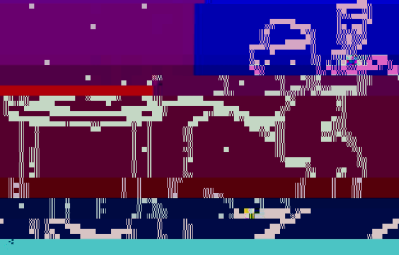
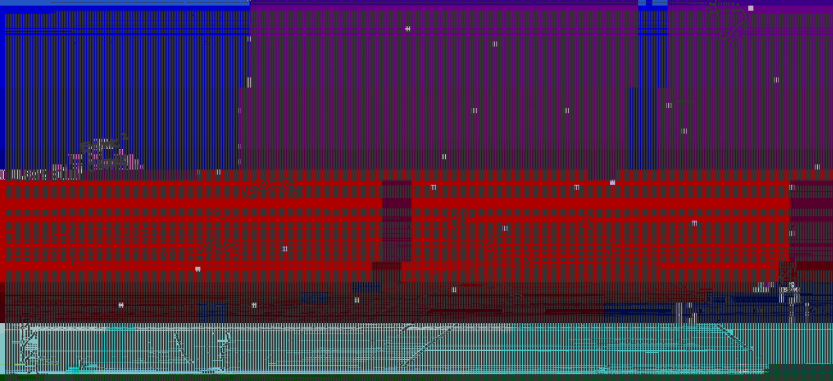


2019-2020 COVID-19

2020-2021 COVID-19

2019-2020 COVID-19



100%

2019-2020 COVID-19

2019-2020 COVID-19

2020-2021 COVID-19

100%

2019-2020 COVID-19

2020-2021 COVID-19

100%



with which galaxy  $x$  recedes from our galaxy is proportional to the speed  $v$  it is moving away from our galaxy. The speed  $v$  is constant in units of  $c$ :

$$v = H_0 r$$

where  $H_0$  is a dimensionless number  $\approx 1$ ,  $r$  is the distance from our galaxy, and  $G$  is the gravitational constant. Both  $H_0$  and  $G$  are dimensionless.

physicist Einstein found a non static solution of Einstein's equation

which was the first step towards the general theory of relativity. In this theory, the geometry of space and time is determined by the distribution of matter and energy. The theory predicts that the universe is expanding, which is in agreement with the observations of galaxies.

filled with a constant magnetic field. Its direction is in the radial direction. The theory predicts that the universe is expanding, which is in agreement with the observations of galaxies. The theory also predicts that the universe is homogeneous and isotropic.

a ROBERTSON-WALKER'S spacetime.

dimensional manifold  $(S, g)$  (the "spatial part" of the spacetime) is a Riemannian manifold. The spacetime is a product  $(\mathbb{R} \times S, g)$  plays the role of a spacetime instead of cosmological time which the actual universe is similar to.

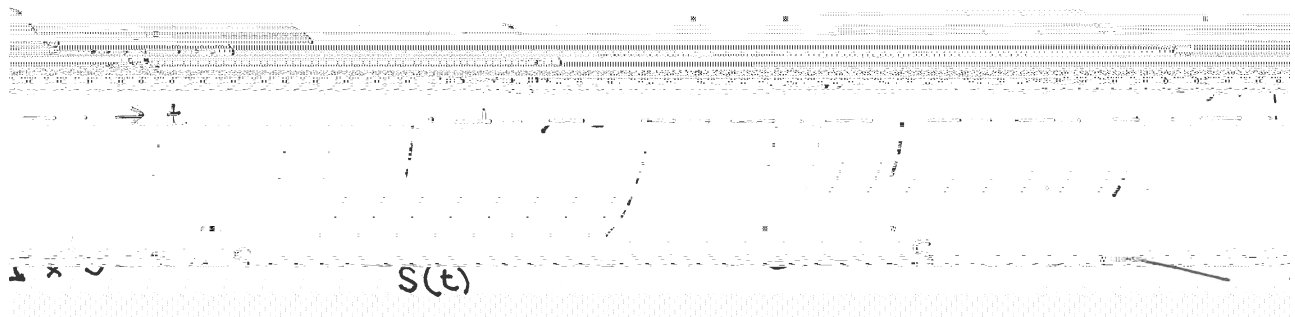
where  $(\mathbb{R} \times S, g)$  is a (hyperbolic 3-space) = open universe

