Generalized Gauss's Law of Gravity with a Conserved and Re-distributed Field Flux of a Transition to Non-spherical Equipotential Surface

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Outline

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- **Background Observations**: **Flat rotation curve, Baryonic Tully-Fisher relation**

- **Model: 1. Gravitational field flux Re-distribution with Cylindrical Gaussian surface**
- **2. Cylindrical to Spherical transition of the Gaussian Surface**

- **Structural Correlation Between Flux model, Rotation curve and Radial acceleration curve**

- **Summary**
- **A field flux picture with generalized Integral Gauss's law of gravity is proposed for**
- **solving mass discrepancy problem of disk galaxies.**

- **Discussions:**
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- **Discussion 2:** The "Cylindrical to Spherical transition" may also occur in the time evolution of galaxies?
- **Discussion 3:** Internal Instability of the Secular evolution of disk-shaped system

Gauss’s law and Field Flux Distributions

Gauss’s law :

The inverse square rule of Electromagnetism and Gravity **:**
field strength is defined by area density of the **flux** through a closed spherical surface containing the mass or electric source.

Newtonian field: $g > 10^{-10}$ N/Kg (m/s^2)

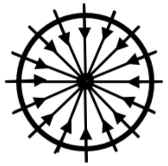
$$F = \frac{GMm}{r^2}$$

Isaac Newton
(1687)

Newtonian field:
Spherical Flux distribution

(2D schematics)

$$g = \frac{4\pi GM}{4\pi r^2} = \frac{GM}{r^2}$$



The inverse square dependence of the Gauss’s law of Gravity and the spherical distribution of the **field flux** through a Gaussian surface.

***Gravitational Field Flux*:**

$$\oiint \boldsymbol{g} \cdot d\boldsymbol{A} = 4\pi GM (= \Phi_G)$$

$$(\nabla \cdot \boldsymbol{g} = 4\pi G\rho \; ; \; \rho = M/V)$$

Carl Friedrich Gauss
(1835)

(A non-relativistic field approach)

Conserved Gravitational Field
Flux Re-distribution

Background Experiments FACT I: Flat Rotation Curves

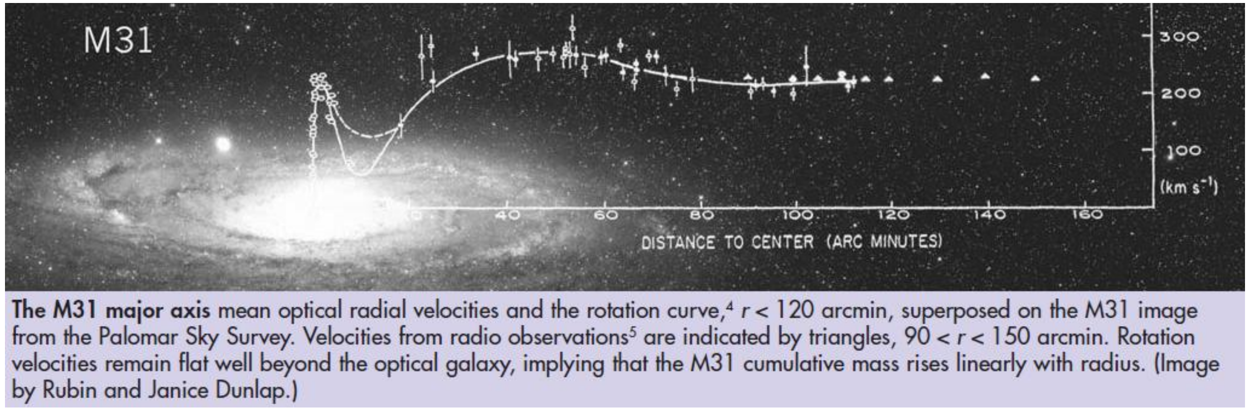


Fig. 1. The rotation curve of Andromeda Galaxy (M31).

