Astrophysical Gas Dynamics

TODAY:

- *Parker wind solution (→ recap)*
- *Bondi accretion*
- *Shu accretion rate*

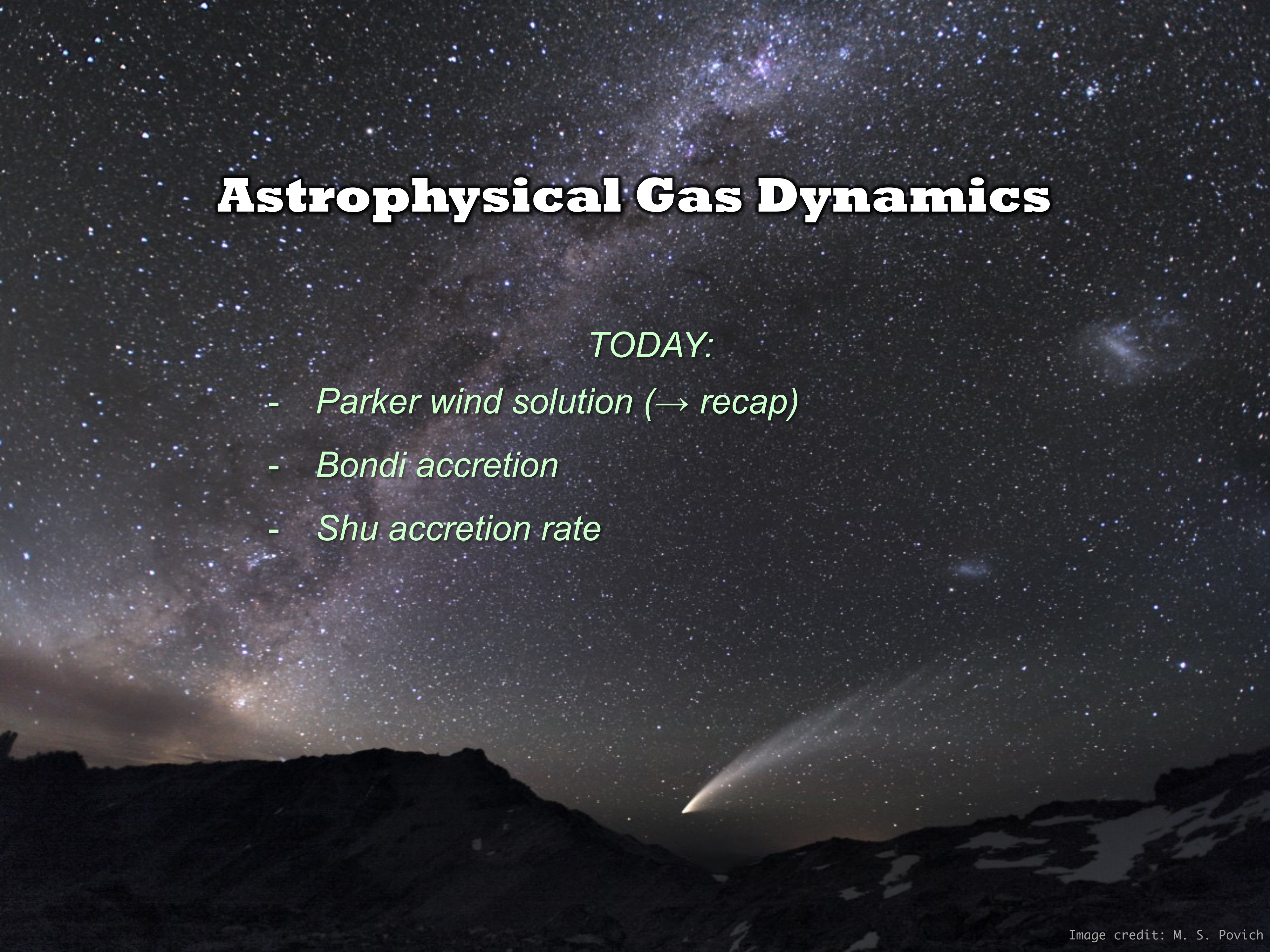

Image credit: M. S. Povich

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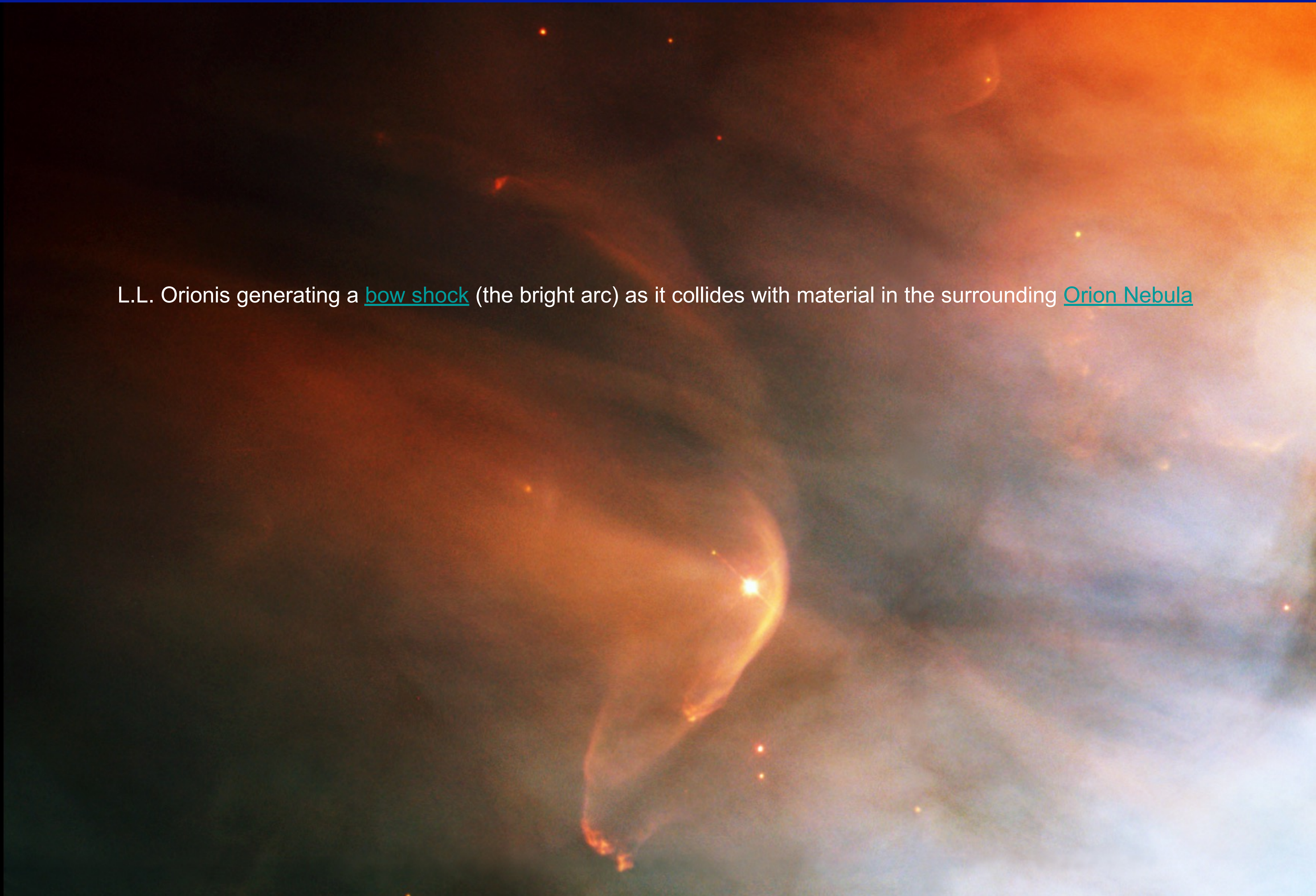
