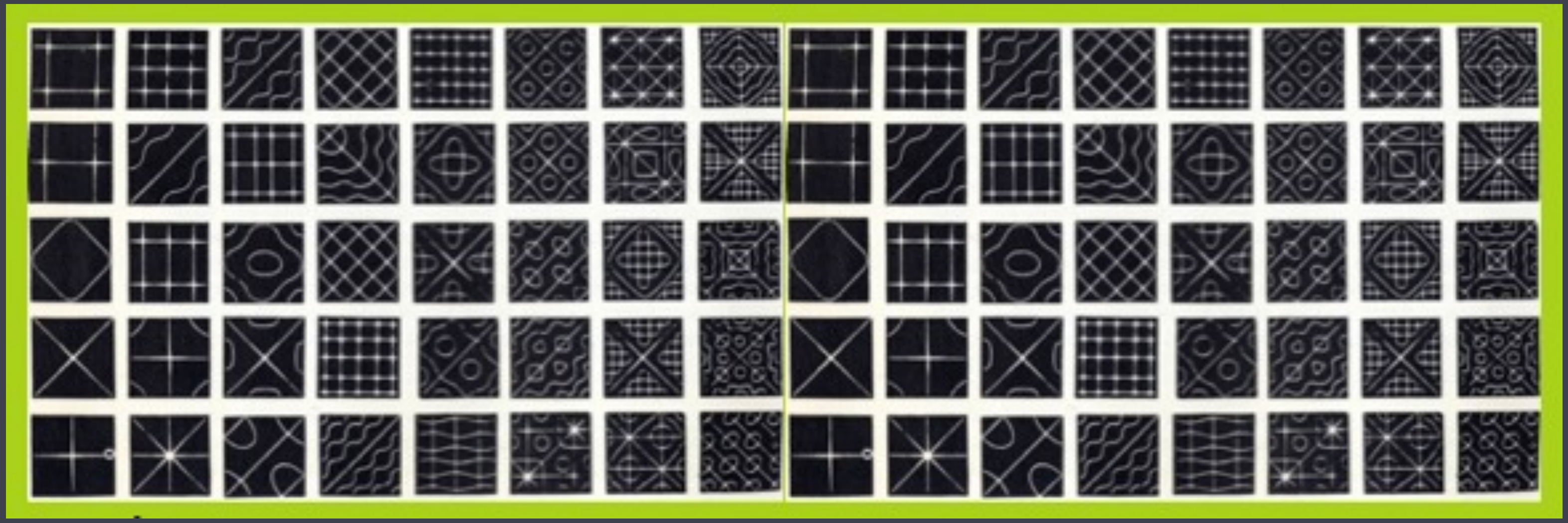
Cosmic Sounds

Thursday, October 16, 2014



Sound: Physics and Perception

Please bring baked goods to class.

Columbia - Visual Arts R6020

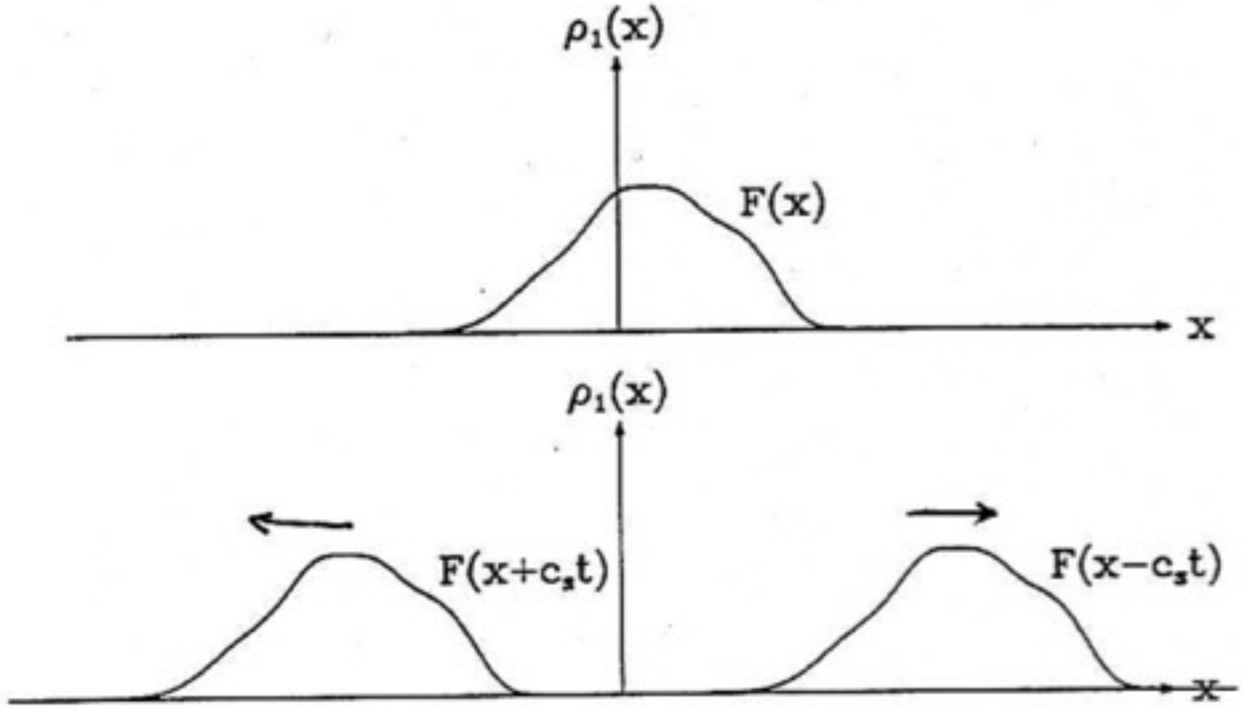
Cosmic Sounds

Thursday, October 16, 2014

with David Cohen and Carl Grossman

Swarthmore College

David's contact info (please feel free to get in touch): dcohen1@swarthmore.edu



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and so

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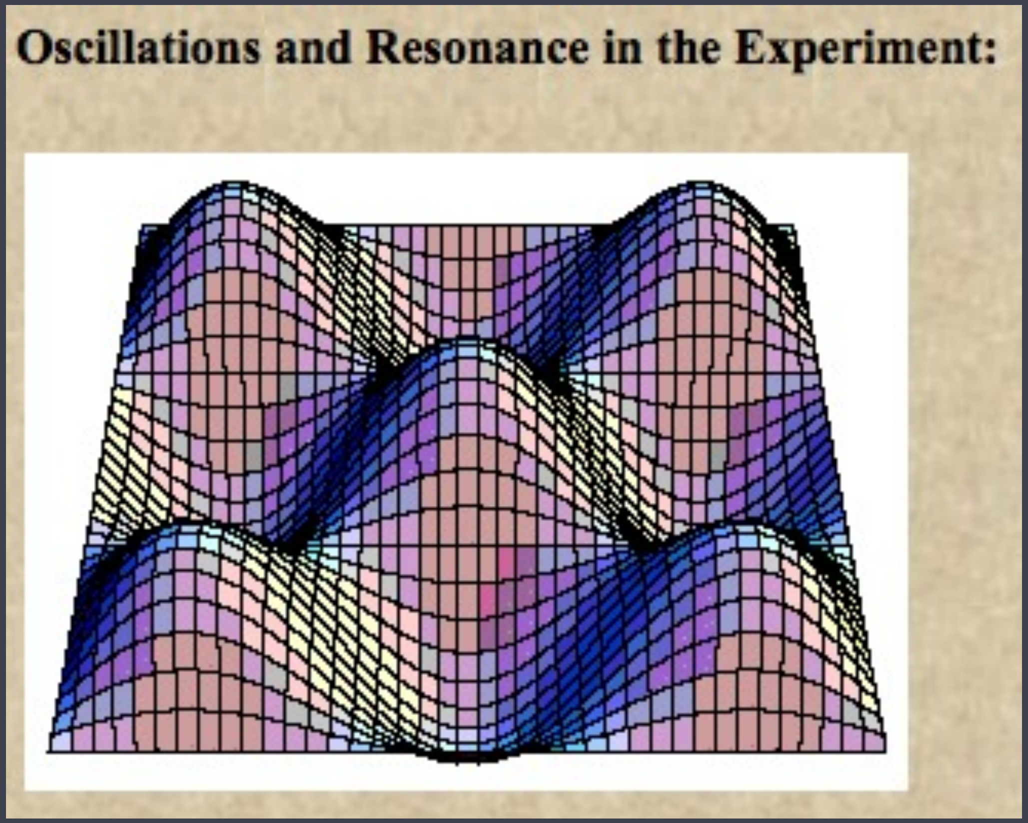
where m is the mass of the fluid particle. c_s is not only the wave speed, but close to the mean speed of the fluid particles.

