Title: Greenhouse gases cannot cause observed global warming—they absorb only spectral lines, not heat

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Abstract: Heat is what a body of matter absorbs when warming and loses when cooling. Traditionally, radiant heat is quantified as a single numeric amount of thermal energy per second flowing spontaneously through a surface area in units of watts per square meter. However, Planck's law, an empirical equation formulated to fit extensive laboratory measurements, shows that heat consists of a very broad continuum of frequencies of oscillation where each frequency transmits thermal energy equal to the Planck constant times frequency—the energy of a single frictionless molecule-size oscillator. A molecule of carbon dioxide gas does not absorb heat; it merely absorbs spectral lines that are the molecule's resonant frequencies of oscillation, making up less than 16% of the broad continuum required to constitute heat.

One Sentence Summary: CO_2 absorbs <16% of Earth's radiant heat

Main Text: Heat is the spontaneous transfer of thermal energy from a warmer body of matter to a cooler body of matter by thermal conduction within matter, by thermal radiation across air and space, and by convection within a turbulent liquid, gas, or plasma. Joseph Fourier (*1*) proposed a detailed analytical theory of heat in 1822, explaining that "heat, like gravity, penetrates every substance of the universe, its rays occupy all parts of space." He described heat as a flux, a single numeric "quantity of heat [per second] which flows at each point across a given surface" in units of watts per square meter. He pointed out that "all bodies have the property of emitting heat through their surface—the hotter they are, the more [heat] they emit." Fourier clearly thought that Sun emits the same generic heat as Earth, just a whole lot more of it. He also thought of heat as additive—the greater the amount of heat absorbed, the hotter the body becomes.

Today, nearly two hundred years later, scientists still follow Fourier's formulation despite several problems. In 1900, Planck developed empirically a law, which, as described below, clearly shows that the physical properties of heat change substantially with temperature of the radiating body. There is no such thing as generic heat. Secondly, it is well known that no amount of heat can raise the temperature of the absorbing body to be hotter than the temperature of the emitting body. For example, no amount of infrared radiation from Earth can cause sunburn. Third, it is the difference in temperature between the emitting and absorbing bodies, the temperature gradient, that has the primary influence on how much heat flows between two bodies at any instant in time. This is why curves of warming and cooling are always asymptotic, as shown by the red calculated curve in Fig. 1.

The purpose of this paper is to explore the reality documented by Planck's empirical law that temperature, heat, and thermal energy all result from a very broad continuum of frequencies of oscillation of all the bonds holding matter together.

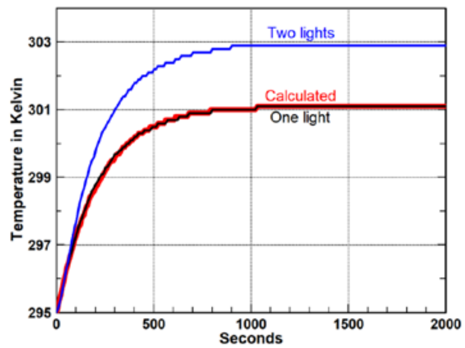

Fig. 1. The rate of warming, the rate of heat flow, decreases with decreasing difference in temperature forming an asymptotic curve. The black line shows temperature increase of a black, 5-cm-square, 16-gauge metal plate caused by radiation from one 50-watt MR16 ESX picture light placed 90 cm away. The blue line shows similar warming caused by two identical lights. The redline shows the temperature calculated by adding 5% times the ending temperature minus the existing temperature at each 10-second interval.

The quantum of thermal energy

In 1899, Max Planck concluded that "thermal radiation most probably arises from certain oscillations that take place within molecules or ions" (*2*). Since that time, spectral physicists have observed in great detail (*3*) that all bonds holding matter together are not rigid. Each mode of oscillation, of each degree of freedom, of each bond, is observed to oscillate between electromagnetic forces repelling like charges and different electromagnetic forces attracting unlike charges. These molecule-size oscillators, with lengths on the order of 10^{-10} meters, are often visualized as behaving according to the Morse potential energy function (*4*) or now more precisely by the Morse/Long-range potential energy function (*5*). As shown in Fig. 2, when thermal energy increases, the amplitude of oscillation increases until the bond comes apart at E_{max}.

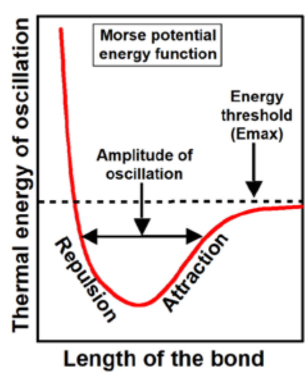

Fig. 2. Each mode of oscillation of each degree of freedom of each bond holding matter together oscillates as a frictionless molecule-size oscillator. As thermal energy increases, the amplitude of oscillation at each frequency of oscillation increases until the bond reaches an energy threshold E_{max} and comes apart.

Electromagnetic forces are frictionless. Therefore, each oscillator has an energy of oscillation (E) that is simply equal to a scale factor (h) times its frequency of oscillation (ν, the Greek letter nu):

$$E=h\nu$$

an equation first postulated by Planck in 1900 (*6*). The important concept here is that energy of oscillation (E) is the same physical thing as frequency of oscillation (ν). To express energy in joules, we multiply frequency of oscillation by h, a scale factor known as the Planck constant—the number of joules of oscillatory energy "contained" in one cycle per second—the slope of the line of energy as a function of frequency passing through the origin. The Planck constant can be estimated easily in a high school physics laboratory (*7*).

In physics, we typically treat energy as a subtle concept (*8*). We think of heat, for example, as a flux of energy per second, but this avoids having to specify the physical nature of the energy within heat. E=hν, on the other hand, says simply that the energy of a single, frictionless oscillator is physically the same thing as its frequency of oscillation. This can be confusing at first because we are not used to thinking of frequency or energy as physical things. They are not material things, but they are things that we know are physically happening around us even though we cannot see them.

The tricky part of this is that frequency of oscillation contained in electromagnetic radiation transporting heat is well-observed to be a continuum. This continuum is a very broad range of values that coexist and do not interact in air and space (Fig. 3). It extends from extremely low frequency radio signals oscillating at cycles per second (10^0), to infrared radiation from Earth whose maximum amplitudes of oscillation (Figure 4) peak around 30 trillion (3×10^{13}) cycles per second, to visible light oscillating at frequencies around 500 trillion (5×10^{14}) cycles per second, and ultimately to gamma rays oscillating at frequencies greater than 100 quintillion (10^{20}) cycles per second.