HSB: Flat Rotation Curves

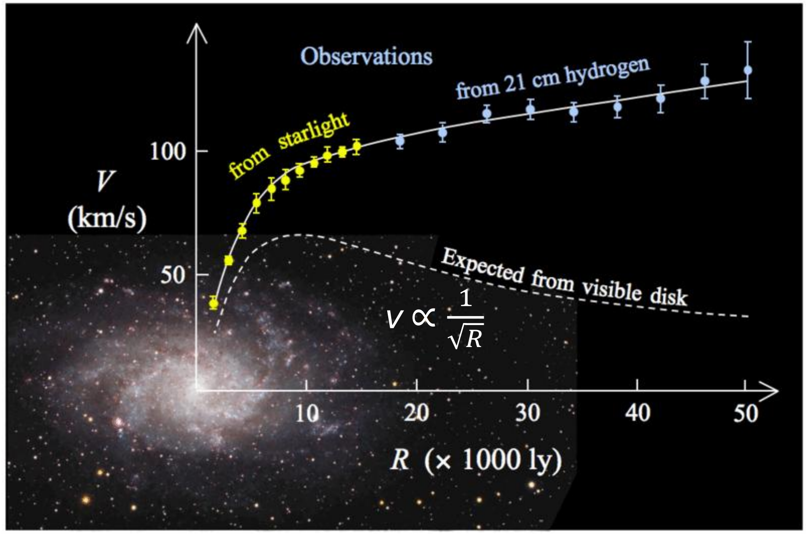


Fig. 2. The observed rotation curve of M33 and a predicted curve.

LSB: Rising Rotation Curves

Keplerian Rotation Curves

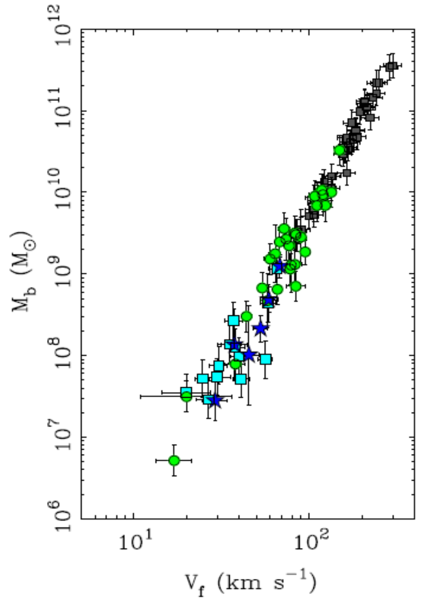
Ref.1. "Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions", Rubin, Vera C.; Ford, W. Kent, Jr., The Astrophysical Journal, 159:379(1970).

Ref.2. "Seeing dark matter in the Andromeda Galaxy", Vera Rubin, Physics Today, December 8(2006).

Background Experiments FACT II:

Baryonic Tully Fisher Relation and Faber Jackson Relation

“Baryonic mass proportional to the flat rotation velocity to the power of approximately 4”, a direct relation between the normal matter and the non-Newtonian dynamics.



$$M_b = A\,V_f^{\,4}$$

$$A=47\pm4\ \ M_\odot km^{-4}s^4$$

$$\sim 0.95 * 10^{20}\ Kg/(m/s)^4$$

Fig.3 Baryonic(stars and gas) mass as a function of circular velocity.

Ref.3. “The Baryonic Tully-Fisher Relation of gas-rich galaxies as a test of ΛCDM and MOND”, Stacy S. McGaugh, The Astronomical Journal, 143:40 (2012)

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VELOCITY DISPERSIONS AND MASS-TO-LIGHT RATIOS FOR ELLIPTICAL GALAXIES*

