Paradigmas em ciência

Revoluções Científicas

- Thomas Kuhn (1922–1996) apresenta em seu livro *"A estrutura das revoluções científicas"* (1962) a noção de mudança de paradigma
  - ***uma mudança fundamental nos conceitos básicos e práticas experimentais de uma disciplina científica***
- Uma revolução científica ocorre quando os cientistas encontram anomalias que não podem ser explicadas pelo paradigma universalmente aceito dentro do qual o progresso científico tem sido feito.

Revoluções Científicas

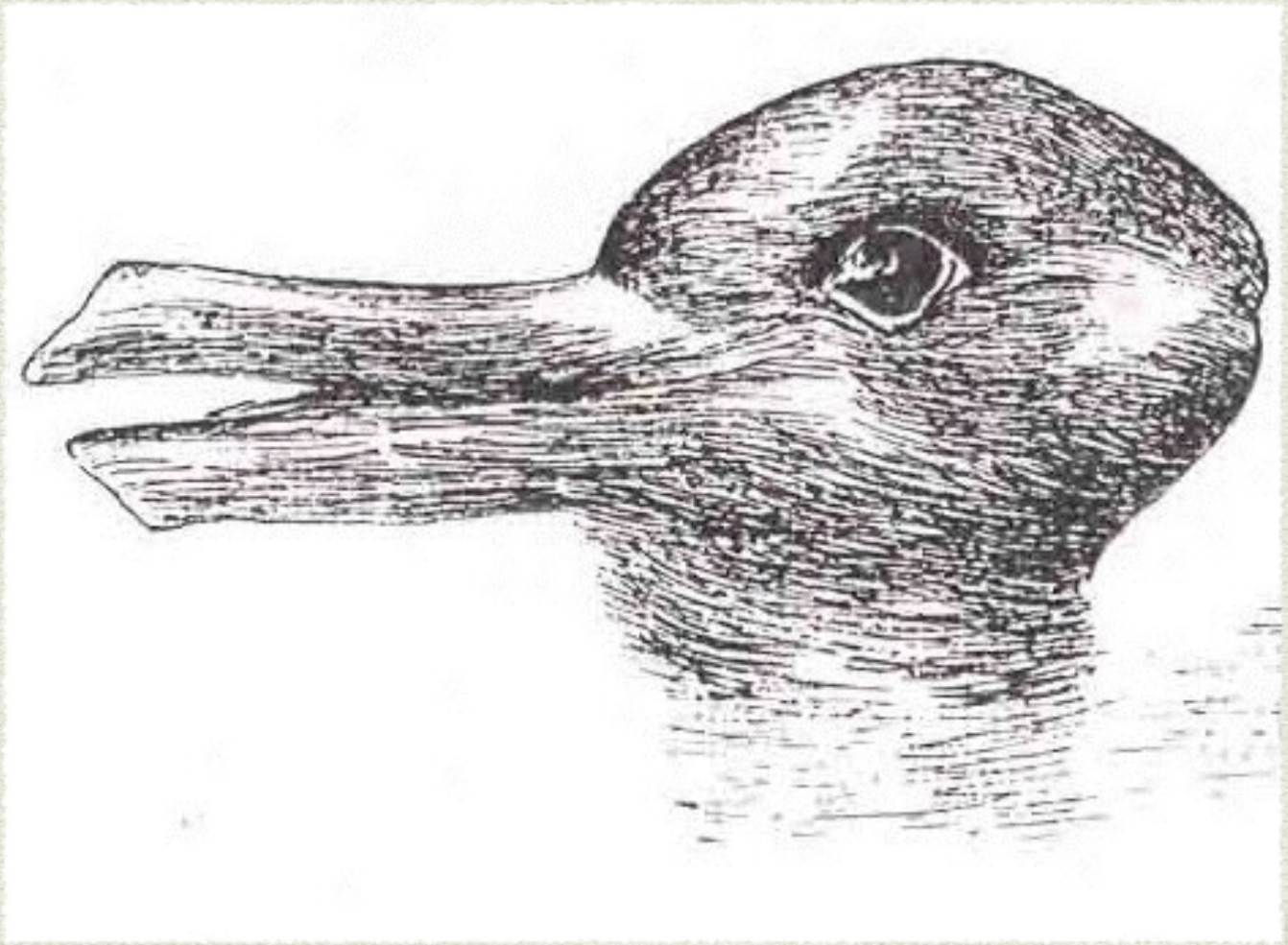
- Há anomalias em todos os paradigmas que são interpretados como níveis aceitáveis de erro, ou simplesmente ignorados e não tratados.

- Quando um número suficiente de anomalias significativas se acumula contra um paradigma atual, a disciplina científica é lançada em um estado de crise. Durante a crise, novas idéias, talvez anteriormente descartadas, são experimentadas.

- Eventualmente um novo paradigma é formado, que ganha seus próprios novos seguidores, e uma "batalha" intelectual ocorre entre os seguidores do novo e do velho paradigma.

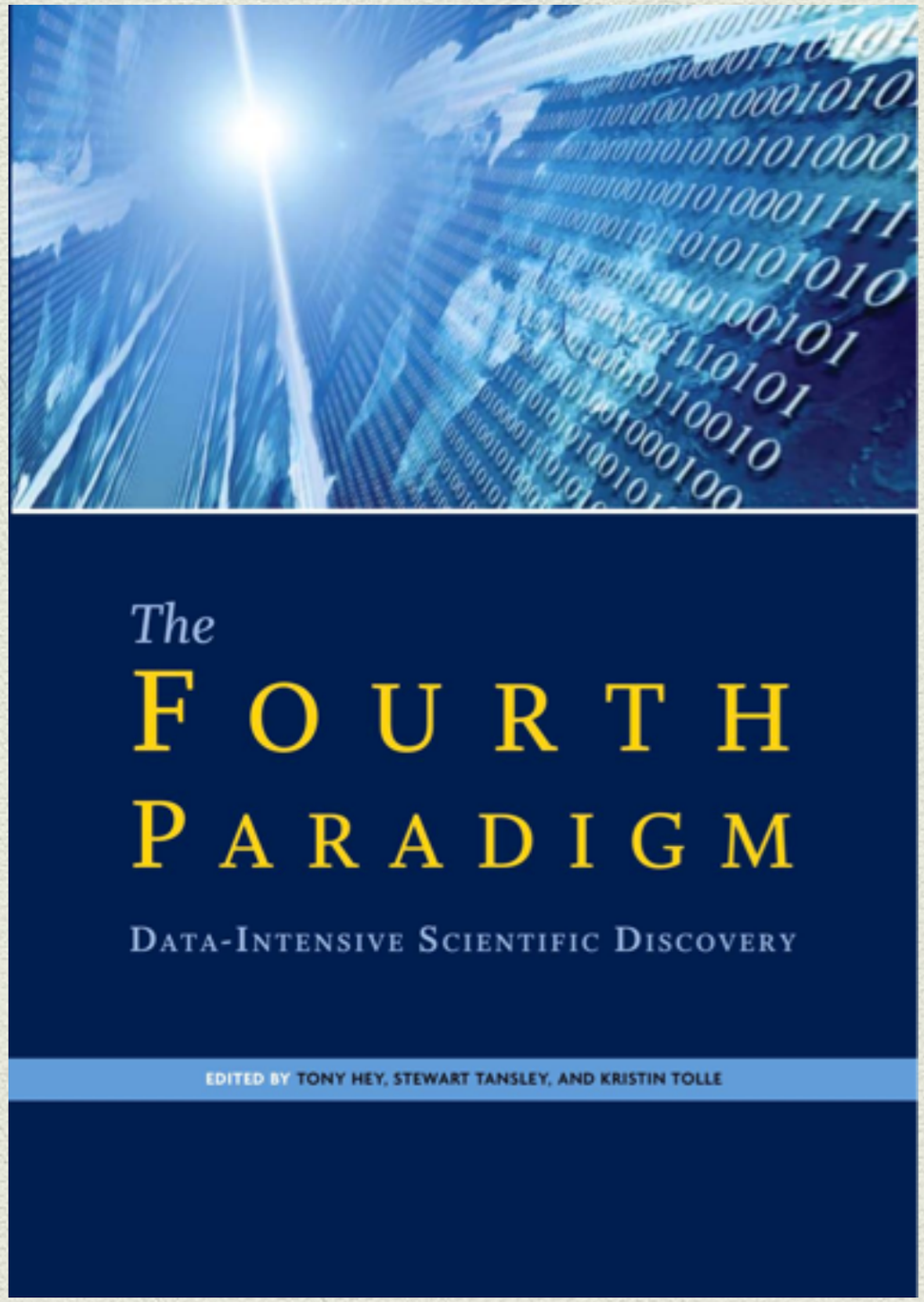
Revoluções Científicas

- Kuhn usou a ilusão óptica tornada famosa por Wittgenstein, para demonstrar a maneira pela qual uma mudança de paradigma poderia fazer com que se visse a mesma informação de uma maneira diferente.



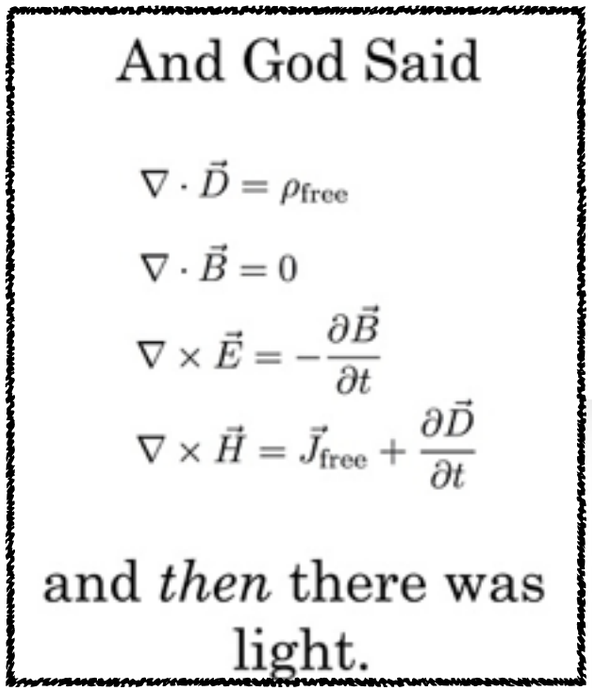
Data-Intensive Scientific Discovery

- Na última década tem sido proposto que estamos vivenciando um quarto paradigma de como a pesquisa científica é feita em geral, independente da disciplina

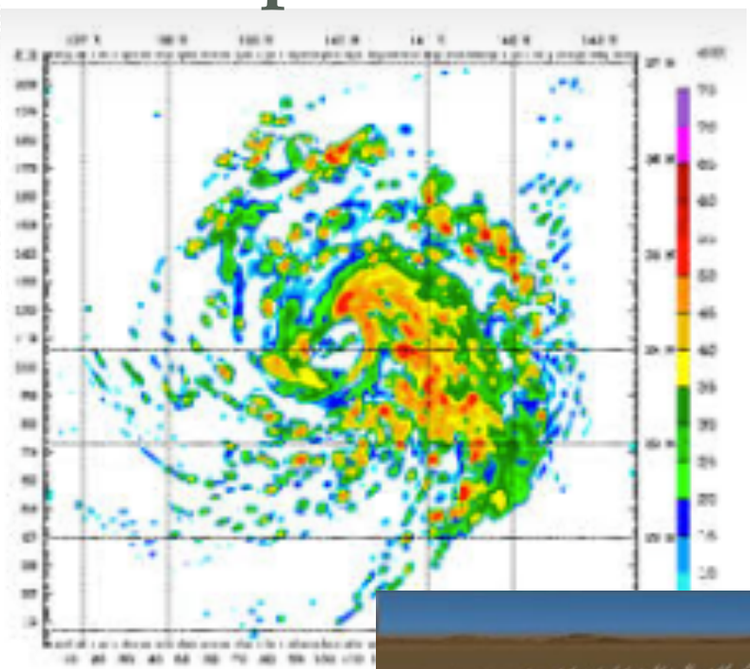


Ciência Empírica

Ciência Teórica



Ciência Computacional



eScience

Evolução dos paradigmas científicos, tal como proposto por Jim Gray, 2007

Ciência Empírica

Nicolas Camille Flammarion, Paris, 1888

Milhares de anos atrás:

