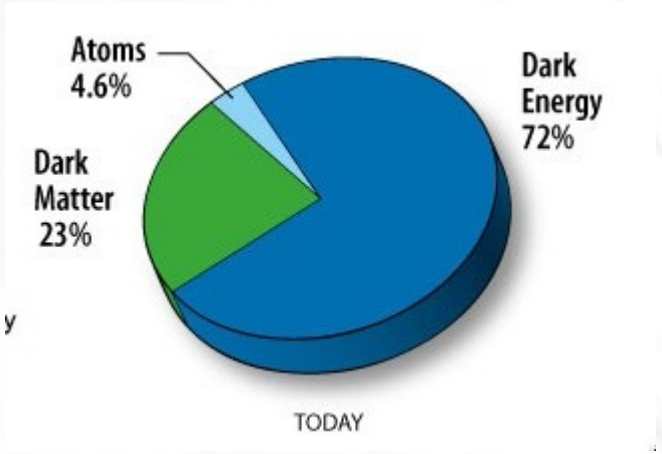
Crises in Cosmology

Frank Potter

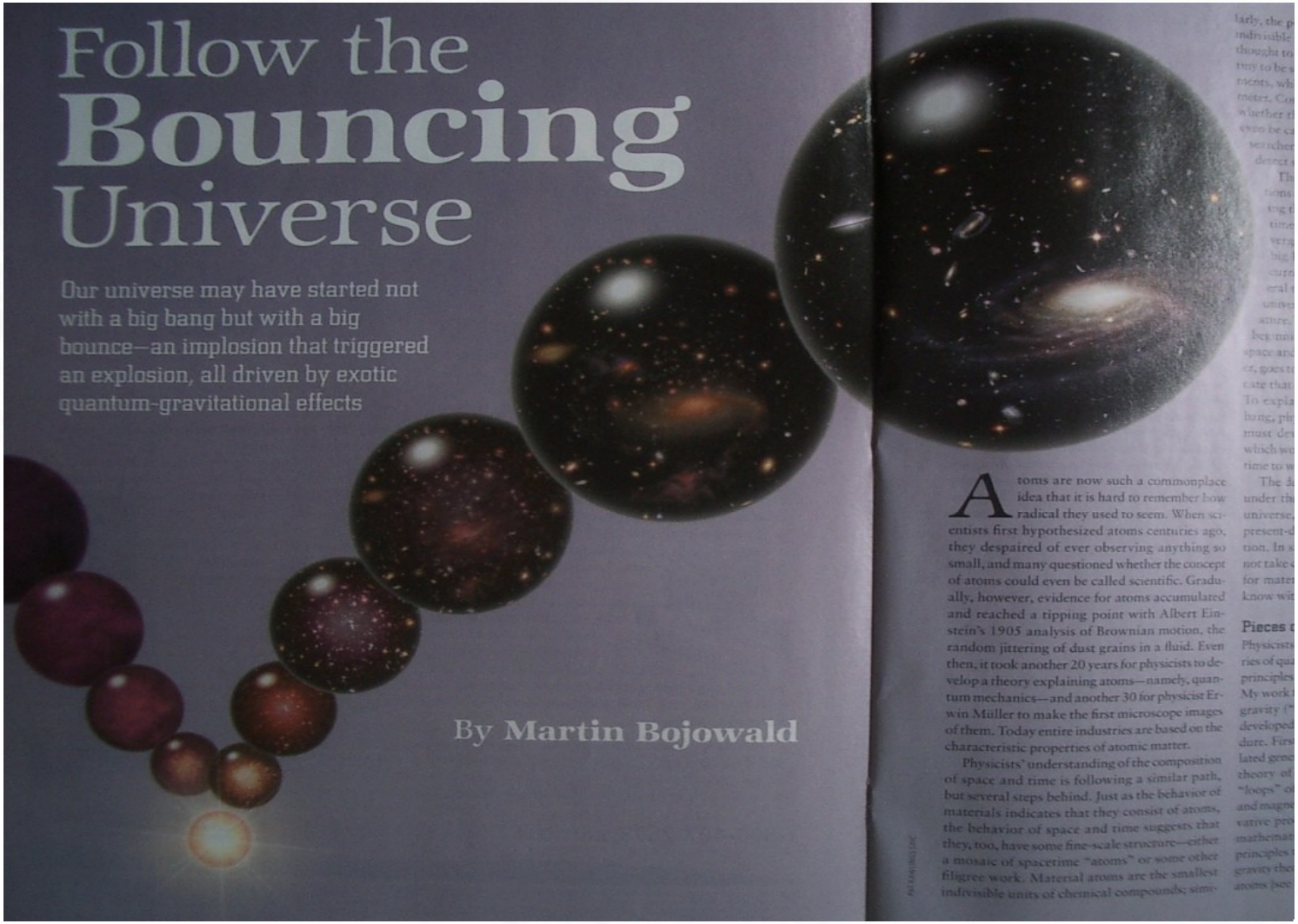
Crises in Cosmology

- Which point of view is correct?
- Why are there so many potential contenders to the standard model of cosmology?
- Can the crises be resolved?



Crisis in Cosmology-2 Conference