sound wave propagating, due to a pressure disturbance

bang on a drum or a metal plate and it vibrates

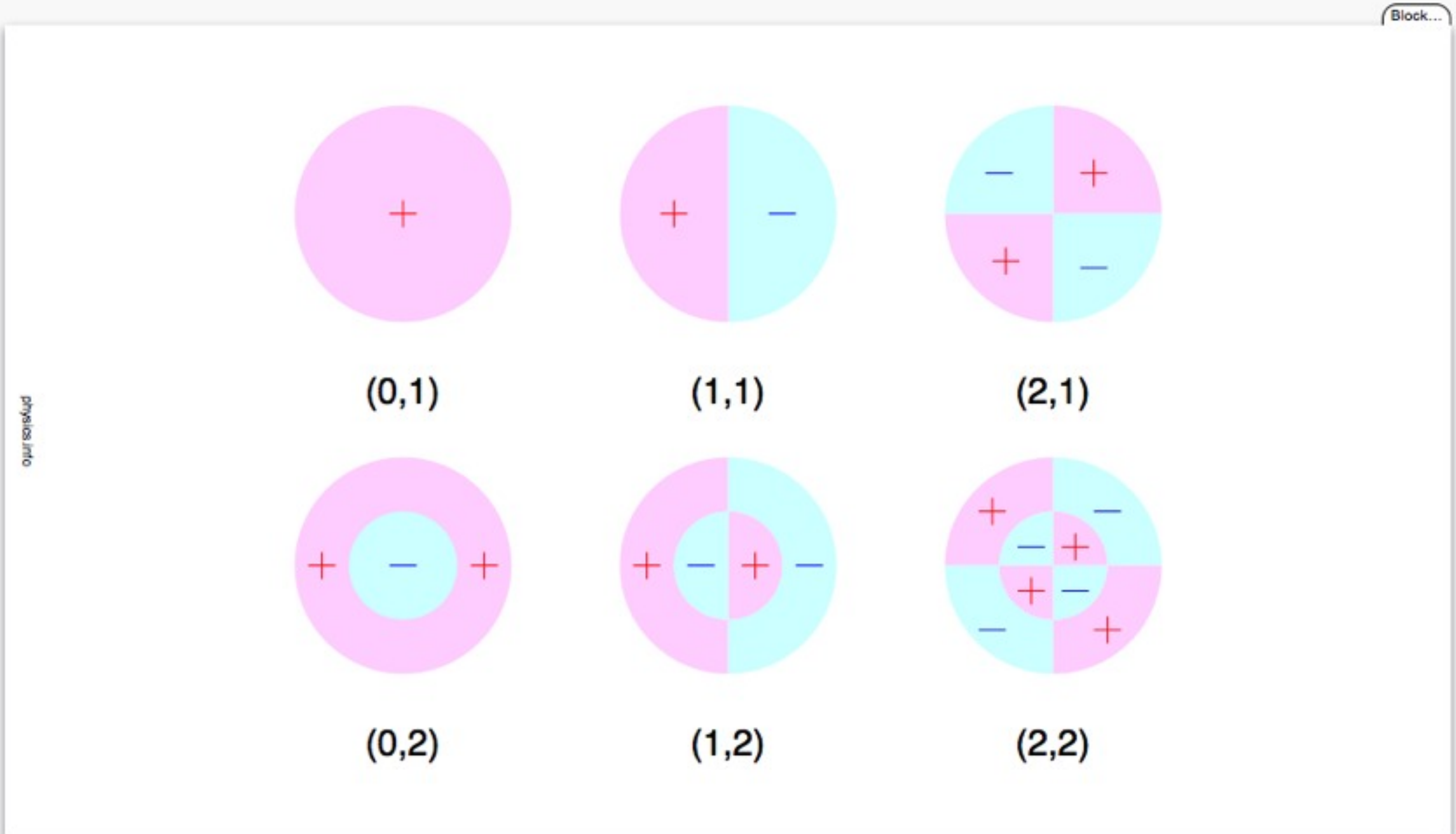
http://www.physicsclassroom.com/class/sound/Lesson-4/Standing-Wave-Patterns

http://snarescience.com/forums/viewtopic.php?f=6&t=9256



http://www.phy.davidson.edu/stuhome/derekk/resonance/pages/plates.htm

drum head vibration modes



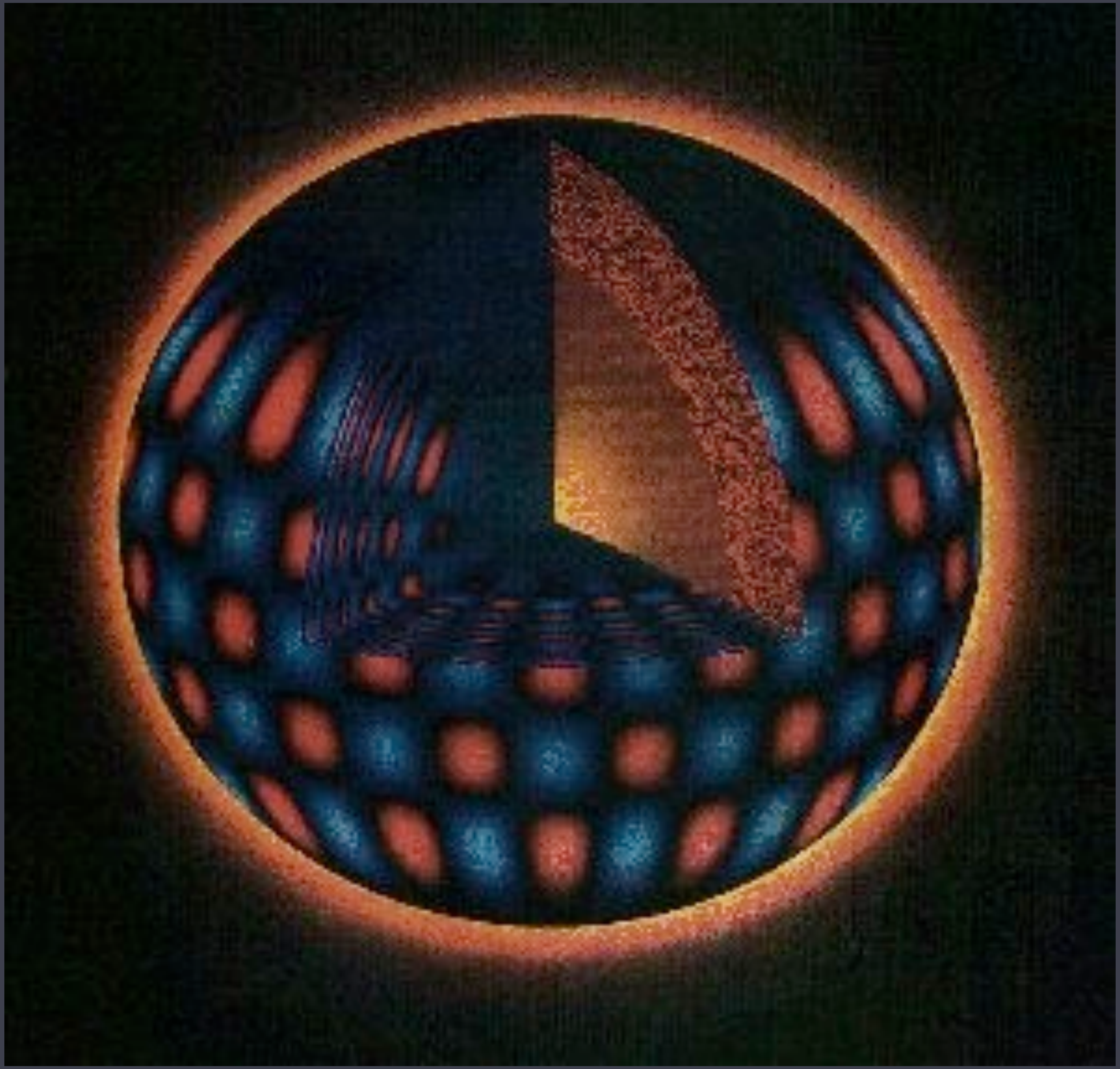
The diagram above shows six simple modes of vibration in a circular drum head. The plus and minus

http://physics.info/waves-standing/

Barnard 68: solar-system-sized gas cloud

http://apod.nasa.gov/apod/ap120129.html

solar oscillations



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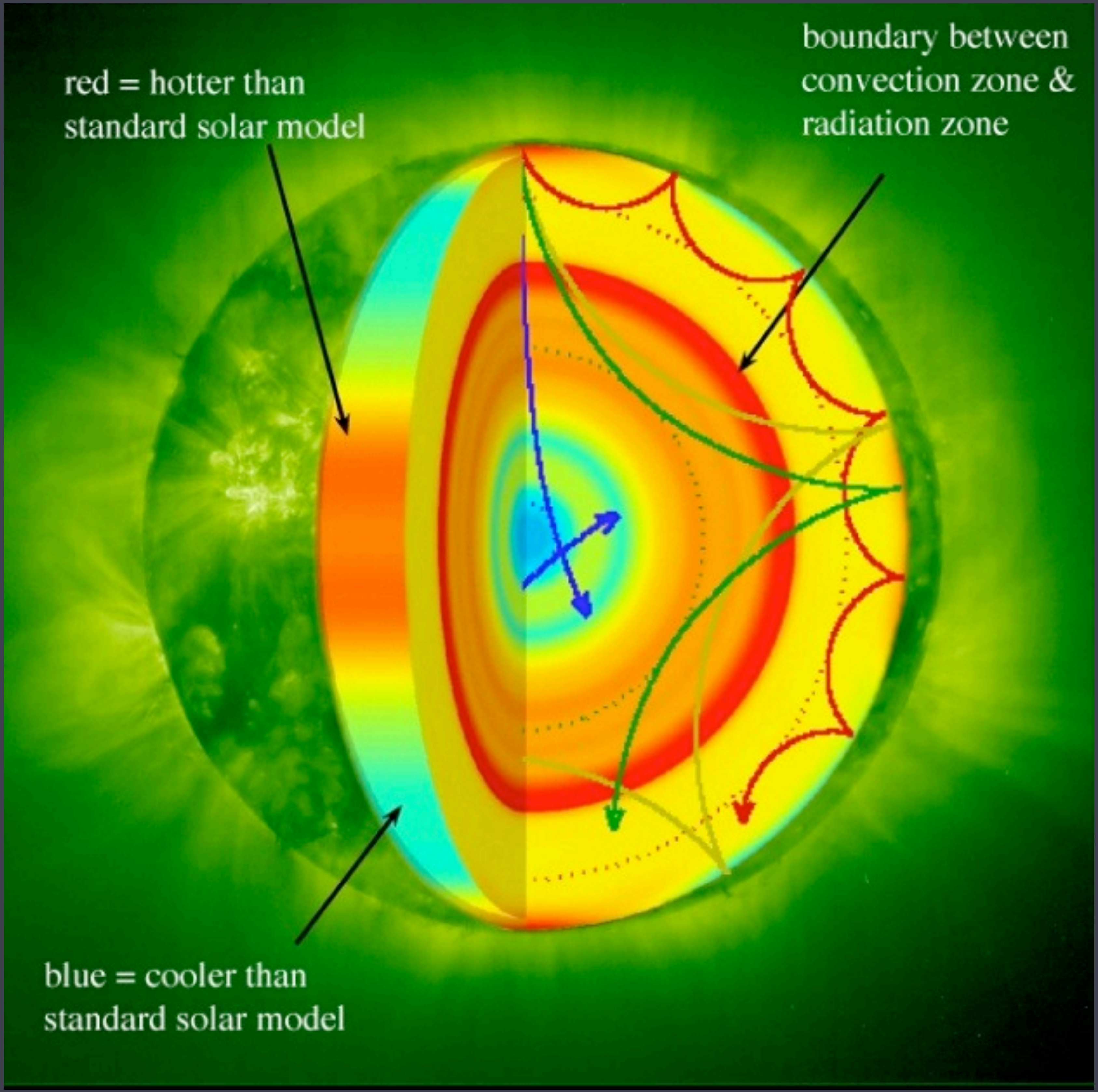