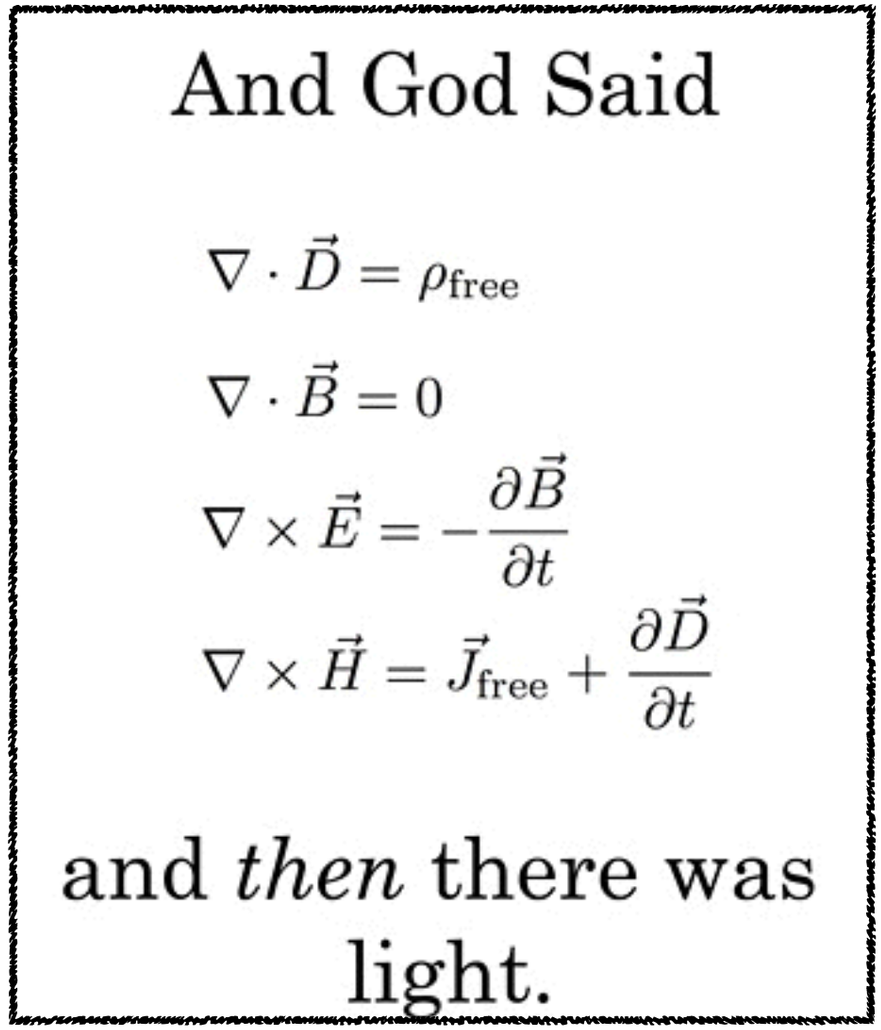
a pesquisa científica era puramente empírica, baseada em observar e descrever os fenômenos naturais

Ciência Teórica

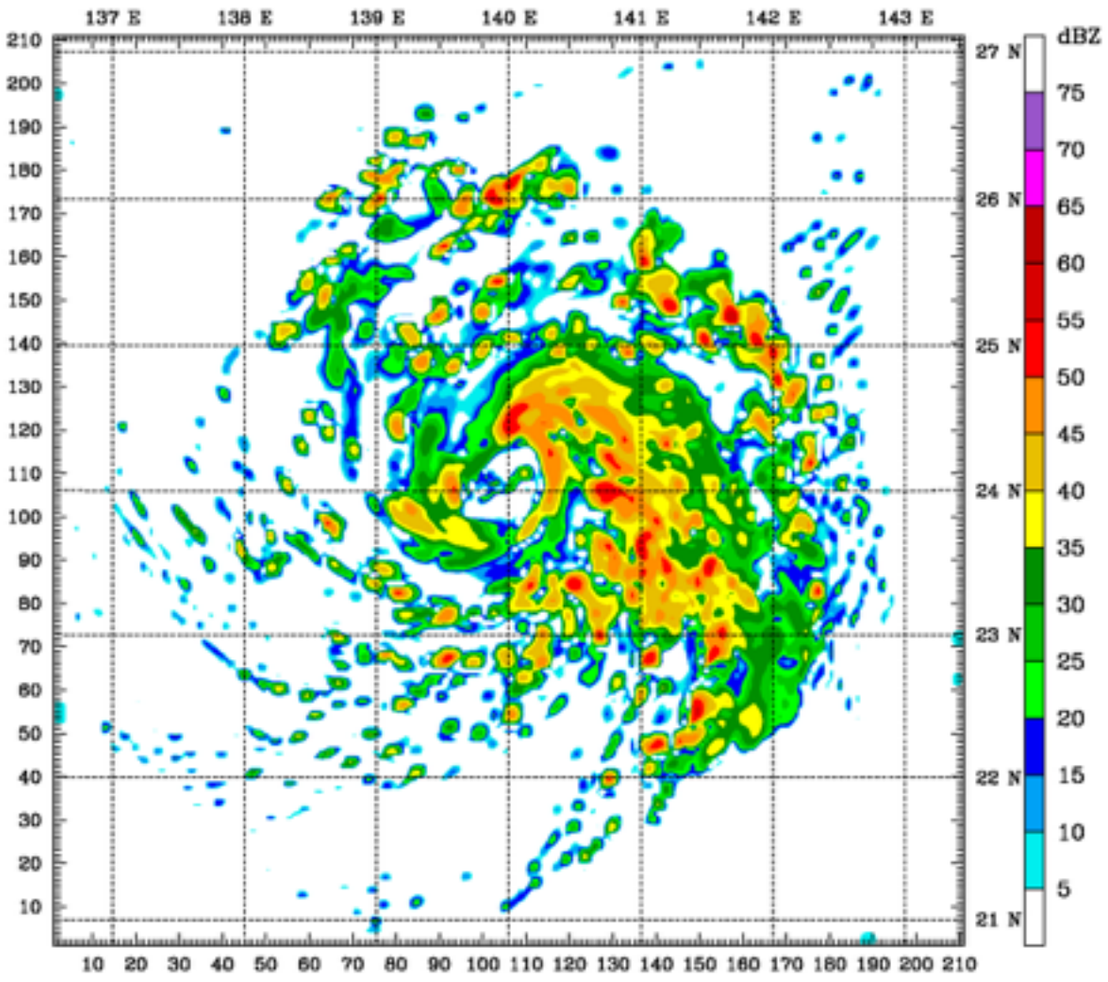
Últimas centenas de anos:

ciência torna-se teórica, com Leis de Kepler, Leis de Movimento de Newton, Equações de Maxwell…

Usam-se modelos e generalizações.



Ciência Computacional



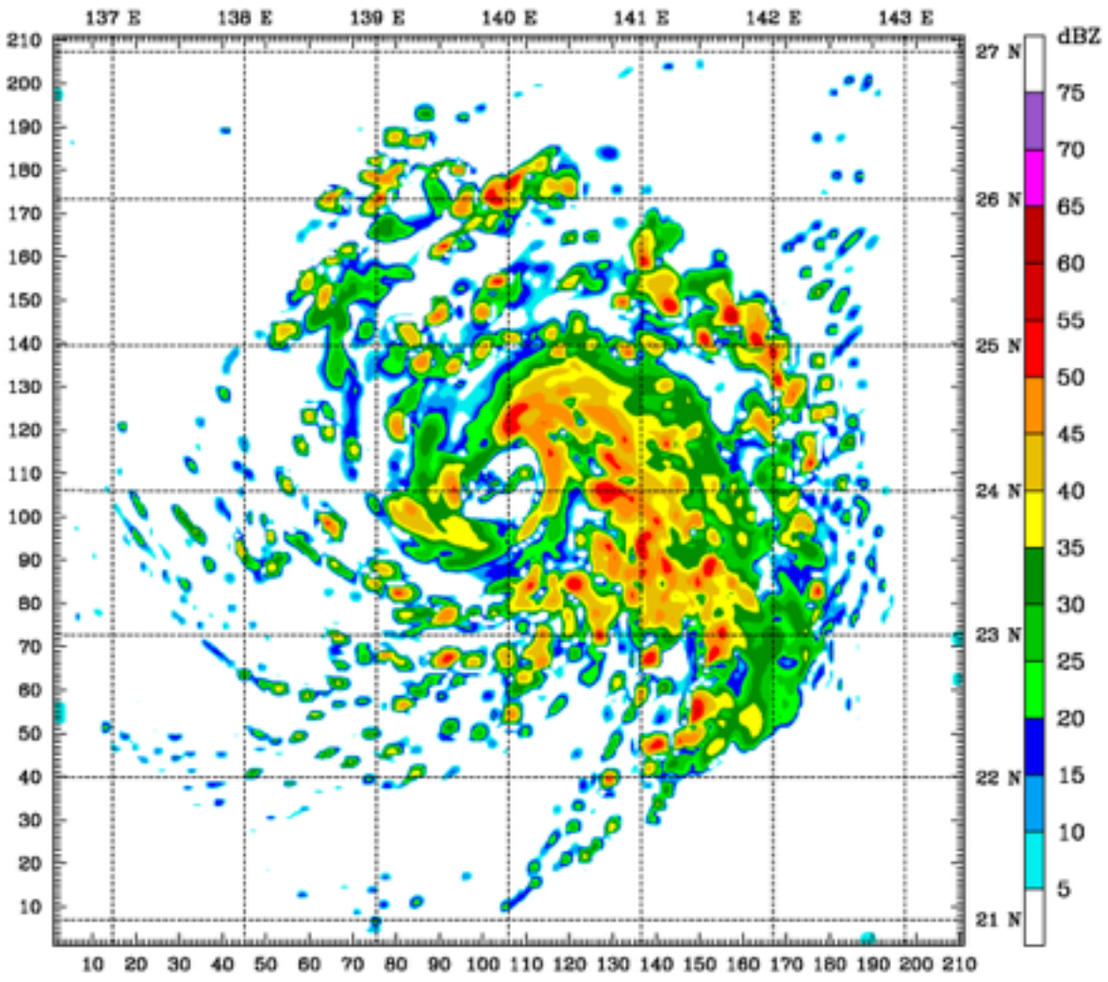
A 48-hour computer simulation of Typhoon Mawar using the Weather Research and Forecasting model

By Atmoz (talk) - Typhoon_Mawar_2005_computer_simulation.gif, CC BY-SA 3.0

Últimas décadas:

modelos teóricos se tornam muito complicados para serem resolvidos analiticamente, e os cientistas começaram a simular. Essas simulações determinaram o desenvolvimento científico recente.

Ciência Computacional



A 48-hour computer simulation of Typhoon Mawar using the Weather Research and Forecasting model

By Atmoz (talk) - Typhoon_Mawar_2005_computer_simulation.gif, CC BY-SA 3.0

Últimas décadas:

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eScience

https://skatelescope.org/

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https://skatelescope.org/

COMPUTERWORLD FROM IDG NEWS TECHNOLOGY TOOLS WHITEPAPERS

SKA telescope to generate more data than entire Internet in 2020

An exaflop-capable supercomputer, storage of at least 1.5 petabytes and data centres around the world will be required say scientists

Hamish Barwick (Computerworld)
07 July, 2011 12:05

"This is a software and IT telescope in many senses because of the data challenges due to the amount it will generate, the amount of information that it passes and is going to process," Quinn said.

"This telescope will generate the same amount of data in a day as the entire planet does in a year. We estimate that there will be more data flowing inside the telescope network than the entire internet in 2020."

eScience

Hoje:

Exploração de dados, dados são capturados por instrumentos ou gerados por um simulador, processado por software, informação é armazenada em computadores, cientistas analisam bancos de dados usando gerenciamento de dados e estatística

"The world of science has changed, and there is no question about this. The new model is for the data to be captured by instruments or generated by simulations before being processed by software and for the resulting information or knowledge to be stored in computers. Scientists only get to look at their data fairly late in this pipeline. The techniques and technologies for such data-intensive science are so different that it is worth distinguishing data-intensive science from computational science as a new, *fourth paradigm* for scientific exploration."

TEDxCaltech - S. George Djorgovski - Evolving Science and Technology in Cyberspace

https://youtu.be/FB33pV2L0Vo

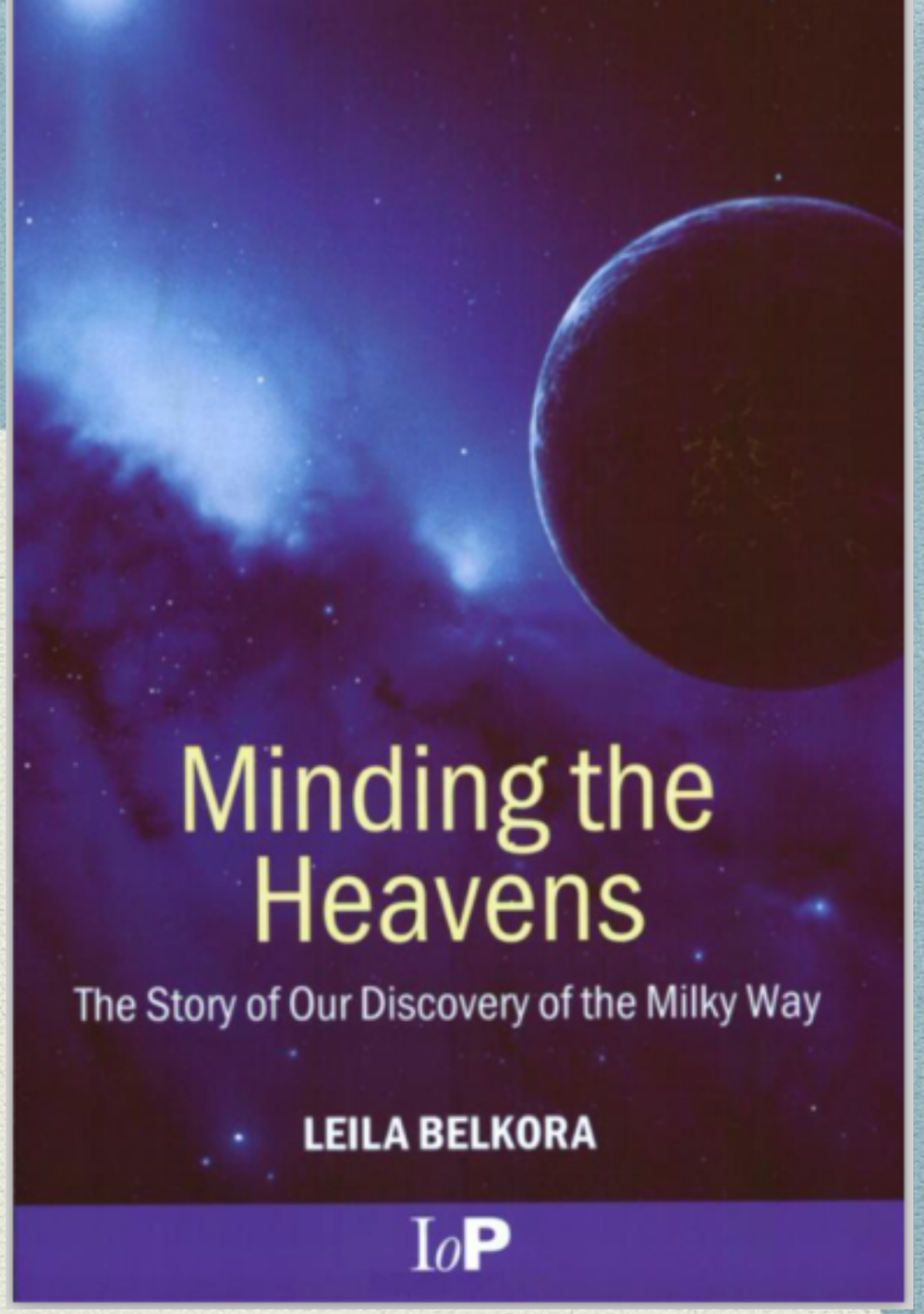
Nossa Galáxia: Perspectiva Histórica

Como a imagem que temos da Via Láctea evoluiu ao longo do tempo

Referências

- "MINDING THE HEAVENS: THE STORY OF OUR DISCOVERY OF THE MILKY WAY", Leila Belkora, 2003, Institute of Physics Publishing