Port Angeles, Washington, USA
September 8 – 11, 2008

Examples



Follow the Bouncing Universe

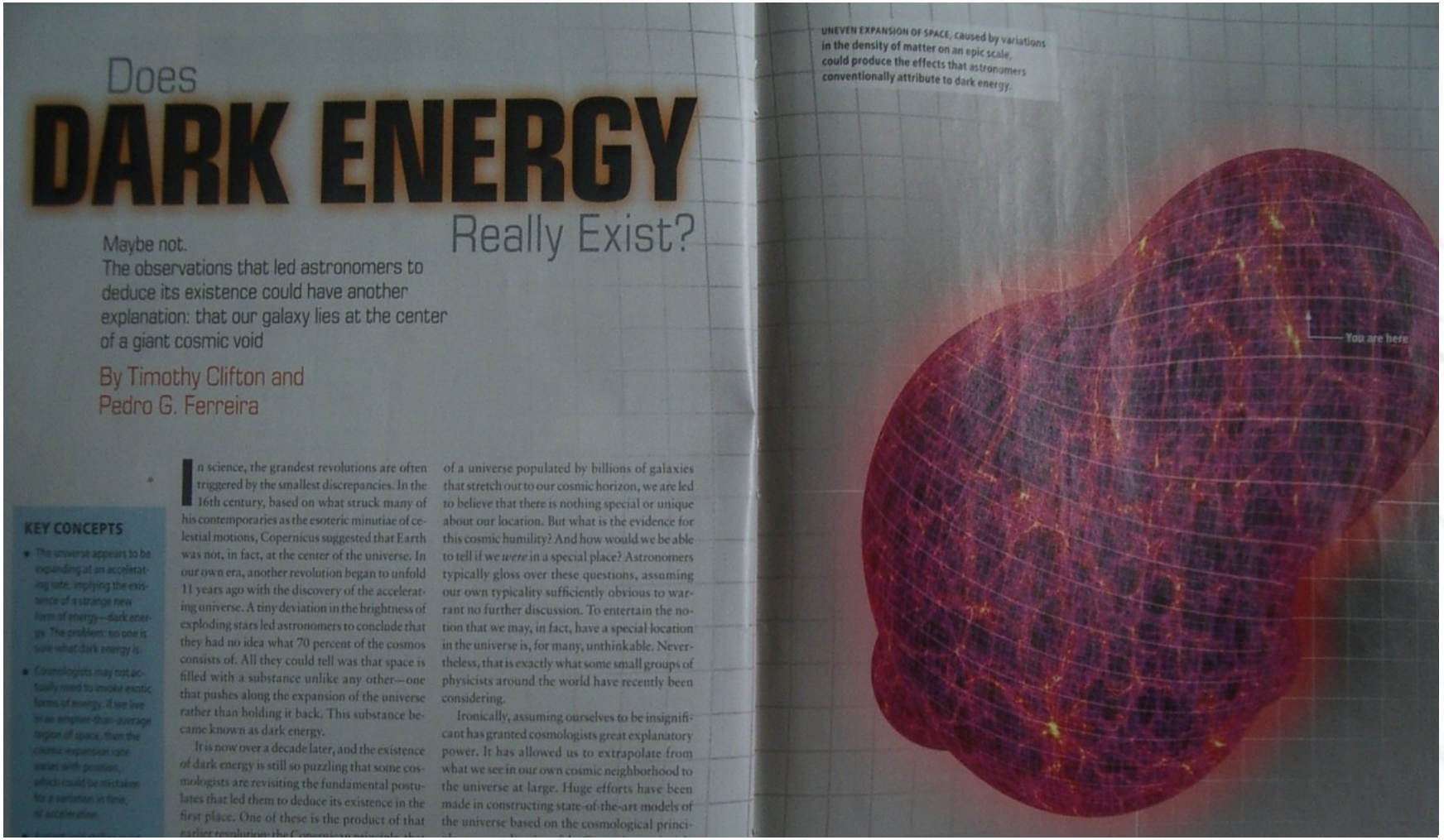
Our universe may have started not with a big bang but with a big bounce—an implosion that triggered an explosion, all driven by exotic quantum-gravitational effects