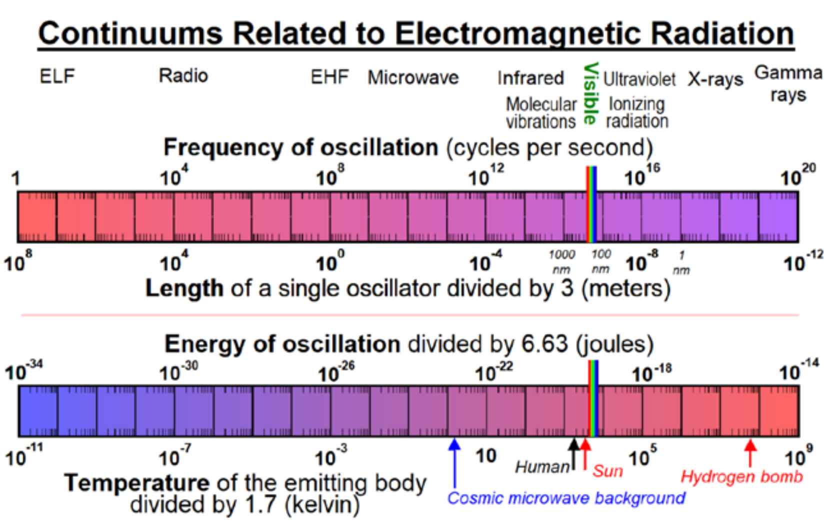

Fig. 3. Electromagnetic radiation consists of a continuum of frequencies of oscillation. The effective length of an individual oscillator, formerly thought of as wavelength in terms of wave frequency, equals, as a first approximation, the velocity of light (3×10^8 meters per second) divided by frequency of oscillation. The energy of oscillation is equal to frequency of oscillation times the Planck constant (6.63×10^{-34} joules per cycle per second). The resulting temperature of matter is equal to the frequency of oscillation times the inverse of the Wien displacement constant (1.7×10^{11} degrees Kelvin per cycle per second).

Since frequency (ν) is a continuum, then energy (E), which equals a constant times a continuum, must also be a continuum. Radiant energy, therefore, is not quantized, although the physical source of radiant energy is physically quantized. For each and every frequency in this continuum, down to some molecular granularity, there is a discrete, molecule-size oscillator on the surface of the radiating body transmitting that frequency. This means that the smallest chunk into which electromagnetic radiation can be subdivided is a physical, molecule-size oscillator—in effect the atom of electromagnetic radiation or the quantum of electromagnetic radiation. Each oscillator is oscillating at a specific frequency of oscillation, which is a specific energy of oscillation. This energy, $E=h\nu$, can take on any numeric value throughout the continuum.

This is not our current understanding. $E=h\nu$ is well-known as the Planck-Einstein relation and is integral to quantum physics where E is thought to be the energy of a photon based on Einstein's interpretation of the photoelectric effect (*9*). A photon is thought to be a type of elementary particle, the quantum of electromagnetic radiation. Energy in electromagnetic radiation is thought to be expressed only in terms of integral numbers of photons: $E=nh\nu$, where n must be an integer. Quantum mechanics is based on the concept that it is the energy itself that is quantized. But radiant energy is well-observed, as shown in Fig. 3, to be a continuum. Therefore, radiant electromagnetic thermal energy is not quantized. What is physically quantized in Nature is the individual, molecule-size, frictionless oscillators for each of the modes of oscillation of each of the degrees of freedom of each of the bonds holding matter together.

Einstein (*9*) proposed the "light quantum," $E=h\nu$, to explain the photoelectric effect discovered by Hertz (*10*), who found that when you shine a light on a fresh metal surface, electrons flow only when the color of light is above some minimum frequency, above some minimum level of energy. Above that level, the higher the intensity of the light, the more electrons flow. Below that level, no electrons flow no matter the intensity. Thus $E=h\nu$ is the minimum level of energy, the minimum frequency of light, that can break the bonds holding an electron on the unoxidized surface of a metal—essentially E_{max} in Fig. 2. We see the same effect with dissociation of molecules such as oxygen (O_2) where frequency of oscillation must be within the ultraviolet-C spectrum at a value of around 1237 terahertz (traditionally thought of as a wavelength of 242.2 nanometers).

Planck's law

In 1900, Planck (*2*) formulated, by trial and error, an equation successfully describing mathematically observed physical properties of thermal radiation (Fig. 4). Thermal radiation is defined as the radiation emitted spontaneously by a body of matter resulting from its temperature. The body is assumed to be black, meaning its surface is a perfect absorber and emitter of radiation, and to be in a state of thermal equilibrium, meaning that the temperature is the same at every point throughout the body such that heat is no longer flowing within the body. This equation, which became known as Planck's law, accurately fit related laboratory data (*11-15*) and still fits extensive data available today.

Planck postulated that there must exist "discrete energy elements", $E=h\nu$, the energy of oscillation of what he thought of as "resonators" (*6*). He introduced $h\nu$ as the main term for energy in his equation (Fig. 4) and multiplied it by two times a frequency of oscillation squared divided by the velocity of light squared ($2\nu^2/c^2$) to make the units watts per square meter. Planck also uses $h\nu$ in the exponential term ($h\nu/k_BT$) (Fig. 4), the ratio of joules of oscillatory energy ($h\nu$) at the molecular level to joules of energy as a function of absolute

