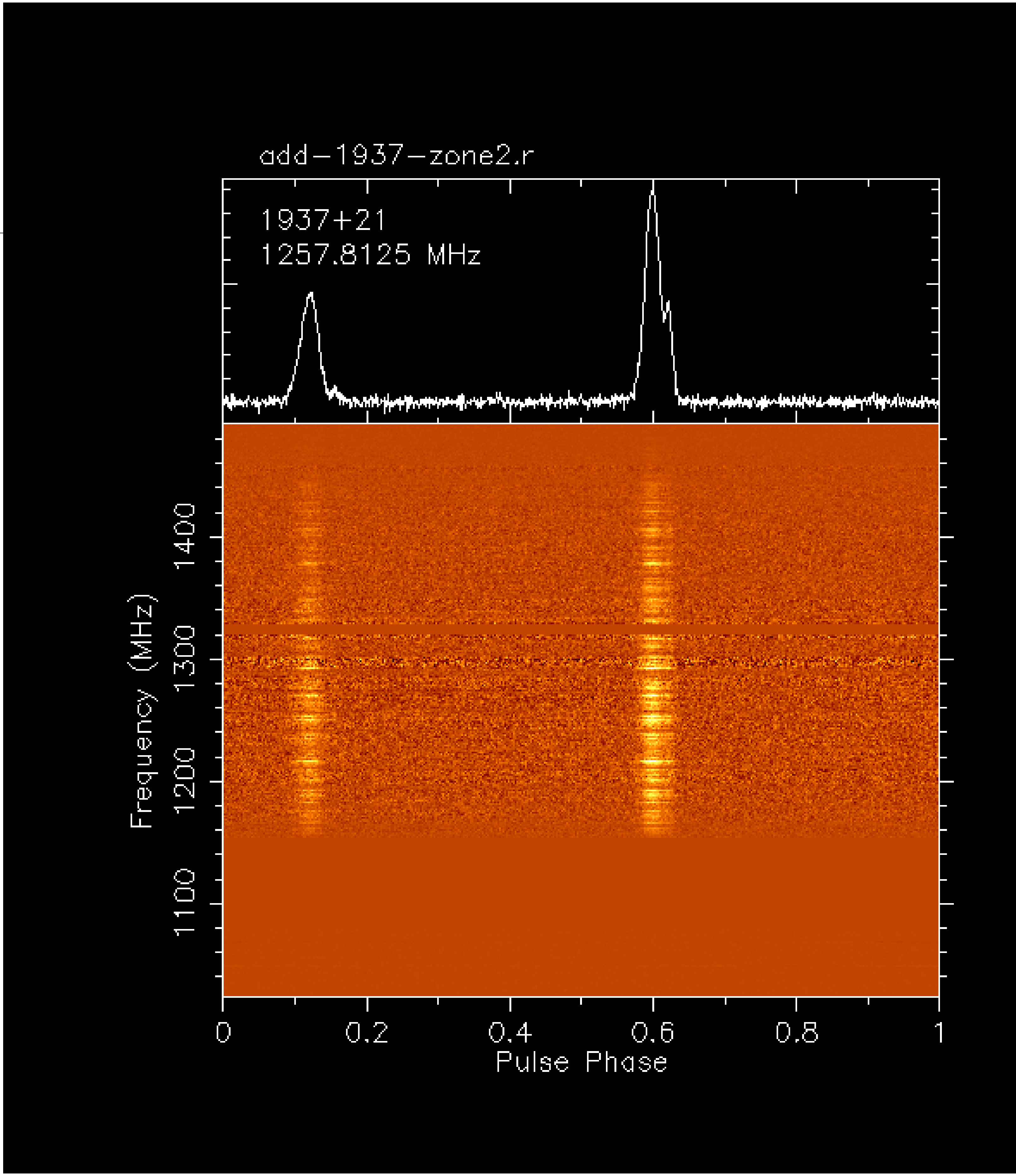
- Proposed to the ERC: 49 K
- Achieved: < 25 K across the band! (Kasemann)
- Potentially, best receiver ever – by far – for pulsar studies!
- Could it be too sensitive?

