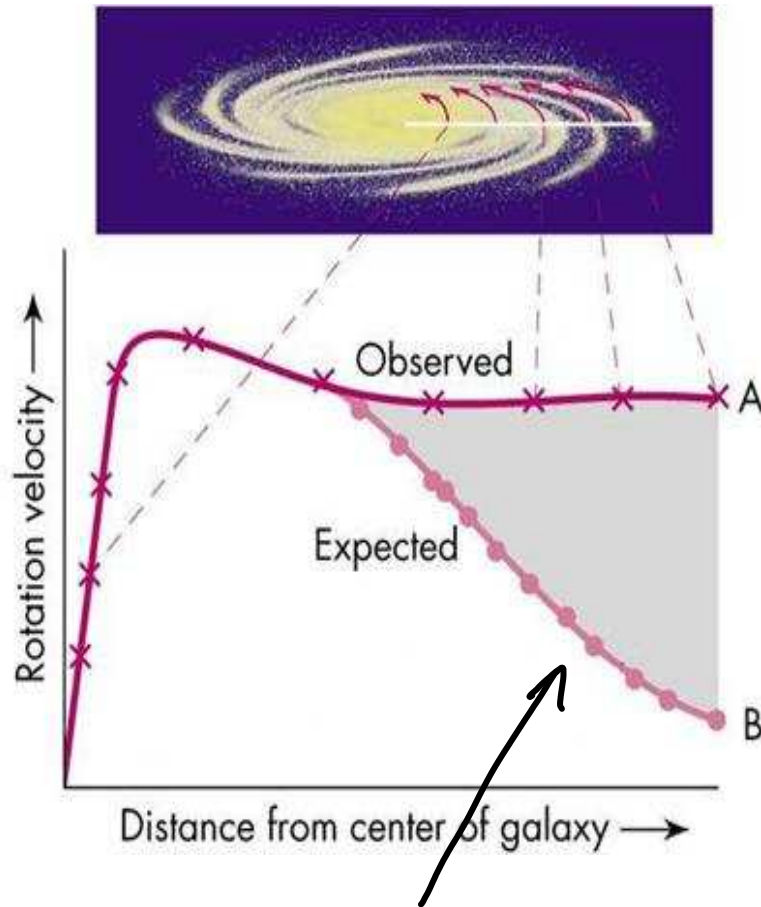


ROTATION CURVES OF SPIRAL GALAXIES:



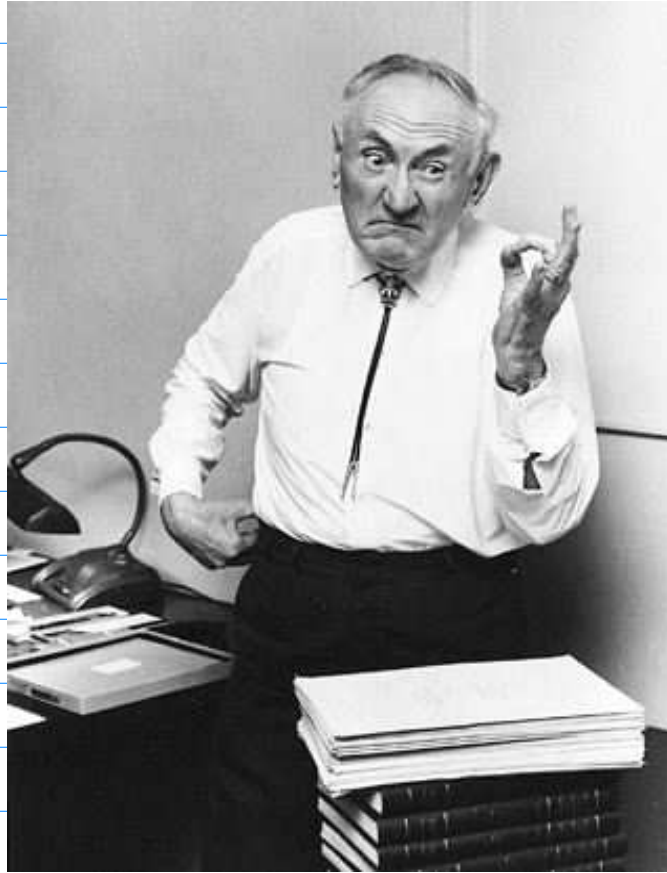
KEPLERIAN ROTATION
CURVE:

$$v = \frac{\sqrt{GM}}{\sqrt{d}}$$

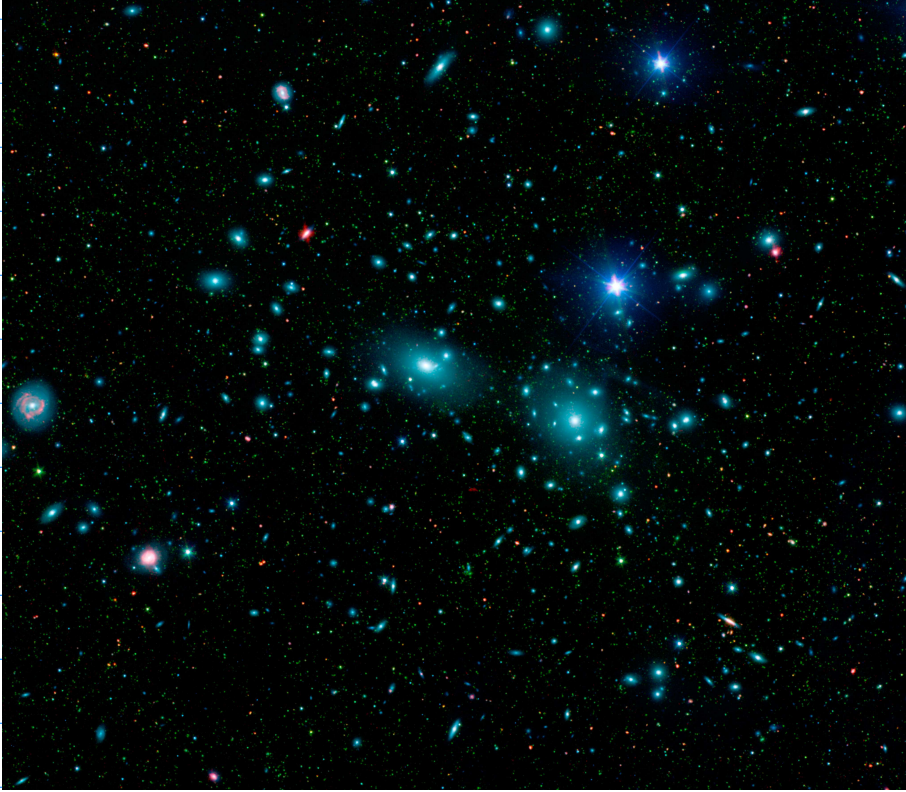
CONCLUSION: THERE IS MASS IN THE GALAXY WHICH DOES NOT EMIT LIGHT - DARK MATTER.

IT IS DISTRIBUTED THROUGHOUT GALACTIC HALO AND ITS MASS IS ABOUT 5 TIMES THE MASS OF THE LUMINOUS MATTER (CONTAINED IN THE STARS).

IN FACT, THE NOTION OF DARK MATTER WAS INTRODUCED IN 1933 BY FRITZ ZWICKY.

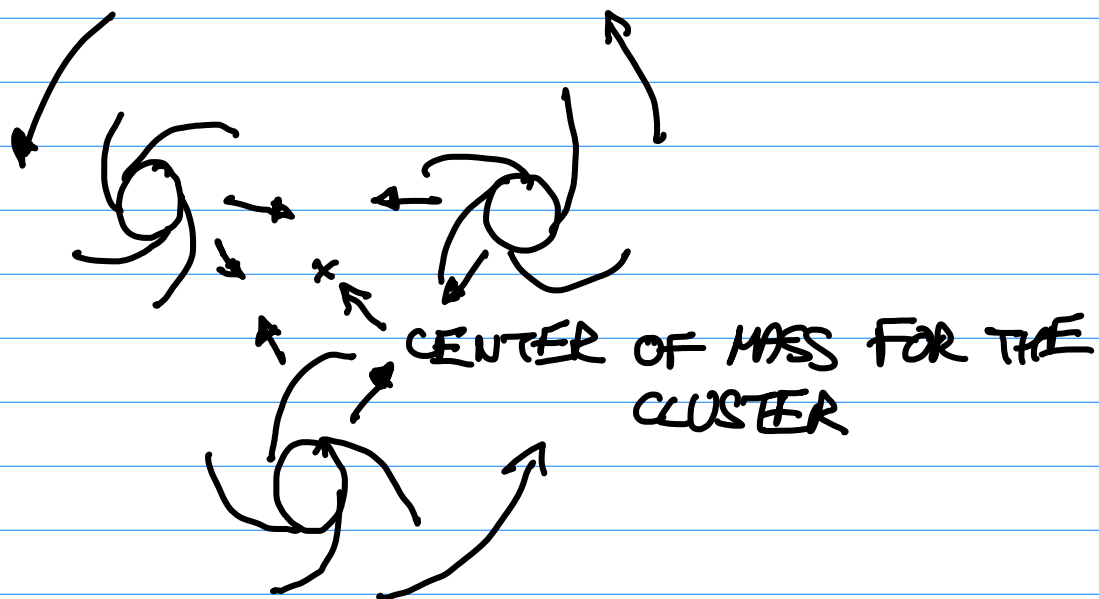


HE OBSERVED THE MOTIONS OF GALAXIES IN A CLUSTER OF GALAXIES CALLED COMA CLUSTER :