Stellar winds

In planetary nebula NGC 6565, a cloud of gas was ejected from the star after strong stellar winds

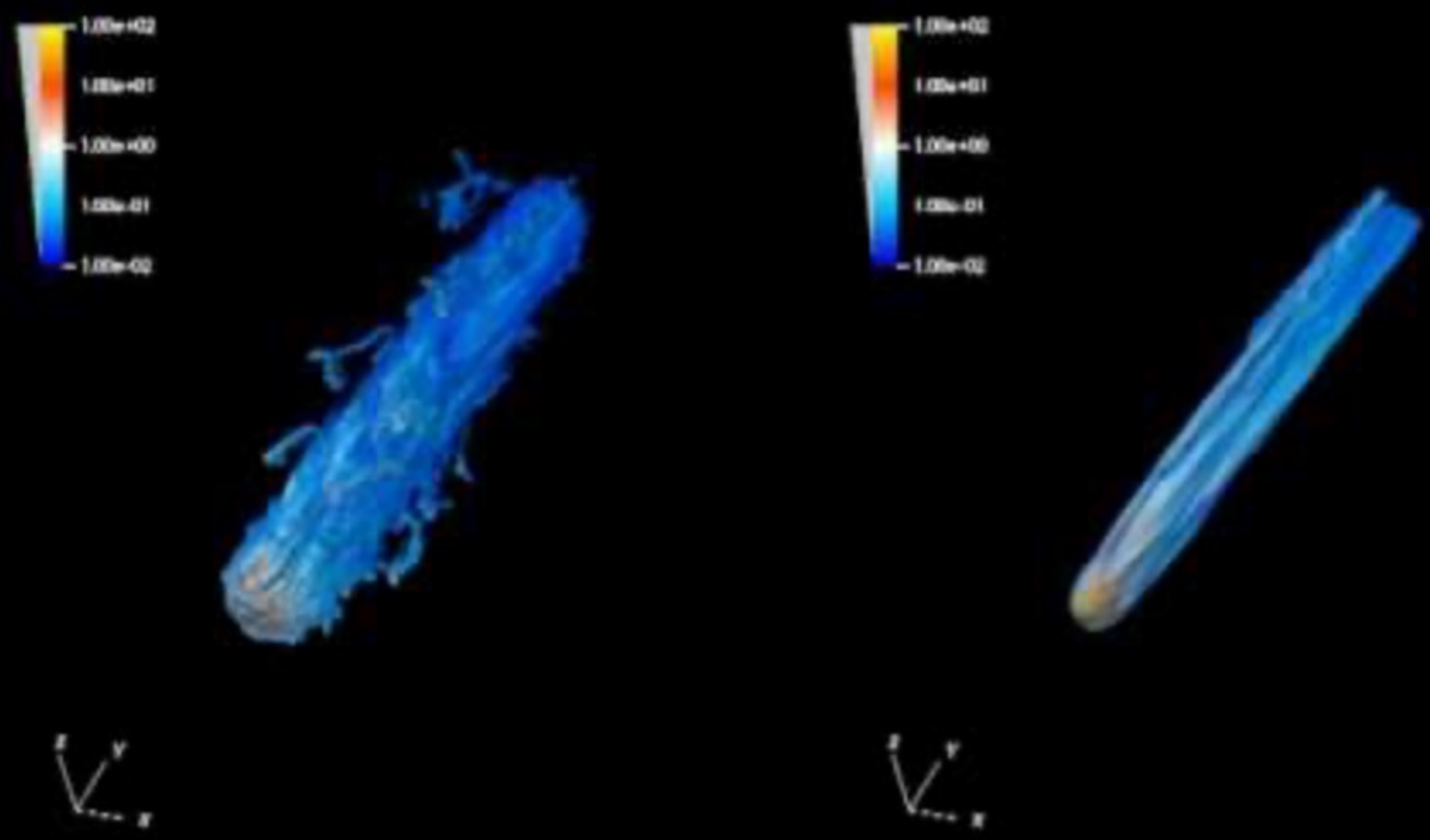
We will now derive the Parker wind solution in spherical symmetry…