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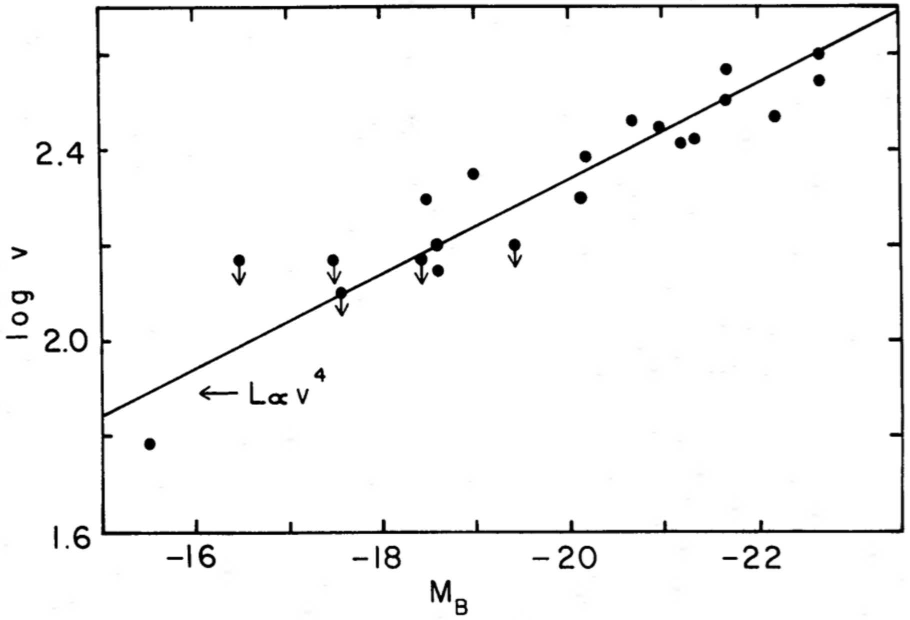


FIG. 16.—Line-of-sight velocity dispersions versus absolute magnitude from Table 1. The point with smallest velocity corresponds to M32, for which the velocity dispersion (60 km s^{-1}) was taken from Richstone and Sargent (1972).

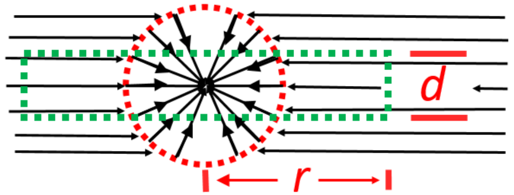
Model (Disk Galaxies)

Gaussian Disk of Gravitational Field Flux **for Flat Rotation Curve**

Cylindrical Flux distribution

$$\underline{g} = \frac{4\pi G M_d}{2\pi r d} = \frac{2 G M_d}{\underline{rd}}$$

(Side view schematics of disk galaxy)



Red dot boundary: **critical field strength** $(g_c \sim 10^{-10}\ N/Kg)$

$4\pi G M_d$ represents a fixed amount of gravitational Field flux entering the Gaussian disk from the side wall, shown above as **the green dot disk**, with thickness *d* and radius *r*.

Rotation curve from Gauss's law with **Cylindrical Flux distribution**

$$g = \frac{2GM_d}{rd};\ a_c = \frac{v^2}{r};\ g = a_c \rightarrow \frac{2GM_d}{v^2} = d\ ;\ v = \sqrt{\frac{2GM_d}{d}}$$

(v →flat as $\frac{M_d}{d}$ is fixed)

(For the milky way galaxy, the **Gaussian disk thickness** is approximately 30K light years, ~10 times of the visible bulge diameter.)

Model (Disk Galaxies)

Spherical to Cylindrical Transition of Flux Distribution **for Tully-Fisher Relation**

Spherical to cylindrical flux distribution transition across the critical field:

$d_c \rightarrow 2R_c$: *disk flux* $4\pi G M_d \rightarrow$ *total flux* $4\pi G M$;

At g_c *(red dot circle)*: $g_c = \frac{GM}{{R_c}^2} \sim \frac{4GM}{{d_c}^2} = \frac{\boldsymbol{v}^4}{\boldsymbol{GM}}$

$d_c \rightarrow 2R_c$

$\left(\text{for } \textbf{disk}: g = \frac{2GM}{Rd} = \frac{v^2}{R} \rightarrow \text{thickness } \; d = \frac{2GM}{v^2}\right)$

