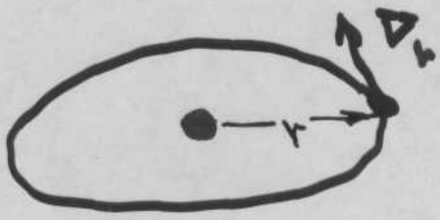
Невидимое вещество в спиральных галактиках.

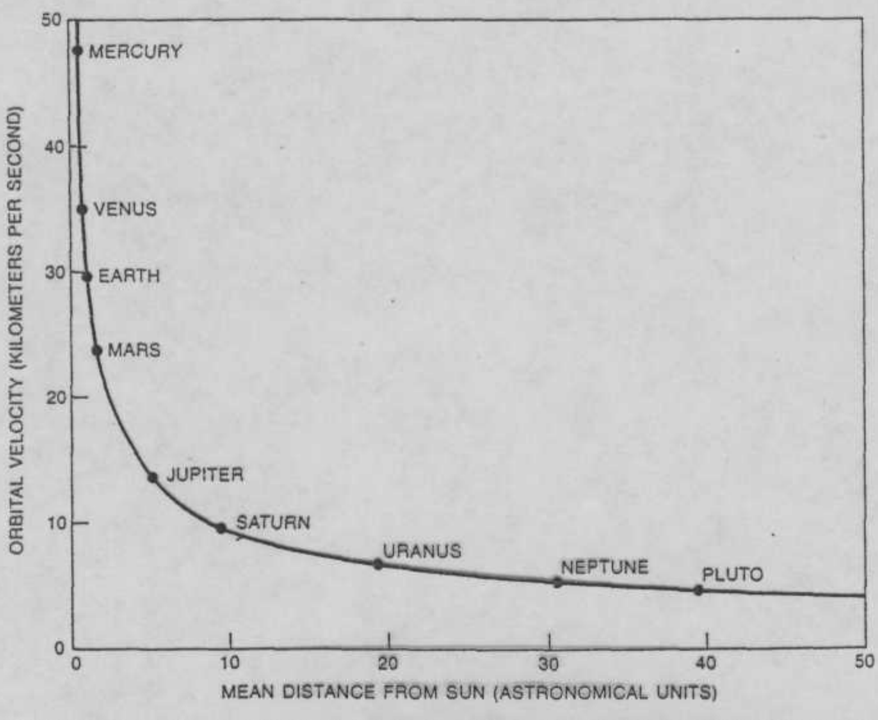
Солнечная система:

