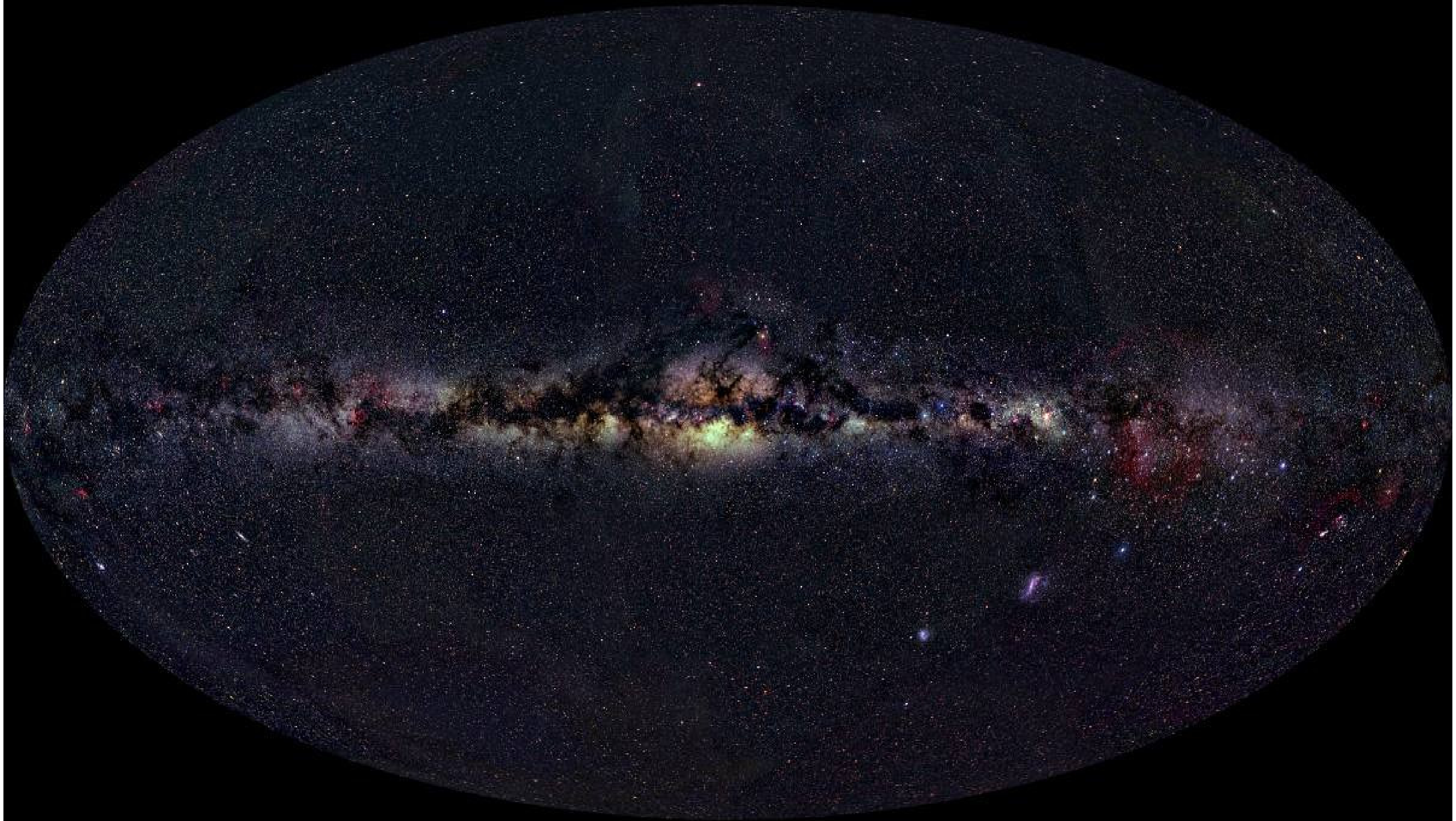
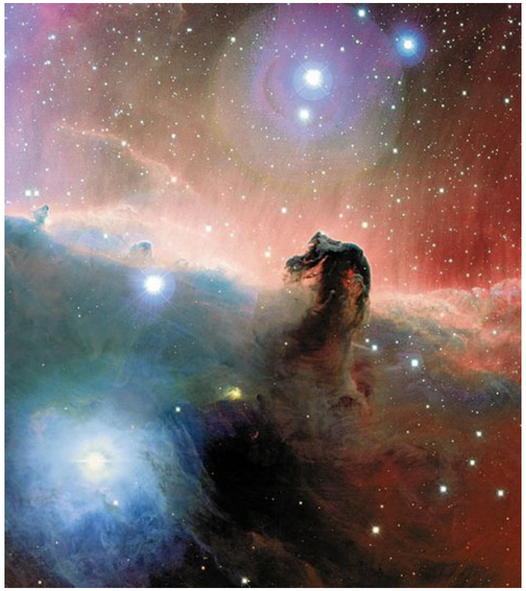
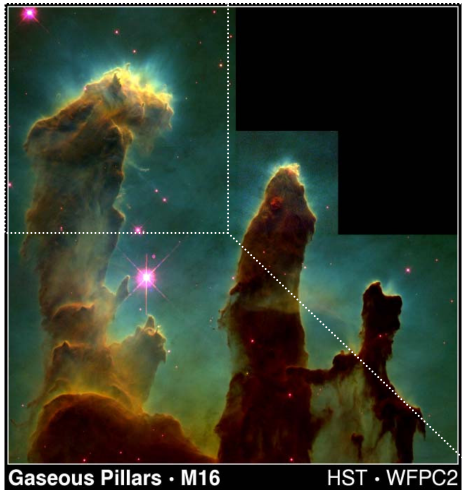
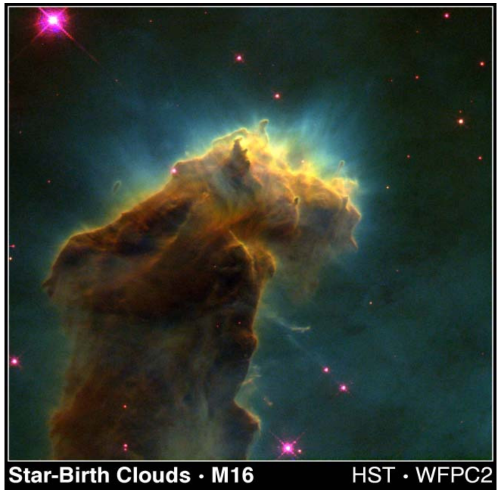
# *Das molekulare Gas in Galaxien*