By Martin Bojowald

Atoms are now such a commonplace idea that it is hard to remember how radical they used to seem. When scientists first hypothesized atoms centuries ago, they despaired of ever observing anything so small, and many questioned whether the concept of atoms could even be called scientific. Gradually, however, evidence for atoms accumulated and reached a tipping point with Albert Einstein's 1905 analysis of Brownian motion, the random jittering of dust grains in a fluid. Even then, it took another 20 years for physicists to develop a theory explaining atoms—namely, quantum mechanics—and another 30 for physicist Erwin Müller to make the first microscope images of them. Today entire industries are based on the characteristic properties of atomic matter.

Physicists' understanding of the composition of space and time is following a similar path, but several steps behind. Just as the behavior of materials indicates that they consist of atoms, the behavior of space and time suggests that they, too, have some fine-scale structure—either a mosaic of spacetime "atoms" or some other filigree work. Material atoms are the smallest indivisible units of chemical compounds; simi-

Examples



Does
DARK ENERGY
Really Exist?

Maybe not.
The observations that led astronomers to deduce its existence could have another explanation: that our galaxy lies at the center of a giant cosmic void

By Timothy Clifton and Pedro G. Ferreira

KEY CONCEPTS

- The universe appears to be expanding at an accelerating rate, implying the existence of a strange new form of energy—dark energy. The problem: no one is sure what dark energy is.
- Cosmologists may not actually need to invoke exotic forms of energy. If we live in an emptier-than-average region of space, then the cosmic expansion rate varies with position, which could be mistaken for a variation in time, or acceleration.

In science, the grandest revolutions are often triggered by the smallest discrepancies. In the 16th century, based on what struck many of his contemporaries as the esoteric minutiae of celestial motions, Copernicus suggested that Earth was not, in fact, at the center of the universe. In our own era, another revolution began to unfold 11 years ago with the discovery of the accelerating universe. A tiny deviation in the brightness of exploding stars led astronomers to conclude that they had no idea what 70 percent of the cosmos consists of. All they could tell was that space is filled with a substance unlike any other—one that pushes along the expansion of the universe rather than holding it back. This substance became known as dark energy.

It is now over a decade later, and the existence of dark energy is still so puzzling that some cosmologists are revisiting the fundamental postulates that led them to deduce its existence in the first place. One of these is the product of that earlier revolution: the Copernican principle, that of a universe populated by billions of galaxies that stretch out to our cosmic horizon, we are led to believe that there is nothing special or unique about our location. But what is the evidence for this cosmic humility? And how would we be able to tell if we *were* in a special place? Astronomers typically gloss over these questions, assuming our own typicality sufficiently obvious to warrant no further discussion. To entertain the notion that we may, in fact, have a special location in the universe is, for many, unthinkable. Nevertheless, that is exactly what some small groups of physicists around the world have recently been considering.