- http://atropos.as.arizona.edu/aiz/teaching/a204/shapley_curtis.html



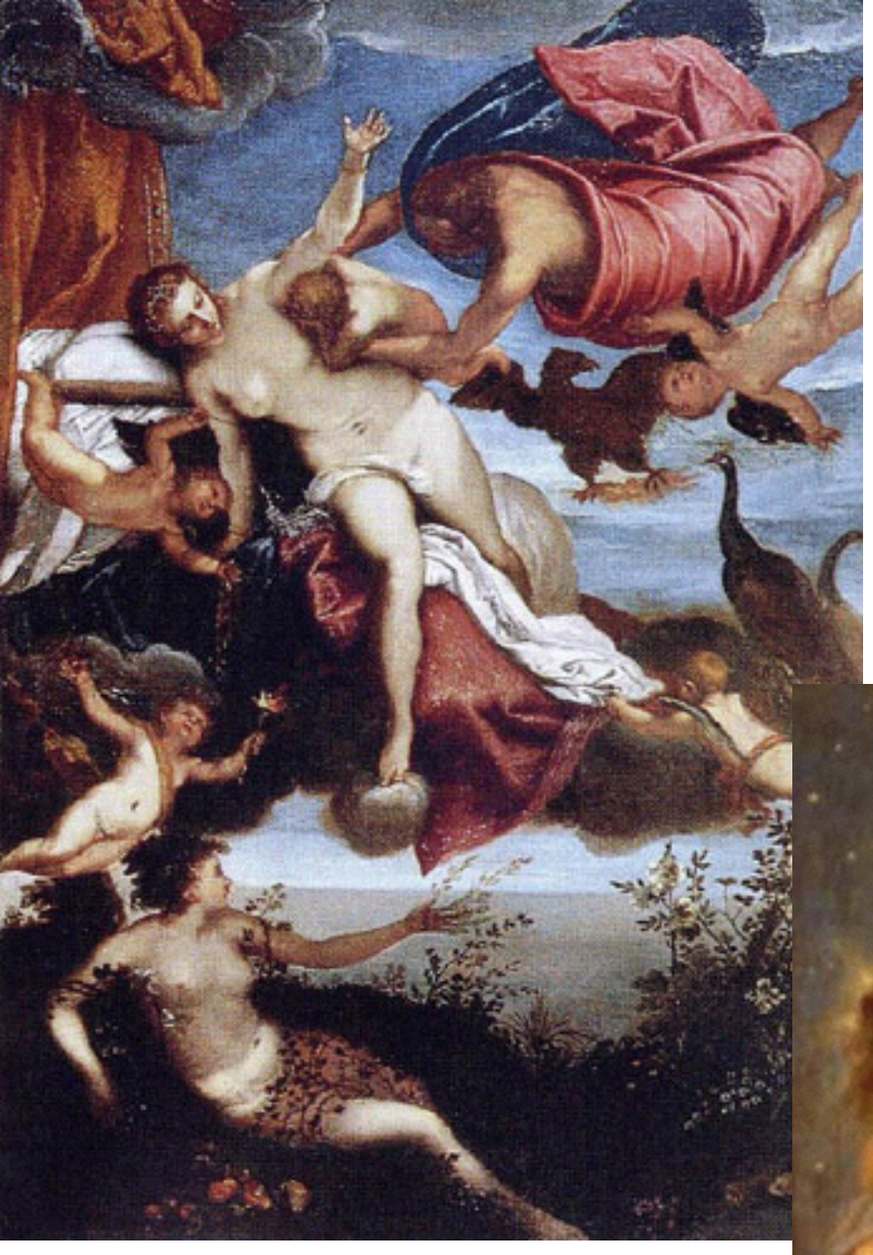
nossa Galáxia a olho nu


You are here.

M31, conhecida pelo menos desde o séc. (astrônomo Persa Al-Sufi)

You are here.

não exatamente :)



TINTORETTO
The Origin of the Milky Way. 1575
National Gallery, London

RUBENS (1577-1640)
The Origin of the Milky Way.
El Prado Museum,Madrid

Desde o mito até o sec. XX

- 1609: Galileu vê que a nebulosidade são estrelas não resolvidas
- Mas é só no séc. XX que temos tecnologia pra começar a mapear a distribuição de estrelas

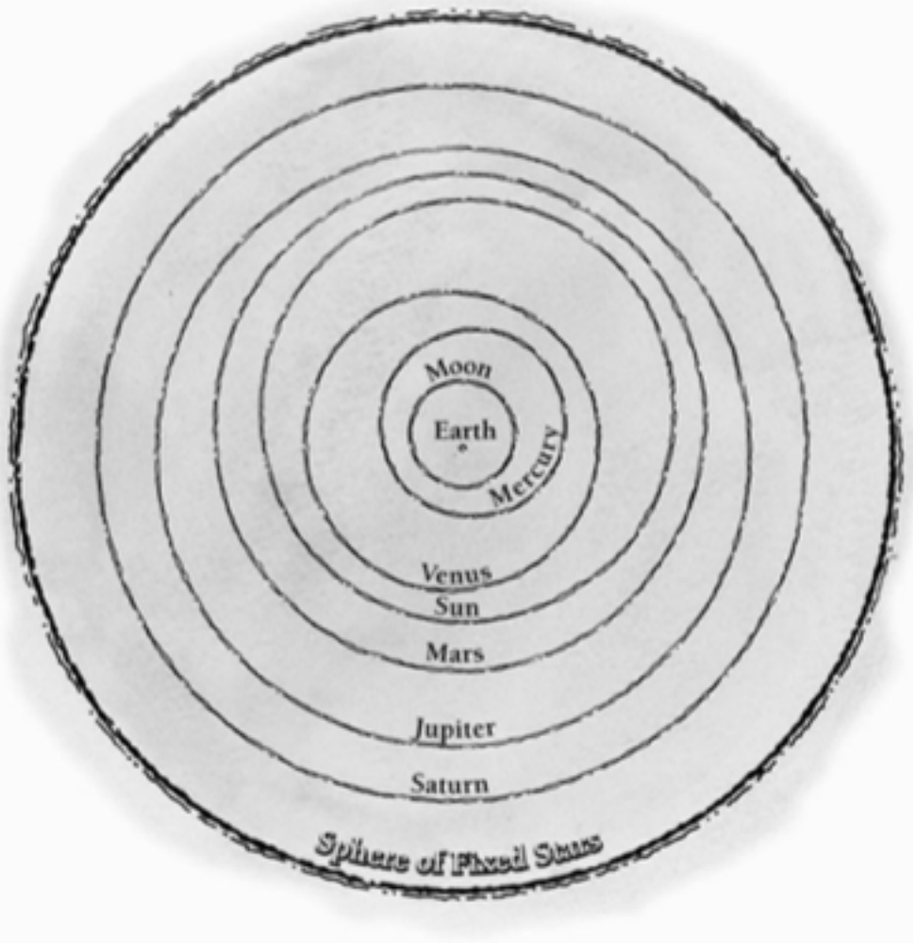


Figure 1.3 An Earth-centered system with the order of the planets as given by Ptolemy. The system ends with the sphere of fixed stars. (Credit: Layne Lundström.)

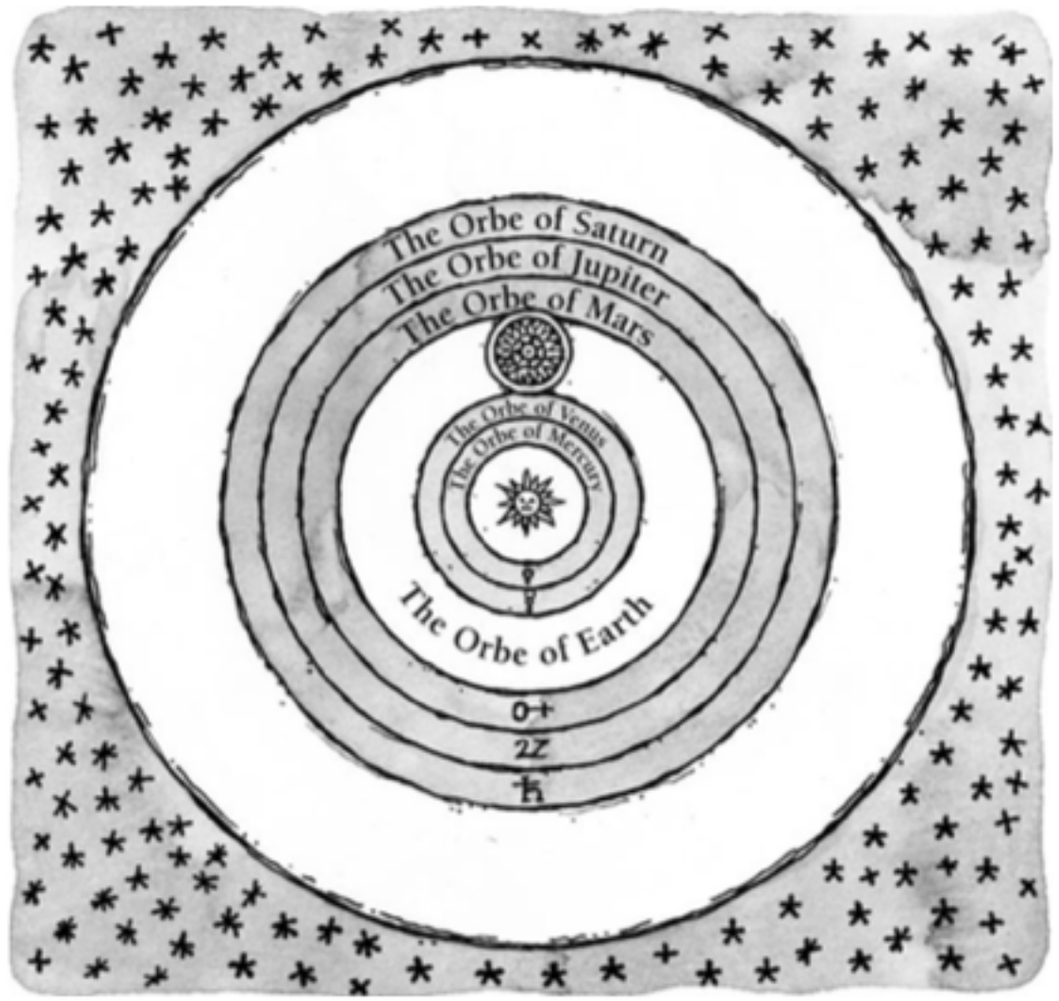


Figure 1.4 System imagined by Thomas Digges (c. 1546–95) and drawn to accompany his *Perfit Description of the Celestiall Orbes*. The label for his outermost sphere says that "the orbe of starres fixed infinitely up extendeth hit self in altitude spherically." This space is also the court of celestial angels and a site of endless joy. (Adapted by Layne Lundström.)