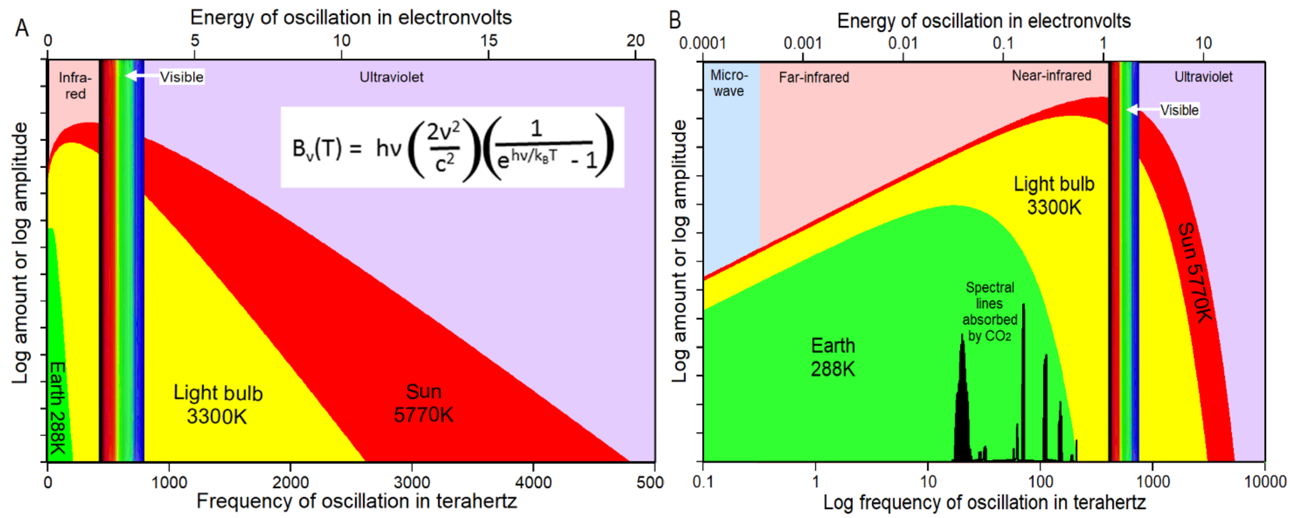

Fig. 4. Planck's law plotted with linear x-axis on the left and logarithmic x-axis on the right. The vertical black lines on the right are the frequencies of spectral lines of radiation absorbed by CO_2.

temperature (k_BT), where k_B is the Boltzmann constant, the number of joules per unit absolute temperature (T).

Planck's law (Fig. 4) calculates, for a body of matter at a specific temperature, the amount of radiant energy at each frequency. Planck's law shows that temperature in matter is the result of a very broad continuum of frequencies of oscillation with several key physical properties. The hotter the body of matter, 1) the broader the continuum of radiated frequencies of oscillation with significant amount, 2) the greater the amount at each and every frequency of oscillation, especially at higher frequencies, and 3) the higher the frequency of oscillation with the greatest amount. No matter how a body of matter is heated, when that body reaches thermal equilibrium, the distribution of frequencies and amounts observed to be emitted are observed to be those described by Planck's law. For example, a body of matter "possesses" a temperature of 3300K only if it contains every single one of the frequencies of oscillation plotted in yellow in Fig. 4 and has the amounts (amplitudes) shown in yellow. If the amounts are less, the temperature is lower. If the amounts are more, the temperature is higher. Note that the basic shape of the Planck curve is always the same for thermal radiation.

Most importantly, Planck's law shows clearly that heat is not a single numeric value of watts per square meter as assumed by Fourier and most scientists today. Heat is a continuum, an infinite series of numeric values. A physical description of the heat that must be absorbed by Earth to become as warm as 3300K is shaded yellow in Fig. 4.

Amount of radiation should be amplitude of oscillation

The data fit by Planck's law were measured by passing light through a prism, spreading the spectrum out spatially into a rainbow, and then placing a sensor at different angles within each narrow band of color. Infrared radiation does not possess enough energy to penetrate glass. The prism, in that case, was made of halite (rock salt) (*16*). The sensor was typically a thermopile or resistor that changed a very small electrical current, measured in watts, as a function of temperature. Scientists were measuring the thermal effect of a narrow band of radiation on a small piece of matter within their sensor. They thought of this as spectral radiance in units of watts per steradian per meter squared per cycle per second, plotting it on the y-axis as a function of wavelength on the x-axis.

Wavelength, however, and wave frequency (the velocity of light divided by wavelength) both assume Maxwell's wave-theory of light, which cannot apply in air and space as described in the Supplementary Materials. Also described is how light can display wave-like features such as interference and reflection, but only when in the immediate presence of matter. What scientists were physically measuring was the intensity or brightness of the radiation within a narrow band of frequencies of oscillation (ν). Energy of light is equal to frequency, $E=h\nu$. A small amount of blue light has the same energy as a large amount of blue light, while blue light has more energy than red light. Thus, energy (E) should be plotted on an alternative x-axis shown at the top of the graphs in Fig. 4, not on the y-axis.

Light has two physical properties: color, which is frequency of oscillation, and intensity or brightness, which is amplitude of oscillation. What scientists were measuring physically was a proxy for what we perceive as intensity or brightness, resulting from amplitude of oscillation. Measuring amplitude of oscillation in picometers (10^{-12} meters) was not easy in 1900 and still takes some effort. Thinking of the y-axis as amplitude of oscillation does not change the basic shape of a Planck curve, but a scale factor replacing $2h/c^2$ for the y-axis needs to be calibrated in the laboratory in units of meters per frequency of oscillation cubed. This constant is, most likely, the slope, on a log-log plot (Fig. 4B) of a Planck curve at low frequencies. In the meantime, I show orders of magnitude without specific values on the y-axes in Fig. 4.

Planck's law calculates, at a given absolute temperature, this normal amplitude of oscillation as a function of frequency of oscillation. All frequencies of oscillation coexist at all locations and at all times throughout the universe. What varies with increasing temperature of the emitting body and decreasing distance squared is amplitude of oscillation at each frequency of oscillation, ranging from imperceptible to dominant.

Thermal radiation propagates by resonance

Electromagnetic forces are frictionless. Therefore, each of these tiny, molecule-size oscillators is frictionless. The only known way to increase or decrease the amplitude of oscillation of a frictionless oscillator is by sympathetic resonance. Resonance is a physical phenomenon where one oscillating system "shares" its amplitude of oscillation with another system oscillating at nearly the same frequency. Resonance is what Einstein referred to as "spooky action at a distance" (*17*). Resonance is the observed physical process that quantum physicists seek to explain as quantum entanglement.

Perhaps the simplest example of electromagnetic resonance is how you hear your favorite radio station. The radio station transmits at a specific frequency of oscillation. You tune your radio receiver to resonate at that frequency, picking the amplitude of oscillation of just that frequency of oscillation out of the broad continuum of all frequencies. This is how signals from hundreds of radio stations, cellphones, WIFI signals, etc. all coexist in the air around us. Amplitude of oscillation is observed to decrease with the inverse square of distance. Your radio, therefore, receives the clearest signals from local stations.