COMA CLUSTER

THE GALAXIES IN THE CLUSTER ARE BOUND BY THE FORCE OF GRAVITATIONAL ATTRACTION



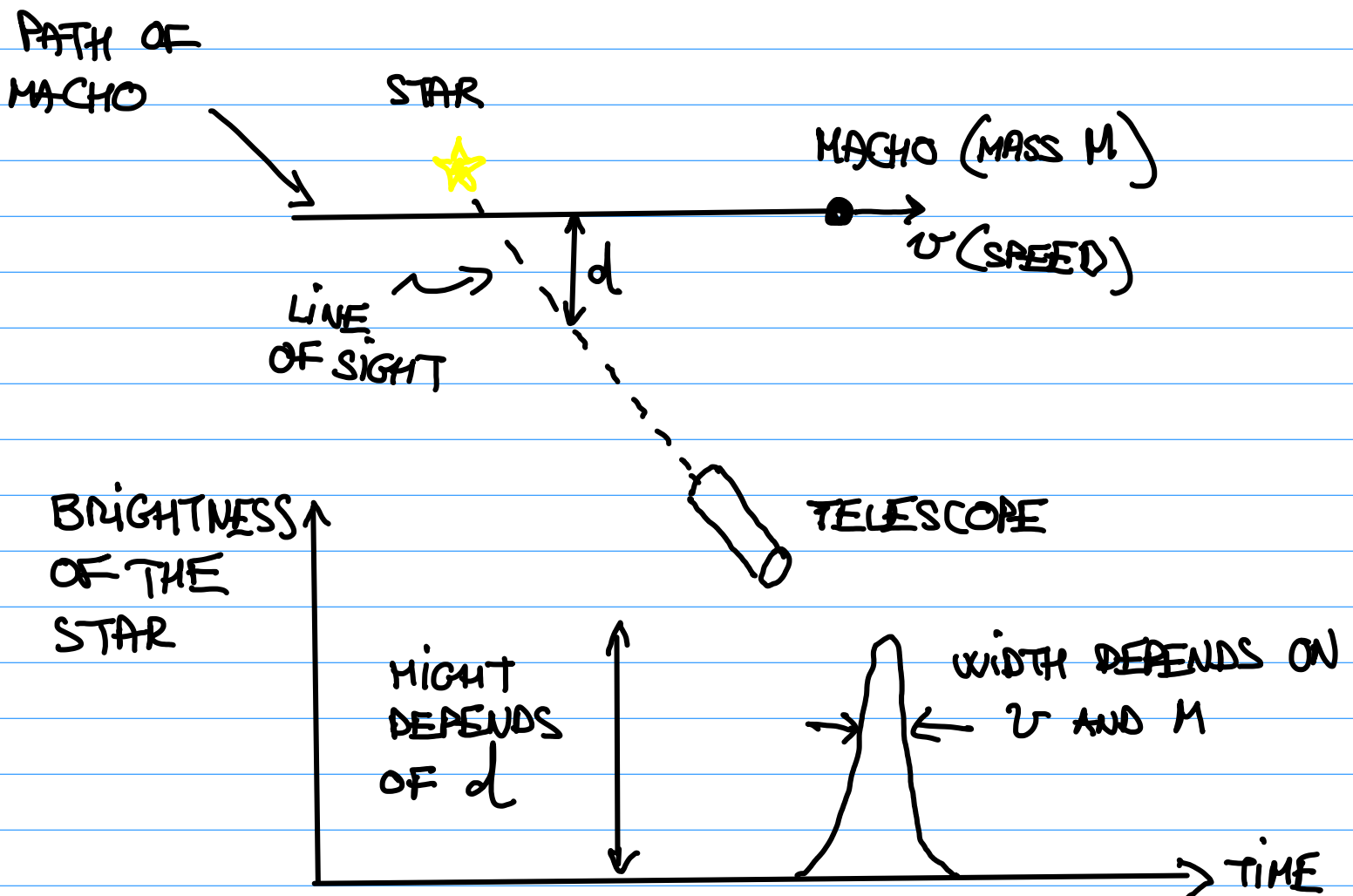
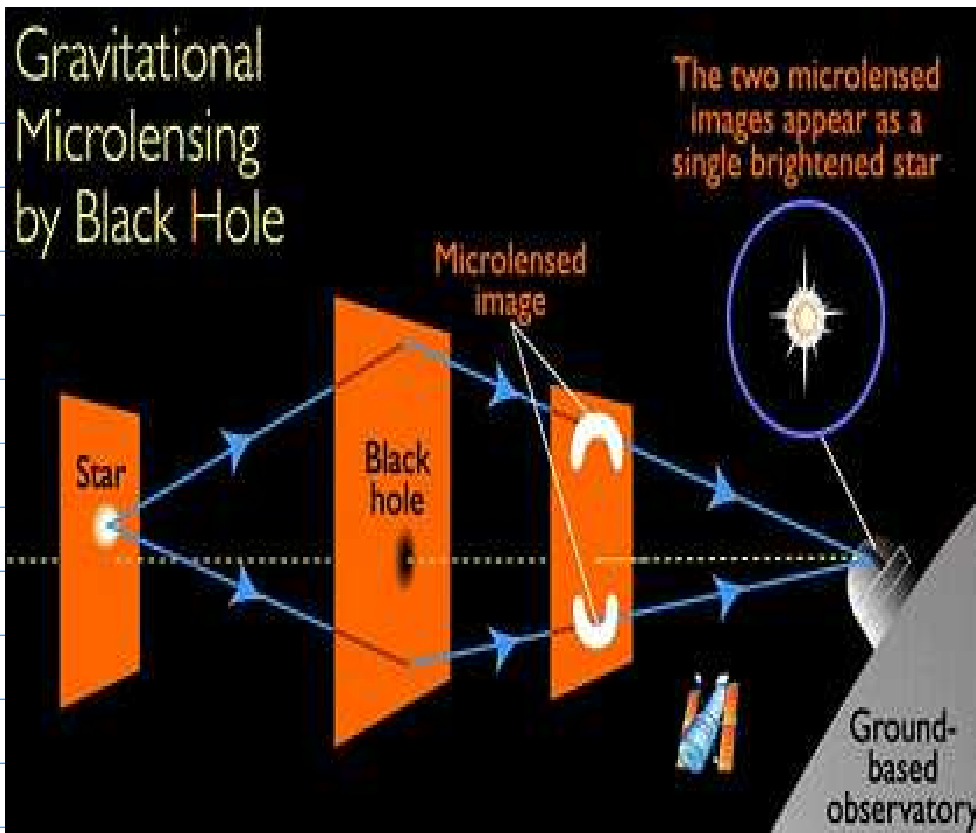
HE OBSERVED THAT THE GALAXIES MOVE TOO FAST IF THE MASS OF THE CLUSTER WAS CONTAINED ONLY IN THE STARS (HE CALCULATED THAT THE LUMINOUS MASS WAS ONLY $\frac{1}{400}$ OF THE TOTAL MASS NEEDED TO EXPLAIN THE ORBITAL SPEEDS OF GALAXIES IN THE CLUSTER). THEREFORE ZWICKY CONCLUDED THAT THERE HAD TO BE "DUNKLE MATERIE" (GERMAN FOR "DARK MATTER") IN THE CLUSTER.

