

The Standard Model

Blue up quark, spin
 $1/2$

Green up, spin
 $1/2$

Gluons

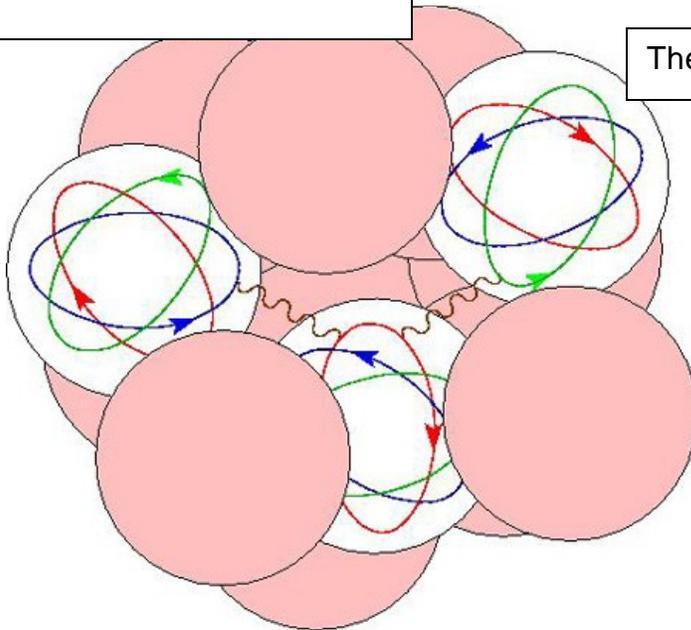
Quantum
Chromodynamics

PROTON, spin
 $1/2$

Red down quark, spin
 $1/2$

Bag Model of the Nucleon (MIT
Model)

The Quark- Meson Coupling (QMC) Model



Relativistic Constituent Quark
Model,
Considers orbital motion of
quarks.

Read up on the Spin Crisis

to spin of gluon, and $1/3$ due to
orbital angular motion of quarks.
Ref: X. Zheng et.al, Physical Rev.
Lett. 92. 012004, 2004.

This note was compiled / updated by Theodore M. Lach, May
21, 2006

Web references for the Nucleon Bag Model:

http://images.google.com/imgres?imgurl=http://www.jlab.org/news/articles/2004/qmc_guichon_sm.jpg&imgrefurl=http://www.jlab.org/news/articles/2004/qmc.html&h=179&w=198&sz=12&tbnid=mK-6OIM6yexrQM:&tbnh=89&tbnw=99&hl=en&start=2&prev=/images%3Fq%3Dquark%2Bmodel%2Bof%2Bthe%2Bnucleon%26svnum%3D10%26hl%3Den%26lr%3D%26sa%3DG

<http://en.wikipedia.org/wiki/Nucleon>

<http://www.phys.nthu.edu.tw/~colloquium/05112005.pdf>

<http://philsci-archive.pitt.edu/archive/00002411/01/Idealization.pdf>

<http://www.citebase.org/cgi-bin/citations?id=oai:arXiv.org:nucl-th/9705045>

<http://physics.bu.edu/cc104/chapters10and11.html>

<http://plato.stanford.edu/entries/models-science/>

Other textbook references for the Bag Model:

Science Vol 283 Jan 22 1999, pg 472 “Exploring the Proton Sea” by Andrew Watson

(I like this the best, since it is easy to understand)

Concepts of Particle Physics Vol II, Kurt Gottfried and Victor F. Weisskopf, pg 404, “the Bag Model” Oxford University Press, N.Y. Clarendon Press Oxford c. 1986

Gauge Theories of the Strong, Weak, and Electromagnetic Interactions, Chris Quigg, Pg. 193, Ch 8, Strong Interactions among Quarks, Addison Wesley Publishing co. c. 1983, ISBN 0- 8053- 6020- 4

QCD and Collider Physics, R.K. Ellis and W.J. Stirling, and B.R. Webber, Cambridge University Press, 1996, Pg 93, The Parton Model from Field Theory, ISBN 0- 521- 58189- 3

The Search for QCD Exotics, American Scientist Vol **88**, pg 406 Sept- Oct 2000.

Nuclear Physics:

Handbook of Nuclear Properties, Dorin N. Poenaru and Walter Greiner, Oxford Science Publications, 1996, Ch 4, Nuclear Deformations by W. Nazarewicz and I Ragnarsson, ISBN 0- 19- 851779- 3

Modern Atomic and Nuclear Physics, Yang and Hamilton, Mc Graw Hill, 1996, starting on page 500 and ending on page 686. ISBN 0- 07- 025881- 3

Excerpts from Proton- Go- Round

“Whence does the proton get its spin”

by Ivars Peterson

Science News Vol 152, Sept 6th, 1997.