Ironically, assuming ourselves to be insignificant has granted cosmologists great explanatory power. It has allowed us to extrapolate from what we see in our own cosmic neighborhood to the universe at large. Huge efforts have been made in constructing state-of-the-art models of the universe based on the cosmological princi-

UNEVEN EXPANSION OF SPACE, caused by variations in the density of matter on an epic scale, could produce the effects that astronomers conventionally attribute to dark energy.

You are here

Some definitions:

- Copernican principle not a special place {not a garbage dump!}
- Cosmological principle – not a special place nor special time
- Homogeneous & isotropic universe – certainly true at 100 Mpc
- Flat space – Euclidean geometry works
- Static vs. expanding space – here's where controversy begins!!
- Coordinates vs. measured distance

1 A.U. = 1.5 x 10^{11} meters

1 light-year = about 10^{16} meters

Galaxy diameter = about 110,000 lt-yrs = 1.1 x 10^{21} meters

'See-able' universe = about 14 billion lt-yrs = 1.4 x 10^{26} meters

Redshift z of emission lines

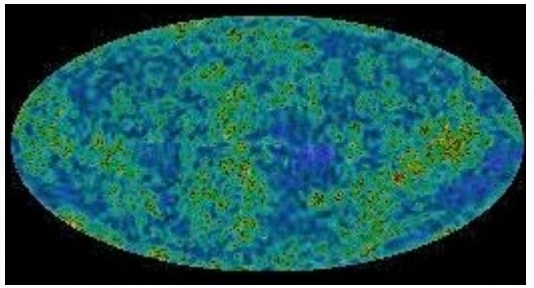
$$1 + z = \lambda_{recd} / \lambda_{emit}$$

1) Doppler – relative velocity
2) Gravitational – GTR – clocks run slower in a deeper gravitational potential
3) Cosmological – space is stretching
4) *molecular scattering effect – clouds around quasars?
5) *plasma scattering effect – limb of the Sun

$$e^{z} = \lambda_{recd} / \lambda_{emit}$$

Horizon Problem

Look left and right and see the same T



Possible solutions?

1. Everything was closer together long ago:

    a. BIG BANG + SUPER INFLATION

    b. Oscillating universe that bounces!!

Horizon Problem

Another possible solution?

2. Universe is much older, so there has been sufficient time for communication

i.e., older than about 14 billion years

Horizon Problem

And another?

3. All galaxies and clusters of galaxies reach about the same T of about 3 K in equilibrium as determined by Energy = σT^4

1926 Eddington
1932 Regener

Some of the Contenders!

1. Standard Hot Big Bang Model ("concordance model") = LCDM

   GTR + Big Bang + superinflation + dark matter + dark energy

   Redshift is cosmological – space expansion – flat space

   Can always be made to fit data by POSTDICTION !!!

2. MOND – modified Newtonian dynamics + TeVeS

   Milgrom 1984 + Bekenstein 2004

   Newtonian gravitation is good until 1.2×10^{-10} m/s^2

   Works extremely well for all galaxies but NOT clusters of galaxies!

   Can be adjusted to fit universe

More of the Contenders!

3. MOG – modified gravity – G and c vary in space and time

Moffat claims there are now no free parameters and all is good!

It is an STeVe approach

4. Brane oscillations – from superstrings

5. Multiverse – many different universes exist and we live in just one – 'anthropic view'

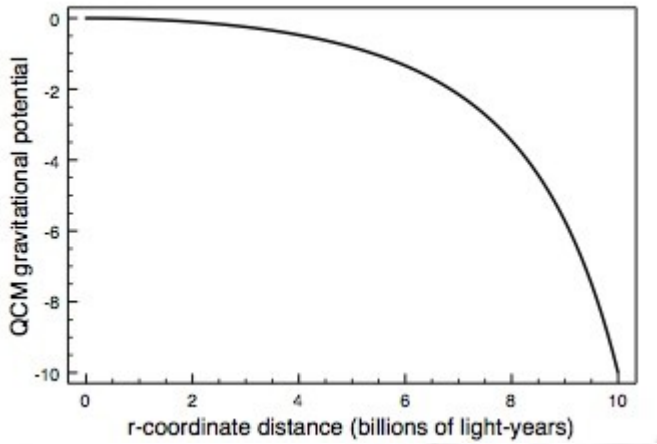
And more of the Contenders!

