

CHRISTINE KELLER, PAM MCKINLAY AND DAVID  
HUTCHINSON.

## **RECIPE FOR A STAR: THE INTERSTELLAR MEDIUM AND THE SUPERNOVA FEEDBACK LOOP**

“The hydrogen emission spectrum, illustrated in this work, is light that gives us information about the underlying quantum world of wave-particle duality. Each spectral line comes from light emitted as an electron drops from one allowed energy orbital about the hydrogen’s proton core to another lower level. The allowed energy levels themselves are determined by the wavelength of the electron particle in its orbital. Explaining the spectrum of hydrogen was the first great success of Schrödinger’s quantum mechanics.”

David Hutchinson

### INTRODUCTION—SPACE IS BACK AND IT’S THE NEW BLACK

Where once the stars were considered a sacred repository of knowledge we now ascribe a different set of meanings when we read the stars. The holders of knowledge have changed and the new storytellers spin the tales, reposing the big questions through the lens of modern space exploration: Who are we? What is Space? Are we alone? (Why is the answer to life, the universe, and everything forty-two?) Radio New Zealand has guests who are interviewed about Space-X and Hyperloop, NASA launches a high altitude balloon to look into deep space, delve into black holes, investigate gamma rays and announces a manned space mission to Mars. Finally....Space is back and it’s the new black. Motes float through the open doorway as I vacuum the dust on the rug. How will the new space race technology impact on appliance design I wonder? What kind of furry granular constellation is forming in the innards of my dust-busting machine? Is this a whirling microcosm of the universal housework taking place on a grander scale in our galactic backyard?



Figure 1. Christine Keller and Pam McKinlay, *INTERSTELLAR - 21 cm - H - SPECTRUM*, 2016. Installation view.



Figure 2. Hoover Constellation vacuum cleaner - close up view.

*In 1957 the launch of the satellite Sputnik spawned a wave of space-inspired home design. A kind of cold war developed in domestic appliance design for example, Russia gave us the "Saturnas" vacuum cleaner and Hoover brought us the Constellation™ (pictured above), boasting it floated on air/in space. The Constellation™ pictured is still in use by local Home Scientist Pam McKinlay.<sup>1</sup>*

## SHARED MOMENTS IN SPACE AND TIME: 1. "MONDLANGDUNG"

There was a moment when many of us, of a certain age, collectively learnt something special about space. Simultaneously around the world we tuned out of whatever it was that we were doing and tuned into outer space to receive the first message from a person walking on the moon in real time. It was transmitted right into our schools, our workplaces, our living rooms and kitchens. There was worldwide euphoria following this accomplishment: "It's one small step for man, one giant leap for mankind."<sup>2</sup> Space exploration was viewed as opening an age of space possibility and inspiration for collective mankind "[to] explore the wonders on the other side."<sup>3</sup> For two young children on opposite sides of the world, it was a moment that set in train a lifelong fascination with space. It would be some forty years before our worldlines intersected and we would meet.



Figure 3. Christine Keller (aged 3) sitting on a Moroccan style footstool with her siblings in front of a neighbour's radiogram, her nurse play set at the ready for any unfolding disaster.



Figure 4. The sacred clipping from the suitcase under Pam McKinlay's bed. Front page, The Christchurch Star, "Moon Edition," Monday 21 July, 1969.

## MORE CHILDHOOD MOMENTS IN SPACE AND TIME: 2. PLANETARIUMS

As with many children growing up in urban environments, we lost touch with the Milky Way. Our access to star knowledge was through planetariums. As a child Christine would visit the Hamburg Planetarium, one of the oldest planetariums in the world. On these monthly visits with her grandmother, planetarium leader Dr Uebelacker would begin the session with the sun setting over the Hamburg skyline, accompanied by classical music from the sound system. The audience would come to under a night sky and learn about the Northern stars, the constellations of the Zodiac, Aurora Borealis, the Great Bear and far away remote volcanic eruptions as once observed by Chinese and Roman astronomers in the South Pacific.<sup>4</sup>

Pam's encounter with planetariums was a less grand, but none-the-less exciting, expedition. The star dome at the Otago Museum was a black inflatable tent infrequently installed in a large space at the back of the Museum. It was accessed by a cramped inflatable tunnel through which one crawled in the dark, nose close to the (often odorous) socked feet of the person in front of you. Emerging to sit in a circle, one looked up to where the star map was projected from a primitive gel and lamp arrangement—tiny points of light picked out on the ceiling of a dome-tent like structure, excited children whapping at the billowing fabric of the walls.