= flat universe

$K = 0$   $S = \mathbb{R}^3$

Space-time is the Cartesian product  $M = \mathbb{R} \times S$ .

is of a space  $S(t)$  visualized as the surface



parameterized curve:

Fig 1.  $\gamma(t) = (t, K)$

lift of the unit vector field on  $\mathbb{R} \times M$ .

... in some way at the ...

$\langle U, U \rangle = -1$

and along  $S_{\text{gal}}$  along  $U$

Following definition of a Robertson-Walker space-time

and (4).]

Robertson-Walker space-time? Well, can we do with a space-time of the following type.

Let  $X$  and  $Y$  be two galaxies. Let  $u, v, x$  be their place in the standardized universe  $S$ . Then their radial distance  $R$  at time  $t$  is given by

$$R(t) = f(t) \phi(x, y) \quad (6)$$

Differentiating (6) we obtain

$$\dot{R} = \dot{f} \phi + f \dot{\phi} \quad (7)$$

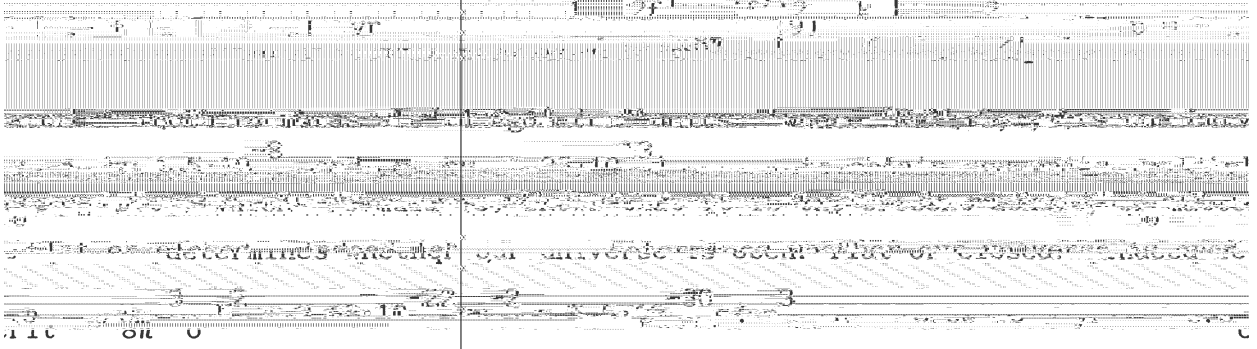
the function

present instant of cosmological time.

density

$$\rho = \frac{3}{8\pi} \left[ \left( \frac{\dot{f}}{f} \right)^2 + \frac{k}{f^2} \right] \text{yr}^{-2} \quad (8)$$

and pressure



where

Thus we conclude

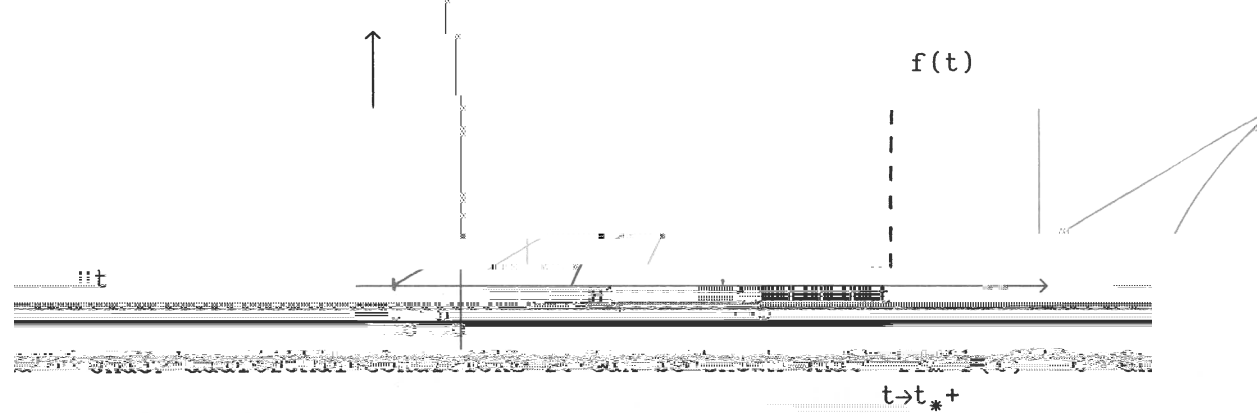
live in an open universe.