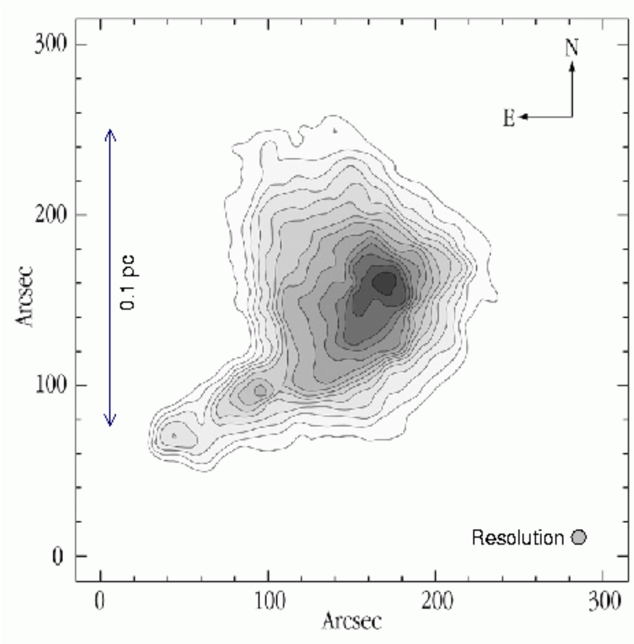
Staub im molekularen Gas **absorbiert** das Licht der Sterne





# *Barnard 68*



Map of the Obscuration in the Dark Cloud B68

(Alves et al. 2001)

| | |
|---|---|
| Entfernung: | 125 pc |
| Radius: | 12500 AU |
| Masse: | $2.1\, M_\odot$ |
| Dichte: | $1.5 \cdot 10^{-19}\ g\ cm^{-3}$ |
| Temperatur: | 16 K |