### SHARED MOMENTS IN SPACE AND TIME: 3...ANGEL'S BREATH AGAINST A FROSTED SKY

So it was with great excitement that we first encountered the new Dunedin Planetarium where we could view the Dunedin "Sky tonight" in high resolution and luxurious comfort.<sup>5</sup> In "Te Marama Whetu" old stories of Māori and Pacific whakapapa shimmered and blinked as cosmic skylscapes of living wisdom. The stars were put back into the stories so that we could see the heavens through the lens of ancient knowledge. Spoilt for choice, our dilemma was what to choose for the Art and Space project. Old friends of the Zodiac,<sup>6</sup> unfamiliar constellations of familiar stars reconfigured from stories of Pacific navigation, the planetary dance from our local galaxy, perhaps Saturn in gorgeous three quarter view with Cassini slicing through its rings, or maybe spectacular features of the southern sky such as the Jewel Box? We took our cue from the "Amazing Universe" written by Ian Griffin, astronomer and Otago Museum Director. Our attention was drawn to the fuzzy patches of the celestial-scape. When magnified these gaseous clouds of the nebulae revealed not only the most glorious picturesque formations but in them we discovered the loci of star nurseries and our Interstellar project was born.<sup>7</sup>



Figure 5. Pam McKinlay, photo taken at Mt John observatory, July 21 2016. The Coal Sack nebula is prominently silhouetted against the southern Milky Way along the edge of the Southern Cross. Many nebulae are visible to the naked eye and have old histories in ancient star lore. Orion's nebulae which is one of the most studied opaque area in the Milky Way has been described as: "... angel's breath against a frosted sky."<sup>8</sup>

## EMPTY SPACE — ETERNAL CHAOS — THE LIFE AND DEATH OF STARS

The space beyond our atmosphere looks empty, and so it is by earthly standards. Observations of aurorae by Samuel L. Thorndike in 1930 concluded that space is not empty. He reasoned that for such ionization to be occurring there must be something to become ionized.

Terrestrial aurorae are not improbably excited by charged particles emitted by the Sun. If the millions of other stars are also ejecting ions, as is undoubtedly true, no absolute vacuum can exist within the galaxy<sup>9</sup>

A cubic centimetre of air on earth contains roughly 25 million million million molecules, the same volume in Space might hold but a single atom which by earthly standards is a vacuum.<sup>10</sup> By comparison nebulae might contain hundreds, or hundreds of thousands, of molecules per cubic cm which, by space standards, is packed and where the action starts. Here, in these relatively dense clouds of gas and dust, stars and other interstellar structures are formed. According to current cosmogenesis theory, eventually these areas will be lit up as new stars form from the thick interstellar clouds of gas and dust.<sup>11</sup> The products of many star deaths are also known as nebulae, in this case great clouds of gas and dust debris are ejected from an exploding star event or super novae. Nebulae are dense but they are still fragile. An intergalactic game of laser tag and space invaders is played in outer space, with fledgling molecules dodging intense ultraviolet and gamma rays, violent bursts from local supernovae and solar and interstellar winds. It's Chaos out there in the space between the stars—the InterStellar Medium (ISM). The ISM is composed mostly of hydrogen gas, the most abundant chemical substance in the universe (99%), and contains ~1% “dust,” matter from exploding stars. It is the dust which causes the cloudy appearance in the night sky, as it blocks the light of stars behind them. Hydrogen exists in two main forms, atomic (neutral) and molecular (and various isotopes of both). As a general galactic rule atomic hydrogen distribution dominates the outer part of our Milky Way spiral arms, and molecular hydrogen the inner part of our galaxy — the molecular regions are star forming areas.<sup>12</sup>

### RECIPE FOR A STAR

#### *Ingredients:*

one ripe old star at close to expiry date.

#### *Method:*

Take star and explode violently.

Gather in far-flung cosmic dust, add to molecular clouds in near vacuum.

Conserve gas reservoir and cool to 10 Kelvin to prevent dissipation.

Observe in the 21cm radio frequency to detect ISM.

Separate neutral hydrogen and put aside in Balmer series chamber.

Shield pooling plasma from differential interference and random colliding radiation.

Rotate with gravity for millennia to desired luminosity.