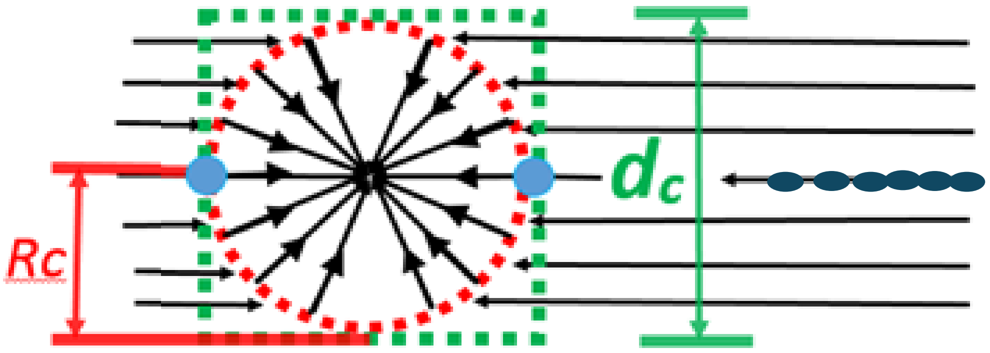
Flatness of the velocity, $\boldsymbol{v} = \boldsymbol{v_f}$

$\rightarrow \boldsymbol{M} = \left(\frac{\mathbf{1}}{\boldsymbol{G g_c}}\right) \boldsymbol{v_f}^{\mathbf{4}}$ → **Tully-Fisher Relation !**

$\left(\frac{\mathbf{1}}{\boldsymbol{G g_c}}\right) \sim 10^{20}\ Kg/(m/s)^4.$

at a critical field strength $\boldsymbol{g_c}$,

Tully-Fisher relation



At the critical transition points, regions shown as **red dots**, the flux distribution experiences a spherical to cylindrical transition. The Tully-Fisher relation is proved valid according to this condition and the flatness of the velocity at extended radius as shown in blue spots.

Model (Elliptical Galaxies/Disk Bulge)

For Faber-Jackson relation in centers of elliptical galaxies or core bulges of disk galaxies

If a critical field strength g_c is assumed within the circular radius R_c , then a velocity dispersion $\boldsymbol{v_d}$ should be hold within this transition region of Newtonian gravity:

$$g_c{}^2 = g_c \frac{GM}{R_c{}^2} = (a_c)^2 = \frac{\boldsymbol{v_d}^4}{R_c{}^2} \rightarrow \boldsymbol{v_d}^4 = g_c\, GM$$

(a_c): centripetal acceleration of the stellar circular motion.

Considering the non-planar oriented motion in the bulge of disk galaxies or core of elliptical galaxies, we have the velocity dispersion measured as Faber-Jackson relation:

$$< \boldsymbol{v} >^4 = g_c\, GM$$

Necessary mechanical properties of Gravitational flux lines

1. Flexibility:

For the flux lines to bend across the transition between Spherical and Cylindrical distribution.