Stellar winds and their impact on the surrounding



L.L. Orionis generating a bow shock (the bright arc) as it collides with material in the surrounding Orion Nebula

Wind-cloud interactions



https://youtu.be/gviipq6EFdw

(Banda-Barragan et al. 2018)

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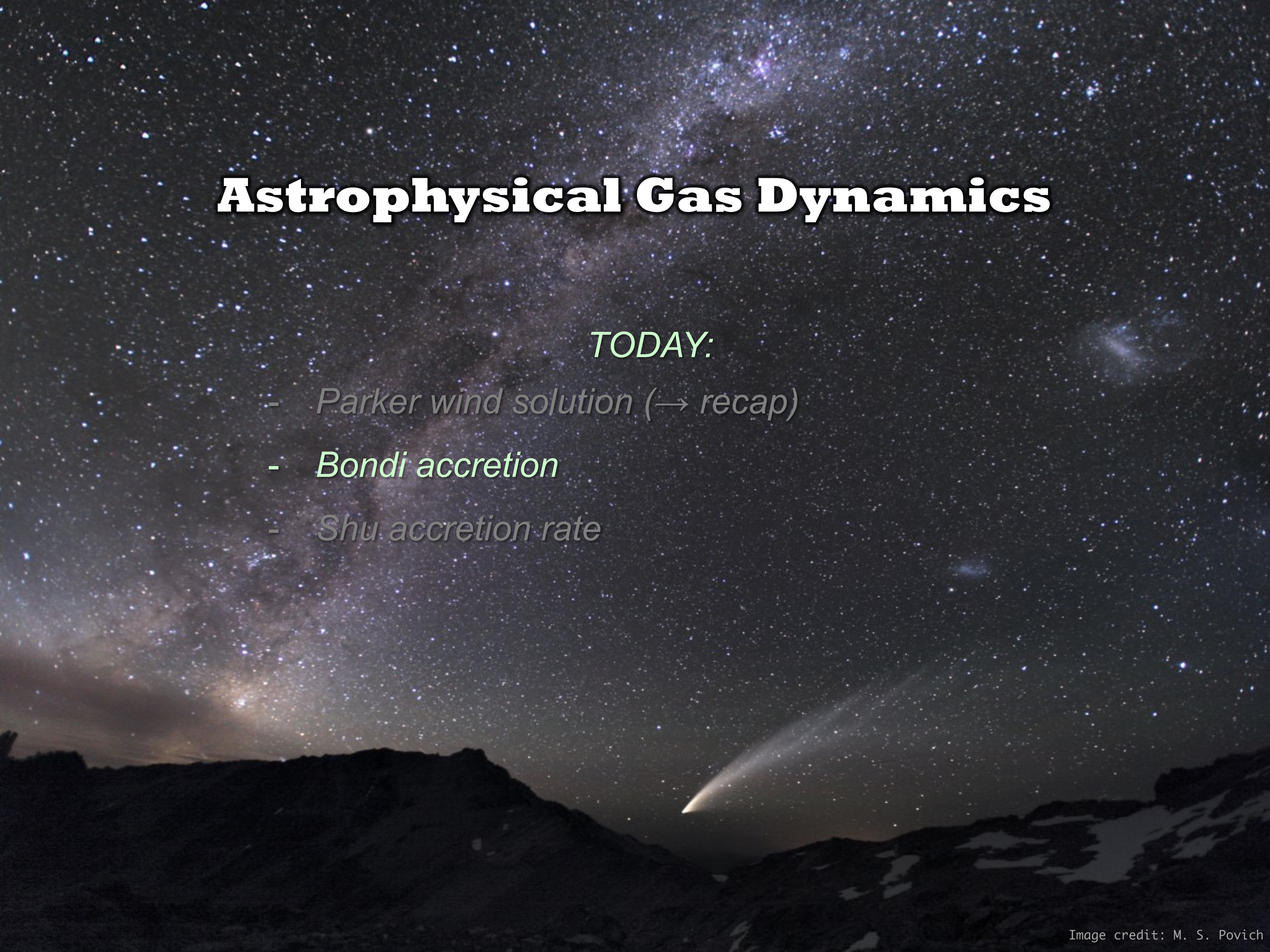
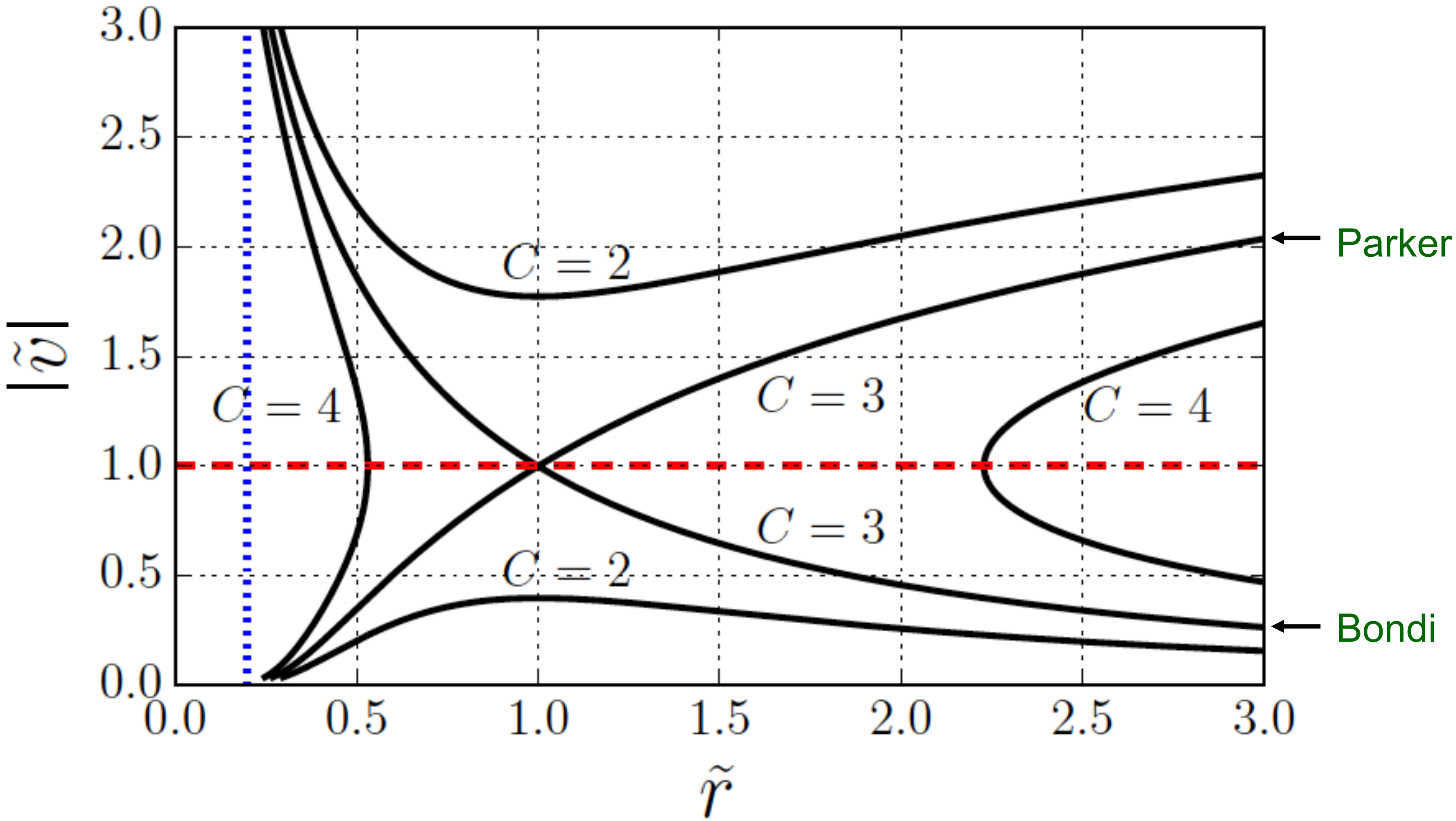