Antes do Conceito de Galáxia

Figuras de L. Belkora, 2003

Filosofando sobre a Via Láctea

- Giordano Bruno (1548 - 1600)
- Thomas Wright, 1750
- Immanuel Kant, 1755
- Figura em L. Belkora, 2003

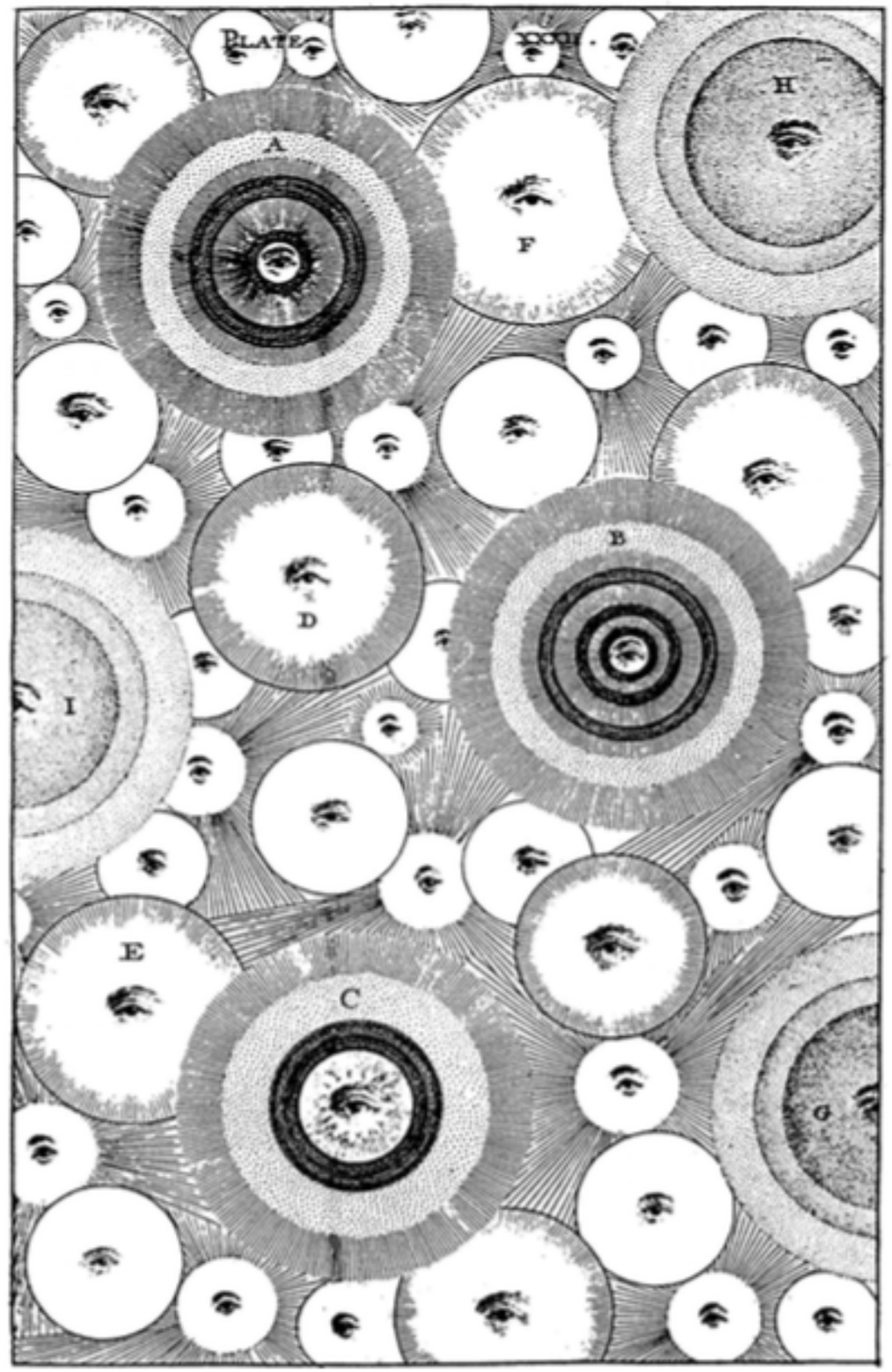


Figure 1.5 Wright's "Plenum of Creations." Wright attempted to show, in cross-section view, a number of "creations" filling the immensity of space. The eye symbols at the centers of the spheres represent the "divine Presence." In some cases, the stars are grouped in nested spheres or shells around their respective centers. (Adapted, with permission, from Hoskin (1971).)

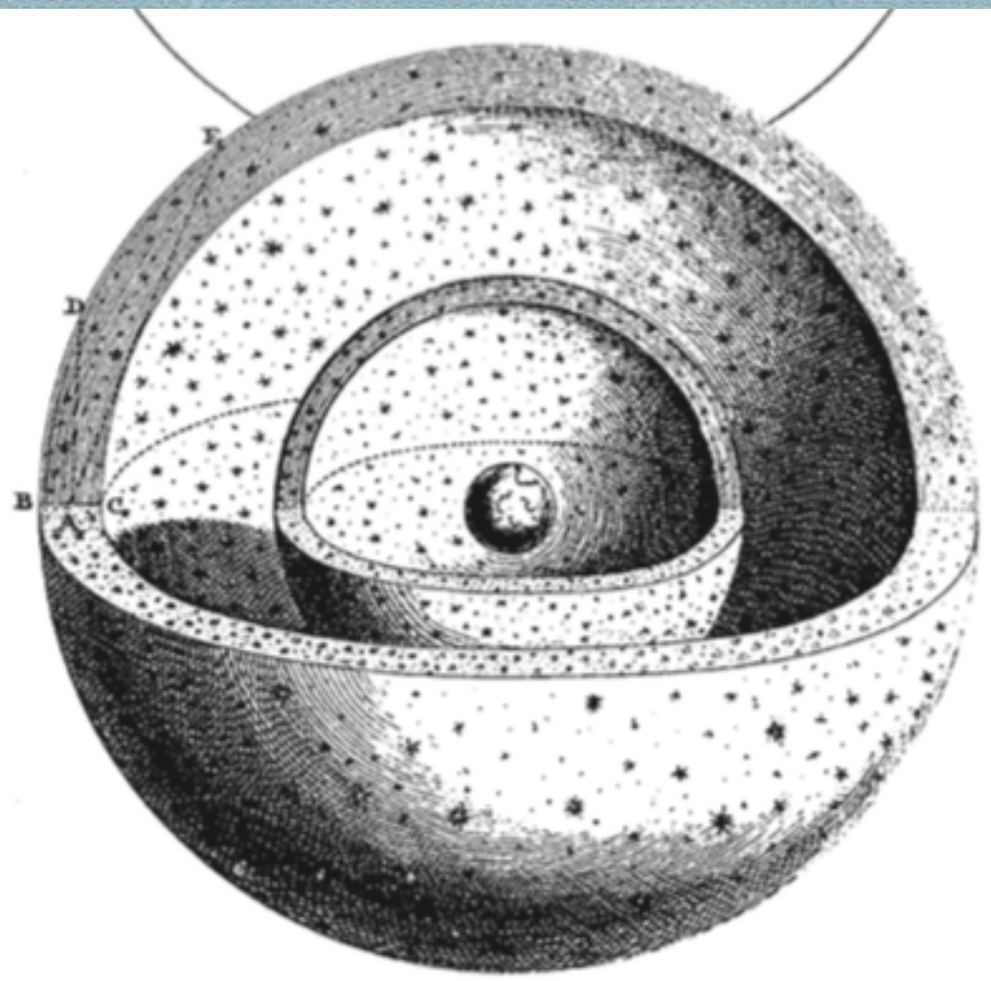


Figure 3.6 Two views of spherical "creation." (Reproduced with permission from Hoskin (1971).)

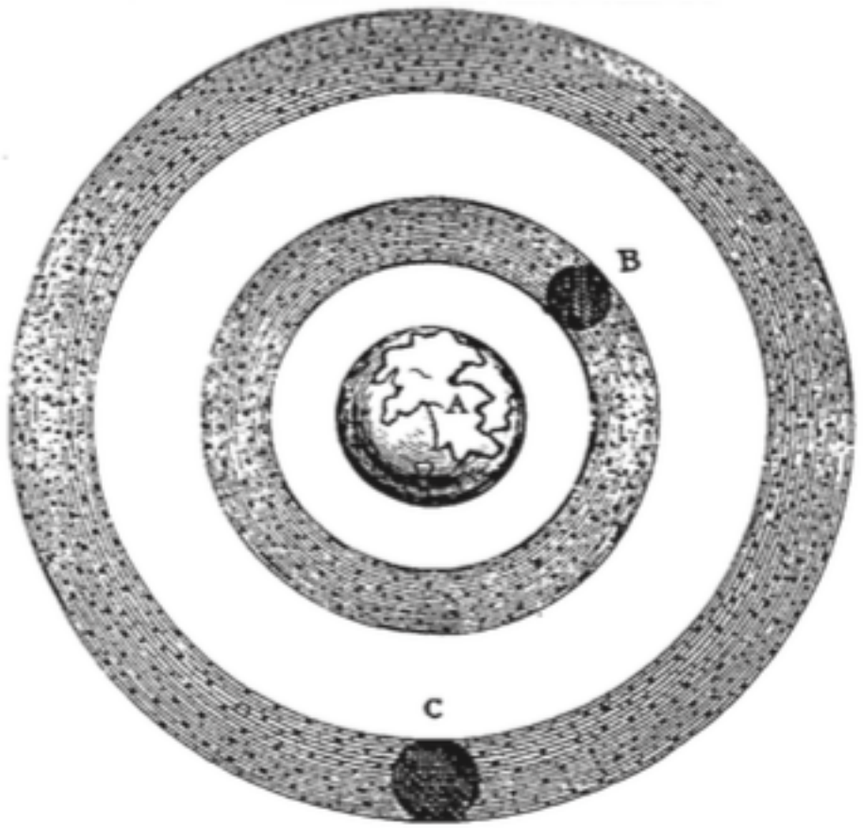


Figure 3.7 An alternative "creation" imagined by Wright; the stars lie not in a spherical shell, but in one or more rings around the divine center. (Reproduced with permission from Hoskin (1971).)

"Universos Ilhas" de Wright

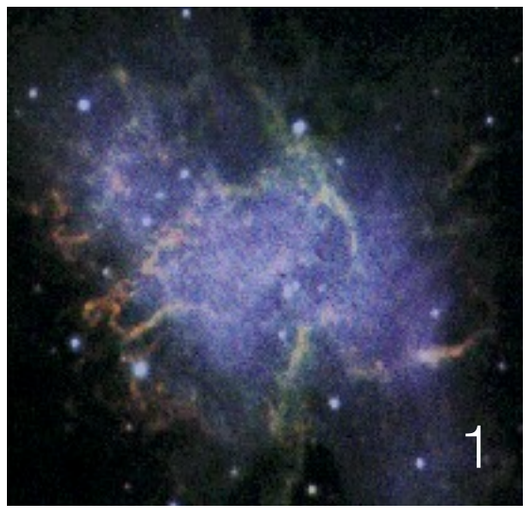
Immanuel Kant

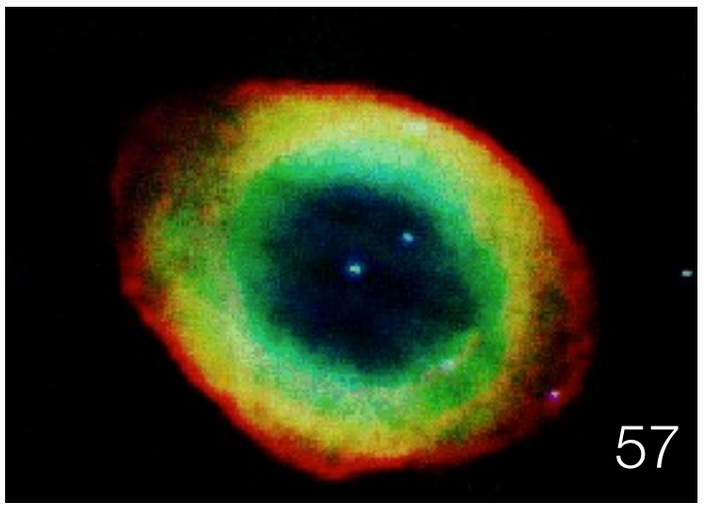
- Figura em L. Belkora, 2003

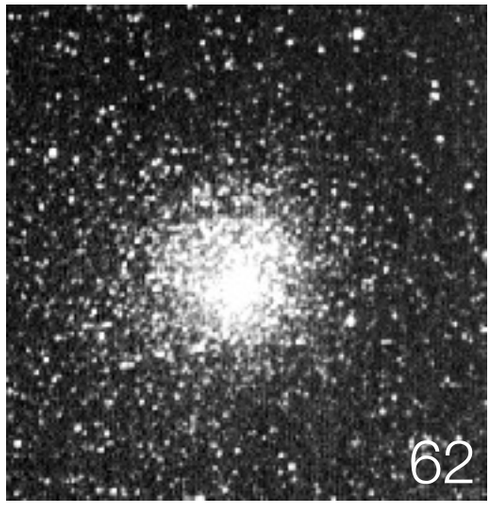
Figure 3.8 A disk of stars, or galaxy, viewed face-on (left view) and edge-on (right view). The middle view is for an intermediate viewing angle. (Credit: Layne Lundström.)

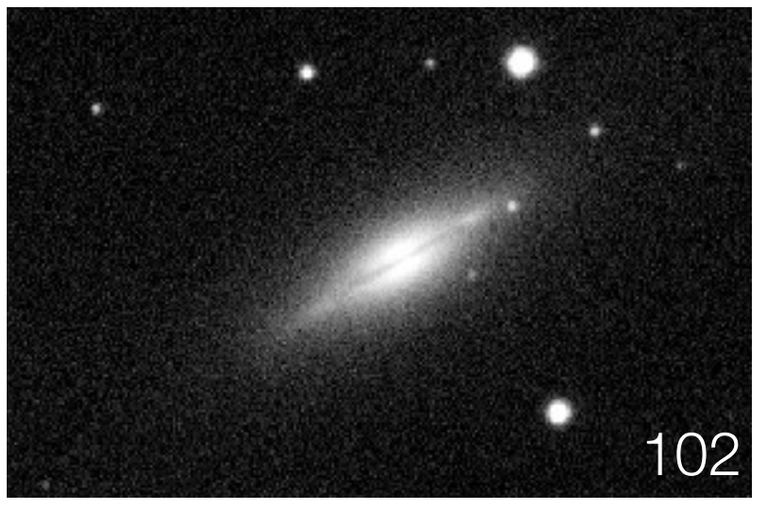
- "I easily persuaded myself that these ["nebulous"] stars can be nothing else than a mass of many fixed stars,"
- if "a system of fixed stars which are related in their positions to a common plane, as we have delineated the Milky Way to be, be so far removed from us that the individual stars of which it consists are no longer sensibly distinguishable even by the telescope […] if such a world of fixed stars is beheld at such an immense distance from the eye […], then this world will appear […] circular if its plane is presented directly to the eye, and elliptical if it is seen from the side or obliquely. The feebleness of its light, […] will clearly distinguish such a phenomenon when it is presented, from all the stars that are seen single."