http://hmi.stanford.edu/Description/hmi-overview/hmi-overview.html

hot things give off light: *blackbody* radiation

Look at the sky...with a radio telescope

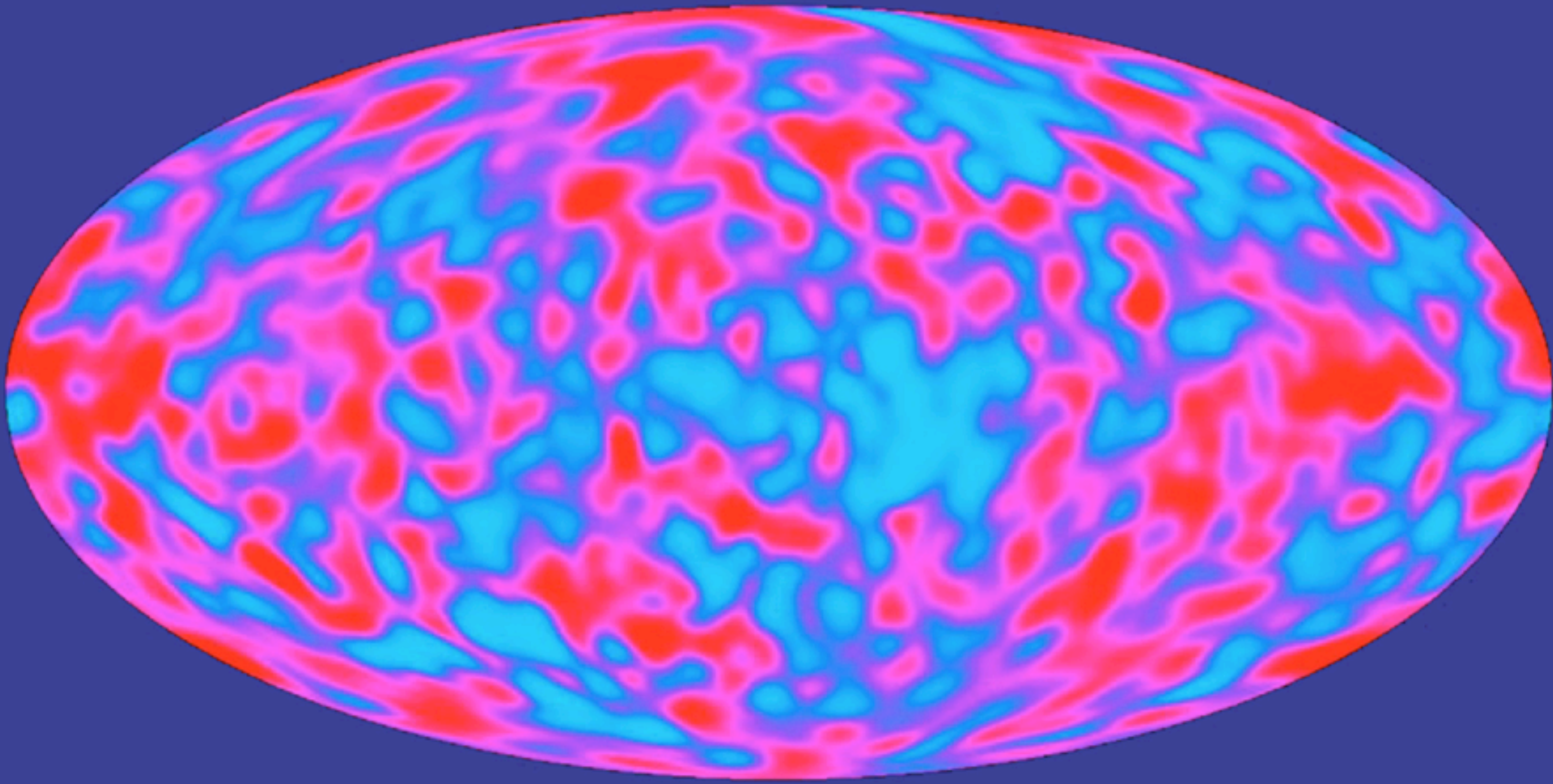
early 1960s - Penzias and Wilson (Princeton)

they see a quite uniform brightness at ~ 1 mm (freq ~ 300 GHz) - glow from the early universe, when it was hot and dense

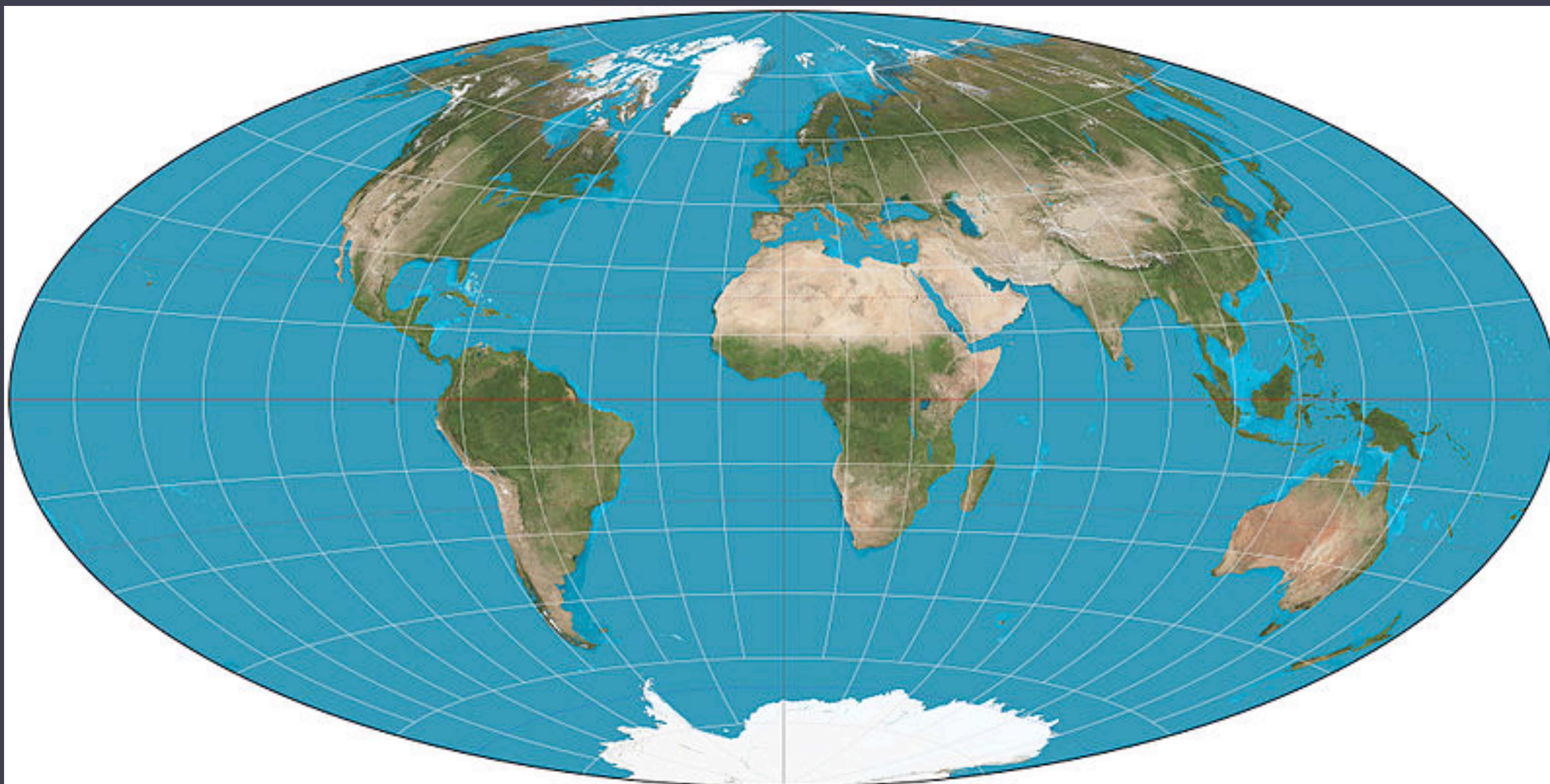
early 1990s - Mather & Smoot (NASA/GSFC)

Map the sky (can think of the measurement as a temperature)