“In 1988, however, physicists were shocked to find experimental evidence suggesting that very little (perhaps none) of the proton’s spin comes from the spin of the quarks... (SN:4/8/89 pg 215). They called this apparent paradox the proton spin crisis.”

... The scope of the problem is now understood and the apparent smallness of the quark contribution confirmed, but the origin of the proton’s spin remains largely a mystery... The first news that the simple quark spin model was inadequate came from the 1988 experiment at the European Laboratory for Particle Physics (CERN) in Geneva. Members of the European Muon Collaboration (EMC) fired a beam of high- energy muons into a frigid ammonia target... The researchers then recorded the directions in which the muons were deflected by the protons... Armed with the EMC results, theorists were able to calculate the total spin content of the proton carried by the quarks. To everyone’s amazement, they came up with an answer that was close to zero... Was there a problem with the theory, the experiment or both? Both the SLAC and CERN data now essentially agree, indicating that only about 30% of the proton’s and neutron’s spin is found among the quarks... The rest of the proton’s spin must come from its gluons and the movements of gluons and quarks within the proton. In the Aug (1997) Physical Review Letters, Ian Balitsky and Xiangdong Ji calculated that gluons contribute at least half of the proton spin... However, there is scant experimental evidence concerning the gluon’s effect on the proton’s spin. At the DESY facility in Hamburg, Germany, physicists participating in the HERMES experiment are now studying collisions between high energy, spin polarized helium- 3 nuclei... the researchers hope to obtain evidence of the presence of strange quarks (inside the proton). At CERN, physicists are looking forward to a new experiment called COMPASS, which stands for Common Muon and Proton Apparatus for Structure and Spectroscopy. They expect to probe the gluon content of the proton by firing high- energy muons at polarized targets and looking for ejected mesons containing the charm quark... High energy collisions between polarized protons should make it possible to detect clear evidence of gluon spin. When these and several related experiments are completed, physicist should have the data they need to tell their story of how the proton’s constituents give it its spin. Studies of the proton furnish insights into the strong force, which governs how quarks bind together and how protons and neutrons form atomic nuclei. There is also a deeper question that underlies investigations of prton spin. In general, why do quantum particles exhibit the quality of spin at all? ... we do not understand where it (spin) comes from or why it is there”

Physicists thrown for a loop

By Dan Vergano, USA TODAY Sept 22, 2002

The humble proton, an atomic particle with mysteries long thought solved, turns out to have a hidden secret, scientists report.

Experimental results released this year by the Department of Energy's Jefferson Lab in Newport News, Va., have upturned the normally placid world of nuclear physics with the suggestion that protons, the positively charged particles found in the center of every atom, aren't round. Instead, they seem somewhat elliptical.

The round proton has been a staple of textbooks for 40 years, tied to the theory that protons and neutrons are built of three smaller particles called "quarks" slowly bubbling inside their interiors.

What difference does it make whether protons are round or elliptical? Plenty, physicists say. Adjustments in protons and neutrons could affect scientific understanding of the magnetic "spin" of atoms. Scientists hope to use "spintronics" in future computers and tiny "nano-scale" devices. Understanding the fundamental shape of particles will affect those application's success.

At a Jefferson Lab meeting in May, about 60 nuclear physicists met to debate the "crisis," in the words of physicist John Ralston of the University of Kansas, over the odd shape of the proton.

During a 10-month experiment, a large team of physicists led by Charles Perdrisat of the College of William & Mary in Williamsburg, Va., gave protons a high-energy smacking-around. The effort involved watching billions of collisions between protons and electrons, which are much smaller negatively charged atomic particles, and recording how they scattered. From those reactions, they assembled a perplexing picture of the proton.

At the May meeting, a consensus emerged that Einstein's theory of special relativity, which explains how things moving near the speed of light have smooshed lengths and increased mass, seemed the likeliest explanation for the weird experiment results.

"The new thing we've figured out is that quarks are moving around inside the proton at relativistic (near speed of light) speeds," says physicist Gerald Miller of the University of Washington-Seattle. Quarks moving at those speeds simply elongate the particle's electromagnetic shape, Miller says. In a paper in the journal *Physical Review C*, he outlines how quarks moving at high speeds, about 90% of the speed of light, stretch out protons.