# Die Bonnor-Ebert Sphäre

**Hydrostatisches Gleichgewicht:**

$$\frac{dP}{dr} = -\rho \frac{GM(r)}{r^2}$$

**Isotherme Zustandsgleichung:**

$$P = n\,R_g T = \frac{\rho}{\mu} R_g\, T = \rho\, c^2$$

Schallgeschwindigkeit

$$c^2 \frac{1}{\rho}\frac{d\rho}{dr} = c^2 \frac{d\ln\rho}{dr} = -\frac{GM(r)}{r^2}$$

$$\frac{d}{dr} r^2 \frac{d\ln\rho}{dr} = -\frac{G}{c^2}\frac{dM}{dr} = -\frac{G}{c^2}\cdot 4\pi\, r^2 \rho$$

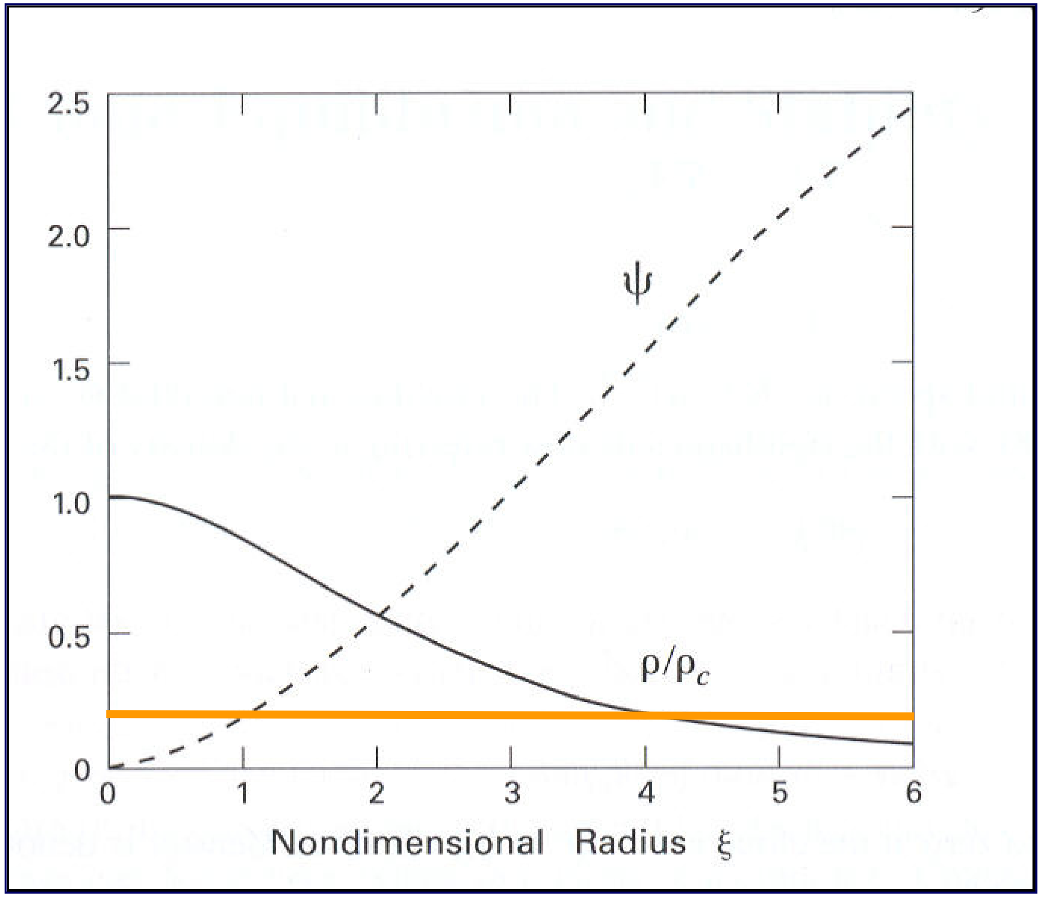
$$\boxed{\frac{1}{r^2}\frac{d}{dr} r^2 \frac{d\ln\rho}{dr} = -\frac{4\pi G}{c^2}\rho}$$