DMR's Two Year CMB Anisotropy Result

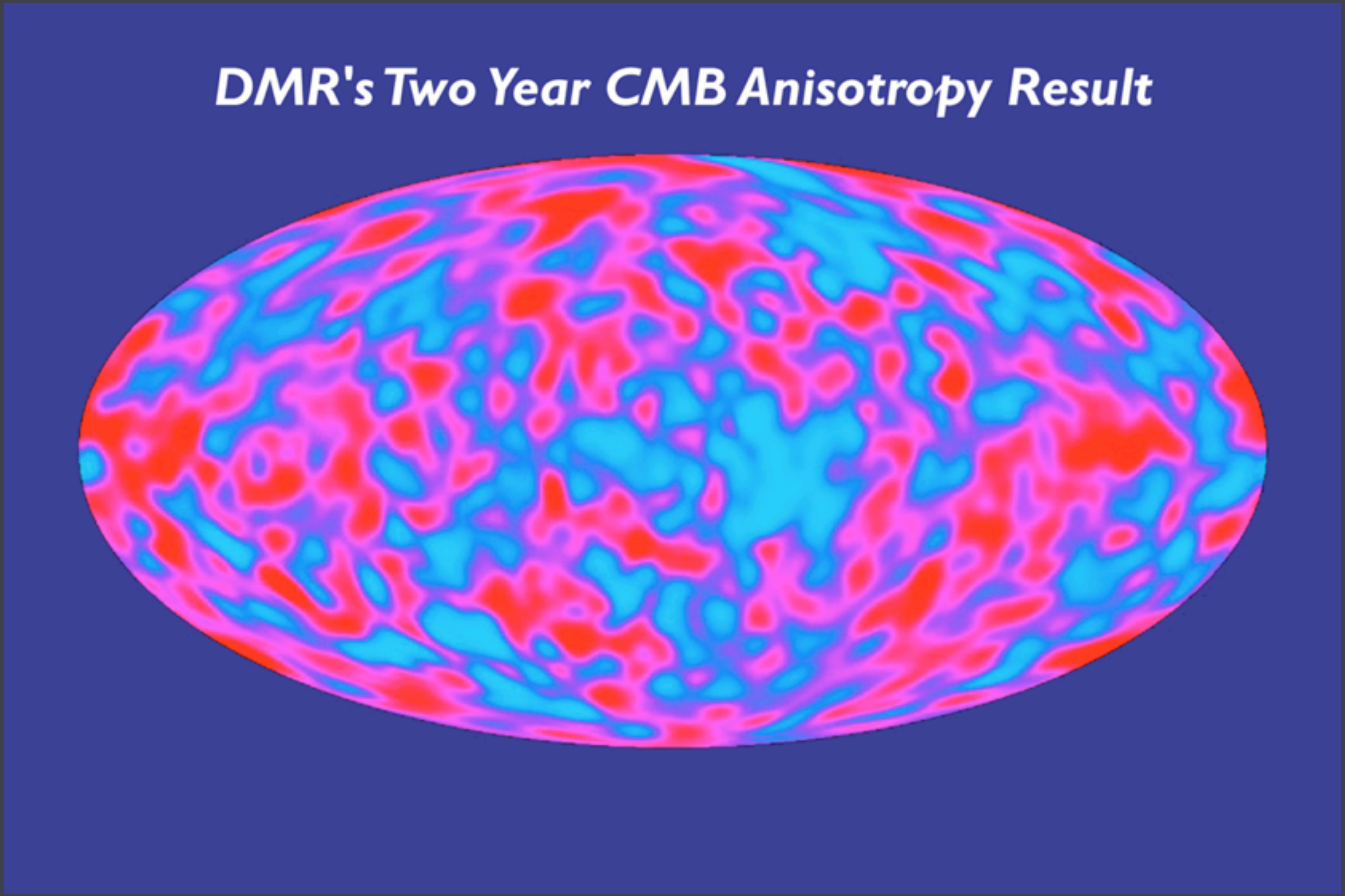


“Aitoff projection” - this is the sphere of the sky, as seen from the Earth’s surface.



COBE (early 1990s) - first detailed map of the CMB

this is the residual CMB signal (after all the foreground subtractions)



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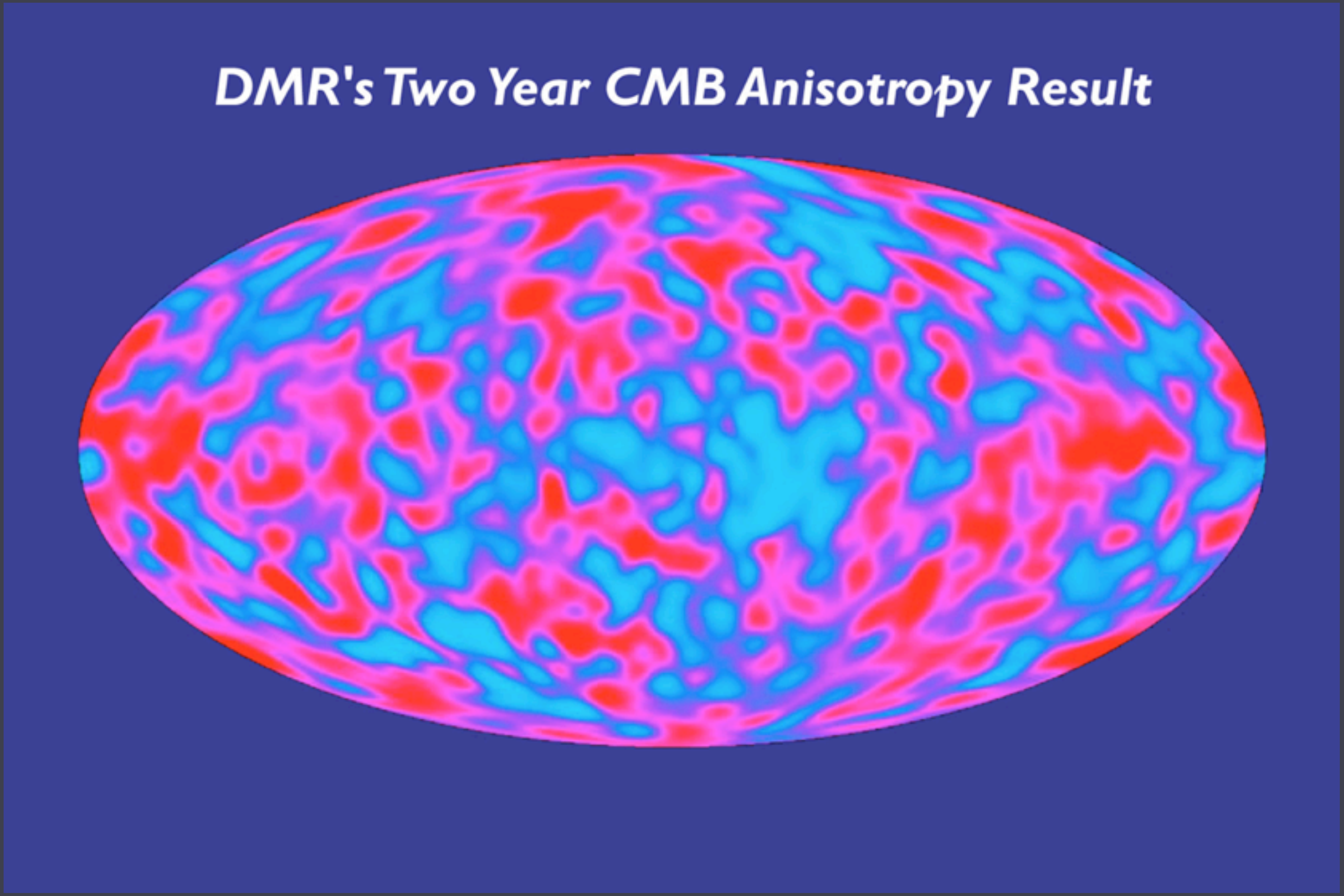
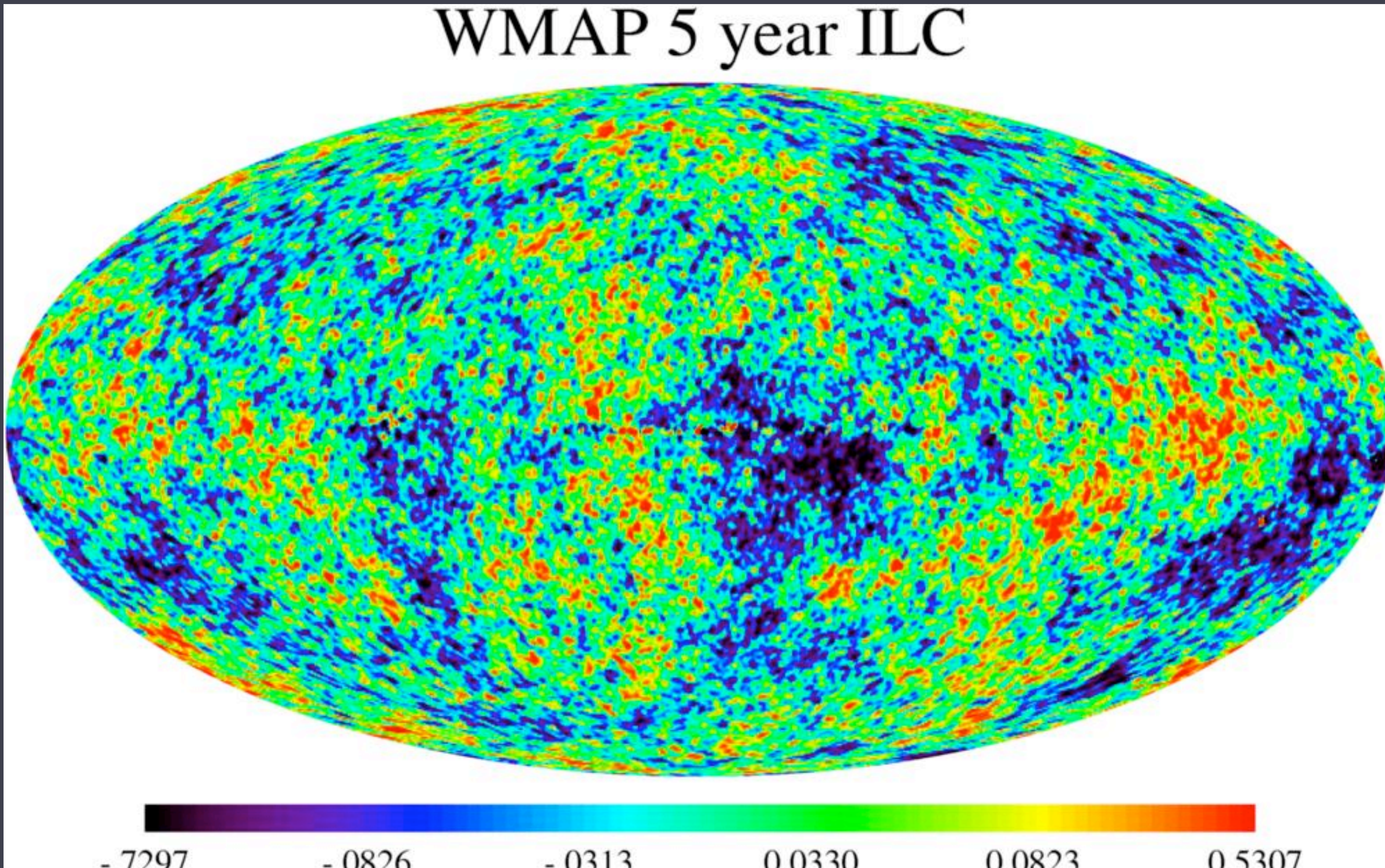
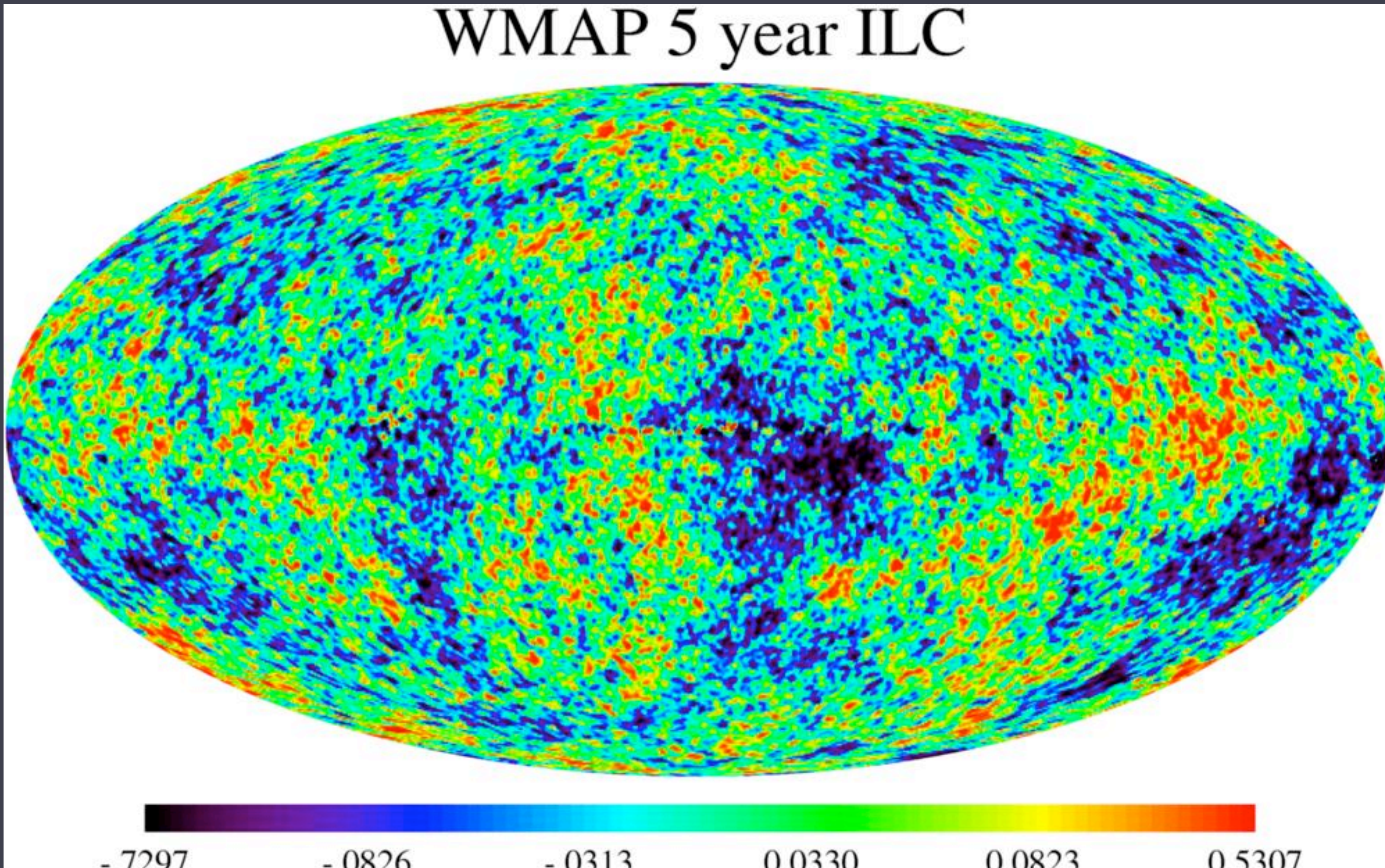
these fluctuations in brightness are at the 1 part in 100,000 level