$$F_{гр} = \frac{G m M_r}{r^2} \; ; \qquad F_{цб} = \frac{m V_r^2}{r}$$

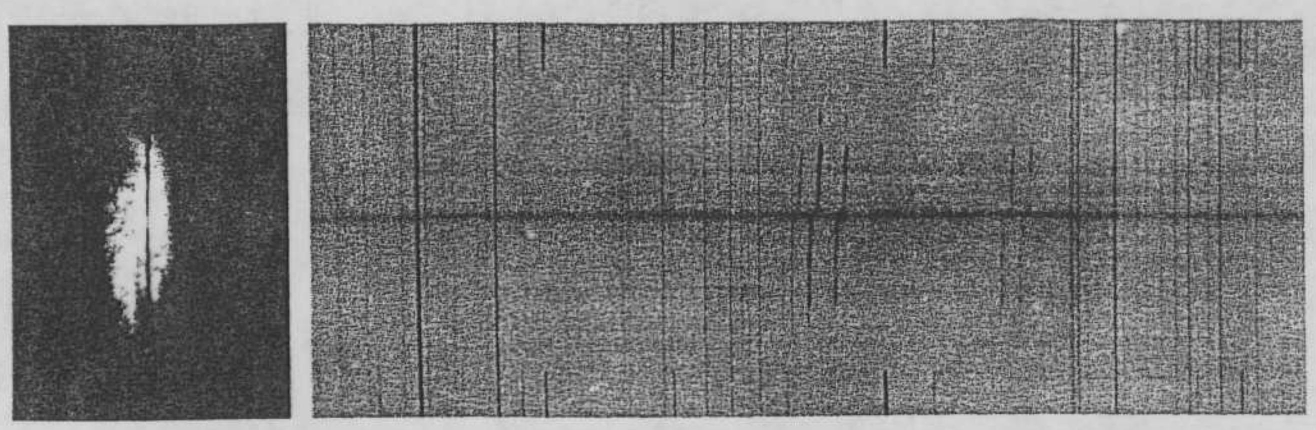
$$F_{гр} = F_{цб} \Rightarrow$$

$$\boxed{M_r = \frac{r V_r^2}{G}}$$

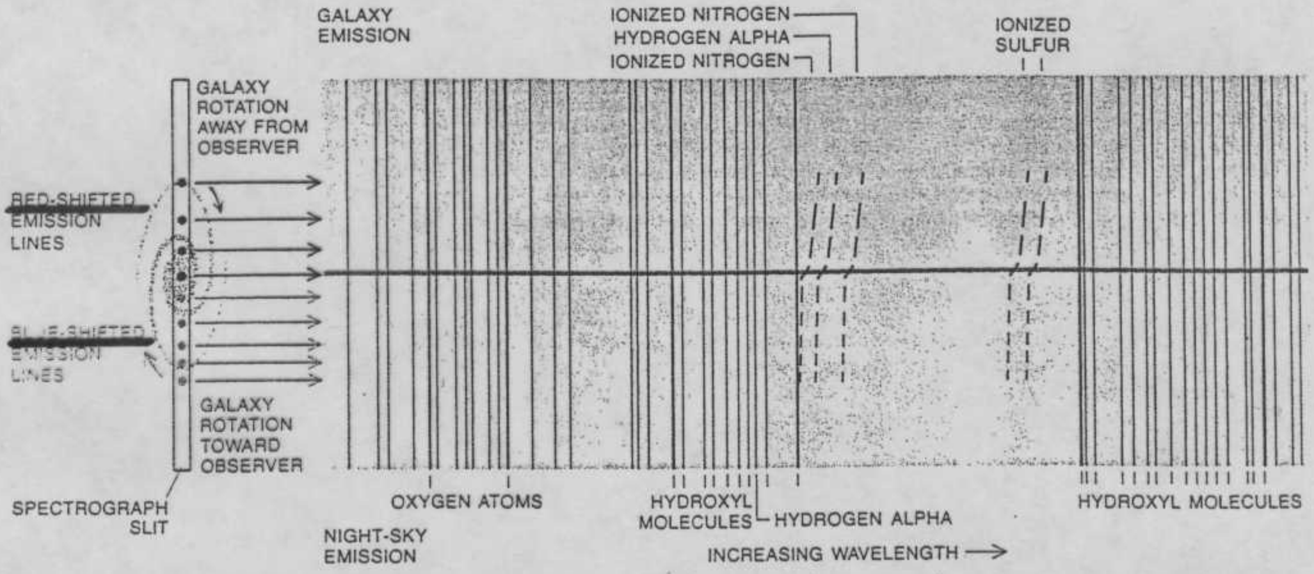




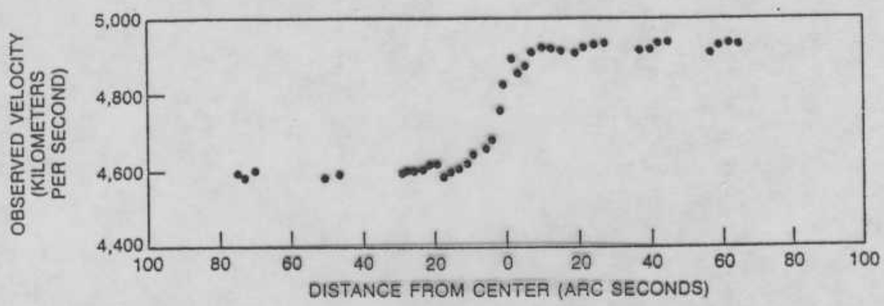
KEPLER'S LAW for the orbital velocity of planets in the solar system, in which more than 99 percent of the total mass resides in the sun, yields this plotted curve. Orbital velocity decreases inversely as the square root of *r*, the planet's mean distance from the sun. The distance is shown here in astronomical units; one A.U. equals the mean distance between the earth and the sun. Pluto, at 39.5 A.U., lies 100 times farther from the sun than Mercury, at .39 A.U. Mercury's orbital velocity is about 47.9 kilometers per second; Pluto's velocity is accordingly slower by a factor of 10, or 4.7 kilometers per second ($47.9 \times 1/\sqrt{100}$). The author's results show that the orbital velocities of stars in a spiral galaxy depart strongly from a Keplerian distribution.

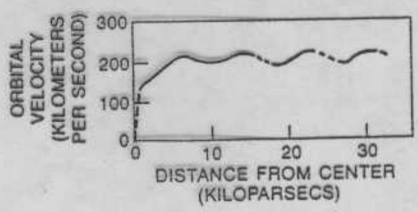


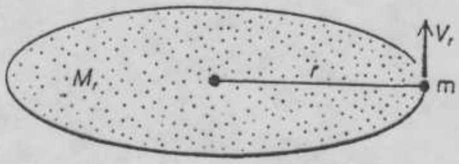
SPECTRUM OF SPIRAL GALAXY NGC 7541 (*right*) was recorded with the four-meter telescope at the Kitt Peak National Observatory by the author and W. Kent Ford, Jr. NGC 7541 is a type Sc spiral, 60 megaparsecs distant. (A megaparsec is 3.26 million light-years.) The exposure time was 114 minutes. The galaxy is seen at the left as it appears on a television monitor in the telescope's console room. The dark line through the galaxy shows the orientation of the spectrograph slit. Light from across the disk is sampled (*see illustration below*).



EMISSION LINES in the spectrogram of NGC 7541 arise from two sources: the night sky and atoms in the gas clouds surrounding bright stars in the galaxy. Most of the night-sky lines, which extend across the entire width of the spectrogram, are from hydroxyl (OH) molecules in the atmosphere of the earth. A few arise from oxygen and hydrogen atoms in the earth's atmosphere. The rotation of NGC 7541 shifts the position of the emission lines from the disk of the galaxy to either a shorter (bluer) wavelength or a longer (redder) one, depending on whether the rotation is carrying the stars and gas in the disk toward or away from the observer. Because the galaxy itself is traveling away from the observer as part of the general expansion of the universe, the hydrogen-alpha line from gas in the galaxy is red-shifted from the position of the same line in the night sky. The displacement is a measure of the galaxy's velocity of recession. The slant of the galactic emission lines shows that the orbital velocity of stars and gas in the disk is increasing with distance from the galactic center.