*Optional: add exo-planets to taste.*

Extract from Pamphlet no.2. “Interstellar”, *Recipe for a Star*, by Pam McKinlay, printed on munched paper. The poem was inspired by the work of New Zealand astronomer and cosmologist Beatrice Tinsley.<sup>12</sup>

## CELESTIAL SIGNATURES: READING THE LINES AND RADIO LIVES — SAMPLING, SURVEYING AND THE RISE OF NEW PATTERNS

How do we know that it is hydrogen gas in the nebulae clouds and what does that mean exactly? In 1814 Joseph von Fraunhofer discovered that, when viewed through a spectrograph, the spectrum of a hot gas was broken by dark lines. Each gas was found to have a unique pattern of these spectral lines. Systemic studies in the nineteenth century of stars and nebulae and other celestial objects, such as comets, revealed that the spectra of stars are very different from the spectra of nebulae. Modern spectral examination of gaseous nebulae, in both the emitted and absorption spectrums, confirm that the major constituent of the universe is hydrogen in one form or another.<sup>14</sup>



Figure 6. Richard Wimmer, *Joseph von Fraunhofer Demonstrating The Spectroscope*, c.1900.<sup>15</sup>

Both neutral atomic and molecular hydrogen emit in the radio region of the electromagnetic spectrum so hydrogen can also be detected by radio astronomy. Radio telescopes peer into the dark reaches of space beyond the reach of conventional optical telescopes and see what can't otherwise be "seen" in deep space. Thus radio waves offer a kind of "radio eye" into the vast clouds of the ISM and look into the heart of regions where stars are forming. Radio astronomers sift through vast fields of radio frequency data from distant cold space and map the universe in what is known as the 21cm hydrogen band.

In 1944 Hendrik van de Hulst predicted that the cold atomic hydrogen (H1) gas should emit a particular wavelength of radio energy from a slight energy change in the hydrogen atoms at a wavelength is 21.1 centimeters (where frequency = 1420.4 MHz). As a consequence, this radiation is called 21-cm line radiation.<sup>16</sup>

As most of the Universe is made of hydrogen, the spectrum of hydrogen is particularly important in astronomy for interstellar astro-cartography. Emission and absorption spectra can describe the makeup of faraway stars and other celestial bodies. H1 is detectable in most external spiral galaxies and so the 1420 H1 line can trace the large-scale distribution of hydrogen in external galaxies.<sup>17</sup> Thus the 21-cm line radiation has become the best way to map the structure of the universe, across space and time. Mapping the background cosmic radiation (from the “Big Bang”) we also get a long view across space and back in time, to the very “beginning”.

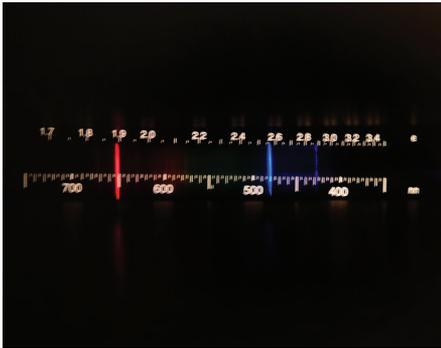


Figure 7. Spectrogram of the Hydrogen gas lamp as photographed during the floor talk.



Figure 8. Participants at the Art and Space floor talks view the light of a hydrogen gas lamp through a spectrograph.



Figure 9. Visible spectrum of Hydrogen, Jan Homann, 2009. The visible hydrogen emission spectrum lines in the Balmer series. H-alpha is the red line at the right. The two leftmost lines are considered to be ultraviolet as they have wavelengths less than 400 nm.<sup>18</sup>



Figure 10. Pam McKinlay, *The Big Picture*, 2016. (Image credit: Composite photograph of nebulae and simulated gravitational waves, Pam McKinlay, 2016 and visible spectrum of hydrogen, Jan Homann, 2009. 1200x800mm.) Installation view in the shadow of the interstellar talismans.

SKY WOMAN: SEARCHING FOR A NEW SPACIOGRAPHIC ICONOGRAPHY  
— A TALISMAN FOR A QUOTIDIAN MOMENT.

“Hence man contains within himself the likeness of heaven and earth”  
Hildegard of Bingen<sup>19</sup>

“We are made of space dust”.