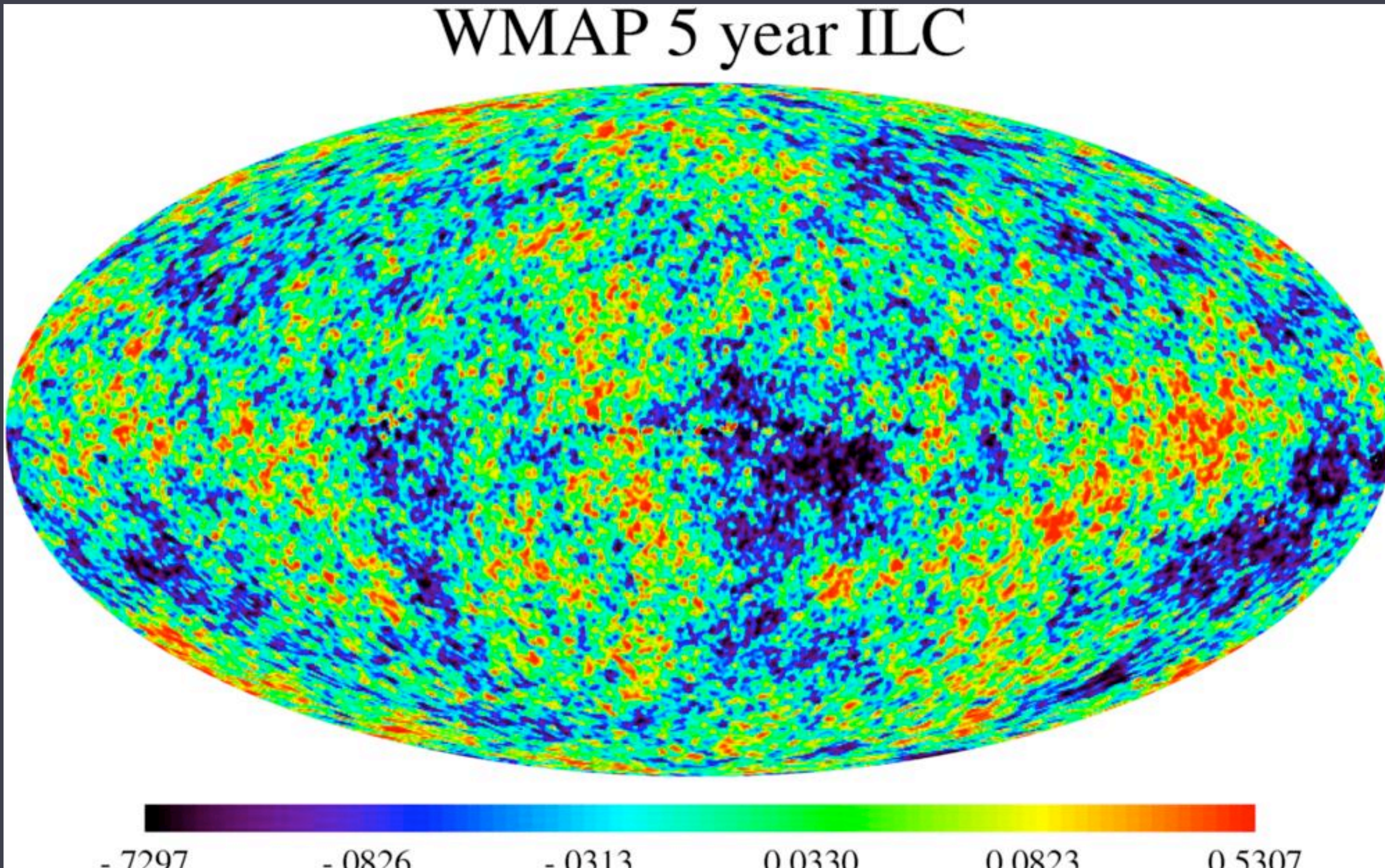
a later mission (early 2000s), WMAP, measured variation, on a smaller spatial scale