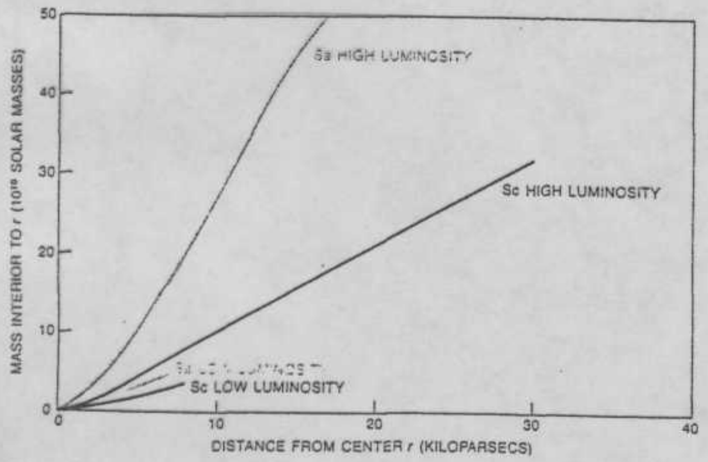


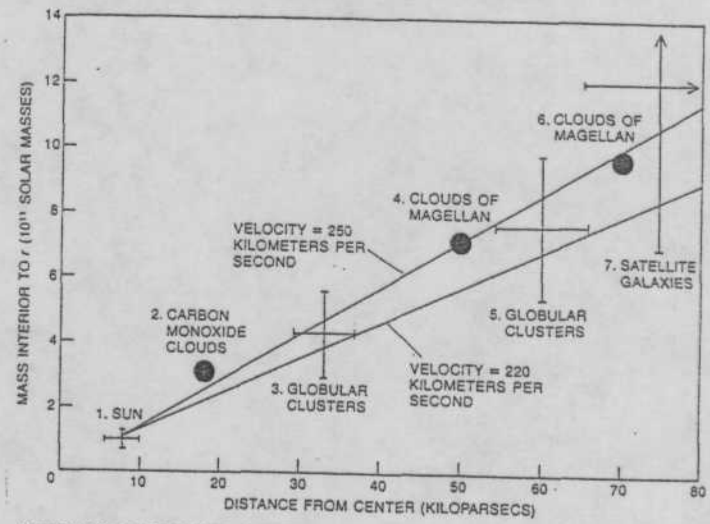




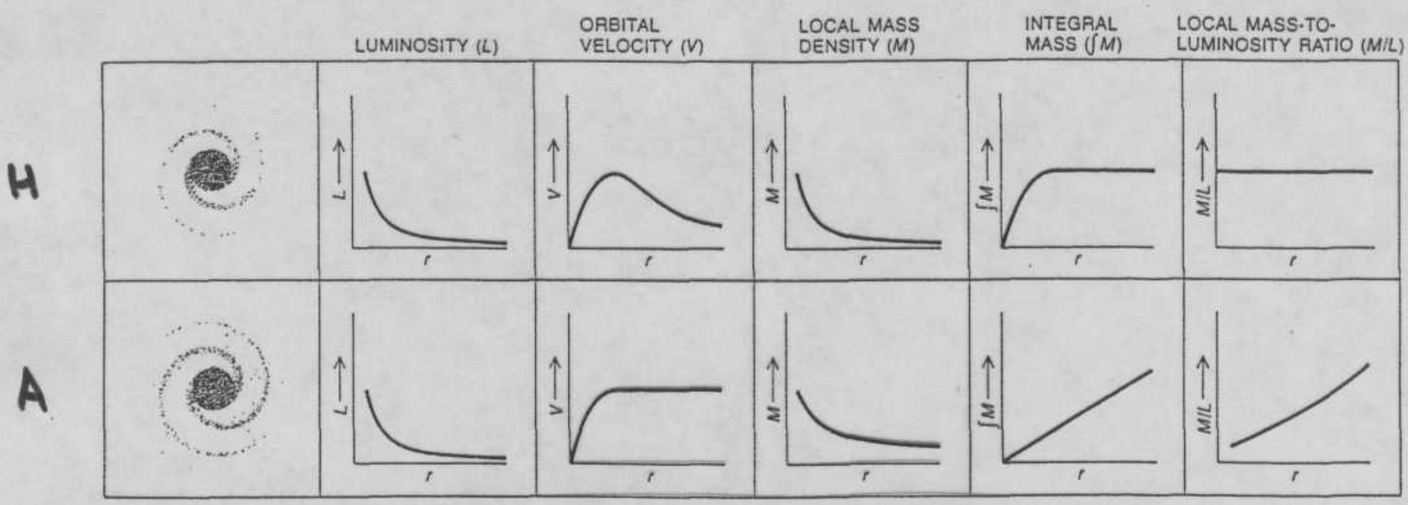
$$M_r = \frac{r V_r^2}{G} \Rightarrow V_r = \sqrt{\frac{G M_r}{r}} \sim \frac{1}{\sqrt{r}}$$