Image credit: M. S. Povich

Parker wind versus Bondi accretion

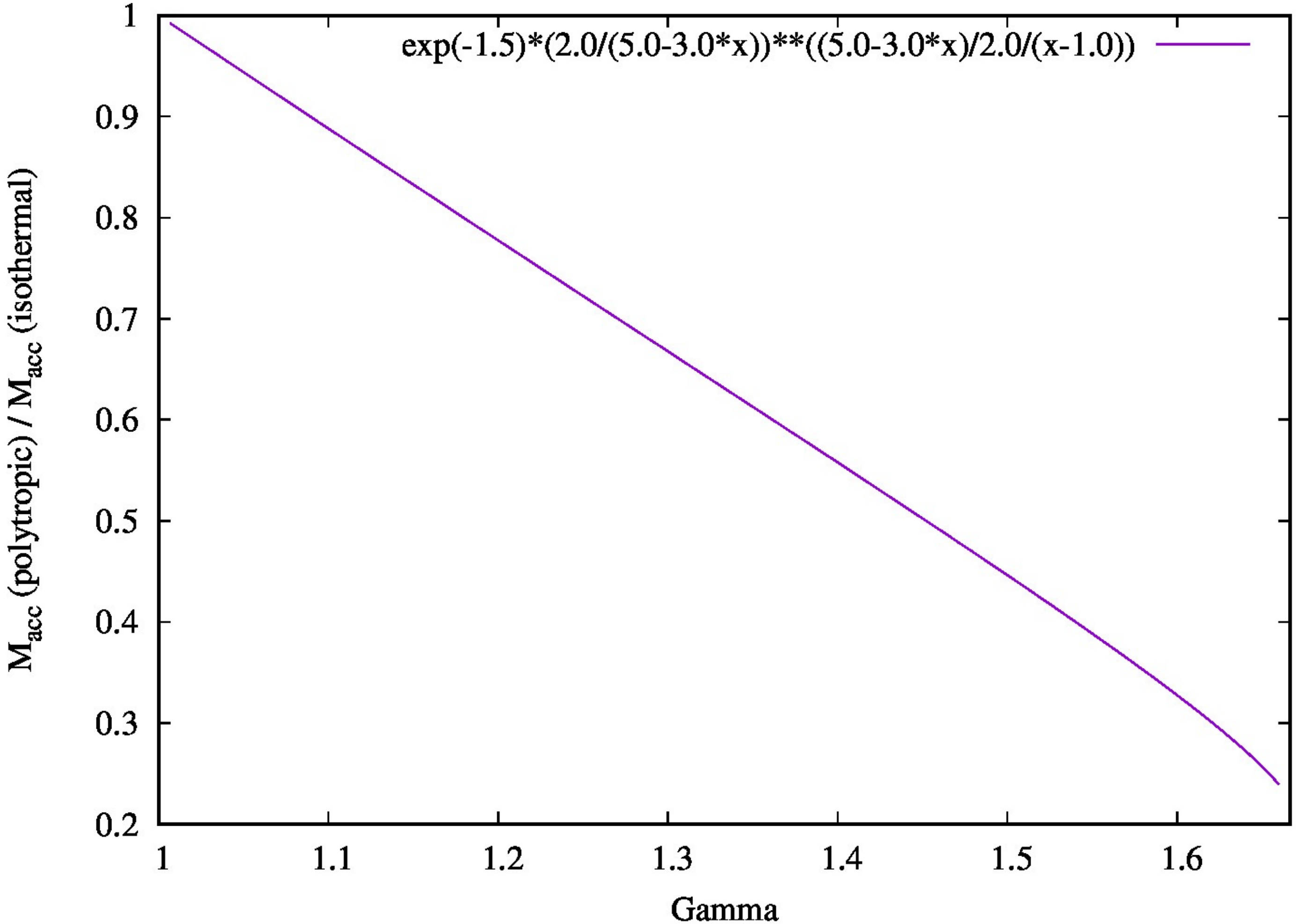
$$\tilde{v}^2 - \log \tilde{v}^2 = 4 \log \tilde{r} + \frac{4}{\tilde{r}} - C$$



