# A Technique for Cataloging Types of Particles and Types of Stuff

**Thomas J. Buckholtz**[*]

## Abstract

We develop theory leading to an ability to catalog types of elementary particles. The resulting catalog provides for known interaction-mediating bosons, non-traditional interaction-carrying bosons, and fermions. Ratios of theoretical numbers of analogs of various types of particles match observed ratios of densities for baryonic matter, dark matter, and dark energy.

## Keywords

Associated universe · Baryonic matter · Dark energy · Dark matter · Density of the universe · Elementary particles · Energy-momentum space · Fundamental forces · Strong interaction · Theory of everything · Unified electromagnetism and gravity · Weak interaction

## Section 1 Context

This work fills a gap in previous, pattern-based work that leads to a catalog of types of elementary particles and fundamental forces. [1] develops a catalog of elementary-particle "zero-energy empty states." [1] indicates that excitations of such empty states match traditional types of elementary particles and point to non-traditional types of elementary particles. Some of the elementary particles are bosons and some are fermions. [1] develops various further results by applying implications of the catalog and implications of other patterns. (Below, Section 5 summarizes some of the results developed in [1].)

In [1], development of the catalog is based on {a} a proposal that, for 3-dimension space (within 4-dimensional space-time), the lowest energy states for a spherically symmetric harmonic oscillator would have a wave-function proportional to r^{-1}exp(-ar^2), in which r denotes the radial coordinate and a is a positive constant; {b} the observation that, in linear coordinates, the harmonic-oscillator occupation numbers n_x=0, n_y=0, and n_z=-1 provide a basis for describing a photon moving parallel to the z-axis; and {c} extrapolating such findings so as develop to a technique for cataloging types of zero-mass and non-zero mass elementary particles.

In [1], development of the cataloguing technique features a concept of "virtual dimension" in energy-momentum space.

---

[*] Electronic mail: Thomas.J.Buckholtz@gmail.com

In this paper, Section 2 proposes a more rigorous development of the cataloguing technique and catalog. Section 3 applies the more-rigorous cataloging to "predict" the ratios of the baryonic-matter, dark-matter, and dark-energy densities of the universe. Section 4 comments on work in earlier sections. Section 5 reprises other results that follow from the cataloging technique and catalog.

## Section 2 Core

We assume that energy-momentum space embeds flat in a 10-dimensional space. This assumption is based on assumptions that {a} space-time embeds flat (in the sense of the Minkowski metric) in a 10-dimensional space; and {b} energy-momentum space constitutes a tangent space to space-time.

We assume there is usefulness in considering that each energy-momentum-space dimension has associated with it a harmonic oscillator. We plan to consider occupation numbers for these oscillators. We plan to use the occupation numbers to explore phenomena such as forces that bosons particles mediate. We are not herein so much interested in concepts such as motion-related energy and momentum.

We assume that it is meaningful to consider that the oscillators can have positive, zero, or negative occupation numbers. The following expressions establish notation for dimensions and occupation numbers.

Energy-momentum space dimensions:
$p_k$, with $k$ being an integer and $0 \le k \le 9$ (1)
Harmonic-oscillator occupation numbers:
$n_k$, with each $n_k$ being a integer and $0 \le k \le 9$ (2)

We assume there is an applicable symmetry such that each oscillator has the same associated "strength." And, we adopt units such that that strength is unity. The following equations provide, respectively, for the "energy" for one oscillator and the energy for the entire set of oscillators.

$$E_k = (n_k + 1/2) \tag{3}$$

$$E = \Sigma_{0 \le k \le 9} E_k \tag{4}$$

We note the following.

If $\Sigma_{0 \le k \le 9} n_k = -5$,
$$E = 0. \tag{5}$$

We anticipate sometimes focusing just on oscillators that align with four energy-momentum dimensions - energy ($k = 0$) and three momentum dimensions ($k = 1$, 2, and 3). We define a total, n, of the occupation numbers for such a subset of oscillators. And we define a "level number," L.

$$n = \Sigma_{0 \le k \le 3} n_k \tag{6}$$

$$L = 6 - n \tag{7}$$

We focus on states that satisfy (5), (8), and (9).

$$n_k \le 0, \text{ for } 0 \le k \le 9 \tag{8}$$

$$1 \le L \le 5 \tag{9}$$

Table 1 provides a directory of states for which at least one of $n_1$, $n_2$, and $n_3$ is zero. (Table 9 and related discussion in Section 4 address other states.)