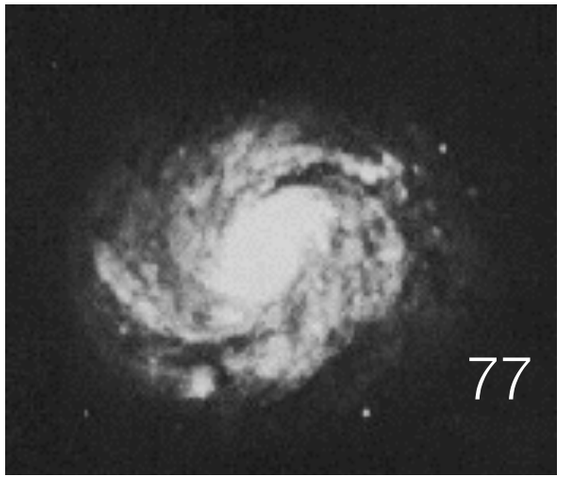
Entre 1758 e 1782, Charles Messier (Francês1730 - 1817) compilou uma lista de aproximadamente 110 objetos difusos que eram difíceis de se distinguir de cometas com os telescópios da época. Apenas em 1924 com E. Hubble foi comprovado que alguns desses objetos eram galáxias além da nossa.

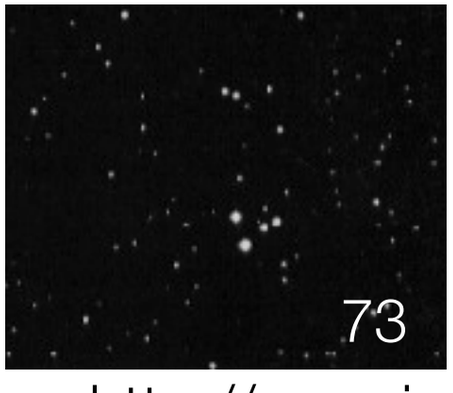












http://messier.seds.org

Mapeando a Galáxia

William Herschel

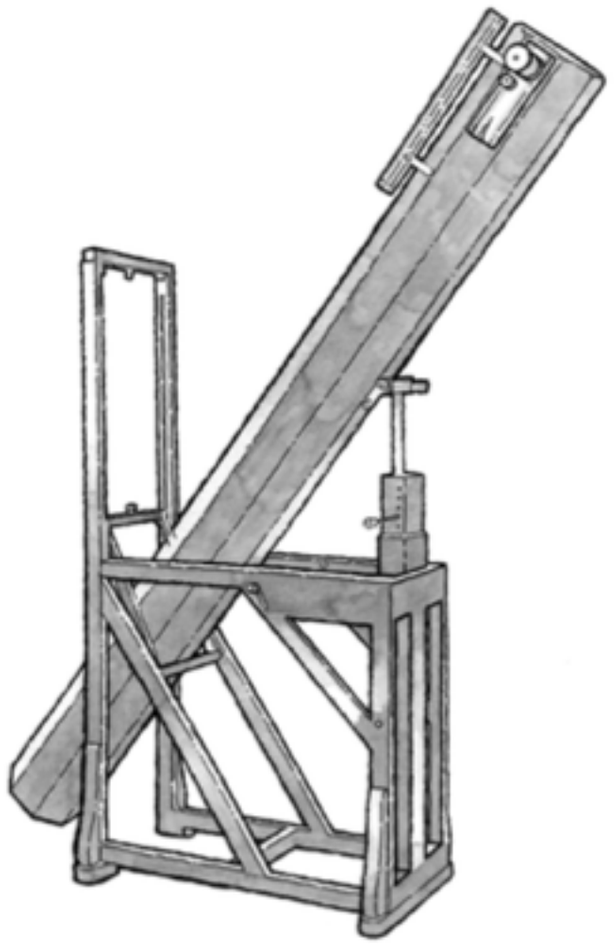


Figure 4.2 Herschel's 7-foot focal length telescope, of aperture about 6 inches. This was the instrument Herschel was using in 1779 when he met William Watson in the street in front of his house. He was using it in 1781, too, when he discovered the planet Uranus. (Credit: Layne Lundström.)

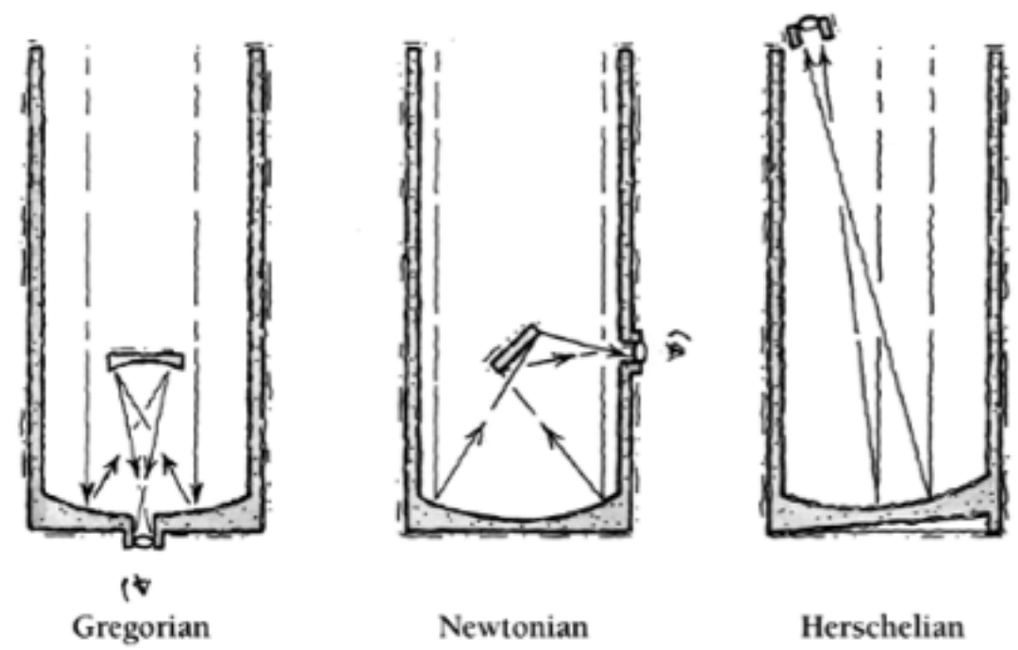


Figure 4.4 Types of telescope. In the Gregorian type of reflecting telescope, shown at left, light from the primary mirror is reflected to a curved secondary mirror, and from there to the eyepiece at the bottom of the telescope structure. The secondary mirror blocks a small part of the incoming light, but does not distort the image formed by the tele-

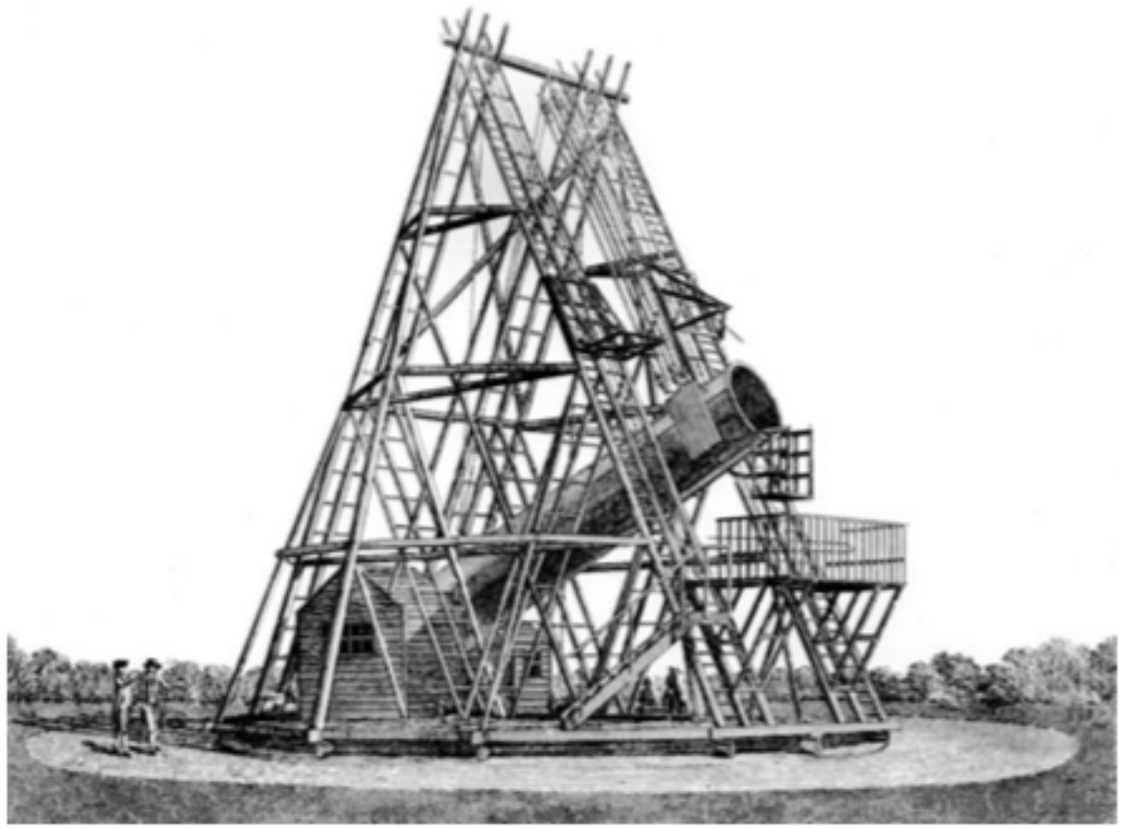


Figure 4.9 Herschel's 40-foot focal length reflecting telescope, of aperture 49 inches. (Credit: Royal Astronomical Society.)

Mapeando a Galáxia

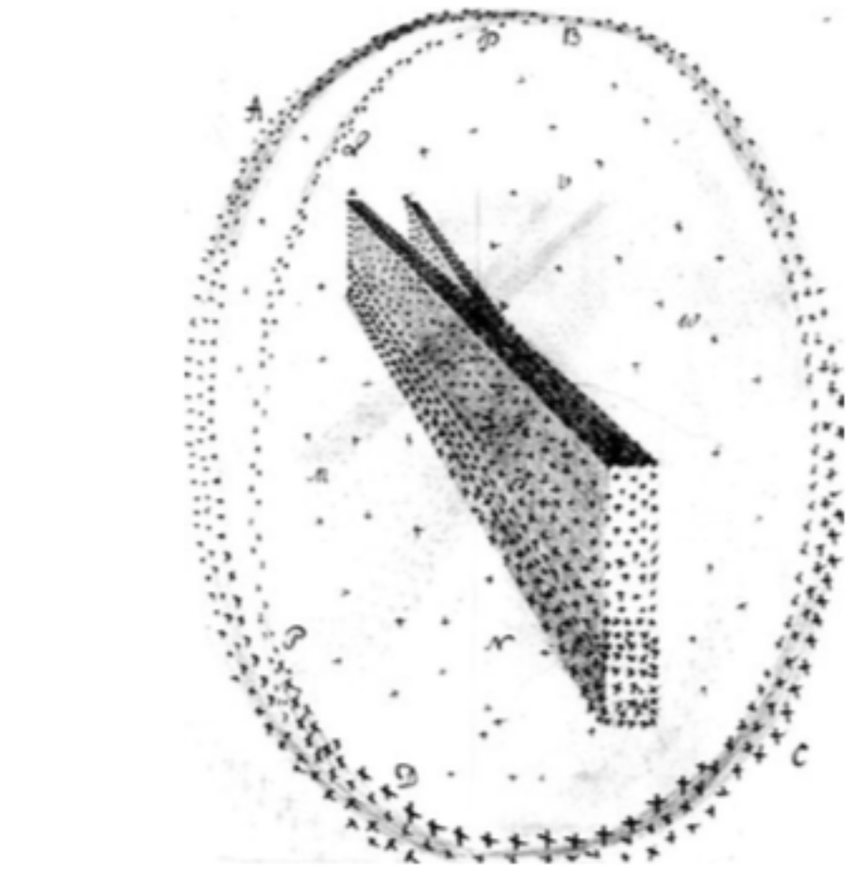


Figure 4.7 Herschel's branched-stratum Milky
Astronomical Society.)

Mapeamento feito por contagem de estrelas. Na época ainda estavam a procura por medidas de paralaxe (Herschel procurou por 40 anos em vão).

William Herschel, 1785

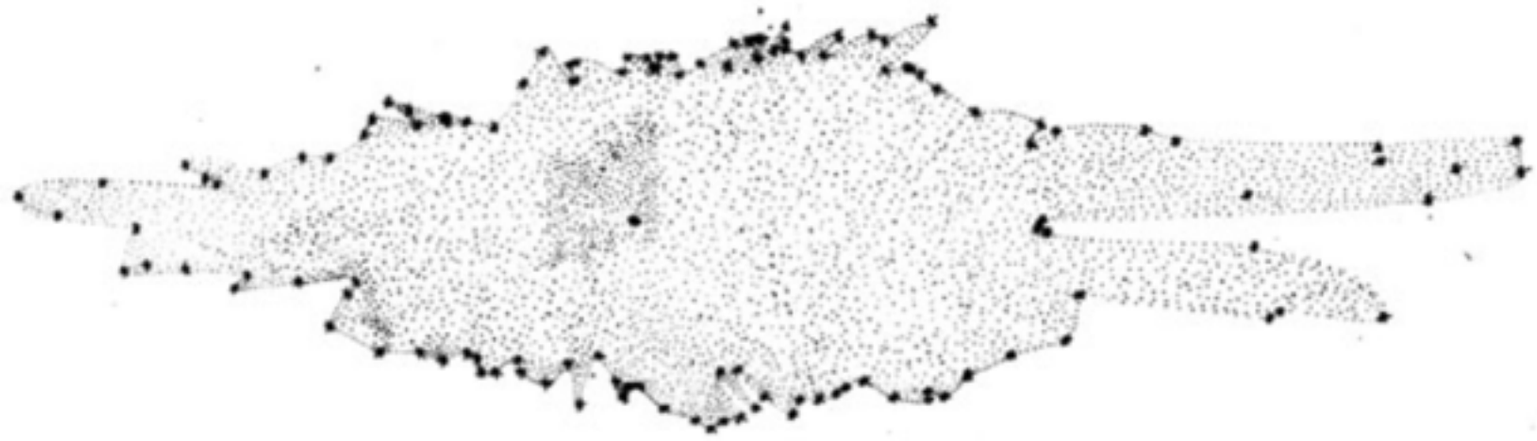


Figure 4.8 Milky Way from "star-gages." (Credit: Royal Astronomical Society.)