(Sormani lecture notes)

Bondi accretion (influence of the EOS)

Bondi accretion rate for isothermal versus adiabatic gas
(Polytropic EOS: $P_{\rm th} = K\rho^{\Gamma}$)



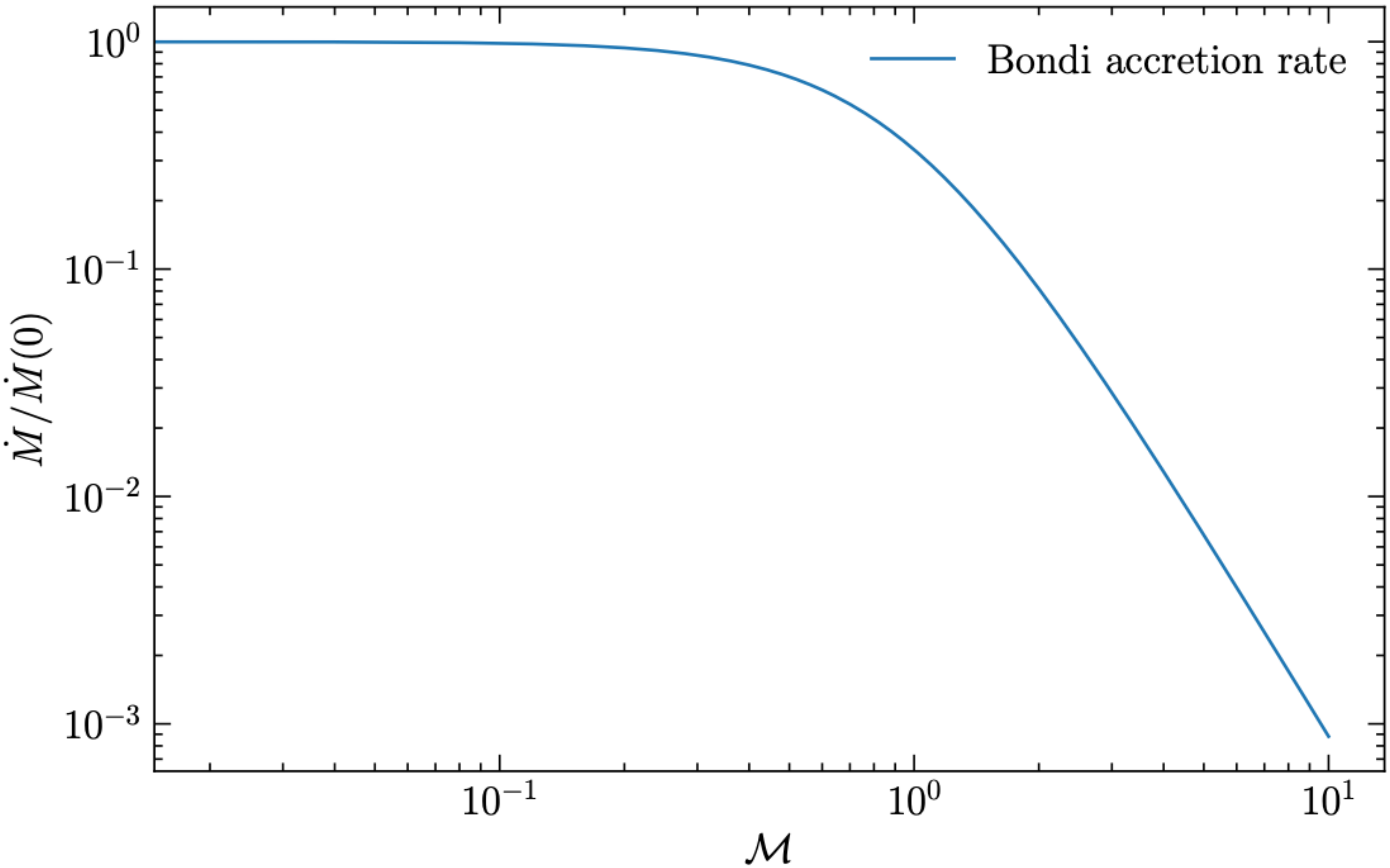
Why is the accretion rate higher for lower Gamma?