$$\Rightarrow M_r \sim r$$

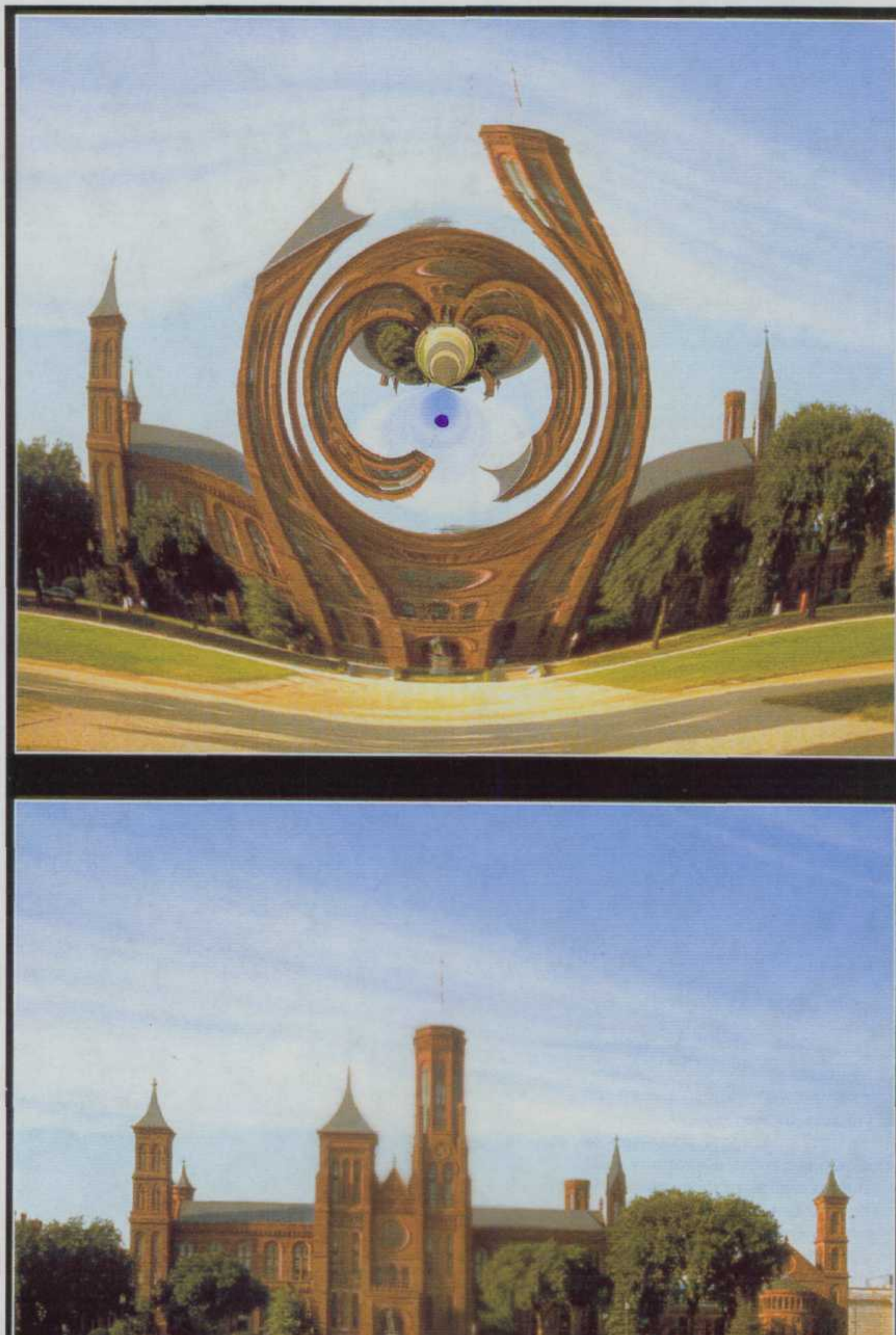




STUDIES OF OUR OWN GALAXY



HYPOTHETICAL AND ACTUAL GALAXIES deviate sharply in all their properties except luminosity. The typical actual spiral galaxy at the bottom has a massive nonluminous halo. The hypothetical galaxy at the top has no halo. Its surface brightness decreases rapidly, orbital velocities outside the nucleus decrease in Keplerian fashion, local mass density falls in parallel with luminosity, integral mass reaches a limiting value and the ratio of mass to luminosity stays approximately constant with increasing radial distance. Such were the expected properties of a galaxy. In an actual galaxy the presence of a dark halo changes everything but the galaxy's optical appearance. The orbital velocities remain high, the local mass density falls only slowly, the integral mass increases linearly with radius and the mass-to-luminosity ratio steadily increases as the halo of the galaxy contributes more mass and the luminous disk falls to the threshold of detectability.