WHAT IS DARK MATTER?

PROPOSALS:

COMPACT OBJECTS
MACHO: BLACK HOLES, NEUTRON STARS, OLD WHITE DWARFS, BROWN DWARFS, JUPITER-SIZED PLANETS
MASSIVE ASTROPHYSICAL HALO

HOW DO WE DETECT A MACHO? BY GRAVITATIONAL MICROLENSING:



RESULTS: THE MACHO CAN ACCOUNT FOR AT MOST 19% OF THE TOTAL MASS OF THE DARK MATTER.

THE OTHER CANDIDATE FOR DARK MATTER ARE

WIMP ← PARTICLES
↑ MASSIVE
↑ INTERACTING
↑ WEAKLY

THEY ARE ASSUMED TO BE MASSIVE PARTICLES WHICH INTERACT WITH OTHER MATTER ONLY VIA GRAVITATIONAL FORCE AND THE WEAK NUCLEAR FORCE.

THEY DO NOT INTERACT VIA ELECTROMAGNETIC FORCE AND THEREFORE THEY DO NOT PRODUCE LIGHT. SINCE THEY INTERACT WITH ORDINARY PARTICLES ONLY VIA THE WEAK NUCLEAR FORCE, THEY ARE HARD TO DETECT. SO FAR NO WIMP HAS BEEN DETECTED. THUS, REALLY, WE DO NOT KNOW WHAT THE DARK MATTER IS.

COMPOSITION OF THE UNIVERSE: 5% ORDINARY MATTER
27% DARK MATTER
68% DARK ENERGY