6. QCM – Quantum Celestial Mechanics – not quantum gravity!

   Preston & Potter 2003

   Schrodinger-like wave equation derived from GTR – but no $\hbar$

   Quantization states of energy and angular momentum *per mass*



Predicts a static universe – no mass currents

Every observer 'sees' an *effective* negative gravitational potential that is deeper with increasing distance, i.e. distant clocks run slower – **cosmological redshift is gravitational**

7. Many other approaches!!

4 Pillars of Cosmology

Standard Model

- Redshift z caused by space expansion
- CMB is from last scattering surface of Big Bang
- Structures dictated by DM & DE
- H, D, He, Li made when BB cooled below 5000 K

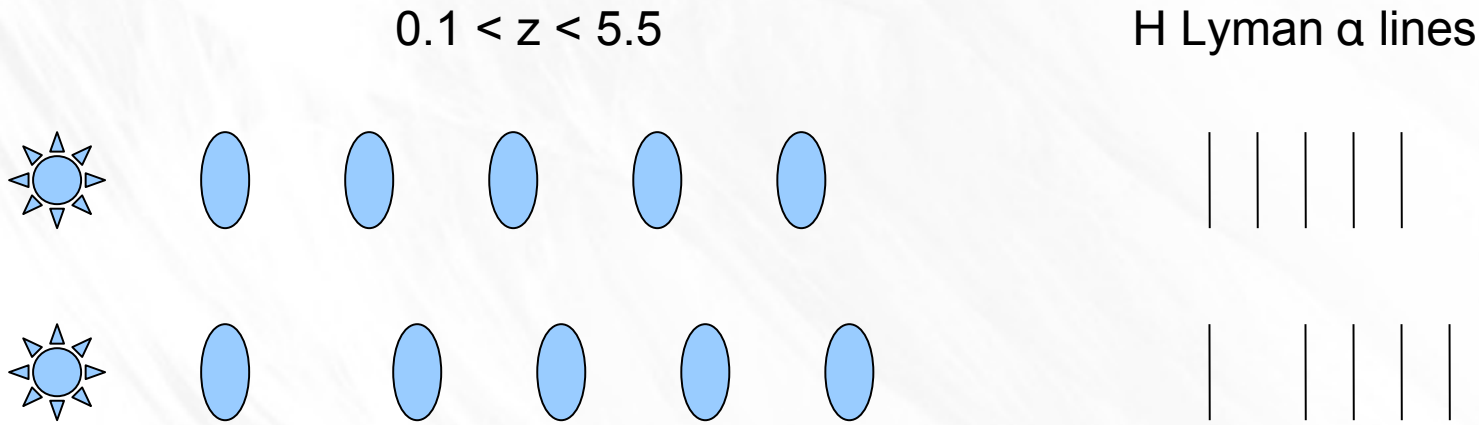
QCM

- Redshift z caused by effective negative gravitational potential
- CMB from everywhere? All in equilibrium.
- Structures continuously forming with no DM nor DE needed
- H, D, He, Li could be made continually, BBFH approach, about 1 H atom per 10,000 years per cubic meter

New Empirical Results

Hydrogen Cloud Separation as Direct Evidence of the Dynamics of the Universe

Ashmore 2009



New Empirical Results

Tolman Test from z = 0.3 to z = 5.7

Lerner, Falomo & Scarpa 2008, 2009

Studied surface brightness of 11 identical disk galaxies in UV

Fits the Euclidean, non-expanding model very well with $d = cz/H_0$

The LCDM approach would need to have these disk galaxies grow!