Exciting an $n_k=0$ oscillator leads $n_k=1$ for the respective oscillator. We assume that a state for which E=1, exactly one $n_k=1$, and all other $n_k<1$ is a state that represents a particle.

**Table 1 Zero-energy states that excite directly to particles**

For each of these states, the name is of the form IFL. F provides a group name. For the e-group, there are 4 series, corresponding respectively to I = 4, 3, 2, and 1. Each other group has 1 series. For the w-group's series and the s-group's series, L satisfies $1 \le L \le 5$. For the other series, L satisfies $1 \le L \le I$. The rightmost column notes phenomena for which table entries provide bases.

| | | $n_k$ | 0 | 1 | 2 | 3 | |
|---|---|---|---|---|---|---|---|
| Name | Group | | | | | | Comments |
| 4wL | w-group | | <0 | 0 | 0 | 0 | • component of the weak force |
| IeL | e-group | | <0 | <0 | 0 | 0 | • electromagnetism, gravity, etc. |
| 4sL | s-group | | 0 | <0 | 0 | 0 | • component of the strong force |
| 4fL | f-group | | <1 | 0 | -1 | -1 | • fermion |
| 2qaL | qa-group | | <1 | 0 | -2 | -2 | • component of the strong force<br>• meson made from a quark and an anti-quark |
| 1qqq1 | qqq-group | | 0 | 0 | -1 | -4 | • component of the strong force<br>• fermion made from 3 quarks |
| 1aaa1 | aaa-group | | 0 | 0 | -4 | -1 | • component of the strong force<br>• fermion made from 3 anti-quarks |

Regarding rows in this table, [1] provides the following. (In [1], the equivalent of $n_0$ is called a "virtual dimension" and the equivalent of $n_1$ is "$n_z$.")

For excited states, the particle mass, m, satisfies the following. (10)
m = 0 if, and only if, n_1 < 0

For e-group excited states and s-group excited states, (11)
p_1 corresponds to the direction of motion for a particle.

For e-group excited states, n_2 and n_3 can be associated with concepts like … (12)
transverse polarization (for photons or gravitons);
vector potential (for photons).

For the qa-group, qqq-group, and aaa-group, excitement related to n_2 associates with anti-quarks and excitement related to n_3 associates with quarks. (13)
1-n_3 denotes a number of quarks needed to produce a particle.
1-n_2 denotes a number of anti-quarks.

For forces (that is, each entry other than those in the 4fL row) other than 4wL forces, the long-range behavior (in the space component of a flat space-time) of the force scales (based on distance r) as follows. (14)
r^{2 n_1}

We assume that the harmonic oscillators can be considered as paired. From above, two pairs are {a} n_0 and n_1; and {b} n_2 and n_3. We assume other pairs are associated, respectively, with {a} n_4 and n_5; {b} n_6 and n_7; and {c} n_8 and n_9.

We posit that the following tables provide a catalog of types of particles. In the tables, each of the rightmost columns (4 columns for Table 2; 3 columns for each of Table 3, Table 4, Table 5, and Table 6) describes a pair of harmonic oscillators for which {a} the net occupation number is -1 or 0; and {b} no experiments or observations in space-time lead to no knowledge of to what extent either oscillator has any particular occupation number.

**Table 2 Empty states for which L = 5**

Occupation numbers for individually distinguishable oscillators run from -1 to 0. Occupation numbers of pairs are -1 and apply to all rows.

| n_k | 0 | 1 | 2-3 | 4-5 | 6-7 | 8-9 |
|---|---|---|---|---|---|---|
| Name | | | | | | |
| | | | -1 | -1 | -1 | -1 |
| 4w5 | -1 | 0 | | | | |
| 4s5 | 0 | -1 | | | | |

We assume that 4w5 can be considered to enable the masses of the 4w4 carriers (Z and W bosons) of the weak interaction. In [1] we speculate that 4w5 can also be associated with there being 3 charges (0 for Z, +1 for W^+, and -1 for W^-) for carriers of the weak interaction. In [1] we speculate that 4s5 can be associated with there being 3 color charges.