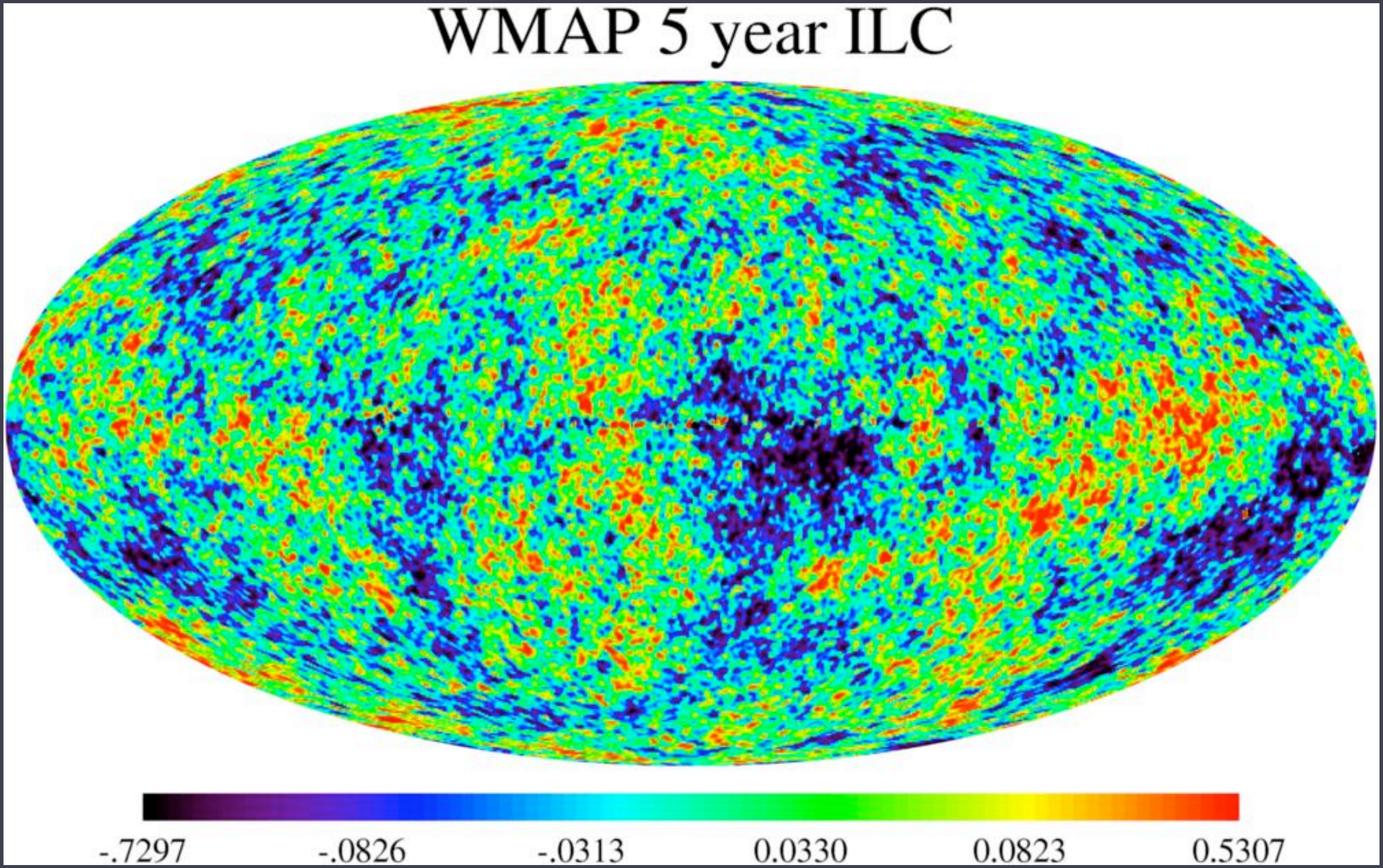
think of this as a snapshot of density or pressure in the universe at the time these photons were emitted



these are peaks and valleys of sound waves propagating in the universe...



really, they're more like the pattern formed on a drum-heat covered in powder when the head vibrates



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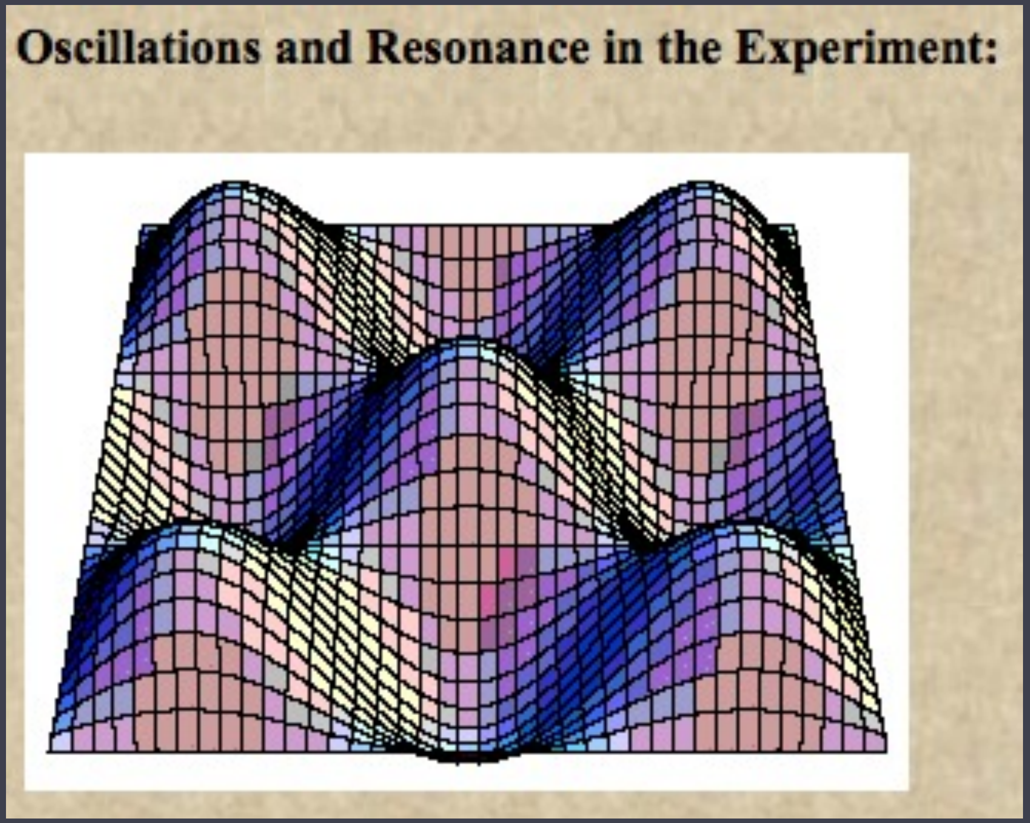

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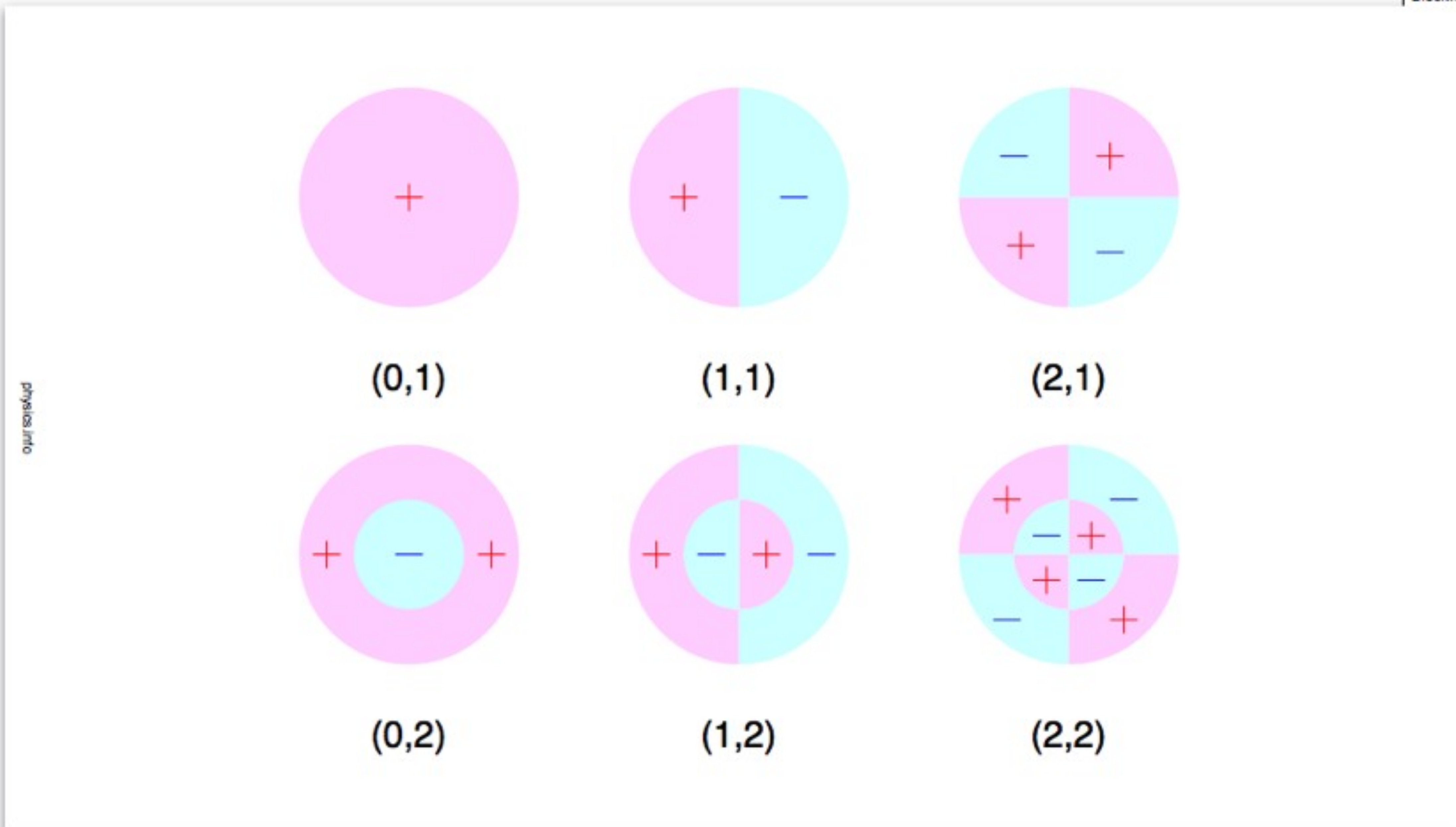