Through resonance, two oscillators typically average their amplitudes of oscillation. The oscillator with the greater amplitude "gives up" one-half of the difference in amplitude while the oscillator with the lesser amplitude "absorbs" one-half of the difference in amplitude. Thus amplitude "flows" from higher amplitude to lower amplitude at the same frequency, which, from Planck's law (Fig. 4), means from higher temperature to lower temperature. Heat "flows" spontaneously when resonance occurs simultaneously across each and every frequency in the continuum.

Resonance also explains how Planck curves maintain their shape. The amount of amplitude transferred at each frequency is the average of the difference in amplitudes at that frequency. Through resonance, amplitudes of oscillation are not physically added together. They are not additive as currently assumed. Rather, they are averaged together at the molecular scale. We could say they are "averative", a word coined here to clarify this distinction. At the macroscopic scale, values of temperature resulting from molecule-size oscillators are also averative. If you take two bodies of matter that are identical in every way except for temperature and connect them together thermally, the resulting temperature, at thermal equilibrium, becomes the average of the initial two temperatures. The greater the difference in temperature, the greater the flux in amplitude and the greater the flux for each particular frequency component of heat.

This averaging is the reason why warming and cooling curves are asymptotic as demonstrated by the red calculated curve in Fig. 1. Temperature rises quickly at first when the temperature difference is greatest. Then temperature rises much more slowly, approaching its warmest temperature asymptotically.

By resonance, amplitude flows only from one discrete physical oscillator on the emitting surface to one discrete physical oscillator on the absorbing surface. Conduction of heat via resonance within matter is enhanced by close proximity of independent oscillators. In air and space, resonance is enabled via line-of-sight by electromagnetic radiation, which is transmitted by molecule-scale motion of charge. Frequency of oscillation of radiation is well observed to travel through air and space without any change, even over galactic distances, except for Doppler effects.

Amplitude of oscillation, alternatively, is well observed to decrease with the square of the distance travelled. This decrease can be understood in terms of the apparent density of molecule-size oscillators on the surface of the near and distant bodies. Over short distances, there is a one-to-one correspondence between oscillators. As distance increases, the distant object looks smaller and smaller. Fewer and fewer molecules on the distant surface are available to resonate with the one molecule on the near surface. Thus, the amplitude transferred by resonance must then be shared by conduction with more and more similar oscillators on the distant surface as they reach thermal equilibrium. In this way, the rate of amplitude transfer slows with the square of increasing distance.

Resonance is all around us

We perceive visible light from 430 to 770 terahertz because these are the resonant frequencies of the cells in the cones of our eyes. Three types of cone cells (L, M, and S) are most responsive or sensitive to three different bands of color shown by the lines in Fig. 5 (*18*). These cone cells transmit simultaneously three different amplitudes of oscillation encoded in nerve impulses to our brain for each pixel that we see. The size of a pixel is determined by the minimum diameter of a cone cell, which is about 500 nanometers (5×10^{-7} meters). Our brain, by reassembling the relative intensities of these three signals, can distinguish approximately 10 million different shades of color. This process is the inverse of the process by which a computer sends amplitudes of oscillation of primary red, green, and blue colors (RGB) encoded in 32 bits to a pixel of a computer monitor that can then display more than 16.7 million different shades of color.

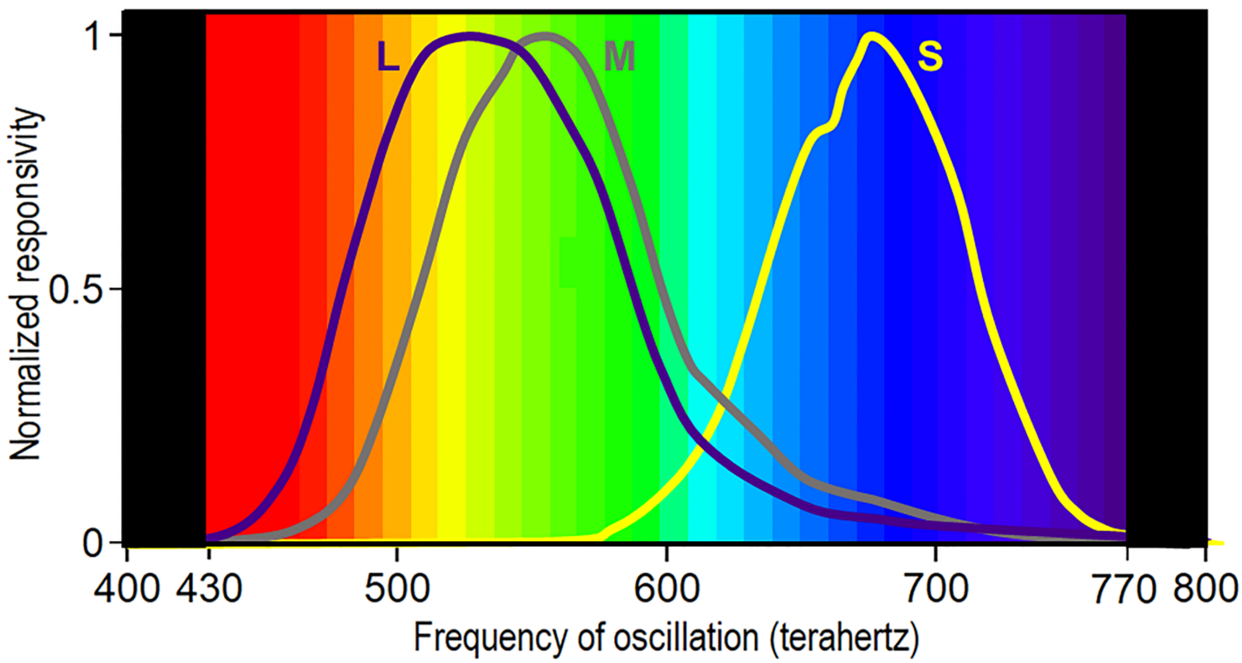

Fig. 5. Human eyes are generally sensitive to frequencies of 430 to 770 THz as shown by the normalized responsivity of L, M, and S cones (solid lines).

Matter illuminated by electromagnetic radiation containing no frequencies between about 430 THz and 770 THz appears black because these frequencies cannot be detected by human eyes (Fig. 5). Thus, black is not a specific frequency; black is what we perceive when there is no visible color. White, on the other hand, is what we perceive when all visible colors simultaneously have substantial amplitudes of oscillation. The more equal the amplitudes of oscillation, the whiter the white.