**Table 3 Empty states for which L = 4**

Occupation numbers for individually distinguishable oscillators run from -2 to 0. Occupation numbers of pairs are -1 and apply to all rows.

| n_k<br>Name | 0 | 1 | 2 | 3 | 4-5 | 6-7 | 8-9 |
|---|---|---|---|---|---|---|---|
| | | | | | -1 | -1 | -1 |
| 4w4 | -2 | 0 | 0 | 0 | | | |
| 4e4 | -1 | -1 | 0 | 0 | | | |
| 4s4 | 0 | -2 | 0 | 0 | | | |
| 4f4 | 0 | 0 | -1 | -1 | | | |

We assume the following associations. 4w4 associates with the Z and W bosons. 4e4 associates with photons. 4s4 associates with gluons. 4f4 associates with fermions, including leptons and quarks.

**Table 4 Empty states for which L = 3**

Occupation numbers for individually distinguishable oscillators run from -3 to 0. Occupation numbers of pairs are 0 or -1 and apply to all rows.

| n_k<br>Name | 0 | 1 | 2 | 3 | 4-5 | 6-7 | 8-9 |
|---|---|---|---|---|---|---|---|
| | | | | | 0 | -1 | -1 |
| 4w3 | -3 | 0 | 0 | 0 | | | |
| 4e3 | -2 | -1 | 0 | 0 | | | |
| 3e3 | -1 | -2 | 0 | 0 | | | |
| 4s3 | 0 | -3 | 0 | 0 | | | |
| 4f3 | -1 | 0 | -1 | -1 | | | |

We assume 4e3 associates with gravity (and, to the extent they become identified experimentally, gravitons). We assume 3e3 is one of a series of bosons associating with r^{-4} forces.

**Table 5 Empty states for which L = 2**
Occupation numbers for individually distinguishable oscillators run from -4 to 0. Occupation numbers of pairs are 0 or -1 and apply to all rows.

| n_k | 0 | 1 | 2 | 3 | 4-5 | 6-7 | 8-9 |
|---|---|---|---|---|---|---|---|
| Name | | | | | | | |
| | | | | | 0 | 0 | -1 |
| 4w2 | -4 | 0 | 0 | 0 | | | |
| 4e2 | -3 | -1 | 0 | 0 | | | |
| 3e2 | -2 | -2 | 0 | 0 | | | |
| 2e2 | -1 | -3 | 0 | 0 | | | |
| 4s2 | 0 | -4 | 0 | 0 | | | |
| 2qa2 | 0 | 0 | -2 | -2 | | | |
| 4f2 | -2 | 0 | -1 | -1 | | | |

**Table 6 Empty states for which L = 1**
Occupation numbers for individually distinguishable oscillators run from -5 to 0. Occupation numbers of pairs are 0 and apply to all rows.

| n_k | 0 | 1 | 2 | 3 | 4-5 | 6-7 | 8-9 |
|---|---|---|---|---|---|---|---|
| Name | | | | | | | |
| | | | | | 0 | 0 | 0 |
| 4w1 | -5 | 0 | 0 | 0 | | | |
| 4e1 | -4 | -1 | 0 | 0 | | | |
| 3e1 | -3 | -2 | 0 | 0 | | | |
| 2e1 | -2 | -3 | 0 | 0 | | | |
| 1e4 | -1 | -4 | 0 | 0 | | | |
| 4s1 | 0 | -5 | 0 | 0 | | | |
| 2qa1 | -1 | 0 | -2 | -2 | | | |
| 4qqq1 | 0 | 0 | -1 | -4 | | | |
| 4aaa1 | 0 | 0 | -4 | -1 | | | |
| 4f1 | -3 | 0 | -1 | -1 | | | |

## Section 3 Consequences

We explore the numbers of ways to associate dimensions and oscillators.

Assume, for example, that {a} dimensions of energy-momentum space are numbered as per (1); {b} "selecting" a p_k to match an n_k proceeds in sequence from n_0 to n_9; and {c} selecting a dimension for an oscillator pair forces selection (for the other member of the pair) of the next-numbered (in the sense of ordering modulo 10) not-yet-assigned p_k. Then, the following apply.