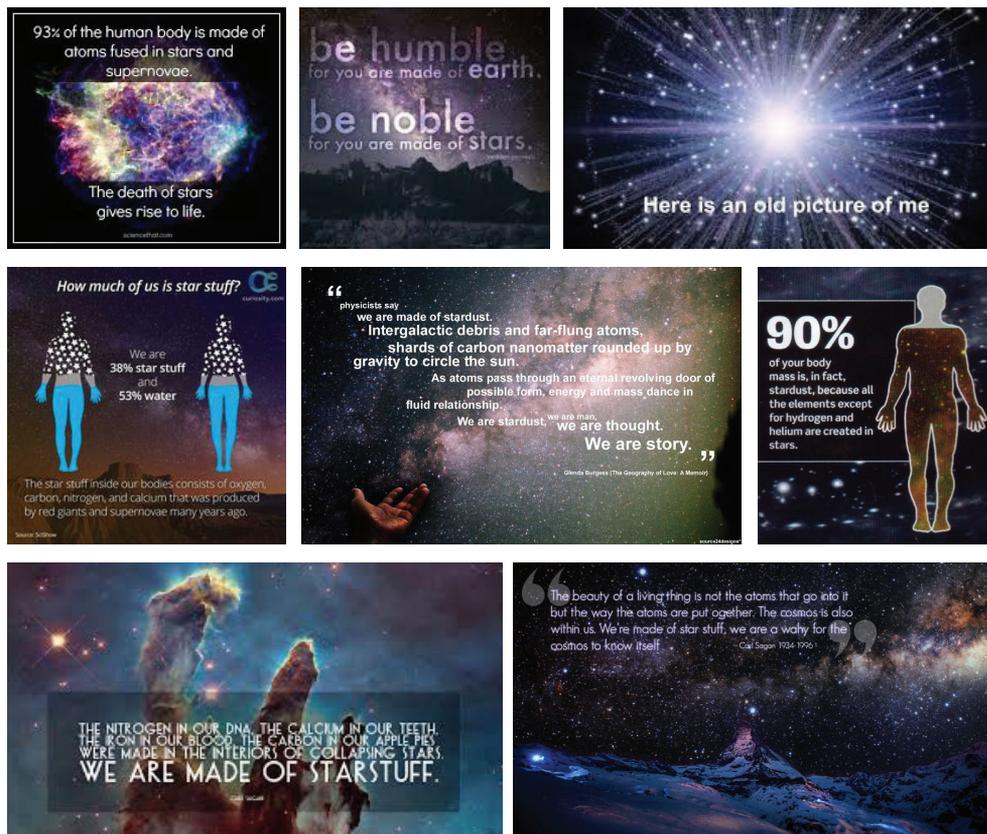


Figure 11. Random sample of “we are made of space dust” memes from “we are made of star dust” google image search

Cosmic memes,<sup>20</sup> compete with cat gifs,<sup>21</sup> on Facebook to tell us this, so it must be true! I whizz around the house vacuuming and consider the nature of the terrestrial dust. Intellectually I know it must once have been cosmic baryonic matter also. Without stars there would be no us—no life. Life on our planet is sustained by our star — the Sun, Sol, Sonne, call it what you will — it supplies us with heat to keep our water liquid and provides light energy for photosynthesis (our food and oxygen). Once upon a time all the earthly elements were also forged somewhere out there in space, and we are a part of it. Space is a living entity. Thousands of years ago our relationship with the macrocosm and microcosm was an intimate personal experience and the stars were our guide. Today we search for a daily reminder, which acknowledges the abstract enormity of space and the humbleness of our personal existence. Our new talisman should tell a story — present the data, but

do so with a humble soul, it should be representative of the macrocosm, and localize and personalize in the microcosm. In this search for a new spaciographic iconography we are interrupted by the pragmatics of conquering chaos and regaining order in our domestic domain—there is dust to chase, dishes to be done, and we must step back into the mundane.



Figures 12. Christine Keller and Pam McKinlay, *INTERSTELLAR—21 cm —H-SPECTRUM*, 2016. Installation view.