Mapeando a Galáxia

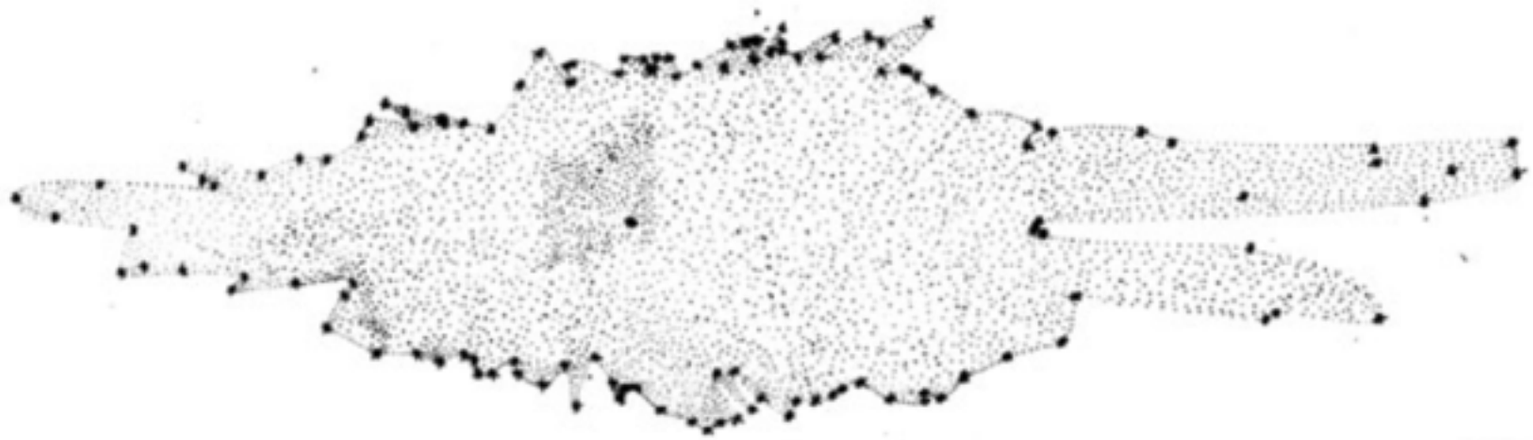


Figure 4.8 Milky Way from "star-gages." (Credit: Roya Society.)

William Herschel, 1785

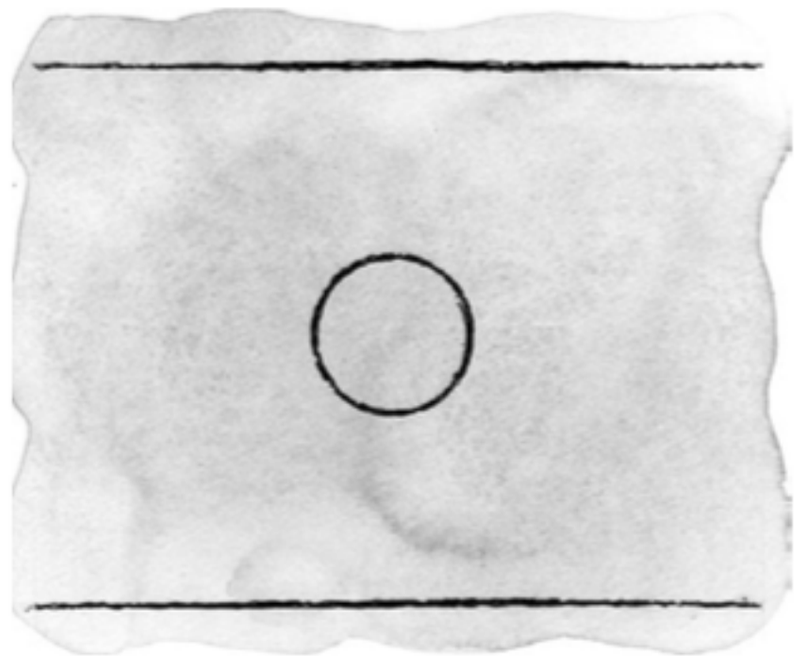


Figure 4.11 Herschel's "Unfathomable" Milky Way. The circle represents the limit to which the naked eye can see; the parallel lines delimit the Milky Way system as Herschel conceived it late in life, when he believed the system extended to an unknown distance in breadth.

A procura da paralaxe

Wilhelm Struve, 1847

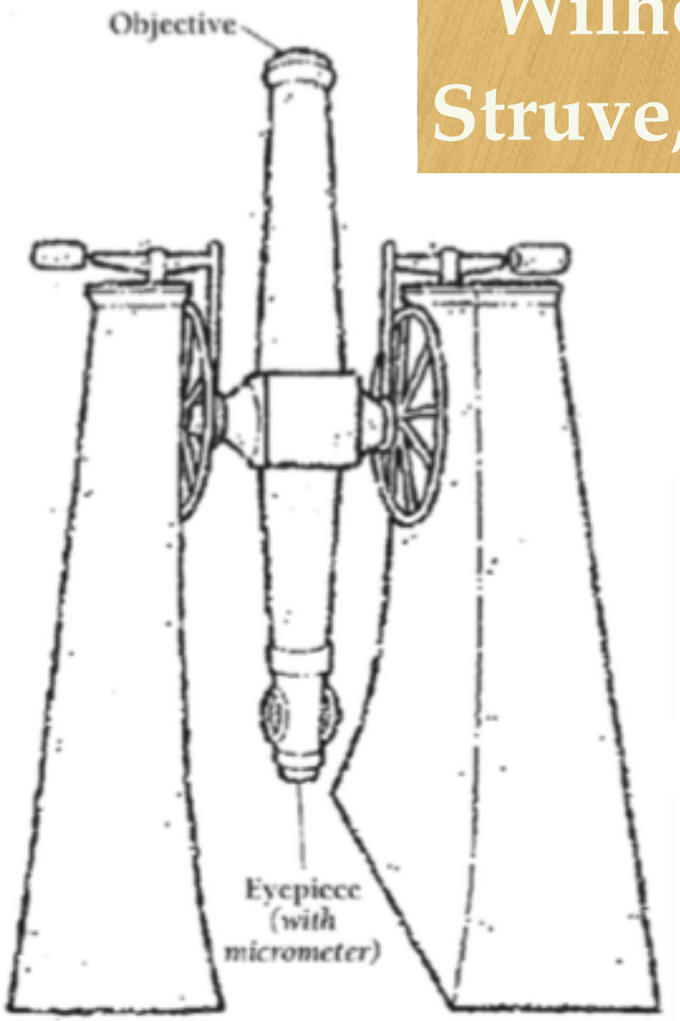


Figure 5.2 The transit telescope. A typical transit telescope is supported between two heavy piers, and can rotate only on one axis to show objects on the observer's meridian. The transit telescope was designed for the measurement of accurate stellar or planetary positions. The angle of elevation of the telescope, and the time at which the object transited the observer's meridian (as seen by the passage of the object across the wire in the micrometer) gave its declination and right ascension. (Credit: Layne Lundström.)

"If it turns out, as I hope, that further calculations confirm this result, this would constitute the important discovery that Alpha Lyrae is at a distance from the solar system of 1 million solar distances.'

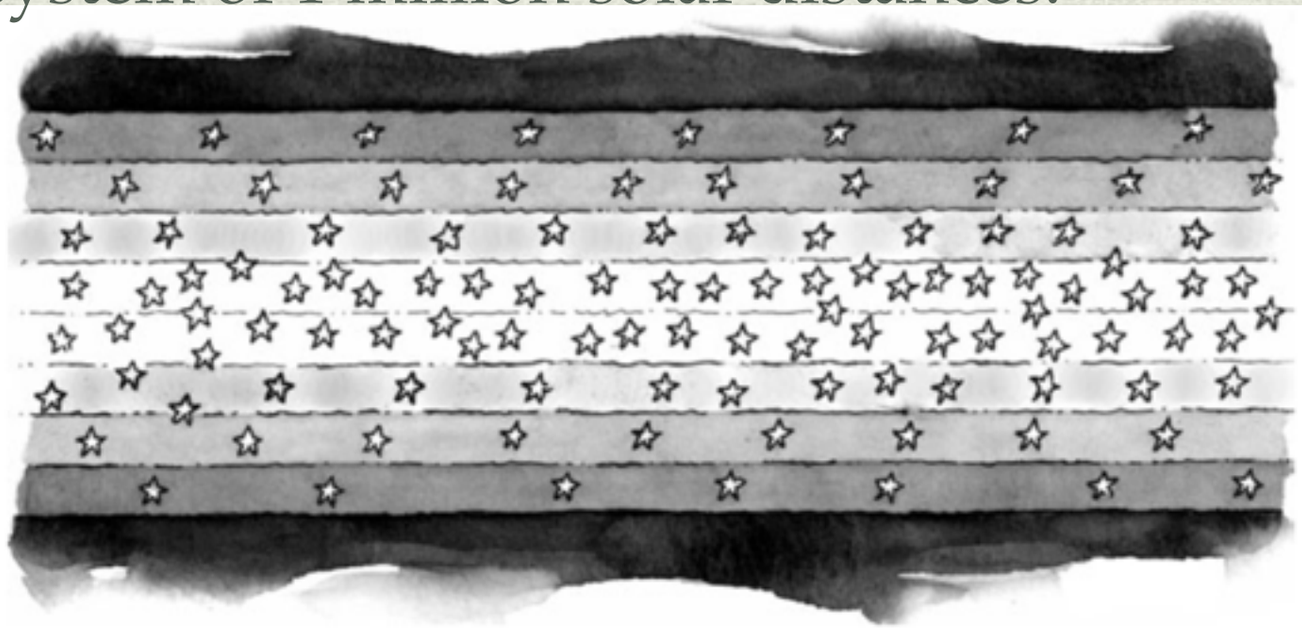


Figure 5.8 Struve's model of the Milky Way, as described verbally in his *Etudes d'Astronomie Stellaire* (1847). The Milky Way system of stars, in his conception, is thin in one direction but extends to unknown reaches in the other direction. Struve described the distribution of stars mathematically, envisioning them as very densely packed in a thin central layer, surrounded by layers of decreasing density. (Credit: Layne Lundström.)

Novas medidas de distância

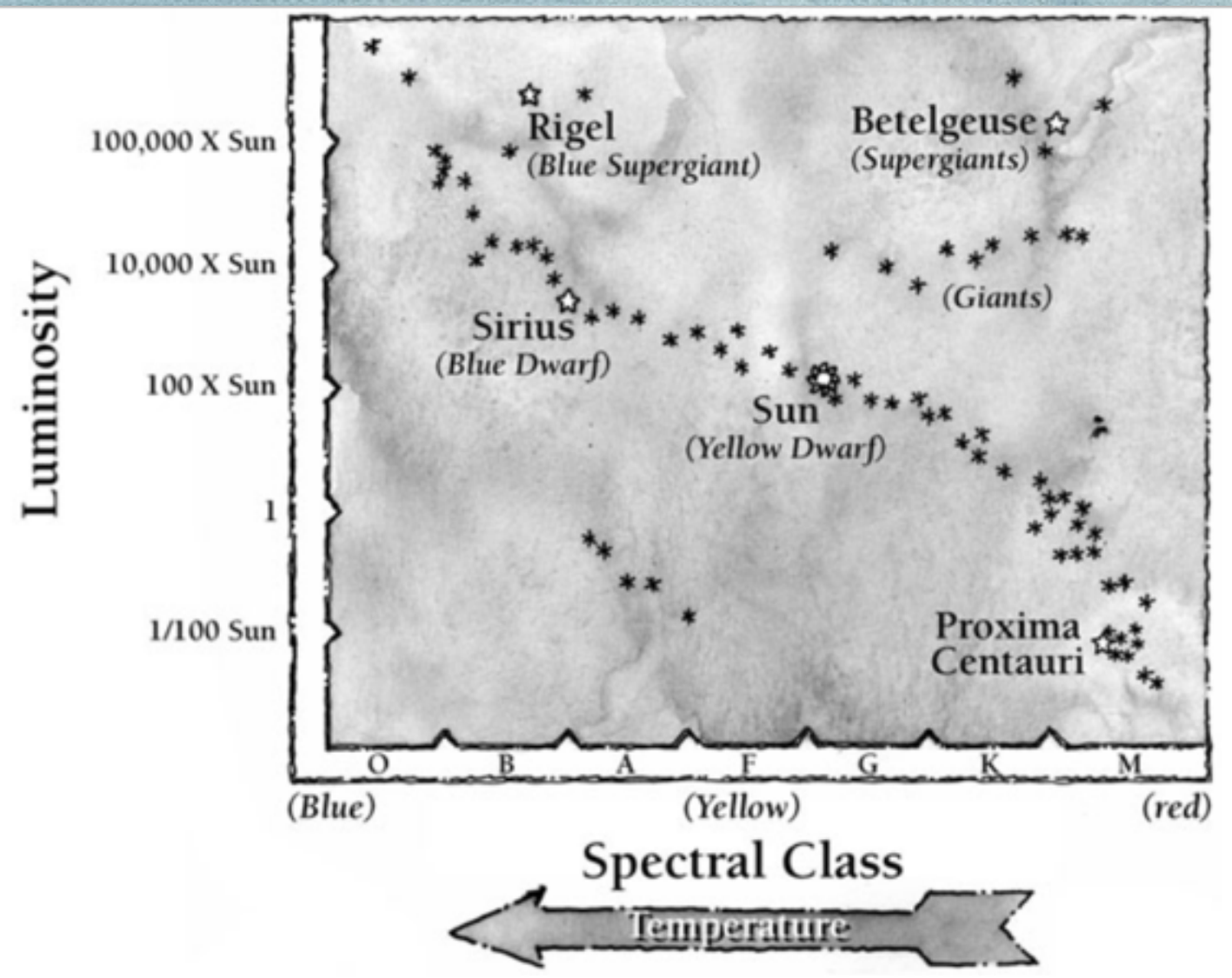


Figure 7.4 The Hertzsprung–Russell or HR diagram, showing the distribution of stars in color and luminosity. The *x* axis shows color from blue to red, or temperature decreasing to the right. The *y* axis shows the luminosity in units of the solar luminosity. Most stars have a color