More data being analyzed

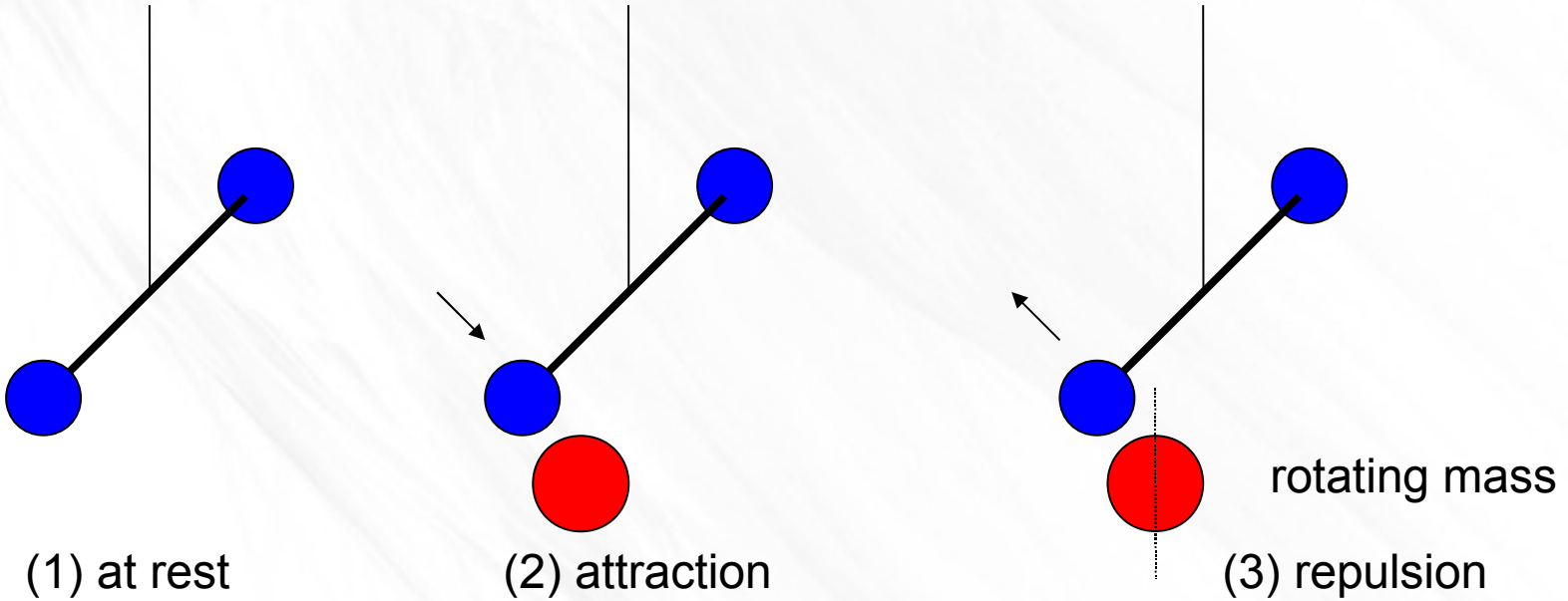
New Empirical Results

Lab Torsion Bar exhibits Repulsive Gravitational Effect of QCM

Preston & Potter 2009

Attractor mass

Newtonian attraction about 10^{-9} Newtons



(1) at rest (2) attraction (3) repulsion

My Biased Conclusions !!

1. Standard Model will be in trouble if no dark matter and dark energy

2. Standard Model is being challenged already by Tolman Test, by H cloud Lyman α data, and by QCM repulsive effect

3. If the QCM repulsive effect is true, the Standard Model based on classical GTR + DM + DE could be history!!

4. Then QCM ***with some improvements*** might become the new standard

Some References

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4. LCDM Cosmology: how much suppression of credible evidence, and does the model really lead its competitors, using all evidence?

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5. Cosmological Redshift Interpreted as Gravitational Redshift

   http://www.ptep-online.com/index_files/2007/PP-09-06.PDF

Bullet Cluster

blue – inferred dark matter
red – measured hot gas