During resonance, amplitude of oscillation normally increases and decreases over a band of frequencies as shown by the curves in Fig. 5, depending on the oscillator's physical structure and its interaction with adjoining oscillators. The breadth of the band is related to the damping of the oscillator often quantified as the quality factor (*19*). It is the slopes of these curves that provide the differences that the brain can use to distinguish about 10 million colors. Scientists are beginning to realize, similarly, that a small number of sensor types involving resonance may enable animals to recognize a very wide range of smells and tastes (*20, 21*). The fact that smells and tastes are much more intense at higher temperatures, higher amplitudes of oscillation, suggests that frequency of oscillation and resonance may play the dominant role. In fact, all five senses may be based on resonance.

Thinking in terms of resonance provides a whole new way to understand the flow of heat. For example, when there are clouds in the sky, the bonds holding molecules of water together resonate with bonds on Earth's surface. Since the clouds are warmer than deep space, the difference in amplitude of oscillation between Earth and the cloud is smaller than the difference between Earth and deep space. Therefore, the flow of amplitude from Earth to the cloud decreases (Fig. 1), making cloudy nights warmer than clear nights.

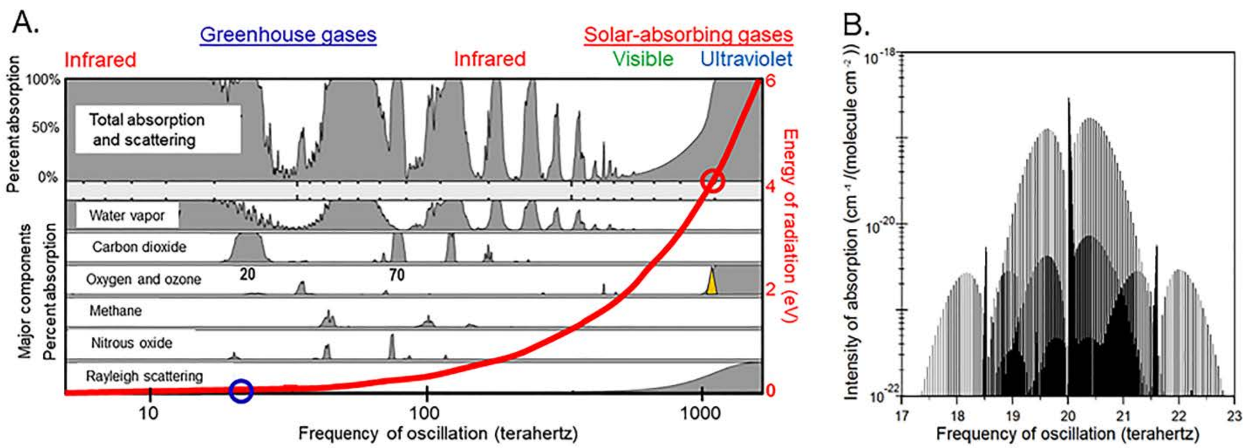

Fig. 6. Spectral regions absorbed by greenhouse gases are shaded gray. Absorption is along spectral lines too close to see in the shaded areas on the left. Individual spectral lines are plotted on the right for the broad band of absorption for CO_2 at 20 terahertz labeled on the left. The red line shows the energy of radiation: E=h*ν*.

Spectral lines and greenhouse gases

Spectral physicists document in detail (*3*) that greenhouse gases merely absorb infrared radiation within narrow bands of frequencies (Fig. 6A) and, within these bands, they only absorb narrow spectral lines of energy that are the resonant frequencies of oscillation of the bonds holding molecules together (Fig. 6B). Ångström concluded in 1900 that “no more than about 16 percent of earth’s radiation can be absorbed by atmospheric carbon dioxide” (*22*). If you have 16% of the frequencies, you do not have heat just as if you have 16% of a person, you do not have a person. No matter how you propose spectral lines absorbed might cause warming of air, greenhouse gases simply do not absorb enough thermal energy—enough heat—to have much effect. In the vernacular, they simply do not have enough skin in the game.

Furthermore, according to the kinetic theory of gases, air-temperature is proportional to the average translational velocity squared of all the molecules making up the gas. Only 0.04% of these gas molecules absorb infrared energy, and conversion of bond energy to velocity through myriad collisions has never been quantified in the laboratory but cannot be very efficient. Plus, by Planck’s law (Fig. 4), radiation from Earth does not contain high enough amplitudes of oscillation at all frequencies of oscillation to warm Earth. A body of matter cannot physically be warmed by its own radiation.

Warming observed from 1970 to 1998 was most likely the result of depletion of the ozone layer caused by manufacture of chlorofluorocarbon gases (*23*). Much more rapid warming since 2014 and episodically throughout all of geologic history appears to have been caused by ozone depletion due to large releases of chlorine and bromine associated with basaltic lava flows covering hundreds to millions of square kilometers of land, all contemporaneous with major warming, major ocean acidification, and major mass extinctions (*24*).

Recognizing that heat flows by resonance over a very broad continuum of frequencies of oscillation makes many things that quantum physics tries to explain, including entanglement, both physically intuitive and deterministic, something Einstein sought in earnest throughout the last 28 years of his life.

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Supplementary Materials:

1. Light cannot physically travel as waves

2. Light cannot physically travel as particles

3. A continuum of frequencies of oscillation

4. Wave-like features of light

5. Temperature of a gas

6. The physical nature of thermal energy

7. Some questions

Figures S1-S2

References (*25*-*31*)

Data for Figure 1

Science AAAS

Supplementary Materials for

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This PDF file includes:

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Figures S1-S2

References (*25*-*31*)

Other Supplementary Materials for this manuscript include the following:

Data for Figure 1

Supplementary Text

1. Light cannot physically travel as waves

In 1864, Maxwell (*25*) developed a series of equations that seemed to describe accurately waves of light traveling through space at the speed of light via electric and magnetic fields. Yet Hooke, Fresnel, and others recognized that waves are the deformation of matter but there is no matter in space to deform. They proposed, therefore, that waves in space must travel in a luminiferous ether, which was thought to be some invisible form of matter. Numerous physicists in the 19th century tried to demonstrate the presence of a luminiferous ether, but in 1887, Michelson and Morley (*26*) showed, in a definitive experiment accepted by most physicists, that such an aether does not exist.

There are other issues with light waves. For example, light travels from point to point with all the energy traveling along what we think of as rays, whereas waves would smear the energy out over space. Furthermore, the higher the wave-frequency of seismic waves, the greater the attenuation with distance. Light has frequencies 10^{14} times higher than the frequencies of seismic waves. There is no material stiff enough to allow such high frequencies to propagate as waves.