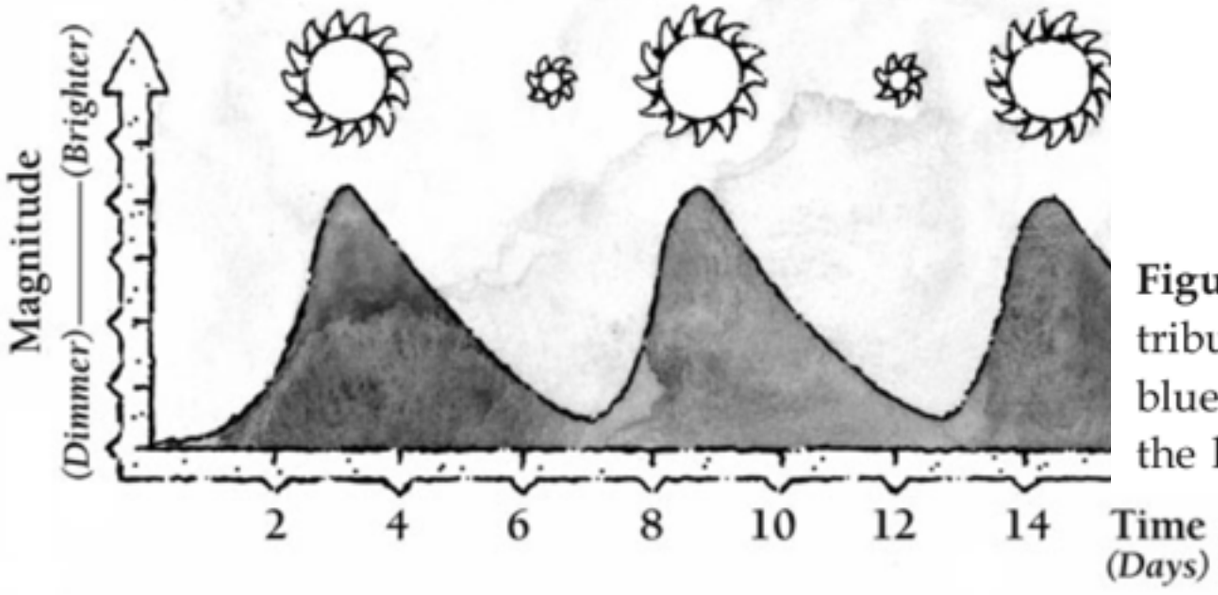
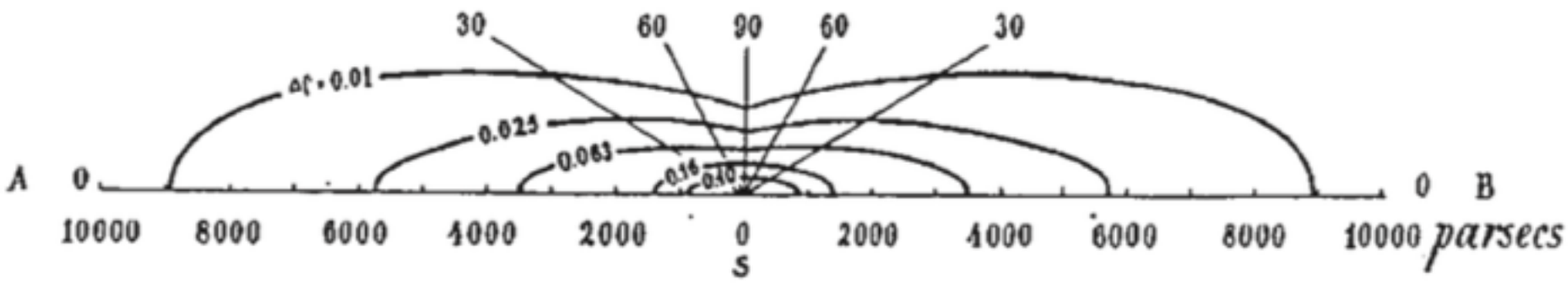


Figure 7.5 Cepheid variables. Cepheid (SEF-ee-id) variable stars, named after the prototype star exhibiting the behavior, Delta Cephei, brighten and dim in a regular pattern as they swell and shrink. At their maximum size, they have their peak brightness. The fact that the maximum brightness of a Cepheid variable is related to the period of time over which the pattern repeats has led to the use of Cepheid variables as distance indicators, as explained in the text. (Credit: Layne Lundström.)

Hertzprung e Russel

Henrietta Leavitt

Mapeando a Galáxia
Kapteyn, 1910s



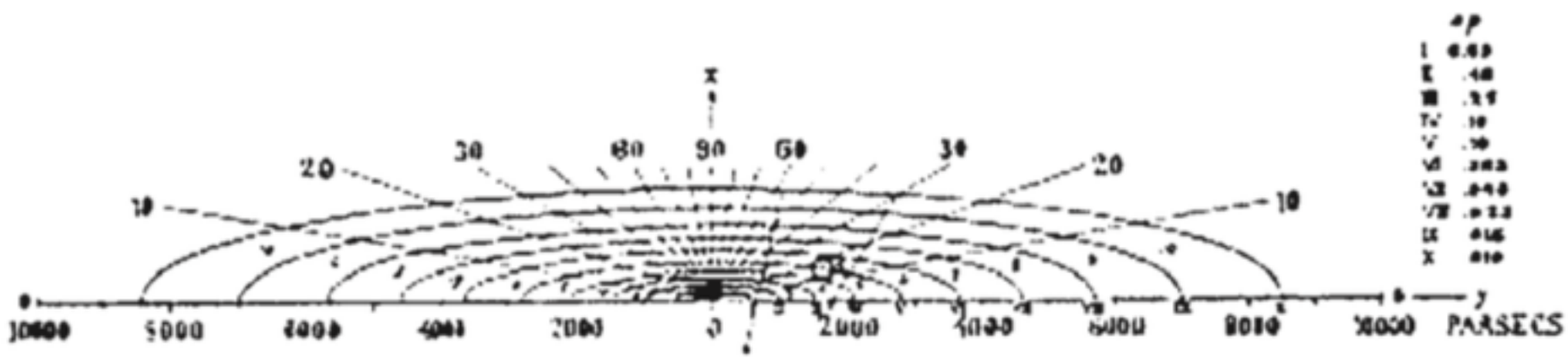


Figure 7.6 The "Kapteyn Universe." Top panel: 1920 model of the distribution of stars in our galaxy, derived by Kapteyn and his student van Rhijn from an analysis of star-counts. The system is assumed to be symmetric, so only the "top half" of the galaxy is shown. The line AB represents the plane of the Milky Way. The Sun is at S, the center of the system. Distances are given along the x axis in parsecs; 1 parsec is

Mapeando a Galáxia - Kapteyn

"Undoubtedly one of the greatest difficulties, if not the greatest of all, in the way of obtaining an understanding of the real distribution of stars in space, lies in our uncertainty about the amount of loss suffered by the light of the stars on its way to the observer."
J C Kapteyn, 1909

E em 2017, muito se discutia sobre a "zone of avoidance" (Curtis)

Até agora…

- Thomas Wright: as várias possibilidades do formato das nebulosas

- Immanuel Kant: universos ilhas

- William Herschel: a forma do Universo conhecido por contagem de estrelas, a possível evolução de nebulosas em estrelas e sistemas estelares…

- no séc. XIX. Struve e Kapteyn procuraram colocar uma escala absoluta nos mapas dos sistemas estelares, e Huggins usou espectroscopia para estudar nebulosas: gasosas e “estelares"

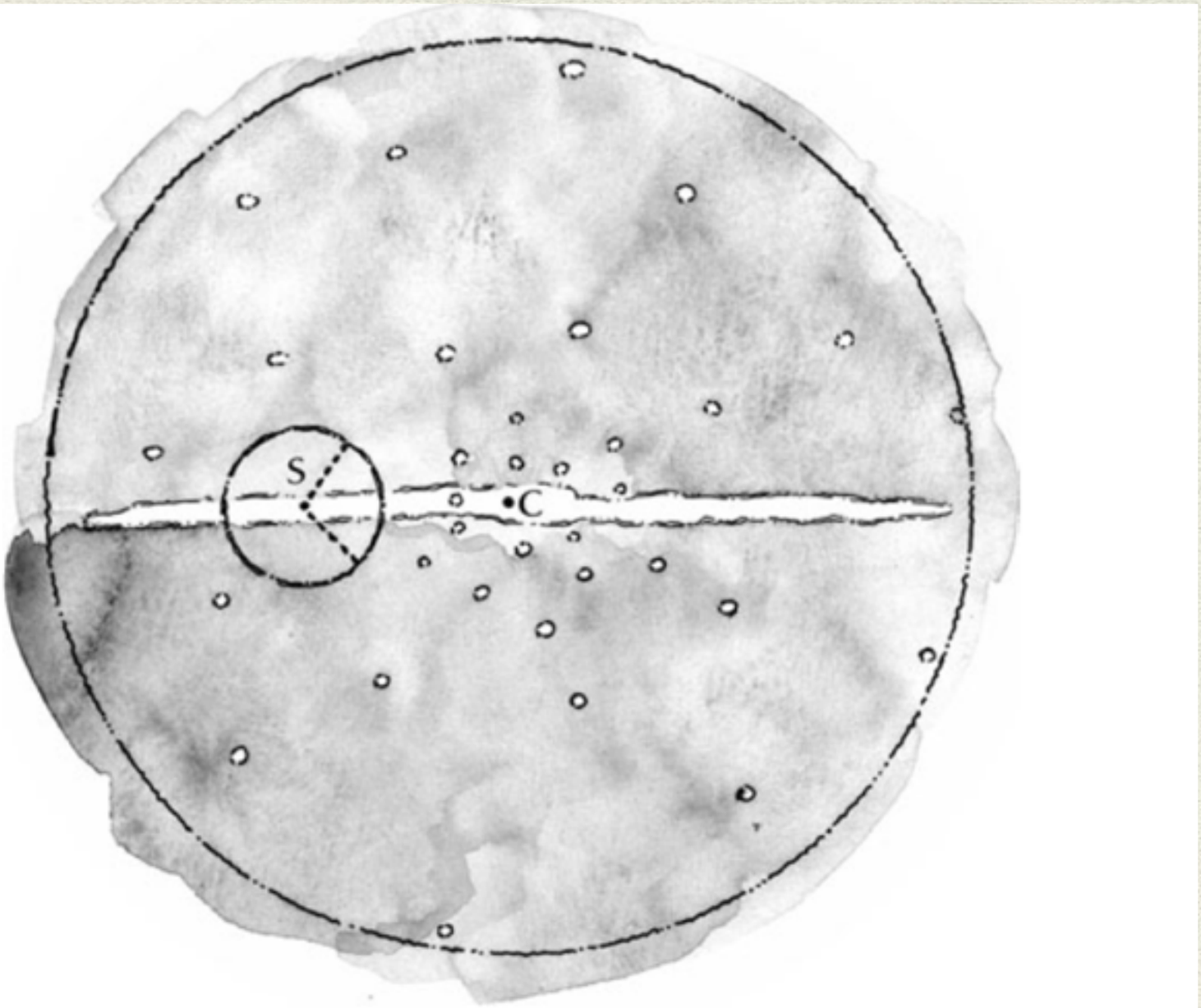


Figure 8.2 Distribution of globular clusters with respect to the Galaxy. Globular clusters fill the spherical space around the disk of our galaxy; in other words, the center of the globular cluster distribution coincides with the center of the galaxy, "C." This is the situation imagined by the Swedish astronomer Karl Bohlin, and later confirmed by an initially skeptical Harlow Shapley. As viewed from the position of the Sun