Bondi-Hoyle accretion

$$\dot{M}_{\rm BH} = 4\pi\rho_\infty G^2 M^2 c_\infty^{-3}\left[\frac{\lambda^2+\mathcal{M}^2}{\left(1+\mathcal{M}^2\right)^4}\right]^{1/2}$$

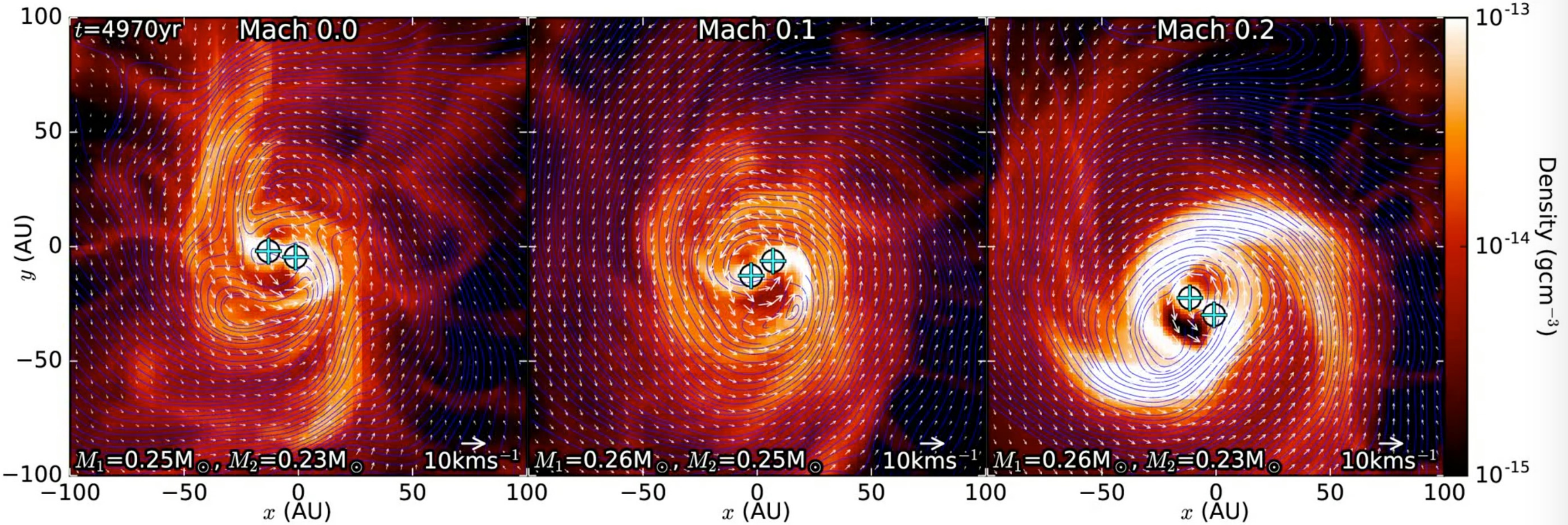
For $\mathcal{M} = 0$ (Bondi accretion)

$\lambda = \exp(1.5)/4$ in an isothermal medium



Build-up of circum-binary discs

No Turbulence **Low Turbulence** **Normal Turbulence**



Movies available: https://www.mso.anu.edu.au/~chfeder/pubs/binary_turb/binary_turb.html

Turbulence makes bigger discs → relevant for planet formation

Kuruwita & Federrath (2019)

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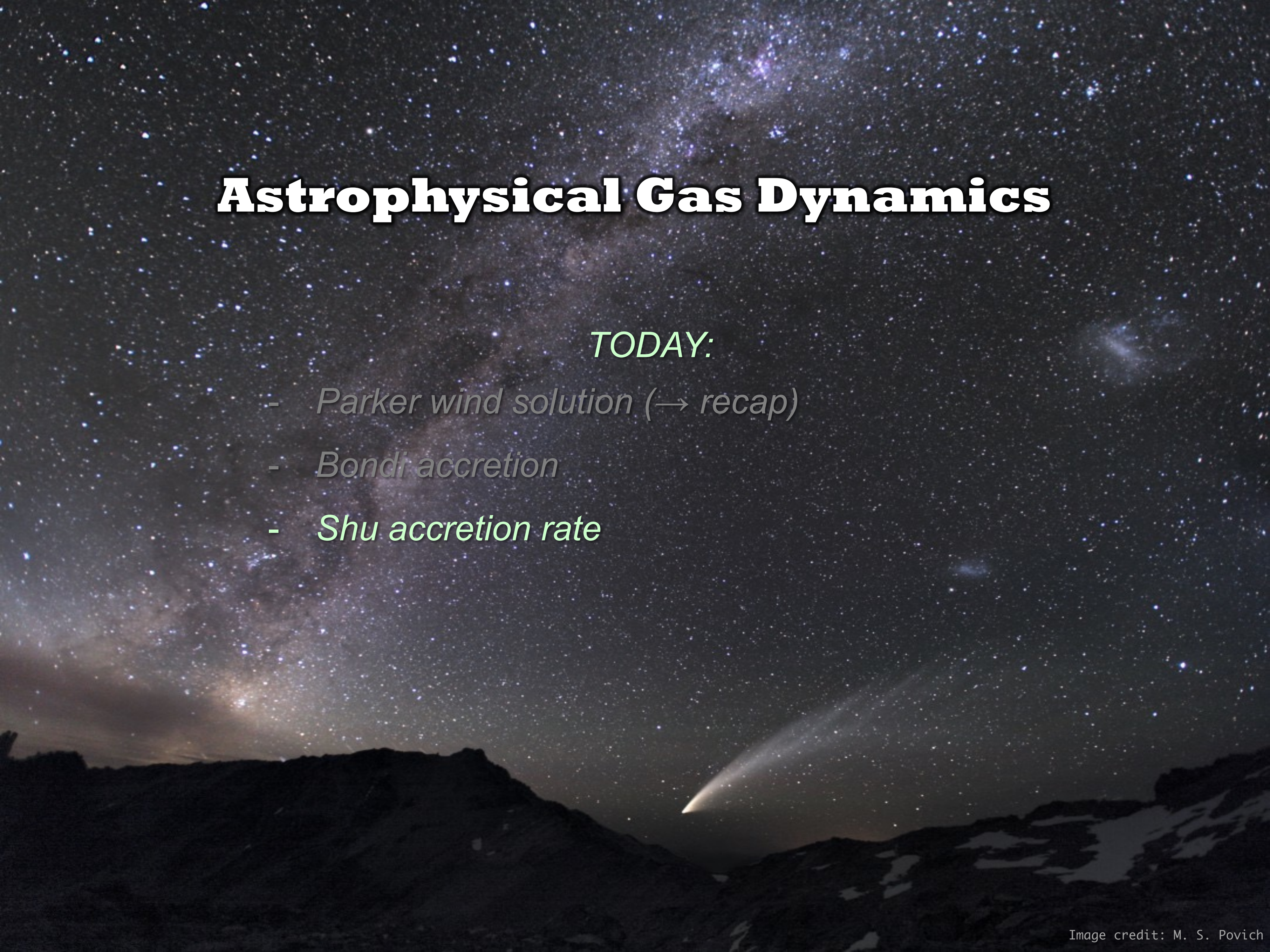