2. Lateral repulsion

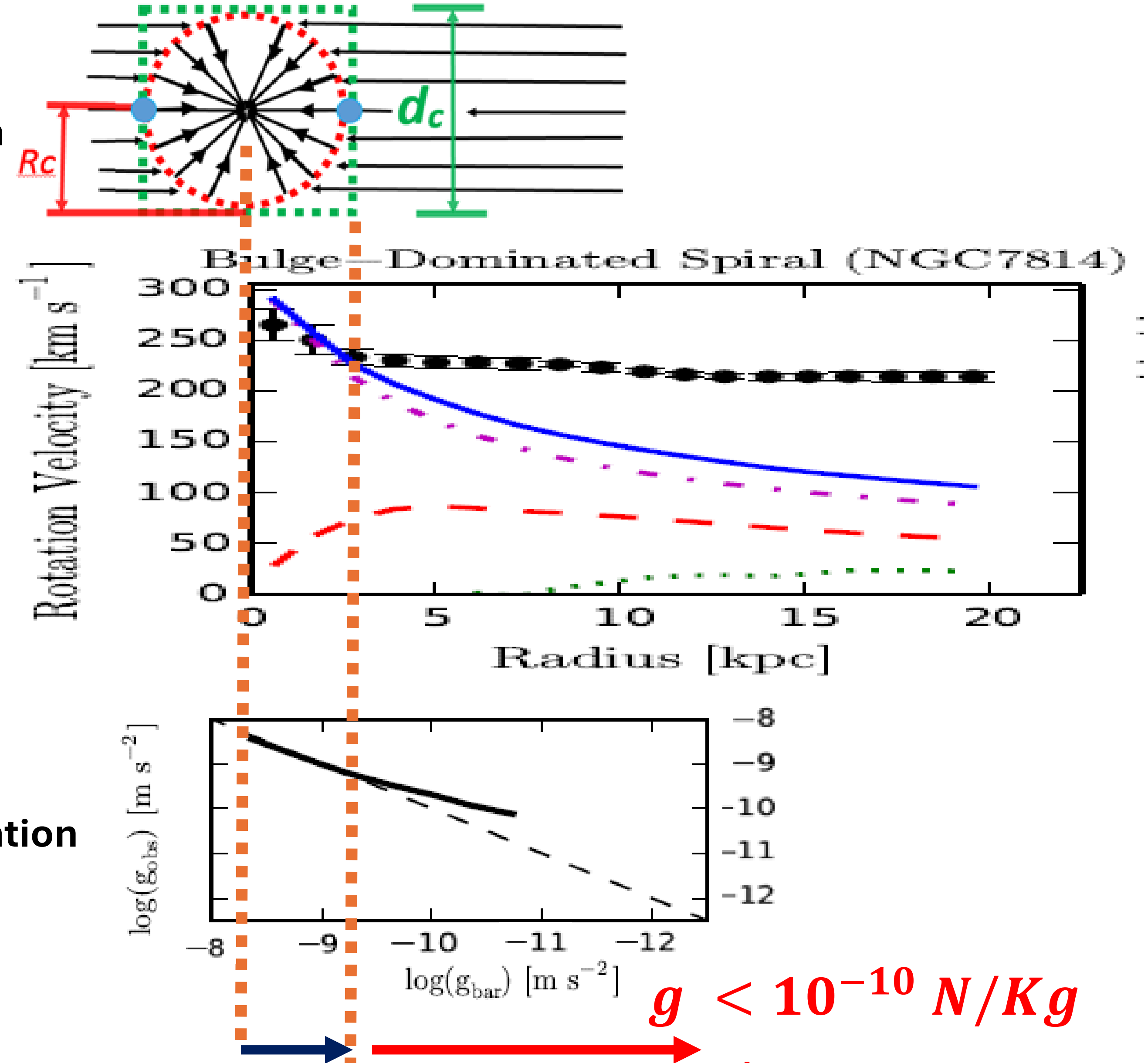
For the area density of flux lines to have a minimum to hold the spherical distribution, higher than this “critical Density g_c”, the flux lines would repel each other along the radial direction to form the spherical distribution.

Spatial Correlation Between Flux model, Rotation curve and Radial acceleration curve

Flux Distribution

Rotation Curve

Radial Acceleration



$g < 10^{-10}\ N/Kg$

Newtonian Non-Newtonian

Discussion 1:

Field Flux converging, as the equipotential Gaussian surface resembles the spatial structure,
from spherical distribution to cylindrical to 1D tube filament to mend the missing mass problem for larger scales.

For example, cluster of galaxies: Gaussian surface area reduction
(Field Flux converging from 3D spherical→ 2D cylindrical → 1D linear)
may further yield a lower value of the needed minimum cluster mass by modifying the Virial theorem 2T+V=0 of 1/r potential.

Discussion 2:

The “Cylindrical to Spherical transition” may also occur in the temporal evolution of galaxies?