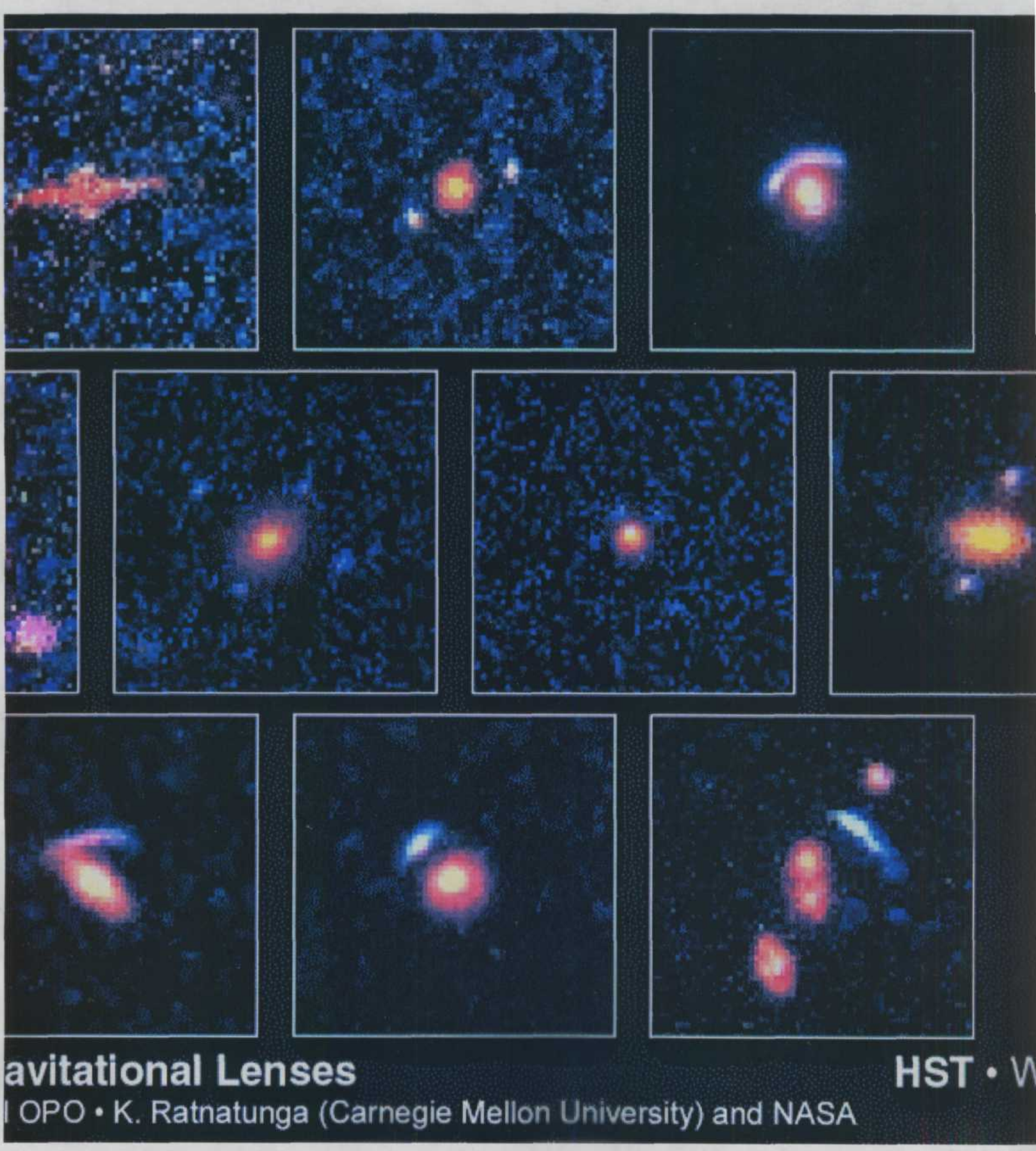


КОГДА ИСТОЧНИК, ЛИНЗА И НАБЛЮДАТЕЛЬ НАХОДЯТСЯ НА ОДНОМ ЛУЧЕ ЗРЕНИЯ, НАБЛЮДАЕМЫЕ ИЗОБРАЖЕНИЯ ЗАВИСЯТ ОТ ФОРМЫ ОБЪЕКТА, СОЗДАЮЩЕГО ГРАВИТАЦИОННУЮ ЛИНЗУ

▲ Если линза сферическая, то наблюдаемое изображение имеет вид «кольца Эйнштейна», то есть светящегося кольца.

▲ Если линза вытянутая, то изображение получается в виде «креста Эйнштейна» (распадается на четыре части).

▲ Если в качестве линзы выступает галактическое скопление, то изображение разбивается на части дугообразной формы.


avitational Lenses
HST •
OPO • K. Ratnatunga (Carnegie Mellon University) and NASA

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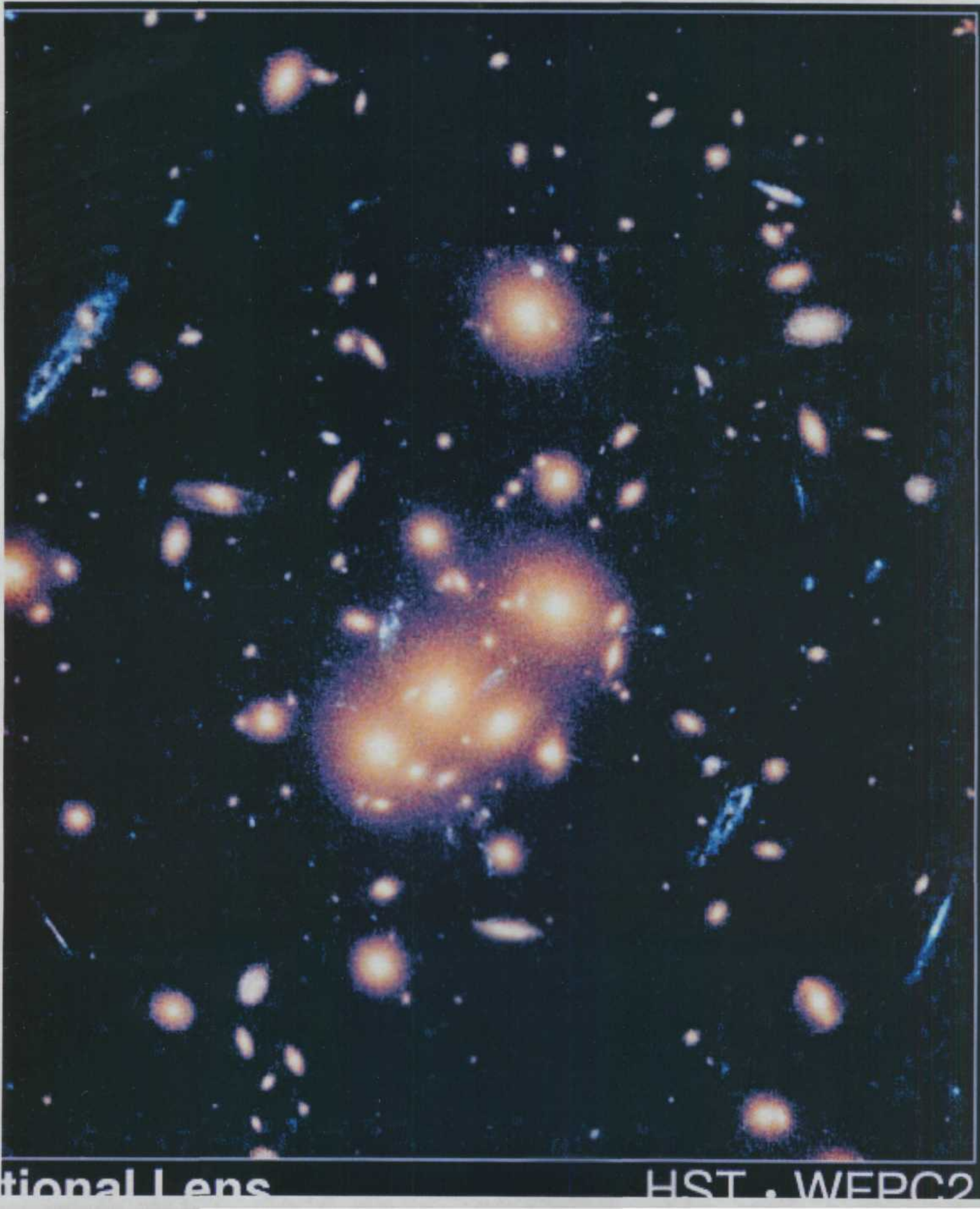


luster Abell 2218 **HST**

chter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

Поиск тёмного вещества в галактиках (ММО, БМО)