Yet to this day, most physicists are convinced that light travels as waves or as wave-particle duality. They rationalize that electromagnetic waves must be different, in some way, from waves in matter. The difference is in what we mean by frequency. When I say light travels as frequency, people always respond "yes but frequency equals the velocity of light divided by wavelength." They are talking about wave frequency. I am talking about frequency of oscillation—something totally different. Wave frequency travels with some velocity and the dominant frequencies typically decrease in frequency with distance. Frequency of oscillation is well observed not to change with distance, even over galactic distances.

Light does appear to have a velocity that Maxwell concluded is equal to one divided by the square root of the product of two constants: the vacuum permittivity, which is the resistance to forming an electric field, times the magnetic permeability, which is the ability to form a magnetic field (*27*). What we think of as velocity of light may simply be the very short but finite interval of time that it takes for what we think of as an electric field to induce a magnetic field to begin to induce an electric field again. It is this very rapid interaction that enables resonance.

2. Light cannot physically travel as particles

In 1704, Newton (*28*) argued that light must be particles because rays of light are so straight. In 1905, Einstein (*9*) showed that the photoelectric effect, which cannot be explained by Maxwell's wave equations (*25*), can be explained by assuming the energy of light is quantized as $E=h\nu$, ultimately thought of as the energy of a photon, a particle of light. While Einstein did not express it this way, it seemed logical that an incoming particle would knock an electron loose much like a billiard ball. To this day, no one has explained physically, in detail, how a photon would interact with a gas molecule nor how a shower of photons would interact with a gas molecule to transfer the spectral lines of energy observed in Figure 6B. The clearest problem with the photon concept is, as explained in the main paper, that frequency and, therefore, energy of electromagnetic radiation are continua. If $E=h\nu$, then energy is not quantized. As explained in the main paper, it is the source of energy that is quantized—the myriad of tiny physical oscillators.

3. A continuum of frequencies of oscillation

We can think of a continuum mathematically as a Fourier series with commas replacing the plus signs and with the number of terms approaching infinity. In a Fourier series, the plus signs implement the principle of superposition, adding up all the single-frequency sinusoidal waveforms to find the solution for a general waveform. This addition is enabled by the bonds holding matter together. In air and space, however, there is no matter and there are no bonds. There is no physical way for the frequencies of oscillation to be added together or to interact with each other in any way. It makes no physical sense to add red light to blue light. You do not get ultraviolet light. You simply get some red light coexisting with some blue light.

All frequencies of oscillation coexist at all locations and at all times throughout the universe. What varies with increasing temperature of the emitting body and decreasing distance squared is amplitude of oscillation at each frequency of oscillation, ranging from imperceptible to dominant.

4. Wave-like features of light

For most physicists, the strongest argument that light travels as waves is that light displays properties such as interference, reflection, refraction, diffraction, dispersion, and birefringence traditionally explained by wave-theory. These properties, however, are not observed in space. They are only observed when light impinges on matter. It is the bonds holding the surface of matter together that enable the interaction of frequencies.

Every mode of oscillation, of each degree of freedom, of each bond on the surface of any object that we see is transmitting a frequency of oscillation based on the temperature of the object. In the temperature range in which humans live, all these frequencies of oscillation with significant amplitude of oscillation are in the infrared and microwave frequency bands (Figure 4). When visible light containing much higher frequencies of oscillation shines on matter, most frequencies of oscillation are absorbed into the matter but some cause molecules on the surface to resonate at specific frequencies that constitute the surface color. This color may be determined by pigments, dyes, or structural coloration. These frequencies then resonate with the cones in our eyes causing us to see that color. Figure S1 shows the response of human eyes to color shown in Figure 5 with the addition of the responsivity of chlorophyll-A and chlorophyll-B, which are green pigments found in cyanobacteria and the chloroplasts of algae and plants. Reds and blues are strongly absorbed into the chlorophyll providing the energy for plants to grow, while greens oscillate on the surface, transmitting the green color where it can resonate with the cones in our eyes. Thus, incoming light is not reflected, it is absorbed by pigments or dyes and selectively retransmitted as color.

Classical laws of reflection, refraction, and interference, for example, rely on the Huygens-Fresnel principle, developed in 1678 and 1818, which assumes that every point to which light reaches becomes the source of a spherical wave of light. This is similar to retransmission discussed above except retransmission occurs only on the surface of matter, not at every point in space and each bond oscillator has an orientation, a correction added to the Huygens-Fresnel principle by Miller in 1991 (*29*).

There are many details to work out, but it appears that the wave-like properties of light may be more precisely explained by retransmission than by classical wave theory.

5. Temperature of a gas

Temperature is proportional to how fast atoms are moving relative to each other (*30*). The higher the velocity of the atoms, the higher the temperature. In a gas, where each atom or molecule is free to move in any direction within a fixed frame of reference, temperature is primarily proportional to the average *kinetic energy of translation* of all atoms and molecules ($E=½mv^2$). In condensed matter, i.e. solids and liquids, where the atoms are all interconnected by chemical bonds into molecules and molecules are all held together by a variety of intramolecular forces, temperature is proportional to the *kinetic energy of oscillation* of all those bonds

The greatest warming of air observed in Earth's atmosphere is daily in the stratosphere where solar radiation maintains the temperature of the stratopause approximately 60K warmer than the temperature of the tropopause. This warming is caused by solar ultraviolet-C radiation dissociating oxygen and other gas species and solar ultraviolet-B dissociating ozone and other gas species. Upon dissociation, the pieces of the gas molecule fly apart at high velocity, converting all the energy stored in the bond directly into air temperature. It has yet to be demonstrated that greenhouse gases absorbing low-energy, terrestrial, infrared radiation cause any significant warming of air.

The stratosphere forms an electric blanket surrounding Earth. Electric in the sense that the energy to warm the blanket comes from a distant source, Sun, not from the body under the blanket, Earth. It is the stratosphere that is observed to keep Earth warm—not greenhouse gases.

6. The physical nature of thermal energy

Thermal energy in matter is the kinetic energy of oscillation of all the bonds holding matter together. It is a continuum of energies, which is a continuum of frequencies of oscillation times the Planck constant. There is an associated continuum of amplitudes of oscillation of these frequencies of oscillation which is a function of temperature of the piece of matter as described by Planck's law.