Figure 1

Figure 2

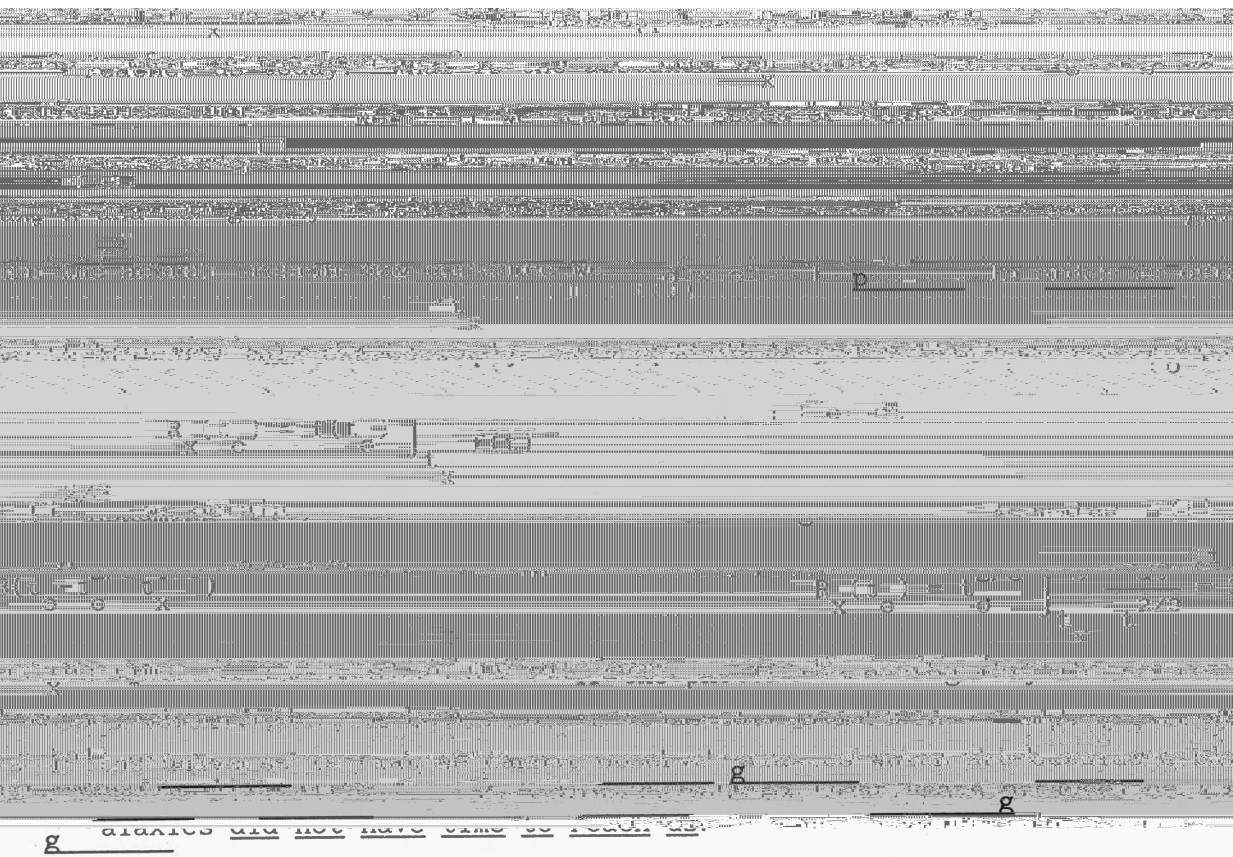
Figure 3

Figure 4



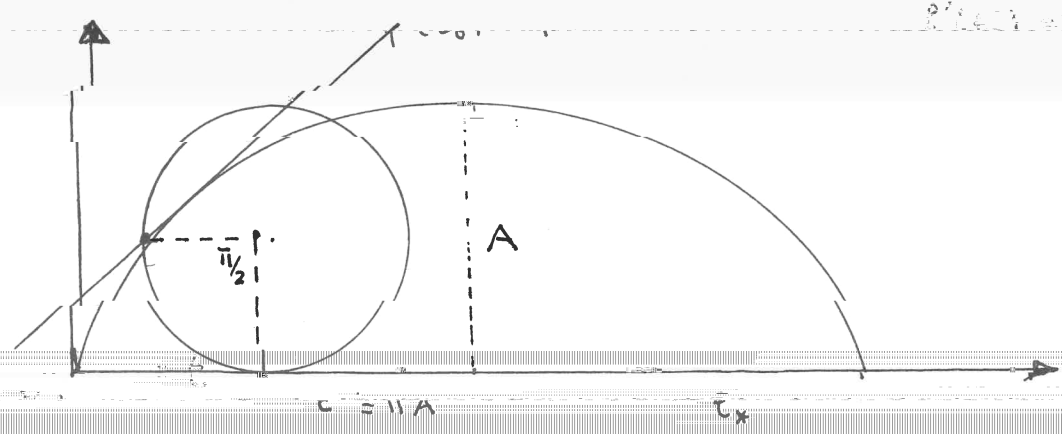
$\lim_{t \rightarrow t_*^+} r(t) = \infty$  i.e. that the singularity is a big bang (cf. Barrett)





g

$$f(t) = A/2(1 - \cos\theta) \quad (12a)$$