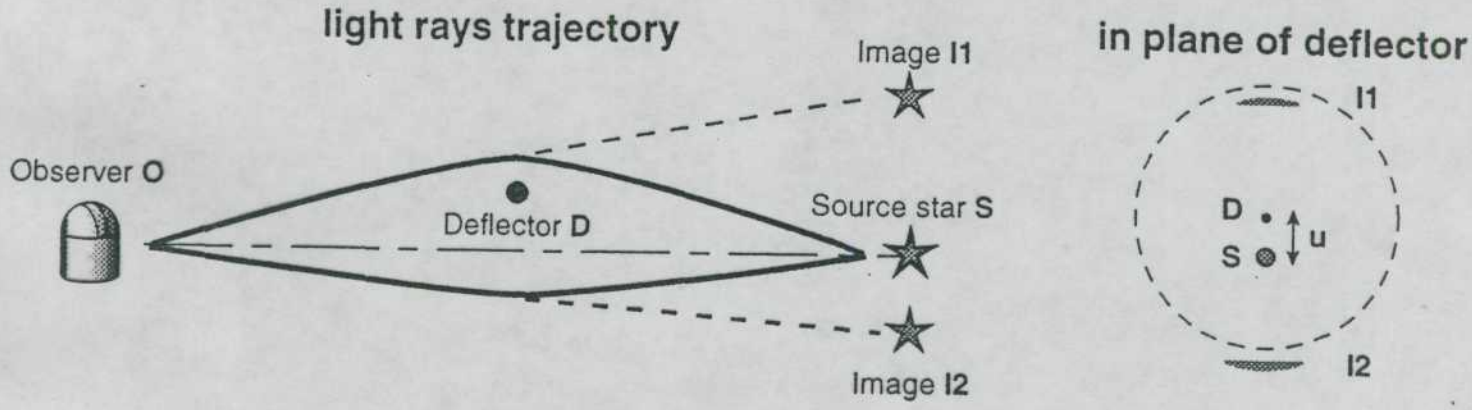


Figure 4. Deflection of light by a massive body D located near the line of sight between the observer O and the source star S. The dotted circle is the Einstein ring.

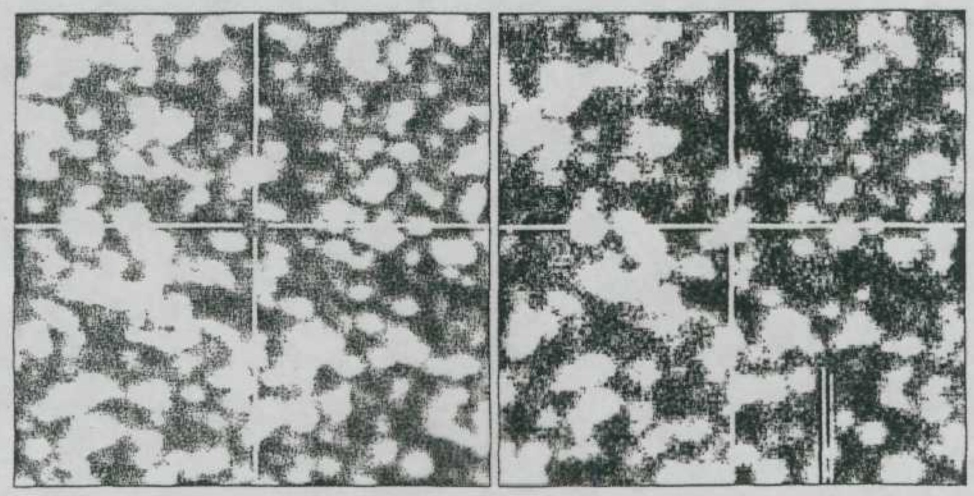
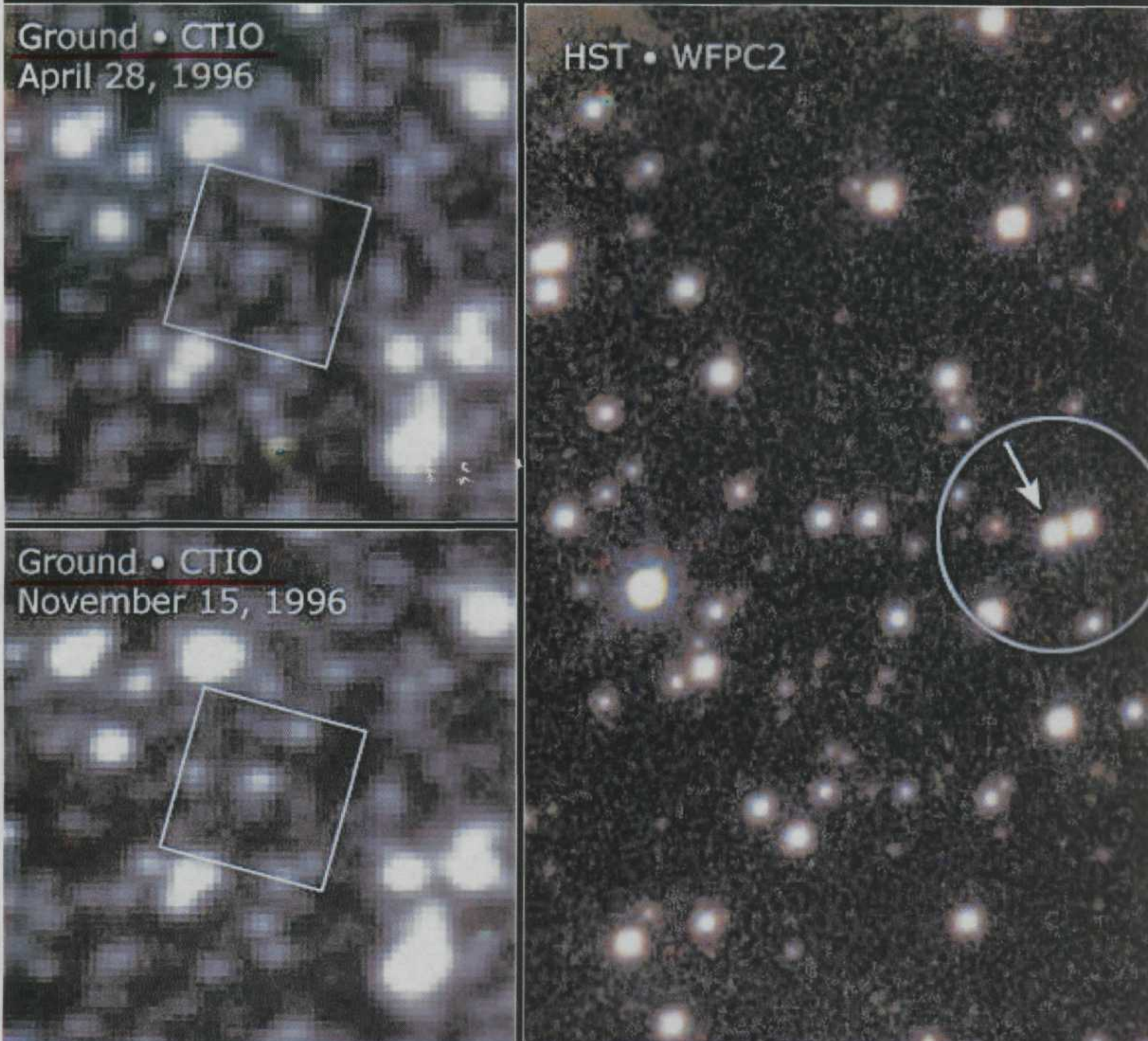