$$\frac{1}{r^2}\frac{d}{dr}r^2\frac{d\ln\rho}{dr} = -\frac{4\pi G}{c^2}\rho$$

Es sei: $\rho = \rho_c \cdot \exp(-\Psi)$ $\quad \xi = \left(\frac{4\pi G\rho_c}{c^2}\right)^{1/2} r$

$$\boxed{\frac{1}{\xi^2}\frac{d}{d\xi}\left(\xi^2\frac{d\Psi}{d\xi}\right) = \exp(-\Psi)}$$

(*Lane-Emden Gleichung*)




- Der Druck $P = \rho \cdot c^2$
  fällt **monoton** nach außen ab.
- **Rand** der Wolke dort, wo
  innerer Druck = externer Druck:

$$P_0 = \rho(\xi_{max}) \cdot c^2 = \rho_0 \cdot c^2$$

$$\rightarrow \quad \boxed{r_{max} = \xi_{max} \cdot \left(\frac{c^2}{4\pi G\rho_c}\right)}$$

## Die Masse der BE-Sphäre:

$$\boxed{\xi = \left(\frac{4\pi G\rho_c}{c^2}\right)^{1/2} r}$$

$$M = 4\pi \int_0^{r_{max}} \rho\, r^2 dr = 4\pi\rho_c \left(\frac{c^2}{4\pi G\rho_c}\right)^{3/2} \int_0^{\xi_{max}} e^{-\Psi}\xi^2\, d\xi$$

$$\boxed{\rho = \rho_c \cdot \exp(-\Psi)}$$

Mit $\frac{1}{\xi^2}\frac{d}{d\xi}\left(\xi^2 \frac{d\Psi}{d\xi}\right) = \exp(-\Psi)$ folgt:

$$\int_0^{\xi_{max}} e^{-\Psi}\xi^2 d\xi = \int_0^{\xi_{max}} \frac{d}{d\xi}\left(\xi^2 \frac{d\Psi}{d\xi}\right) d\xi = \left[\xi^2 \frac{d\Psi}{d\xi}\right]_{\xi=0}^{\xi=\xi_{max}} = \left(\xi^2 \frac{d\Psi}{d\xi}\right)_{\xi=\xi_{max}}$$