The number of choices for a p_k for n_0 is
10. (15)

The number of choices for a p_k for n_1 is (16)

9. (17)

And so forth. (18)

For the oscillator pair denoted by n-{n+1}, the number of choices is (19)

(10-n)!!.

For the adjacent pair of oscillator pairs n-{n-1} and {n-2}-{n-3}, the ratio of numbers of choices is (20)

10-n.

We note the following.

For the 4-5 harmonic oscillator pair, (21)

(10-n)!! = (10-4)!! = 6!! = 48.

For the 6-7 harmonic oscillator pair, (22)

(10-n)!! = (10-6)!! = 4!! = 8.

For the 8-9 harmonic oscillator pair, (23)

(10-n)!! = (10-8)!! = 2!! = 2.

[1] derives the numbers 48, 8, and 2 via a less-rigorous, pattern-based approach. Based on such numbers, [1] posits from a theoretical perspective various numbers of types of "stuff" comprising the "t-universe." The t-universe contains the "known universe," which is the concept commonly called "the universe." The t-universe may also contain an "associated universe." [1] defines a concept of an "ensemble" of stuff. [1] defines a concept of an "egl-L" group of ensembles. Here, L is identical to the L defined in (7). An egl-L group includes one or more ensembles. Baryonic matter comprises one ensemble. The t-universe includes 24 ensembles (if there is no associated universe) or 48 ensembles (if there is an associated universe). Each ensemble shares some characteristics with baryonic matter.

Rules pertain as to which fermions and bosons interact. For example, considering the level L=4, each ensemble interacts with its own photons (4e4) but not with photons associated with other ensembles. For instance, baryonic matter does not interact with dark-matter photons. At level L=3, baryonic matter interacts with gravity (4e3) associated with the 6 ensembles that include baryonic matter and dark matter. Baryonic matter does not interact with the 4e3 bosons associated with the other 18 ensembles (if there is no associated universe) or 42 ensembles (if there is an associated universe).

Table 7 and Table 8 summarize results. As noted in [1], the 1:5:18 ratios match, within observational error, observations [2] based on measuring cosmic microwave background radiation. To the extent observed ratios are actually (or would become, as the universe evolves) 1:5:18:0+, the associated universe likely contributes (or will contribute) the 0+.

**Table 7  Numbers of empty states and types of stuff**

L is as defined in (7). (19) provides the "numbers of similar sets …". (20) provides the numbers in the "ratio" column. Each "ratio of identified stuff …" number comes from apportioning the "ratio" in the next row. The "egl-3 group that contains baryonic matter" also contains the 5 ensembles of dark matter. The "egl-2 group that contains baryonic matter" also contains 18 ensembles (or 3 egl-3 groups) of dark energy. In the rightmost columns, "other stuff" refers to the stuff named in the next-to-rightmost column.

| L | Number of similar sets of empty states | Ratio | Ratio of identified stuff to unidentified stuff | Indentified stuff | Other stuff | Ratio of baryonic matter to other stuff |
|---|---|---|---|---|---|---|
| 6 | 3840 | | | | | |
| | | 10 | | | | |
| 5 | 384 | | | | | |
| | | 8 | | | | |
| 4 | 48 | | 1:5 | egl-4 group that is baryonic matter | dark matter | 1:5 |
| | | 6 | | | | |
| 3 | 8 | | 1:3 | egl-3 group that contains baryonic matter | dark energy | 1:18 |
| | | 4 | | | | |
| 2 | 2 | | 1:1 | egl-2 group that contains baryonic matter | associated universe | 1:24 |
| | | 2 | | | | |
| 1 | 1 | | | egl-1 group that contains the t-universe | - | |

**Table 8 Matches between forces and types of stuff**

L is as defined in (7). The two rightmost columns specify the extent to which forces that interact with baryonic-matter stuff interact with other stuff. In the rightmost column, each entry shows two possible numbers of ensembles. The first number pertains if there is no associated universe. The second number pertains if there is an associated universe. Presumably, one can substitute "ensemble x" for "baryonic matter" throughout those two columns, with "ensemble x" denoting any one of the 24 or 48 ensembles of stuff.