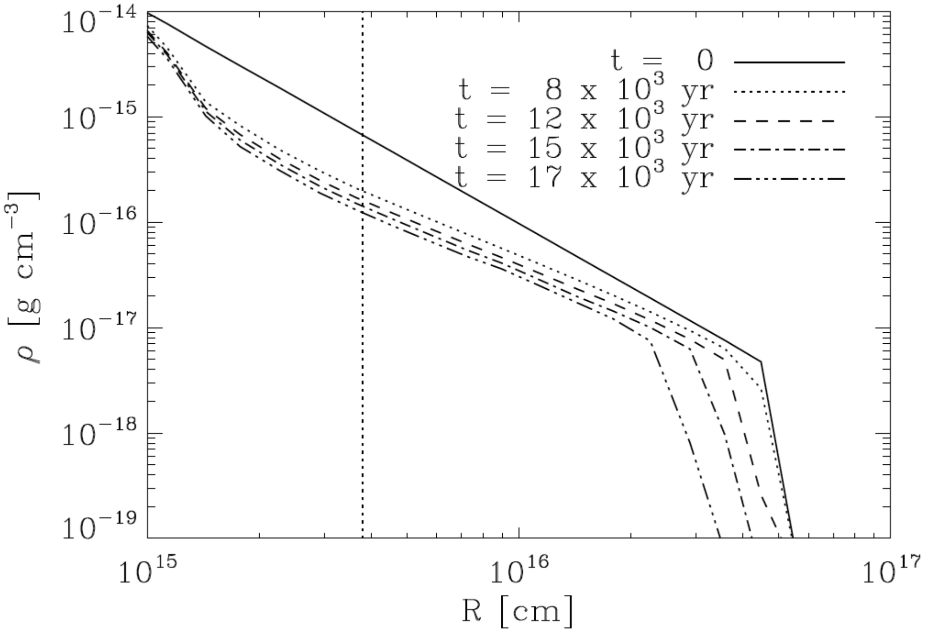
Image credit: M. S. Povich

Shu accretion rate

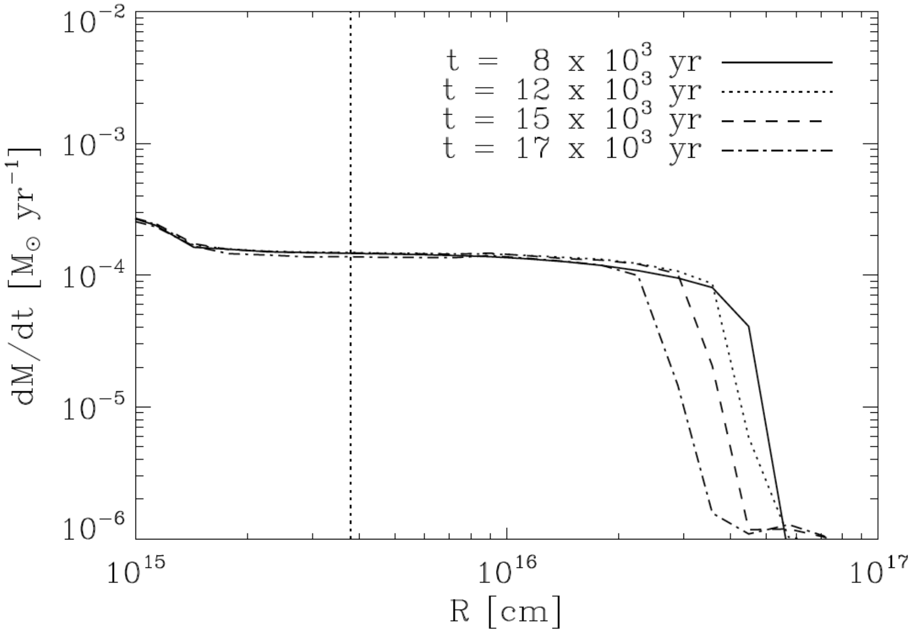
Collapse of a singular isothermal gas sphere

Accretion rate: $$\dot{M} = m_0 \frac{c_s^3}{G}$$ (Shu 1977)

Gas Density



Accretion Rate



(Federrath et al. 2010)