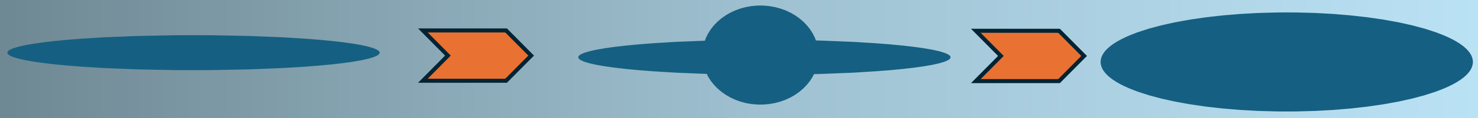
Gravitational field flux distribution evolution

Cylindrical flux distribution

Cylindrical flux distribution
With core Spherical flux distribution

Spherical flux distribution

Galactic Structural evolution



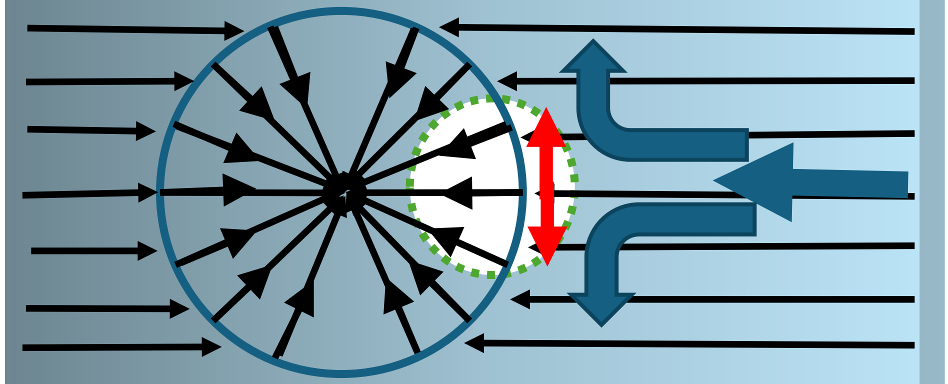
Disk

Disk with core bulge

Elliptical

Discussion 3:

Internal instability caused by cylindrical to spherical transition of flux distribution at Bulge boundary region



(Intrinsic) Instability

Summary

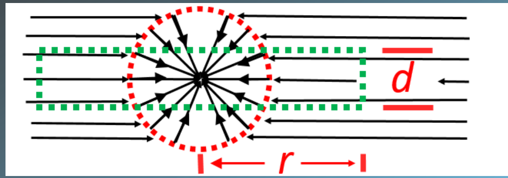
A field flux picture with generalized Integral Gauss's law of gravity is proposed for solving mass discrepancy problem of disk galaxies.

1. Flat rotation curve of disk galaxies: a cylindrical distribution of the gravitational field flux.
   The radius dependence of the field strength becomes 1/r, instead of Newtonian 1/r^2.
   In addition: a disk thickness dependence of the field strength is suggested.

2. Below a critical field ~$10^{-10}\ N/Kg$(which is a minimum area density for flux lines to maintain spherical distribution,
   the gravitational flux distribution turns from spherical to cylindrical. The Tully-Fisher relation can be obtained from this transition.

3. From radial acceleration relation of disk galaxies, with or without bulge, a structural-dynamical
   correlation can be explained by a flux distribution transition across the critical field.

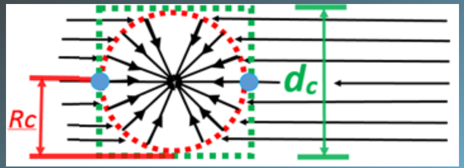
1



$$g=\frac{2GM_d}{rd} = a_c = \frac{v^2}{r} \rightarrow \frac{2GM_d}{d} = v^2$$

$$v = \sqrt{\frac{2GM_d}{d}}$$ (v →flat @$\frac{GM_d}{d}$ fixed)

2



$$g=\frac{2GM}{Rd} = \frac{v^2}{R} \rightarrow d = \frac{2GM}{v^2}$$

$$g_c = \frac{GM}{R_c^2} \sim \frac{4GM}{d_c^2} = \frac{v^4}{GM}$$

$$v = v_f \rightarrow M = \left(\frac{1}{Gg_c}\right) v_f^4$$

3