| L | Number of similar sets of empty states | Forces | The versions of these forces that interact with baryonic matter interact with the … | The versions of these forces that interact with baryonic matter do not interact with the … |
|---|---|---|---|---|
| 6 | 3840 | | | |
| 5 | 384 | | | |
| 4 | 48 | IF4, including … 4e4 (photons) | egl-4 group that is baryonic matter | other 23 or 47 ensembles |
| 3 | 8 | IF3, including … 4e3 (gravity) | egl-3 group that contains baryonic matter | other 18 or 42 ensembles |
| 2 | 2 | IF2, including … 3e2 | egl-2 group that contains baryonic matter | other 0 or 24 ensembles |
| 1 | 1 | IF1, including … 3e1 | egl-1 group that contains the t-universe | - |

## Section 4 Comments

Table 9 provides a directory of zero-energy empty states for which excitement does not lead to results we herein consider further.

**Table 9 Zero-energy states not further considered above**

For each "maps to" state, the state can be considered to be similar to a state in one of Table 3, Table 4, Table 5, or Table 6. For each remaining state, at least one of the following pertains regarding first excitements (for 1 \le k \le 3). No excitement is possible. (That is, n_1 = n_2 = n_3 = -1.) The excitement of n_1=0 would lead to a "would-be particle" with a charge that is not an integer multiple of the charge of a positron. The excitement of any n_k<-1 oscillator leads to another empty state.

| Name | Group | n_k | 0 | 1 | 2 | 3 | Comments |
|---|---|---|---|---|---|---|---|
| | | | .. | 0 | 0 | <0 | • maps to \| {..,<0,0,0} > |
| | | | .. | 0 | -1 | -2 | • non-integer charge; or<br>• excites to another empty state |
| | | | .. | 0 | -1 | -3 | • non-integer charge; or<br>• excites to another empty state |
| | | | 0 | 0 | -2 | -3 | • non-integer charge; or<br>• excites to another empty state |
| | | | .. | <0 | 0 | <0 | • maps to \| {..,0,<0,<0} > |
| | | | .. | <0 | <0 | 0 | • maps to \| {..,0,<0,<0} > |
| | | | .. | <0 | <0 | <0 | • excites to another empty state; or<br>• (for \| {..,-1,-1,-1} >) cannot be excited |

Table 3, Table 4, Table 5, and Table 6 exhibit a pattern of "nature's deploying," with respect to paired oscillators, -1:s and 0:s. We hypothesize the following. Deploying a -2 (or -3) would correspond to an implied new pair of space-time real dimensions. Deploying 0:s and -1:s in other than the manner shown in the table would violate the 10-dimensional parity principle implied in the modulo-10 ordering discussed in Section 3 before (15).

## Section 5 Continuation

[1] provides a continuation of this paper. That work discusses {a} an estimated range for the size of object in the known universe for which repulsion caused by the 3er boson (for which either r=2 or r=1, but for which we have yet to determine which alternative applies) matches attraction caused by gravity (4e3); {b} a formula approximating the masses of the 6 fundamental baryonic-matter quarks and charged leptons; {c} possible masses for the electron-neutrino, mu-neutrino, and tau-neutrino; {d} spins for the bosons and fermions that form based on exciting empty states shown in Table 3, Table 4, Table 5, and Table 6; {e} a possible mathematical closed-form expression for a ratio involving the q_e (the charge of an electron), 1/4πε_0 (the Coulomb constant), m_e (the mass of an electron), and G_N (the gravitational constant); and {f} opportunities for observations and experiments that can help confirm or

refute implications of such work. (Regarding {a}, the range of linear size is about one order of magnitude.)

## References

**1** T. J. Buckholtz, *Physics 642b: Patterns, Forces, Particles, and Stuff*, T. J. Buckholtz & Associates, Portola Valley, California, May 2012. (http://www.amazon.com/Physics-642b-Patterns-Forces-Particles/dp/1475113528/)

**2** K. Nakamura et al. (Particle Data Group), J. Phys. G 37, 075021 (2010) and 2011 partial update for the 2012 edition. (http://pdg.lbl.gov/2011/reviews/rpp2011-rev-phys-constants.pdf)