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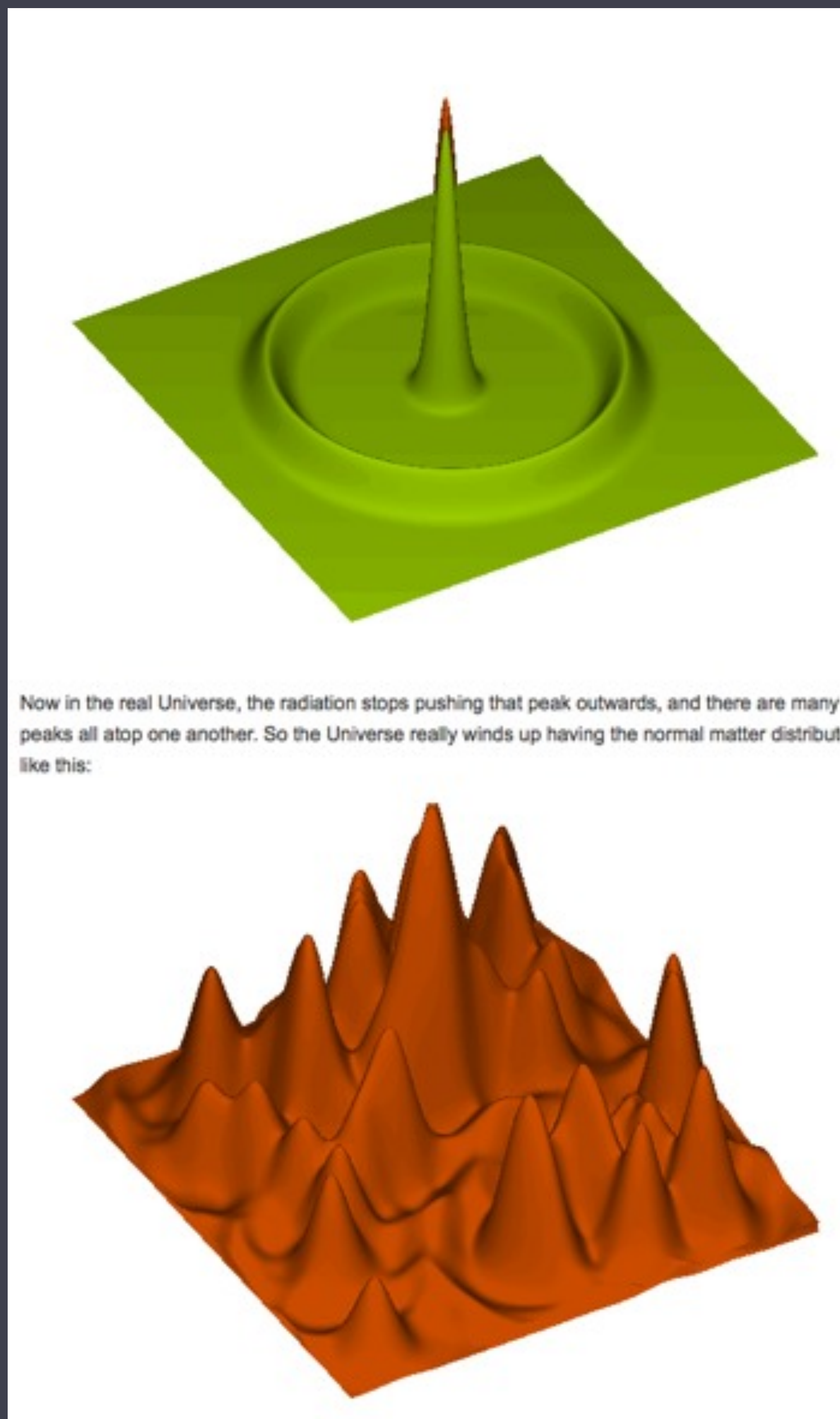
cosmic sound waves

http://scienceblogs.com/startswithabang/2008/04/25/cosmic-sound-waves-rule/



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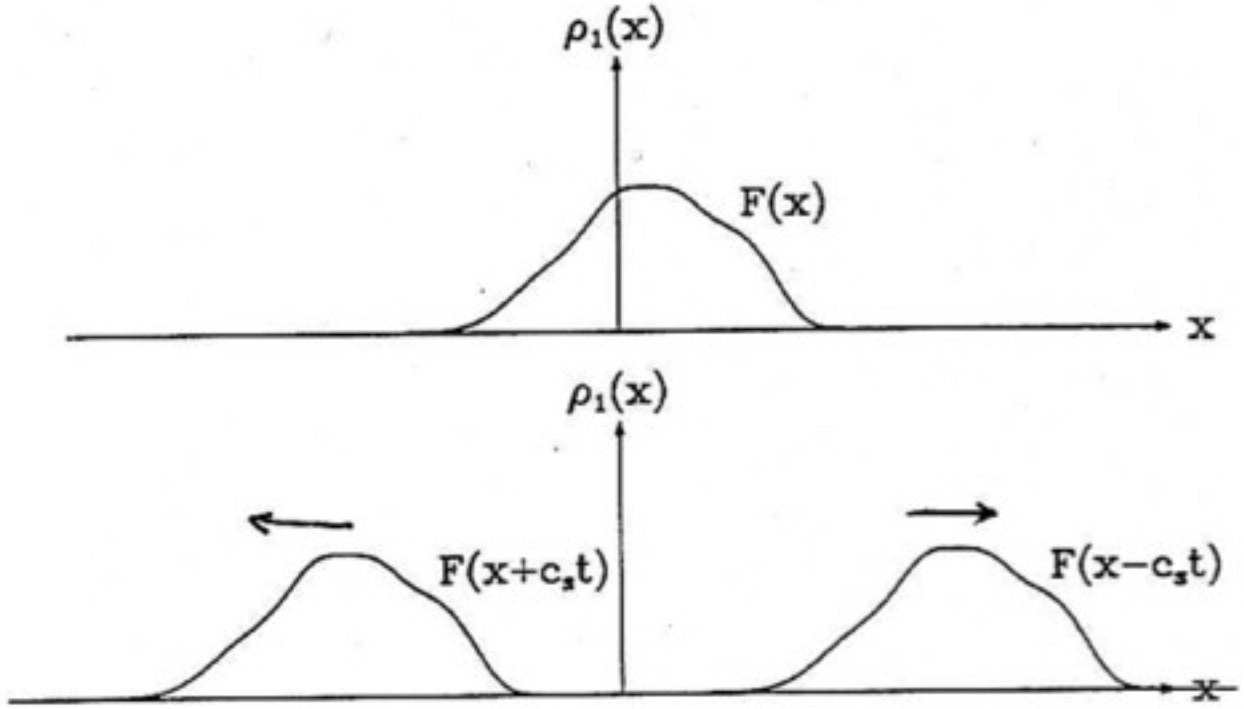

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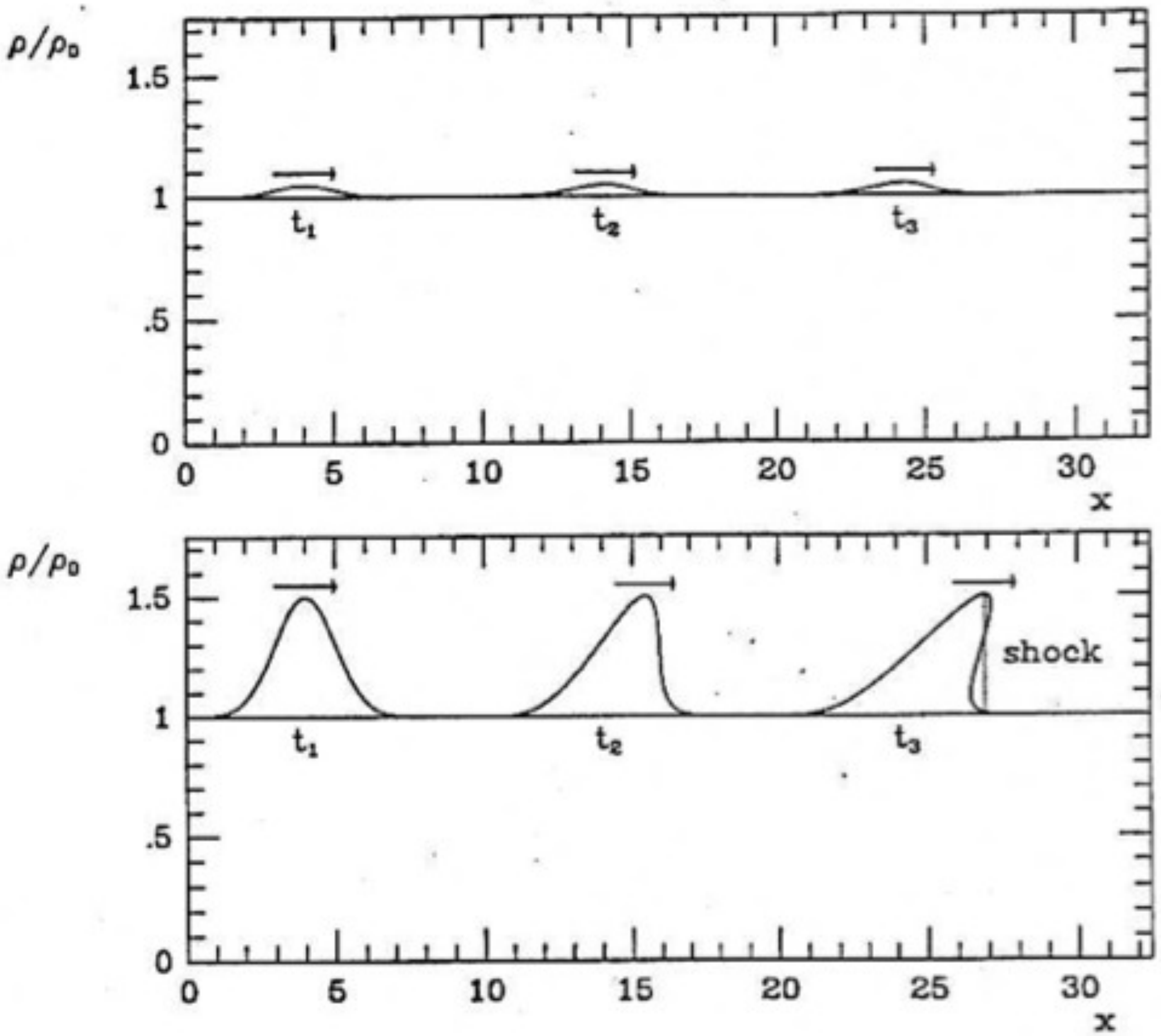


sound wave steepens into a shock wave; it breaks

Because large waves tend to "break," a region develops where at a given x the density $\rho(x)$ attempts to become multivalued. But the density (or pressure, or temperature) cannot become multivalued. So something strange must happen when the gradient of ρ_1 (or P_1, or T_1, or u_1) becomes infinite.