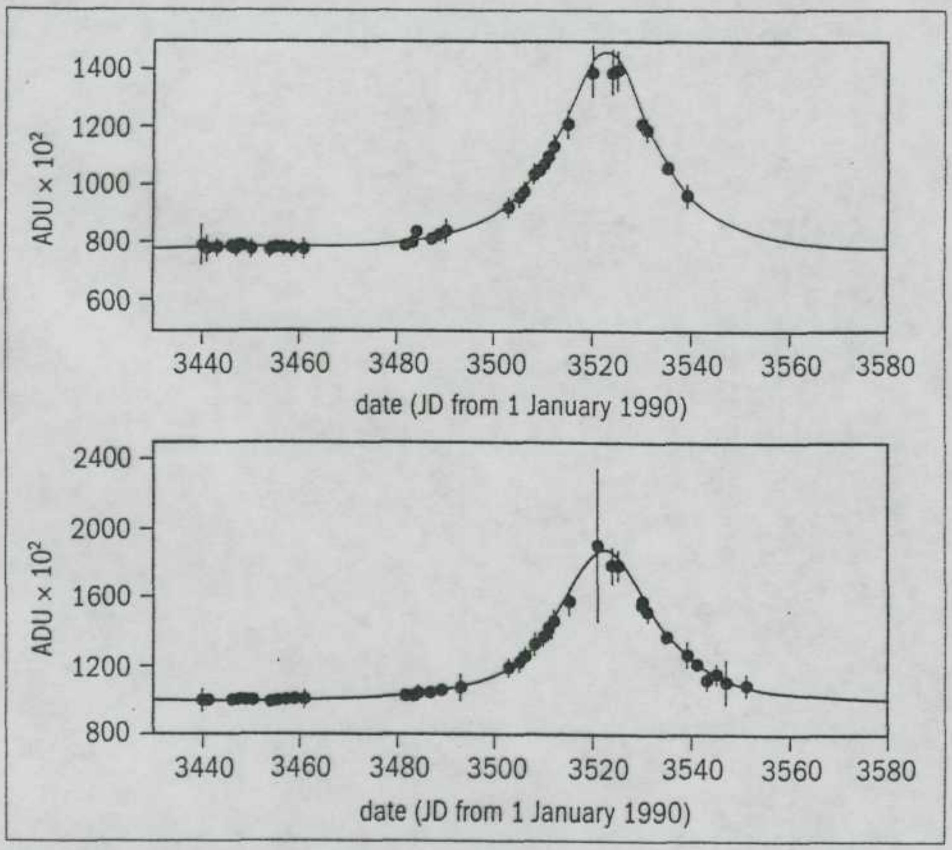
Figure 2: An example of a spectacular microlensing event in the Large Magellanic Cloud, first detected by the MACHO group in May 1999. Left: the position of the corresponding source star is indicated by the cross on this composite image, constructed from 10 EROS images taken many months before the magnification. (The star, barely visible, was not detected by EROS.) Right: the star is magnified by microlensing 40-fold in this image taken two days before maximum magnification.


телескоп.



Microlens Event MACHO-96-BLG-5

NASA and D. Bennett (Notre Dame University) • STScI-PRC00-03



В видимом свете

В красном

Microlensing signal ("light curve") from a bright Galactic Bulge star, as seen by the EROS detector. The blue dots indicate visible light and the red dots show red light. An intervening but otherwise invisible object crossing the line of sight briefly boosts the brightness. Days (horizontal axis) are counted since 1 January 1990. The curves show the best fit to the microlensing hypothesis. The observed magnification is independent of the wavelength.