The Great Challenge: RFI! (as expected…)



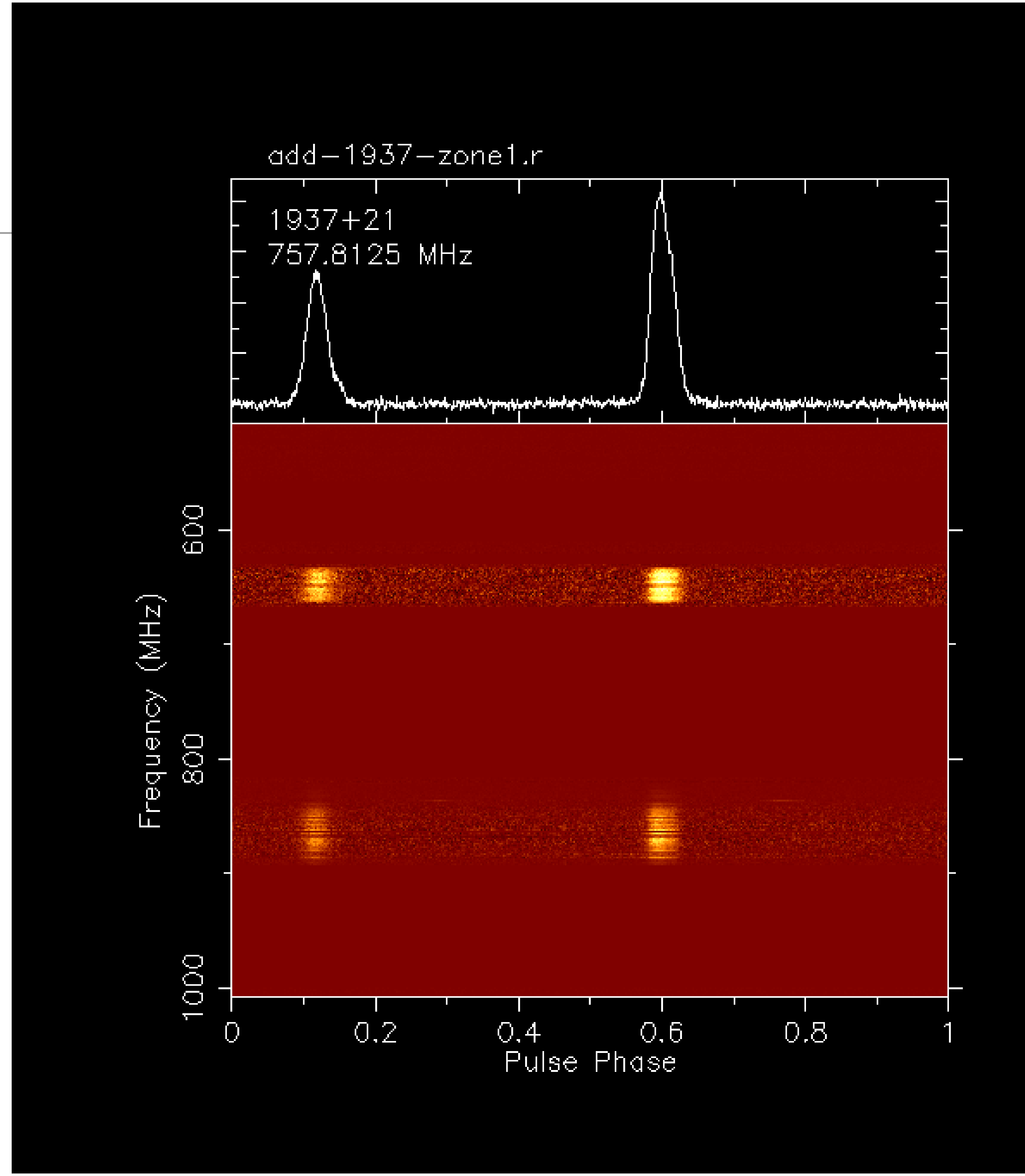
First light!

- The UBB receiver was placed at the focus of the Effelsberg telescope at the start of June 2012
- First pulsar observations in July 18! Using the ROACH/Asterix system (Karuppusamy)
- Pulsars observed PSR B0329+54, B1937+21 (dedispersion) and J1713+0747 (timing)
- **Severe constraints on the system caused by RFI**!



Lower band

- Not much band usable at the lower end. Still useful!
- Soon these observations with the present ROACH system will cover simultaneously all useful parts of the 0.5 – 2 GHz band.
- Later, full ROACH system *and* new Uniboard/GPU system (Knittel) will cover the whole 0.6-3 GHz band – and perhaps go to even higher frequencies.



The near future:

- Horn picks a lot of RFI, particularly when telescope is pointing near the zenith.
    - Make a better measurement of the antenna beam pattern, and see it is illuminating the horizon. Study mitigation measures.
- Lots of new RFI even within “clean” bands (1300-1500 MHz)
    - Look at possible intermodulations and dynamic range limitations in the system.
- Better identification of new RFI sources, and specific, case by case source mitigation.
- Online RFI mitigation with the Uniboard and other hardware systems (Knittel/Comoretto/Russo/Spitler).

Even better laboratories?

- New pulsar surveys, like the ALFA pulsar survey and the HTRU surveys now being carried out with the Parkes and Effelsberg telescopes, will greatly expand the number of millisecond pulsars.
- This will raise the possibility of *even better* systems being found for these tests.
- **We might have found some very exciting systems already! Stay tuned!**

… to be continued!

- Thank you for your time!