$$\int_{\pi/2}^{\pi} \frac{d\theta}{1 - \cos\theta}$$

10 years to go!

we still have ~103

Literature:

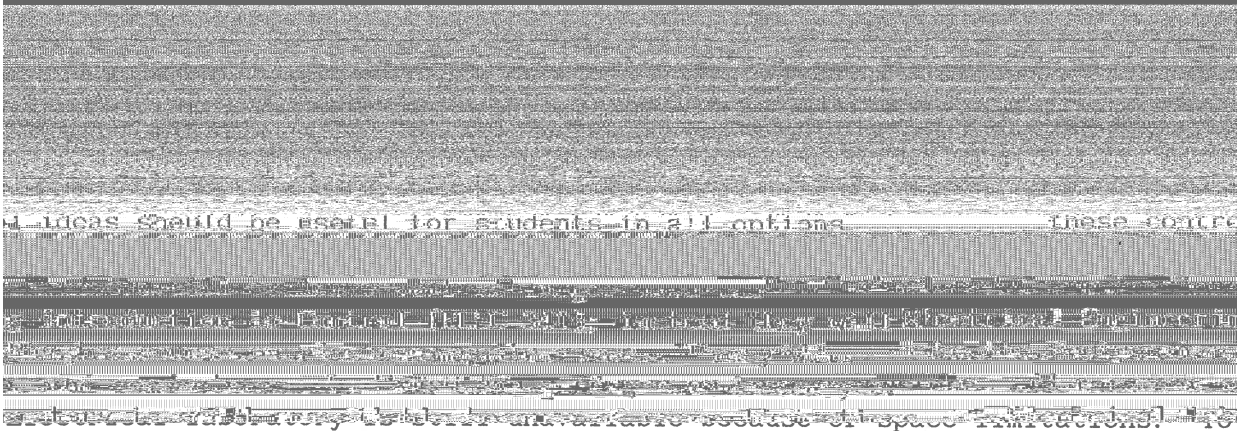
Barrett O'Neill: Semi-Riemannian Manifolds with Application to Relativity  
AP 1984.

ery serious about this.