The amount or amplitude of oscillation of each component of these energies can only be increased by resonance with an oscillator, oscillating at nearly the same frequency on the surface of a warmer body and can only be decreased by resonating with a similar oscillator on the surface of a cooler body. Conduction within matter can be thought of the same way across molecular surfaces within matter.

Thermal energy, therefore, is stored within these bonds and is only accessible as a component of heat. When the bond is broken, bond energy of oscillation is converted instantly to kinetic energy of translation. This kinetic energy is not accessible for use until the bond is broken. One way to look at Einstein's famous equation $E=mc^2$ is that it says matter is made up of a very large number of bonds containing very large amounts of energy. The more matter, the more bonds.

The shorter the length of the bond, the higher the frequency of oscillation, which, by $E=h\nu$, means the greater the energy. Nuclear bonds contain much greater energy than molecular bonds. Molecular bonds begin coming apart at ultraviolet energies just above the visible range leading to fading of colors, decay of materials in lawn furniture, sunburn, skin cancer, and such.

Recognizing the importance of resonance means that thermal energy is not radiated through air and space, it is transmitted simultaneously at each frequency of oscillation, just as a radio transmitter transmits a single frequency by motion of charge. Nothing physically exists in space other than the ability to foster resonance even over galactic distances—something we still need to look into in more detail.

7. Some questions

The Morse potential energy function is asymmetric because the force of repulsion appears to be proportional to the cube of frequency of oscillation while the force of attraction appears to be proportional to the square of frequency of oscillation. Thus, as thermal energy increases, the length of each bond increases, so the density decreases, and the volume increases as widely observed. As thermal energy decreases to absolute zero, bond lengths decrease, the density increases, and the volume decreases. Thermal energy depends on the motion of charge. As the body cools to absolute zero, the motion approaches zero, the forces approach zero, the density approaches infinity. Is this a black hole?

Dark energy is energy that we cannot see. It is hypothesized to permeate all of space to explain accelerating expansion of the universe and is thought to make up 68.3% of the total mass-energy of the universe. All radiation from Sun and other stars is dark until it impinges on matter. If we put matter in space, we can then see the radiation, which is always there. Can this explain the evidence for dark energy?

Dark matter is a theorized form of matter thought to account for 26.8% of the total mass-energy of the universe. We see the gravitational effects of this matter but cannot see the matter. As shown in Figure S2, as temperature of matter approaches absolute zero, the radiation from that matter is only in the far-infrared and microwave regions. These are the frequencies that instruments aboard the Planck spacecraft were sensitive to (esa.int/Our_Activities/ Space_Science/Planck/Planck_and_the_cosmic_microwave_background). Just as high-frequency gamma rays and x-rays have enough energy to penetrate matter, infrared and visible frequencies may have enough energy to penetrate very cold matter, making it dark, not visible to most instruments. The average temperature of matter emitting the cosmic microwave background (CMB) is thought to be 2.72548K (31). What's the possibility that variation in the cosmic microwave background reflects the age of dark matter, with the coldest being the oldest?

In 1930, Hubble discovered that light from remote galaxies was redshifted, suggesting the universe is expanding. An alternate explanation is that our part of the universe is contracting as it cools, as it becomes denser. What are the possibilities?

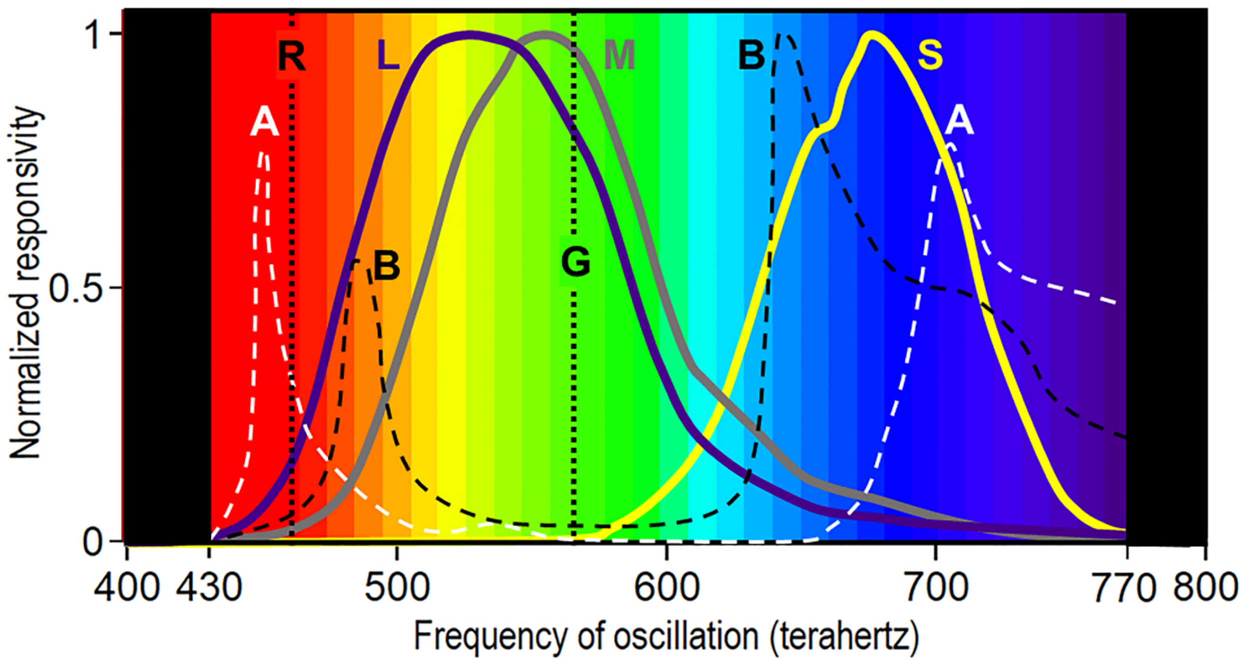
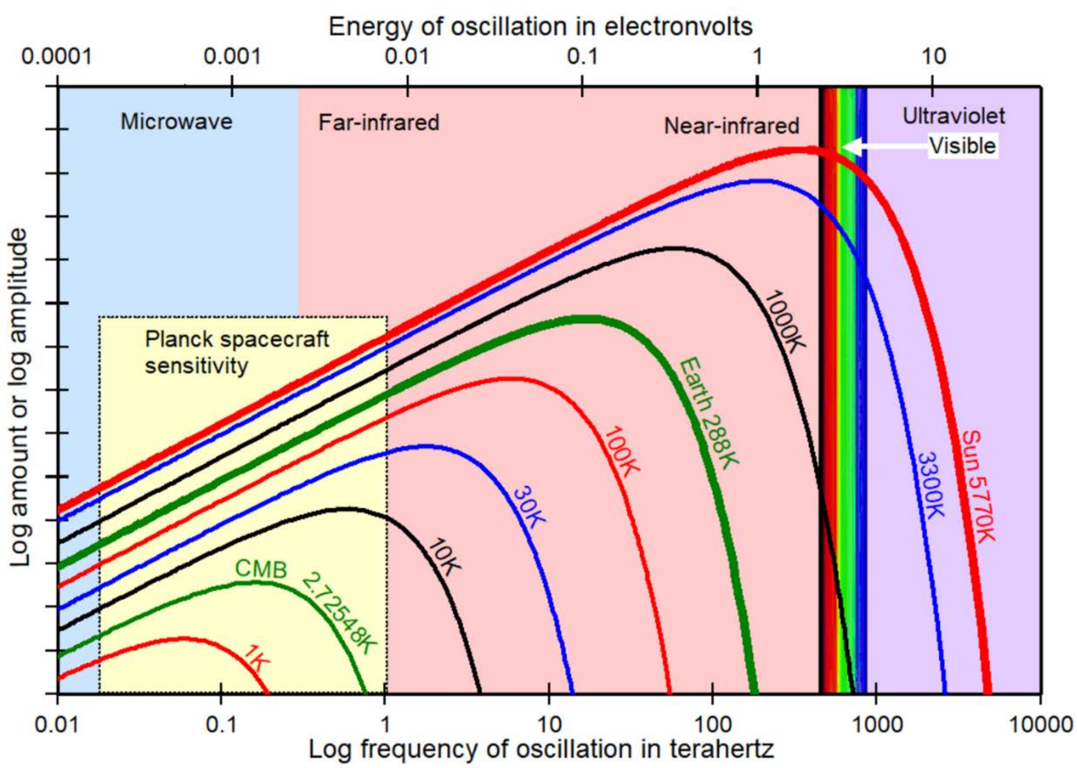