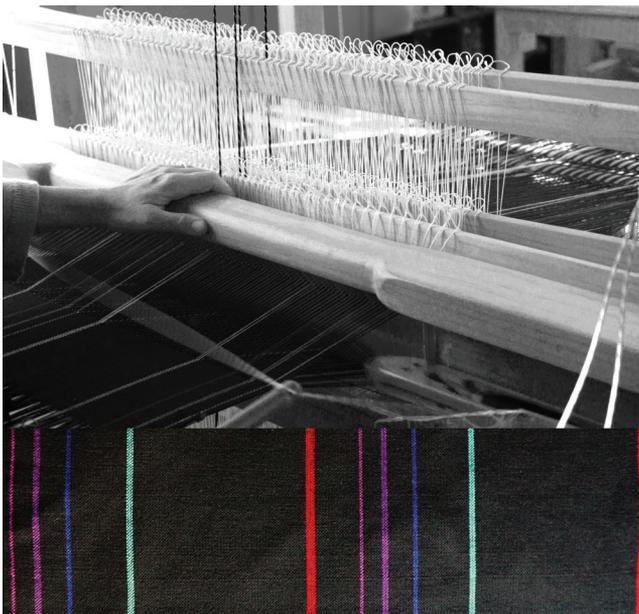


Figure 13. Composite photograph: Weaving in progress and detail of the 21 c — H- SPECTRUM. The textiles were handwoven by Master Weaver Christine Keller on a self-built flying-8 loom (fly shuttle counter-march loom) with 8 harnesses, designed by Hamburg weaver Andreas Moeller) as a 25 meter fabric in the LOOM ROOM weaving studio in Dunedin.

German-born New Zealand based artist **Christine Keller** holds an MFA from Concordia University (2004) and a Masters equivalent from Gesamthochschule Uni Kassel, Germany. In late 2012 she founded the Dunedin-based Weaving Studio, Weaving on Hillingdon and in 2015 opened Dunedin's LOOM ROOM where she teaches weaving.

Home Scientist and weaver **Pam McKinlay** works at the Dunedin School of Art. She has a Dip HSC (Clothing/Fashion Design and Textile Science) and a BA in Art History from the University of Otago. She prominently drives a Nissan Leaf EV on Dunedin's roads

**Ian Griffin** is a British astronomer, discoverer of minor planets and a public spokesman upon scientific matters. He is currently the Director of the Otago Museum, Dunedin, New Zealand.

**David A.W. Hutchinson** is the Director of the Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics at the University of Otago, Dunedin, New Zealand.

1. Oliver Wainwright, "How Russia fought the cold war with space-age washing machines," *The Guardian*, 19 June, 2014, On October 4, 1957, the Soviet Union launched a small object, about the size of a beachball, into orbit around earth. This was the first artificial earth satellite to be launched into space. In 1959 Khrushchev and then US vice-president Richard Nixon had an impromptu war of words memorialized as the "kitchen debate," at the American National Exhibition in Moscow. See 1960s space-age Hoover television commercial for its float on air claims. <https://www.youtube.com/watch?v=HxqUoB2Ggo8>
2. Neil Armstrong, transcript Apollo 11 moon landing 1969. NASA, "July 20, 1969: One Giant Leap for Mankind," Apollo 11, Moonwalk Montage, July 15, 2014, [https://www.nasa.gov/mission\\_pages/apollo/apollo11.html](https://www.nasa.gov/mission_pages/apollo/apollo11.html)
3. Quote by John F Kennedy the day before he was assassinated. Quote in speech notes by Michael D. Griffin, Administrator, National Aeronautics and Space Administration, World Economic Forum, Jan. 26, 2007, Speech Transcript "Incorporating Space into our Economic Sphere of Influence", NASA. [http://www.nasa.gov/home/hqnews/2007/jan/HQ\\_mg\\_speech\\_econ\\_forum.html](http://www.nasa.gov/home/hqnews/2007/jan/HQ_mg_speech_econ_forum.html)
4. Contrary to popular belief the constellations are not named because they look like a bear or crab etc but because of the calendar events their appearance signified e.g. bears coming out of hibernation in Northern Europe, Aquarius associated with destructive floods.
5. Otago Museum, "Perpetual Guardian Planetarium," 360° immersive theatre with various shows: The Sky Tonight, The Amazing Universe, Te Marama Whetu, Spacetronauts, Invaders of Mars, <http://otagomuseum.nz/whats-on/do/planetarium/> (accessed 17 Sep 2016)
6. Animistic principles dominated a belief in the relationship between man and the cosmos and formed the basis of astrology, still with us in the daily horoscopes and signs of the Zodiac.
7. Marc Lachièze-Rey and Jean-Pierre Luminet, *Celestial Treasury: From the Music of the Spheres to the Conquest of Space* (Cambridge University Press, 1992) 152-53. In 1796, Pierre-Simon Laplace and William Herschel, turning their telescopes to view nebulae, concluded that they must be areas containing primitive matter which condense into stars. Many nebulae were proven to be clouds of gas. Some had bright points which proved a star was in the process of formation, which is the basis of the nebular theory of cosmogenesis.
8. Stephen James O'Meara, *Deep-Sky Companions: The Messier Objects* (Cambridge University Press, 1998) 170, when describing features in Orion nebulae.
9. Ivan G. Shnitko, "Absorption spectroscopy of carbon and sulphur chains in 6 K neon matrices," Thesis, Basel, 19.02.2008, [http://edoc.unibas.ch/705/1/DissB\\_8187.pdf](http://edoc.unibas.ch/705/1/DissB_8187.pdf) (accessed 17 Sep 2016).
10. "Exploring the Density of Gas in the Atmosphere," NASA, <http://spacemath.gsfc.nasa.gov>. At sea level, there are approximately  $2.5 \times 10^{25}$  air molecules in a cubic meter of air, i.e. 25 trillion (long scale).
11. Ken Croswell, *Magnificent Universe* (New York: Simon & Schuster, 1999) 54.
12. *Ibid.*, 57.
13. Beatrice Tinsley was a British-born New Zealand astronomer and cosmologist. Her work on red shifted spectra of stars in our solar system (Evolution of Galaxies and its Significance for Cosmology) shifted our understanding of the evolution of light elements and galaxies in the universe and was of great importance in understanding the notion of the "expanding universe," as proven by Hubble, and which was the basis of the prevailing model for the creation of the universe—the Big Bang theory.
14. Department of Physics and Astronomy, Michigan State University, "Emission Spectra." If you shine white light through a prism it spreads the light out into a rainbow,