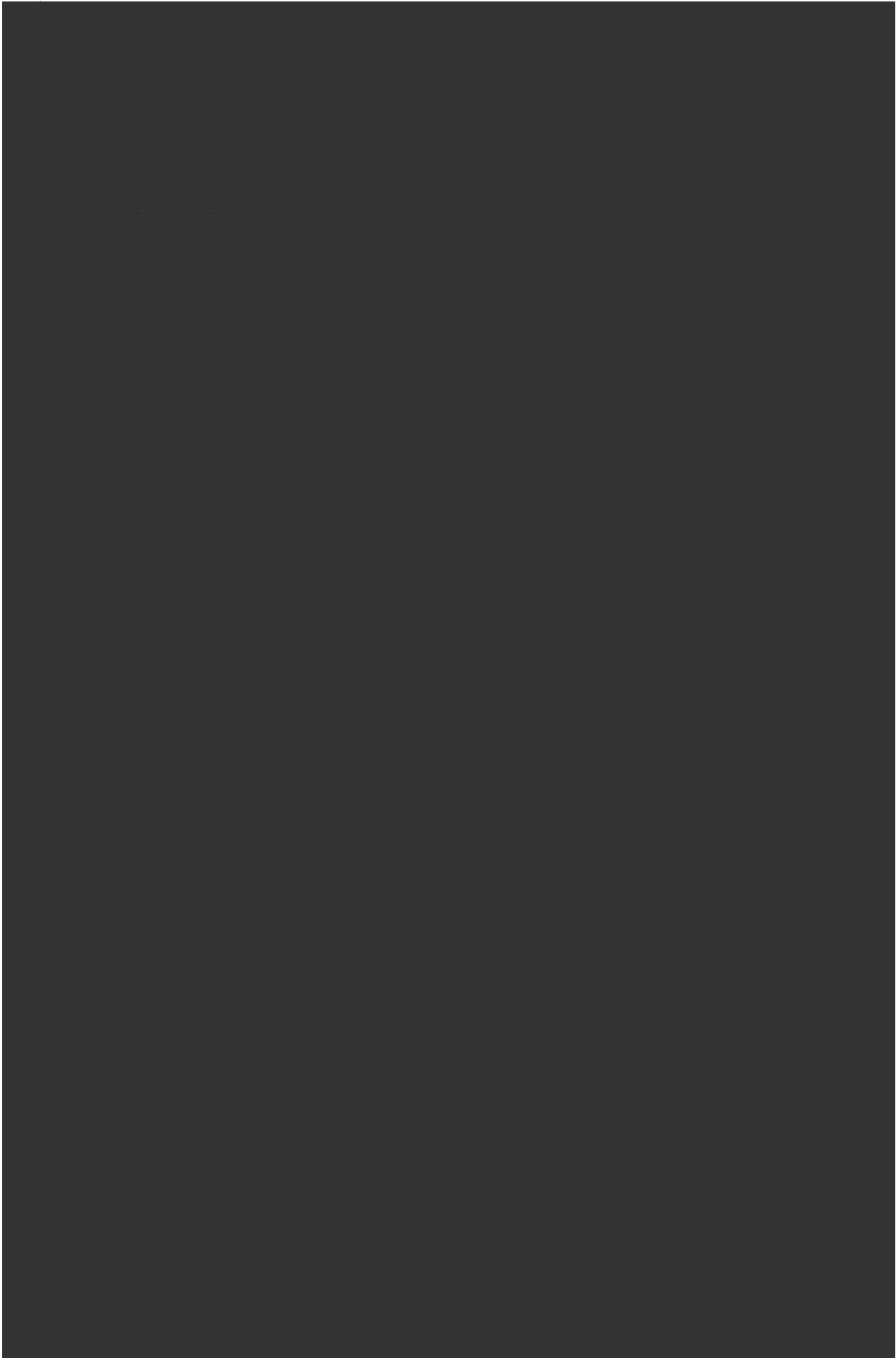
ray 101: 1 m v

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the Committee.



(D. Norman)

FOUR NEW START MEMBERS

10

(N. Rice)

(M. Gillis)

NEWS

12

(COVER: R. R. Erdős, "The Restaurant at the End of the Universe").

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