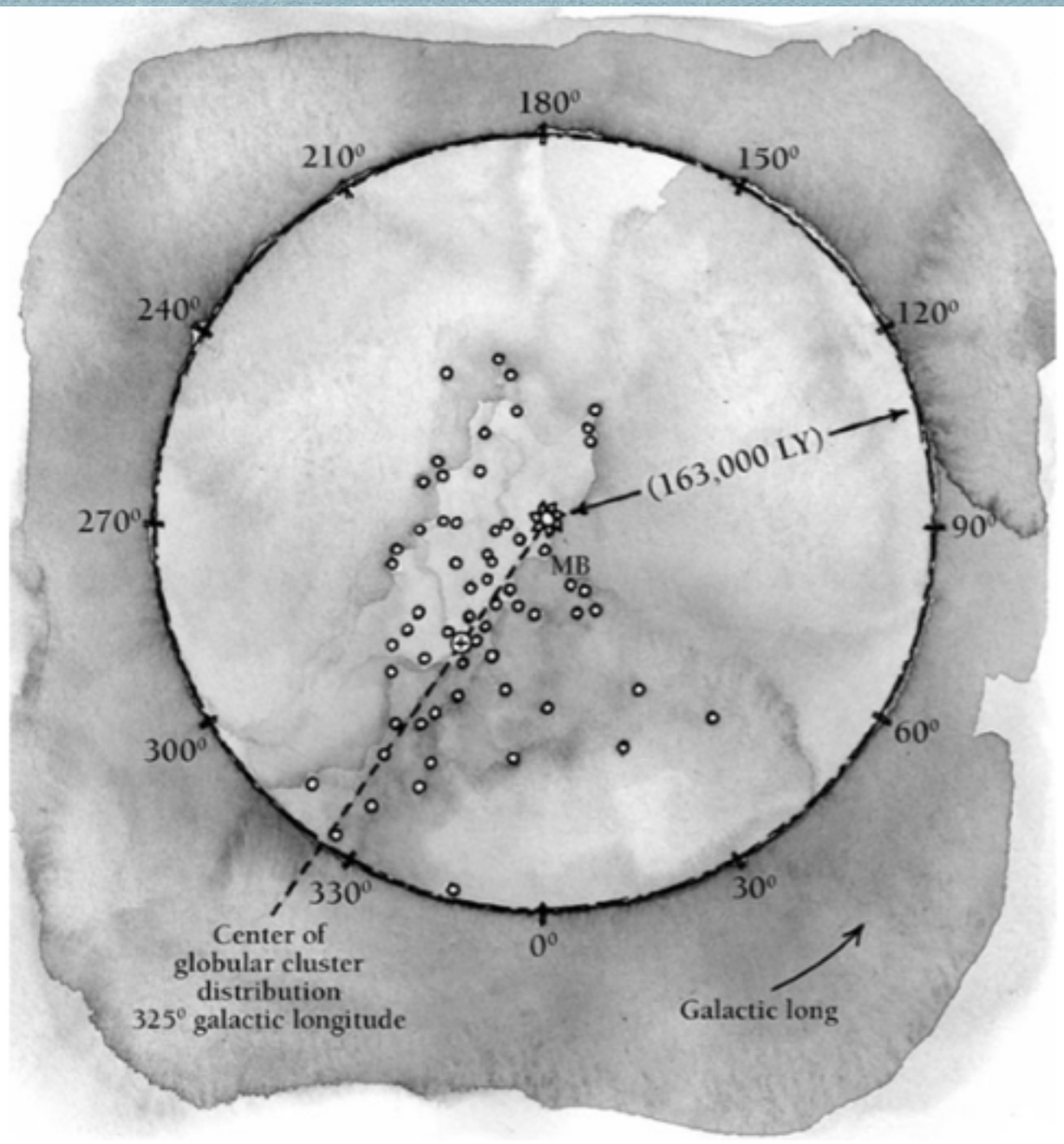


Figure 8.3 Distribution of globular clusters mapped by Shapley. The diagram is a kind of bird's-eye-view of the Galaxy, showing the globular clusters asymmetrically located in galactic longitude with respect to the sun. Shapley found that the center of the globular cluster distribution (marked by a + symbol), which he correctly assumed matched the center of the galaxy, lay tens of thousands of light-years from the Sun. (Note that the longitude system Shapley used is no longer the standard.) (Credit: Layne Lundström.)

Shapley, 1917

Distância aos aglomerados foi obtida a partir das hipótese de que a luminosidade máxima do RGB é a mesma, e que o diâmetro físico é o mesmo entre os aglomerados.

O "Grande Debate", 1920

- Entre Harlow Shapley e Heber D. Curtis
- Qual o tamanho da Galáxia?
- Qual a posição do Sol dentro desta?
- Qual a natureza das “nebulosas"?

http://atropos.as.arizona.edu/aiz/teaching/a204/shapley_curtis.html

O nascimento da Astrofísica Extragaláctica

- "You will be interested to hear that I have found a Cepheid variable in the Andromeda nebula (M31)“, Edwin Hubble para Shapley, 1924

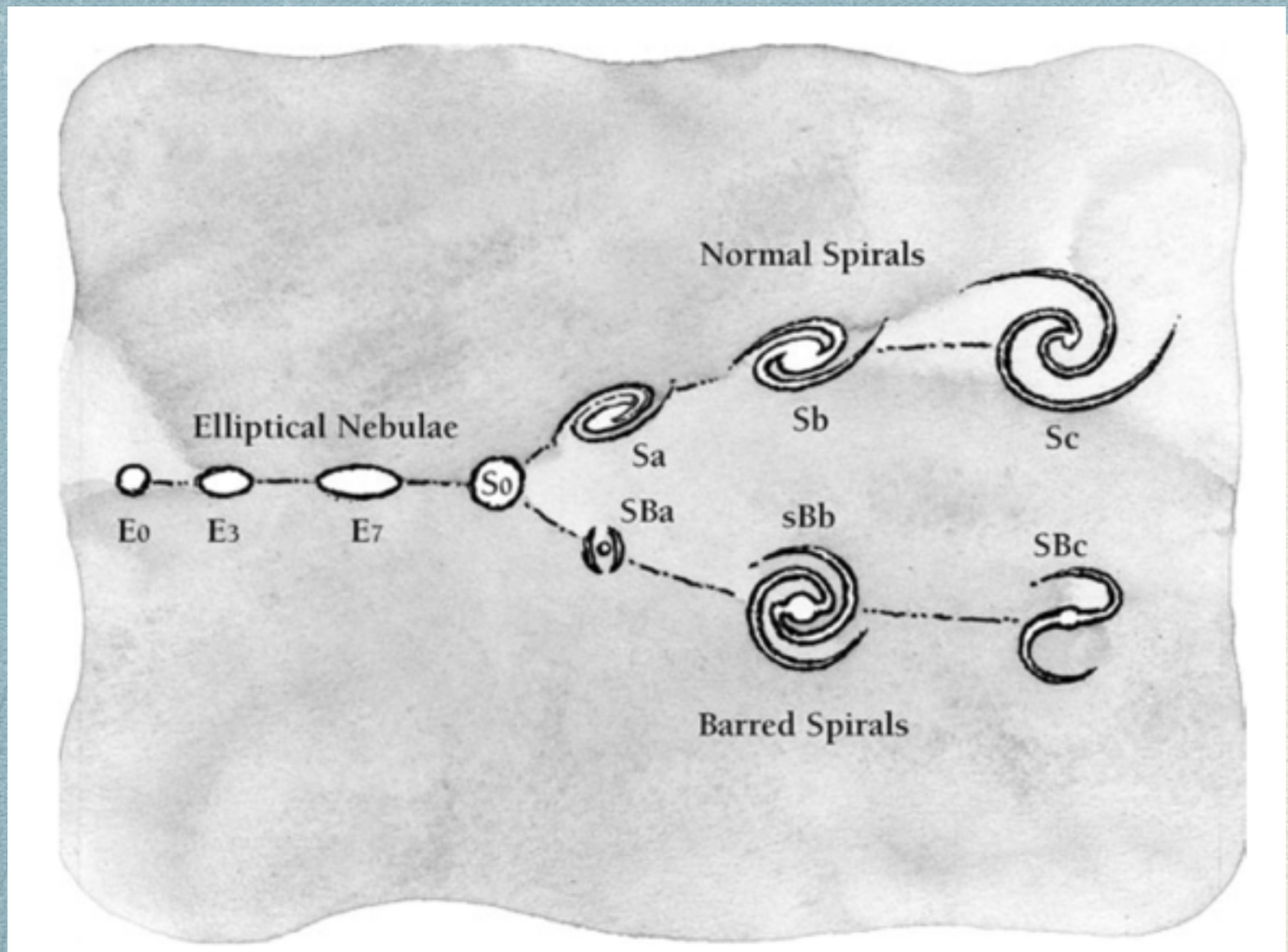


Figure 9.3 Hubble's classification of the galaxies. Hubble arranged the different types of nebulae he distinguished in a sequence, which he believed corresponded to an evolutionary sequence. At the left are the elliptical nebulae, more or less egg-shaped, without spiral structure. The more round galaxies he called E0, and the more "squashed" E7. At the right are the normal spirals (top branch) and the barred spirals, in which the spiral arms emerge not from the center of the galaxy but from a prominent bar running through the center. The spiral (S) and spiral-barred (SB) galaxies are designated also by the letters a, b or c, according to various morphological features such as the degree to which the arms appear "unwound." (Credit: Layne Lundström.)

Dados numéricos entram na Cosmologia (Hubble, 1929)

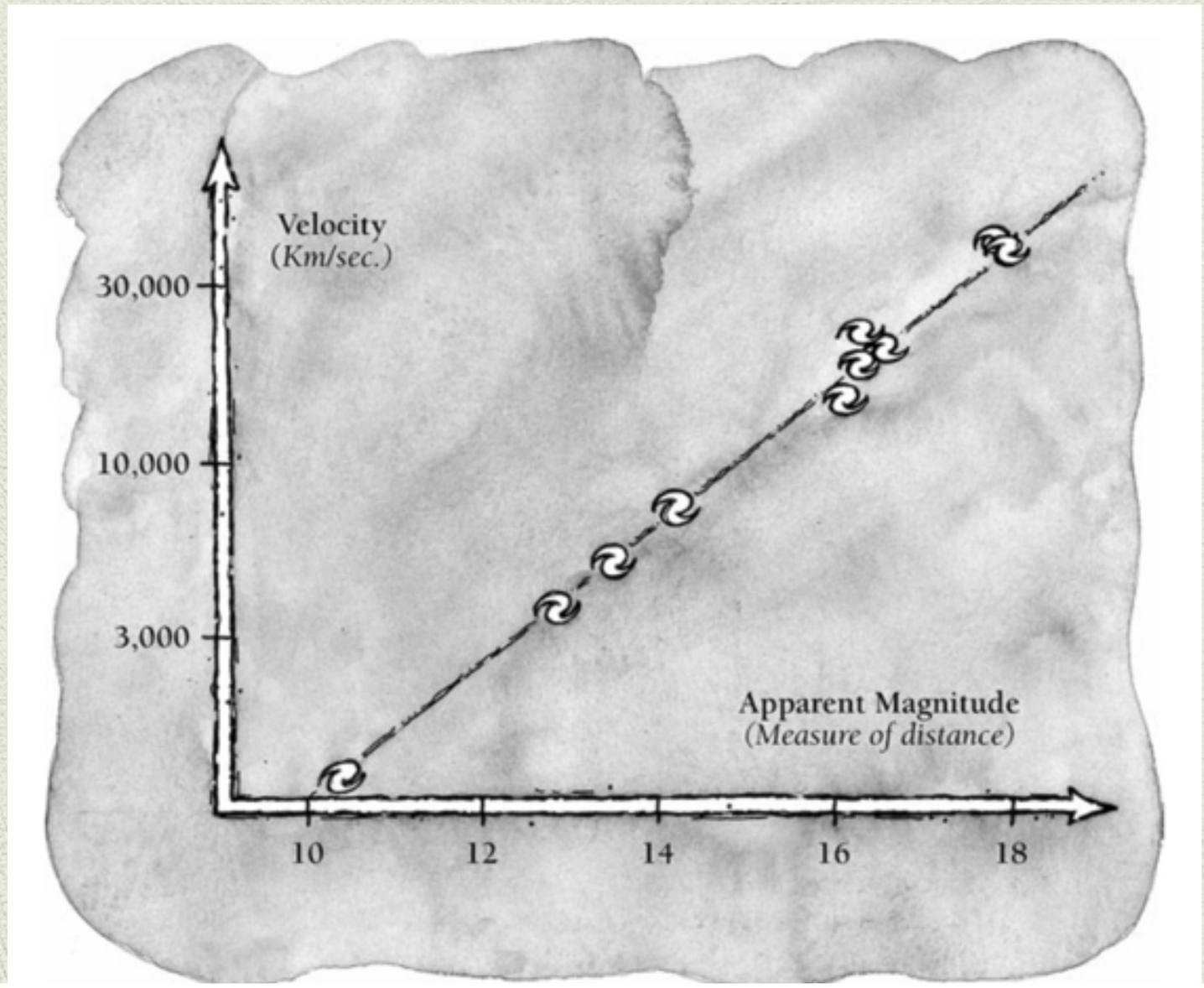


Figure 9.4 First hints of an expanding universe. Hubble plotted the velocity of galaxies (measured from the redshift of lines in the galaxies' spectra) against their apparent magnitude, an estimate of their distance.

Contribuições de Hubble

- Um sistema de classificação para as nebulosas que estimulou o estudo de suas origens e evolução
- Cefeidas foram descobertas em M31, fornecendo fortes evidências das grandes distâncias extra-galácticas e colocando a Galáxia em "seu lugar"
- Identificou a relação linear entre distância e velocidade de recessão de galáxias
- Com base na observação de 80000 nebulosas extragalácticas, mostrou pela primeira vez a isotropia do Universo

Distâncias e mais distâncias…

- A idade do Universo pelos primeiros resultados de Hubble era de 1.8 bilhões de anos ?!

- O trabalho de Baade sobre as populações das “nebulosas" acabou por demonstrar que as Cefeidas de Pop. I são intrinsecamente mais brilhantes do que as variáveis de Pop. II (W. Virginis)