- because different wavelengths of light have slightly different indexes of refraction, called dispersion. If you heat up a gaseous element, such as hydrogen, until it glows, and send that light through a prism, you see discrete lines at specific wavelengths. This is called an emission spectrum, because the light is emitted from the element. Alternatively, if you shine white light through a gaseous element and then let the light pass through a prism you see dark lines in the continuous spectrum. This is called an absorption spectrum. When an electron jumps from a low energy level to a higher level, the electron will absorb a photon of a particular wavelength. This will show up as a drop in the number of photons of this wavelength and as a black band in this part of the spectrum. Since the electrons only absorb light of certain frequencies, the absorption spectrum will show up as a series of black bands on an otherwise continuous spectrum. <http://www.pa.msu.edu/courses/2014spring/PHY252/Lab10.pdf> (accessed 17 September, 2016).
15. Joseph von Fraunhofer (1787- 1826) demonstrating his 1814 invention, the spectroscope, a device used to examine properties of light, to Joseph von Utzschneider, Georg von Reichenbach and Georg Merz in Munich the same year. Photogravure from a painting by Richard Wimmer, 1900. [https://en.wikipedia.org/wiki/Joseph\\_von\\_Fraunhofer#/media/File:Fraunhofer\\_spectroscope.JPG](https://en.wikipedia.org/wiki/Joseph_von_Fraunhofer#/media/File:Fraunhofer_spectroscope.JPG)
  16. "The 21-cm Line: The Hydrogen 21-cm Emission Line", *MIT Haystack Observatory*, <http://www.haystack.mit.edu/edu/pcr/Data/pdf/Hydrogen%2021-cm%20Emission%20line-final.pdf> (accessed 17 Sep 2016).
  17. It may be prudent to note that in the final works we wove the spectrum two up. Scientifically it makes no sense at all but aesthetically it looked better and of course  $2 \times 21 = 42$ . (Who could resist?)
  18. Drew Cylinder, "Atomic Spectra" Chemistry Libre Texts. org, 20 July 2015. [http://chem.libretexts.org/Core/Physical\\_and\\_Theoretical\\_Chemistry/Quantum\\_Mechanics/09\\_The\\_Hydrogen\\_Atom/Atomic\\_Theory/Electrons\\_in\\_Atoms/Atomic\\_Spectra](http://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Quantum_Mechanics/09_The_Hydrogen_Atom/Atomic_Theory/Electrons_in_Atoms/Atomic_Spectra) (accessed 8 November 2016)
  19. Hildegard of Bingen, *Scivias*, Book Two, Vision One: Translation by Mother Columba Hart and Jane Bishop, (New York, Mahwah: Paulist Press, 1990) 151.
  20. Meme— an image and text, etc., typically humorous in nature, copied and spread rapidly by Internet users, often with slight variations.
  21. " GIF image" - a lossless format for image files that supports both animated and static images.