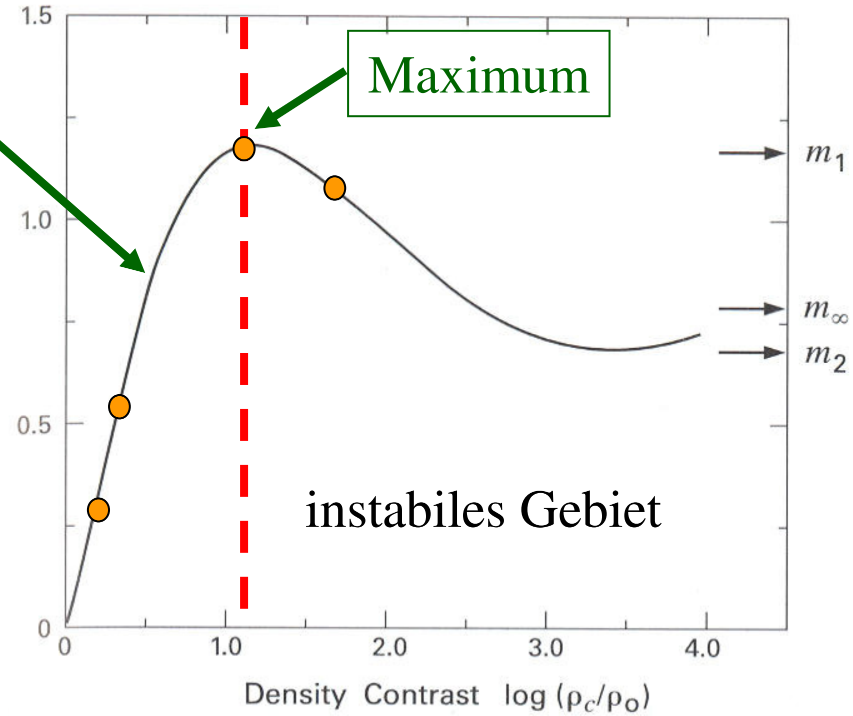
$P_0 = \rho_0 c^2$ $\rightarrow$

$$\frac{P_0^{1/2}\, G^{3/2}\, M}{c^4} = \left(4\pi\frac{\rho_c}{\rho_0}\right)^{-1/2} \left(\xi^2 \frac{d\Psi}{d\xi}\right)_{\xi_{max}} = f(\rho_c/\rho_0)$$

Dichte am äußeren Rand

$$\frac{P_0^{1/2}\,G^{3/2}\,M}{c^4} = \left(4\pi\frac{\rho_c}{\rho_0}\right)^{-1/2}\left(\xi^2\frac{d\Psi}{d\xi}\right)_{\xi_{max}} = f(\rho_c/\rho_0)$$

$$\boxed{\frac{P_0^{1/2}G^{3/2}M}{c^4}}$$

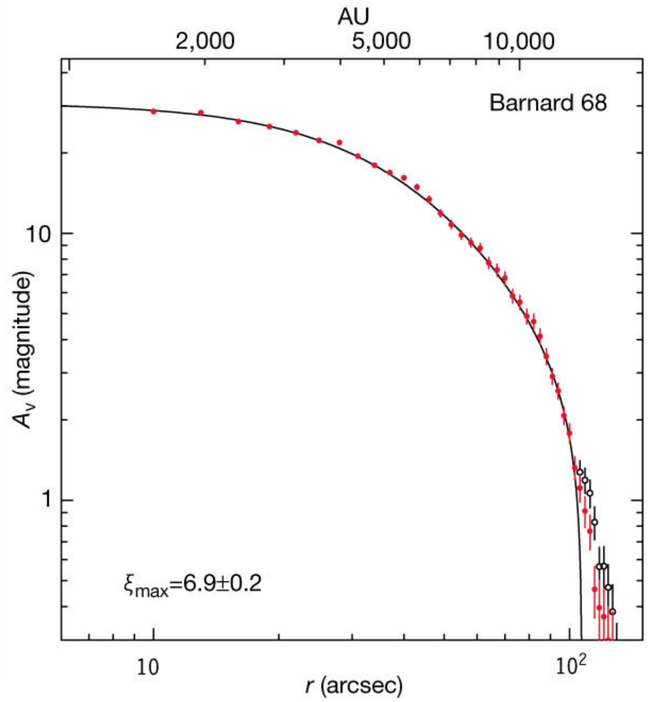



• Maximum bei: $$\rho_c/\rho_0 = 14.1$$

**Gaswolken sind gravitativ instabil für:**

$$\boxed{M \geq \frac{1.1\,c^4}{P_0^{1/2}\,G^{3/2}}}$$

# *Barnard 68*




(Alves et al. 2001)

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**Beobachtet:**

$$\xi_{max} = 6.9$$

**Instabilität bei:**

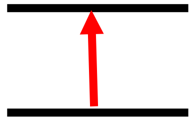
$$\rho_c / \rho_0 = 14.1 \;\rightarrow\; \xi_{max} = 6.5$$

## Das $H_2$ molekül

- **Diatomares Molekül:** das einfachste bekannte Molekül

- **Anregungszustände:**

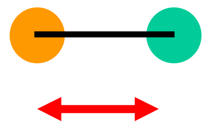
**Elektronischer Übergang:**



$$E = 11.2\,\mathrm{eV} \;\rightarrow\; \lambda = 1240\,\mathrm{nm}\cdot\left(\frac{\mathrm{eV}}{E}\right) = 111\,\mathrm{nm}$$

liegt im **UV-bereich**

**Elektronische Übergange** spalten in **Vibrationsübergänge** auf:



Die **Amplitude** wird durch die **Quantenzahl** $v = 0, 1, \ldots$ beschrieben:

$$E_v - E_{v-1} = 0.15\,\mathrm{eV}$$