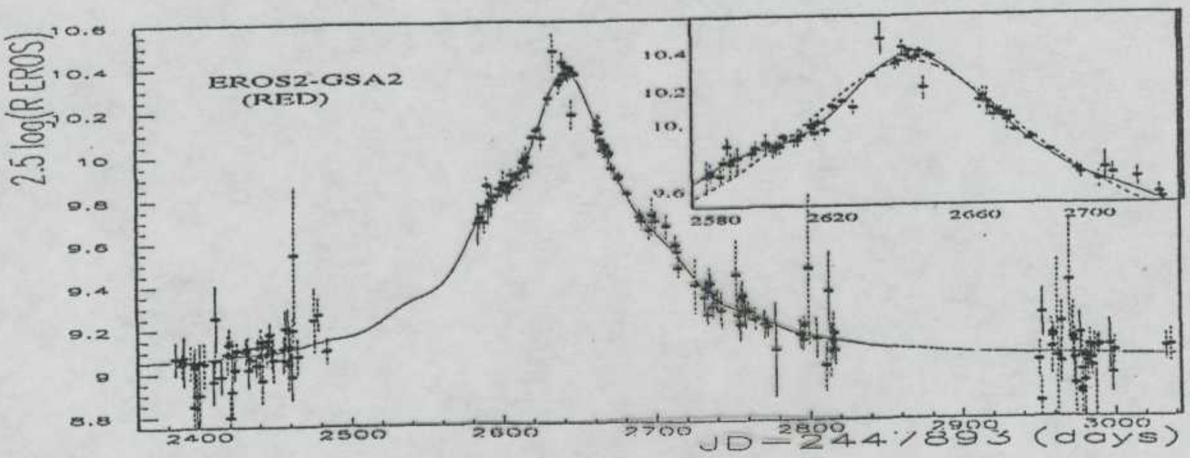


Figure 4. *Red light curve of GSA-2 candidate. The full line shows the fitted microlensing curve taking into account the oscillations due to a dominant source orbiting in a binary system with periodicity $T_0 = 53$ days. The dotted line corresponds to the best standard microlensing fit.*

Микролинзы.

$$\Delta t(days) = 78 \times \left[\frac{V_T}{100 km/s}\right]^{-1} \times \left[\frac{M}{M_\odot}\right]^{\frac{1}{2}} \times \left[\frac{L}{10\ Kpc}\right]^{\frac{1}{2}} \times \frac{[x(1-x)]^{\frac{1}{2}}}{0.5}$$

Δt – время нарастания

V_T – поперечная скорость

M – масса дефлектора

L – расстояние до источника

xL – расстояние до дефлектора.

Эксперименты.

EROS – Expérience de Recherche d'Objets Sombres.

MACHO – Massive Astronomical Compact Halo Objects

OGLE – Optical Gravitational Lensing Experiment

Table 1. Summary of Microlensing Survey Data.

collaboration	sky area (deg^2)	stars (10^6)	time monitored (years)	Events
MACHO LMC	$15 \rightarrow 40$	$12 \rightarrow 22$	5	$14 \rightarrow ?$
MACHO SMC	3	2.3	5	2
MACHO bulge	$25 \rightarrow 40$	$20 \rightarrow 40$	5	$250 \rightarrow ?$
EROS I LMC	25	6	3	2
EROS II LMC	$66 \rightarrow 88$	35	1	?
EROS II SMC	10	5.3	1	2
EROS II bulge	80	56	1	?
EROS II disk	16	12	1	?
OGLE I bulge	?	1.4	~ 2	~ 12
OGLE II LMC	4.2	7	$\sim 3/4$	?
OGLE II SMC	2.3	2	$\sim 3/4$	?
OGLE II bulge	10	30	$\sim 3/4$	?
OGLE II disk	0.7	0.6	$\sim 3/4$	?

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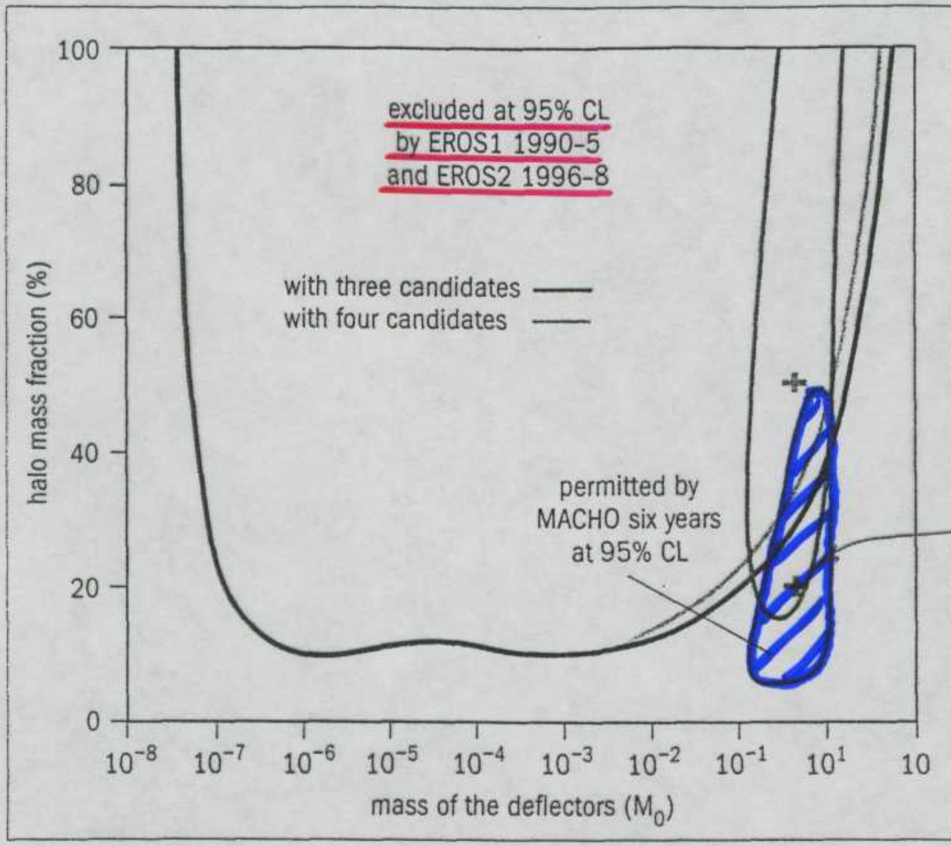

$M = 0.4 M_\odot$

$f \simeq 20\%$

Figure 1: The EROS experiment excludes, at a 95% confidence level, that the galactic halo contains a fraction of objects of solar mass above the plain red curve. (The green curve indicates how the limit would change if the SMC event were due to a halo lens.) MACHO finds a microlensing rate consistent with a mass fraction of 20% and half a solar mass object (blue contour). The orange contour shows the former MACHO result that was compatible with a galactic halo made up of dark objects.