Shu accretion rate

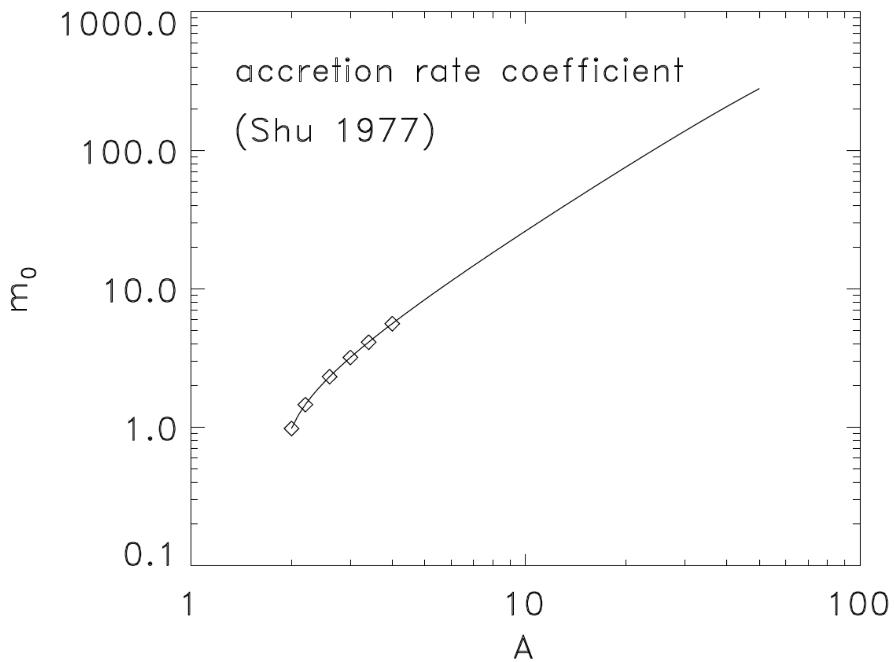
Collapse of a singular isothermal gas sphere

Shu (1977)

$$\dot{M} = m_0 \frac{c_\mathrm{s}^3}{G} \quad \text{with} \;\; m_0 \; = \; 0.975 \;\; \text{would give} \;\; m_0 c_\mathrm{s}^3/G = 1.06 \times 10^{-6}\, M_\odot\, \mathrm{yr}^{-1}$$

...but here, the gas cloud is highly unstable!

Accretion Rate Coefficient



Instability parameter $A = 4\pi G\, \rho(R)\, R^2/c_\mathrm{s}^2$

With A = 29, we get m_0 ~ 130, which gives exactly the correct accretion rate.

Conclusion:
Beware, m_0 is not necessarily 1.
And hence c_s^3/G may be way off!

(Federrath et al. 2010)

Astrophysical Gas Dynamics

NEXT TIME:

- *Steepening of sound waves → shocks*

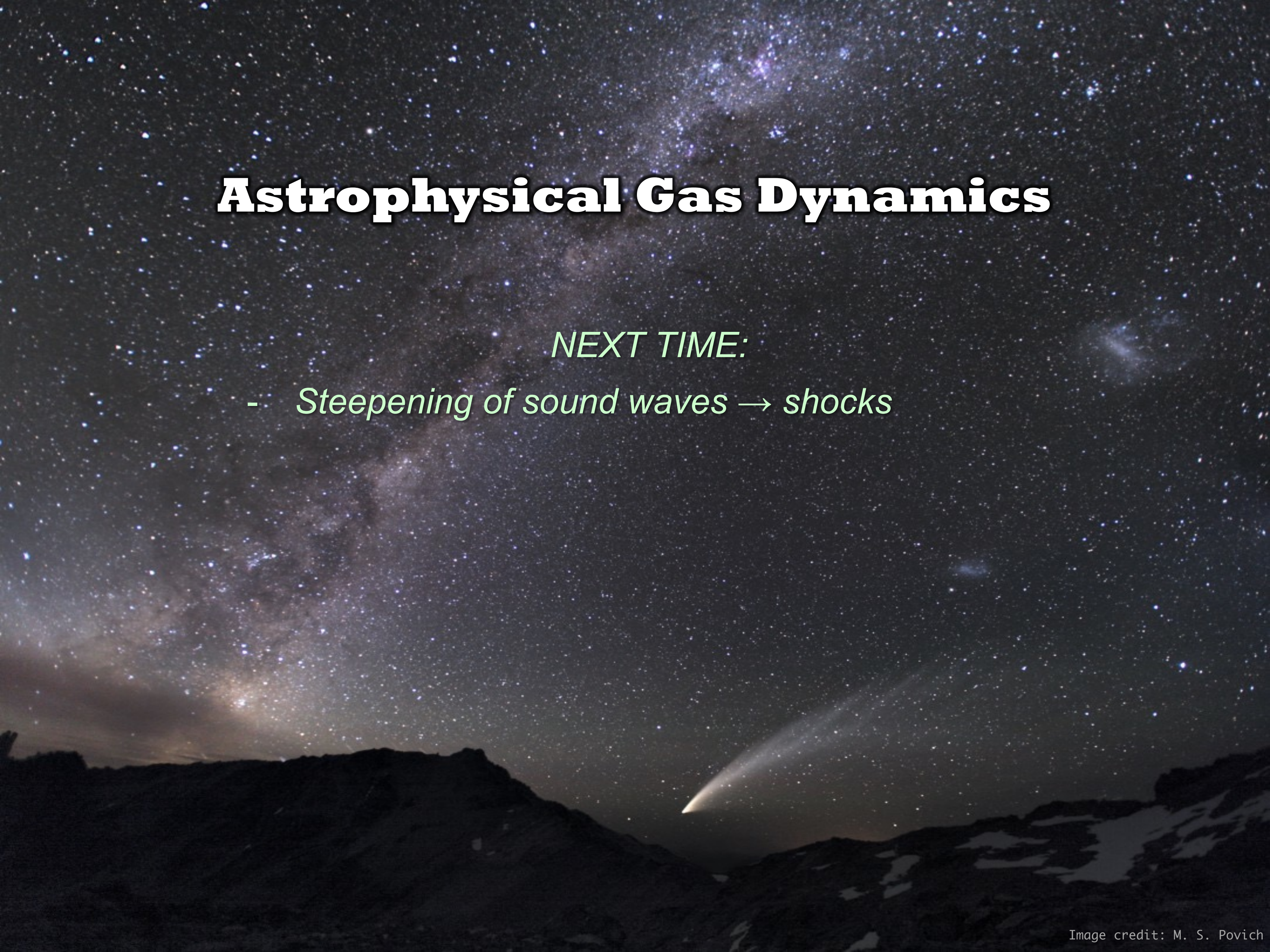


Image credit: M. S. Povich