"The proton is the simplest thing around, and it is not spherical," says physicist Charles Glashausser ([Charles was past chair of DNP. My follow up discussions with Glashausser, indicated that the proton was squashed in the](#)

shape of an oblate solid, not prolate)) of the Rutgers University campus in Piscataway, N.J. The neutron, the uncharged partner- particle to the proton in the nucleus of atoms, also is built of quarks, he notes.

A Jefferson Lab experiment now underway is looking for similar effects, harder to tease out, in the neutron. Neutrons contain three quarks, like protons, but they're organized in a different fashion.

"We've got to understand protons and neutrons. They are all the matter in the nearby universe," Miller says. "These are tremendously exciting new results."

End Quote

Spinning the nucleon into sharper focus.

Physics Update

Physics Today, Feb 2004, AIP. Pg 9. by B.P.S

"In the simplest picture, a proton or neutron is made up of three "valence" quarks. A more complete picture also includes not only the sea of quark-anti quark pairs that pop in and out of the vacuum but also gluons, which hold the quarks together. Working at Thomas Jefferson National Accelerator Facility in Virginia, a multinational research team has precisely measured the distribution of spin for a neutron's valence quarks. Firing a 5.7 GeV polarized electron beam at a polarized helium 3 target, the researchers could focus on the valence quarks by choosing an excitation region where electrons interactions with gluons and sea quarks are screened out. The physicists then combined their new neutron data with existing proton data and **concluded that the spins of the proton's two valence up quarks are aligned parallel to the overall proton spin, but the same is not true for the proton's valence down quark. The results agree well with predictions from the relativistic constituent quark model, which**

considers the quarks' orbital angular momentum within a nucleon.

However, they disagree with the predictions from a commonly used approximation of perturbative quantum chromodynamics that does not account for the quarks' orbital angular momentum.

(X. Zheng et. al. Phys. Rev. Lett. **92**, 012004, 2004.)”

(Red highlighted for emphasis, since it tends to support my CBM theory and definitely a blow to Q. Chromodynamics)

Where is the Nucleon Spin?

It's a twenty- year- old question: How much do the constituent quarks and gluons contribute to the spin of the nucleon? New results from the COMPASS experiment add to the picture.

By Erwin Gabathuler (U. of Liverpool)

Nature Physics Vol 2, No. 5, May 2006 pg 303.

Summary: The latest data from the COMPASS (CERN) collaboration show that the debate over the spin composition of the nucleon is far from over (Phys. Lett. B **633**, 25- 32, 2006). The latest data from COMPASS indicates that $\Delta G/G = 0.024 \pm 0.089 \pm 0.057$, which means that the contribution from the polarization of the gluons has a minor effect on the spin of the nucleon. Similarly the PHENIX collaboration (Brookhaven's RHIC) gave similar results. To add to the controversy the HERMES experiment at DESY came up with a $\Delta G/G = 0.41 \pm 0.18 \pm 0.03$, which means that the gluons could account for a significant part of the spin. The debate continues. Unfortunately it is not obvious that the L(Z) the angular momentum of the quarks can be experimentally measured.

Other reading:

The Rise of the Standard Model, Particle Physics in the 1960's and 1970's, Edited by

Lillian Hoddeson, Laurie Brown, Michael Riordan, and Max Dresden.

Chapter 34, Hadron Jets and the Discovery of the Gluon. Pg 600 – 621., Chapter 35, Quarks, Color and QCD by Murray Gell- Mann. Pg 625.,

Pg 347, pg 23, pg 405- 408, Ch 36 and 37.

[http://en.wikipedia.org/wiki/Occam's Razor](http://en.wikipedia.org/wiki/Occam's_Razor)

Occam's razor (also spelled **Ockham's razor**) is a principle attributed to the [14th-century](#) English logician and [Franciscan](#) friar [William of Ockham](#). Originally a tenet of the [reductionist](#) philosophy of [nominalism](#), it is more often taken today as a [heuristic maxim](#) that advises economy, [parsimony](#), or simplicity in scientific theories.

Occam's razor states that the explanation of any [phenomenon](#) should make as few assumptions as possible, eliminating those that make no difference in the observable predictions of the explanatory [hypothesis](#) or [theory](#). The principle is often expressed in [Latin](#) as:

entia non sunt multiplicanda praeter necessitatem ,
which translates to:

entities should not be multiplied beyond necessity.
Furthermore, when multiple competing theories have equal [predictive powers](#), the principle recommends selecting those that introduce the fewest assumptions and postulate the fewest hypothetical entities. It is in this sense that Occam's razor is usually understood.

There are 19 independent parameters in the Standard model used in the study of high- energy physics.

There are 18 independent parameters in the Urbana 18 model of nuclear physics used at Argonne Nat. Lab.