We call a region where something changes very fast a *shock front*. In such regions, the continuum approximation about the gas breaks down – things are changing a lot on a scale of one mean free path – so the fluid equations are not valid.

Shocks are a tracer of *supersonic motion*. In the example above, the top of the strong wave is traveling faster than the speed of sound in the undisturbed medium. This is why a shock develops.

Sonic boom: plane traveling faster than the speed of sound

http://apod.nasa.gov/apod/ap070819.html

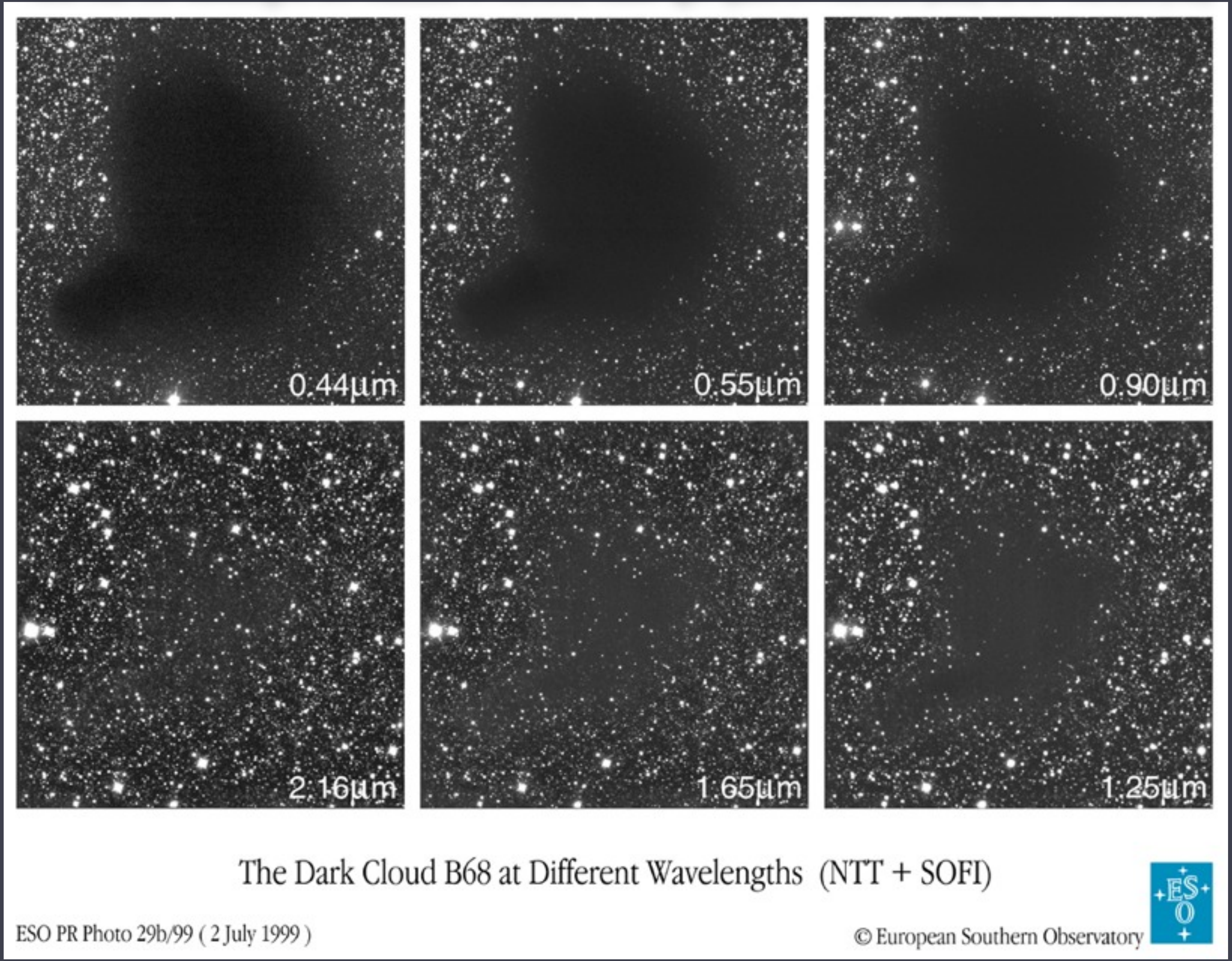
shock waves in outer space

http://apod.nasa.gov/apod/ap130529.html

additional, follow-up, information/elaboration

Here's Barnard 68 in various wavelengths, including some infrared wavelengths where the cloud is much less opaque

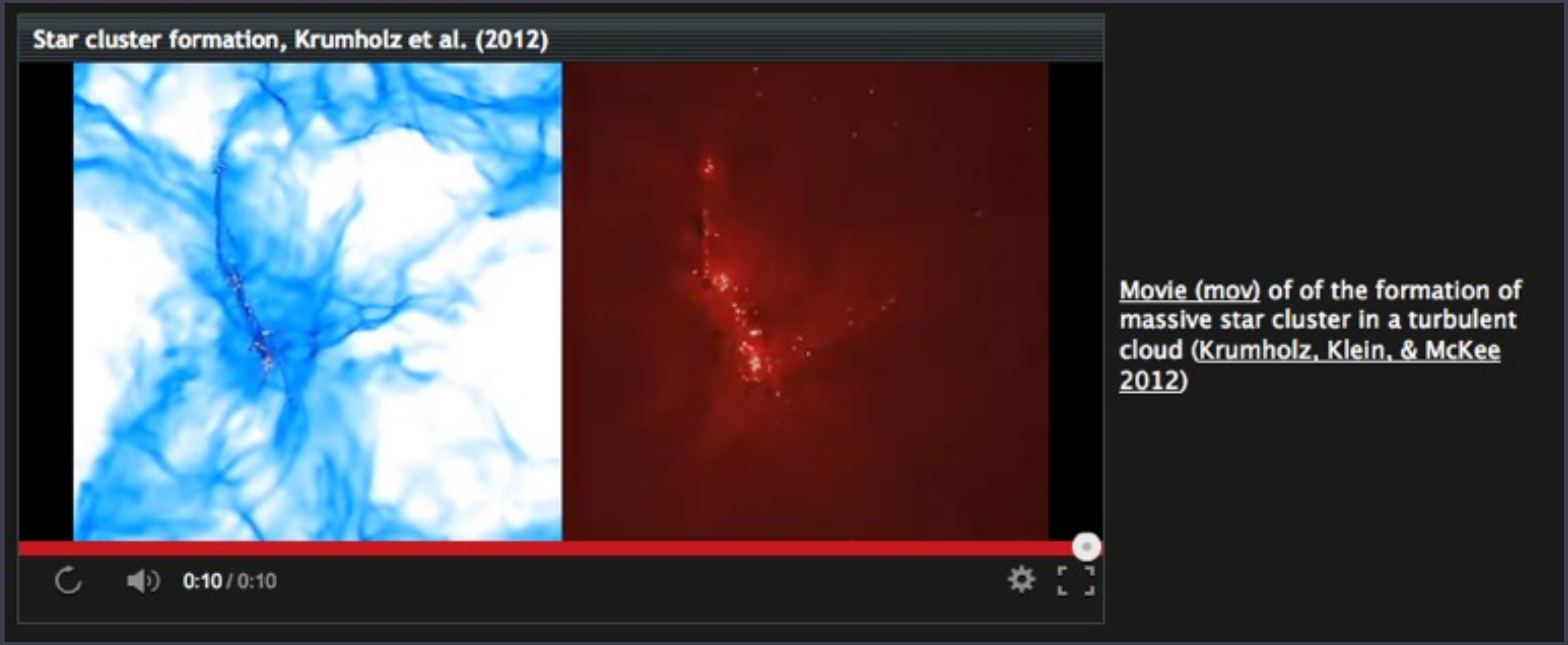
note that the wavelengths are indicated in microns; visible light spans 0.4 microns (blue) to 0.7 microns (red)



also, following up on the concept of star formation and cloud collapse

check out some of the movies of numerical simulations of the process made by Mark Krumholz at U.C. Santa Cruz:

https://sites.google.com/a/ucsc.edu/krumholz/movies



finally, the phenomenon of the sound waves in the early universe producing the hot and cold spots in the CMB is called - I forgot to mention - baryon acoustic oscillations

here are some resources for you to investigate

http://scholar.harvard.edu/deisenstein/book/baryon-acoustic-oscillations

http://astro.berkeley.edu/~mwhite/bao/

http://background.uchicago.edu/~whu/power/bao.html