Fig. S1. Human eyes are generally sensitive to frequencies of 430 to 770 THz as shown by the normalized responsivity of L, M, and S cones (solid lines). The dashed lines show the responsivity of chlorophyll-A and chlorophyll-B. The dotted lines show the frequencies typical of red and green laser pointers.

Fig. S2. Planck's law as plotted in Figure 4B, but extended to very low temperatures.



Data for Figure 1

Seconds	1 light	Calculated	2 lights
0	295.0	295.0	295.0
10	295.2	295.3	295.2
20	295.4	295.5	295.4
30	295.7	295.8	295.7
40	296.0	296.0	296.0
50	296.3	296.3	296.3
60	296.5	296.5	296.6
70	296.7	296.7	296.9
80	296.9	296.9	297.2
90	297.1	297.1	297.5
100	297.3	297.3	297.7
110	297.5	297.5	298.0
120	297.7	297.6	298.3
130	297.8	297.8	298.5
140	298.0	297.9	298.7
150	298.1	298.1	298.9
160	298.3	298.2	299.1
170	298.4	298.4	299.3
180	298.6	298.5	299.5
190	298.7	298.6	299.6
200	298.8	298.7	299.8
210	298.9	298.8	300.0
220	299.0	298.9	300.1
230	299.1	299.0	300.3
240	299.1	299.1	300.4
250	299.3	299.2	300.5
260	299.3	299.3	300.6
270	299.4	299.4	300.7
280	299.5	299.5	300.8
290	299.6	299.5	300.9
300	299.7	299.6	301.0
310	299.7	299.7	301.1
320	299.8	299.7	301.2
330	299.8	299.8	301.3
340	299.9	299.9	301.4
350	299.9	299.9	301.4
360	300.0	300.0	301.5
370	300.0	300.0	301.6
380	300.1	300.1	301.6
390	300.1	300.1	301.7
400	300.2	300.2	301.8
410	300.2	300.2	301.8

420	300.3	300.3	301.9
430	300.3	300.3	301.9
440	300.3	300.3	302.0
450	300.4	300.4	302.0
460	300.4	300.4	302.0
470	300.4	300.4	302.1
480	300.4	300.5	302.1
490	300.5	300.5	302.1
500	300.5	300.5	302.2
510	300.5	300.5	302.2
520	300.6	300.6	302.3
530	300.6	300.6	302.3
540	300.6	300.6	302.3
550	300.6	300.6	302.3
560	300.6	300.7	302.4
570	300.7	300.7	302.4
580	300.7	300.7	302.4
590	300.7	300.7	302.4
600	300.7	300.7	302.4
610	300.7	300.8	302.5
620	300.7	300.8	302.5
630	300.8	300.8	302.5
640	300.8	300.8	302.6
650	300.8	300.8	302.6
660	300.8	300.8	302.6
670	300.8	300.8	302.6
680	300.9	300.9	302.6
690	300.9	300.9	302.6
700	300.9	300.9	302.7
710	300.9	300.9	302.7
720	300.9	300.9	302.7
730	300.9	300.9	302.7
740	300.9	300.9	302.7
750	300.9	300.9	302.7
760	300.9	300.9	302.7
770	300.9	300.9	302.7
780	300.9	300.9	302.7
790	300.9	301.0	302.7
800	301.0	301.0	302.8
810	301.0	301.0	302.8
820	301.0	301.0	302.8
830	301.0	301.0	302.8
840	301.0	301.0	302.8
850	301.0	301.0	302.8

860	301.0	301.0	302.8
870	301.0	301.0	302.8
880	301.0	301.0	302.8
890	301.0	301.0	302.8
900	301.0	301.0	302.9
910	301.0	301.0	302.9
920	301.0	301.0	302.9
930	301.0	301.0	302.9
940	301.0	301.0	302.9
950	301.0	301.0	302.9
960	301.0	301.0	302.9
970	301.0	301.0	302.9
980	301.0	301.0	302.9
990	301.0	301.0	302.9
1000	301.0	301.0	302.9
1010	301.0	301.0	302.9
1020	301.0	301.0	302.9
1030	301.1	301.1	302.9
1040	301.1	301.1	302.9
1050	301.1	301.1	302.9
1060	301.1	301.1	302.9
1070	301.1	301.1	302.9
1080	301.1	301.1	302.9
1090	301.1	301.1	302.9
1100	301.1	301.1	302.9
2000	301.1	301.1	302.9