SU(2) YM thermodynamics and photon physics

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plan

- sketch: deconfining SU(2) YMTD
  [RH, IJMPA 2005, MPLA 2006; F. Giacosa and RH, EPJC 2007; F. Giacosa and RH, PRD 2007; D. Kaviani and RH, MPLA 2007]

- $SU(2)_{CMB}$: photon polarization ↔ propagation
  [M. Schwarz, RH, F. Giacosa IJMPA 2006, JHEP 2006]

- physics at the phase boundary
  [F. Giacosa and RH, EPJC 2006]

- evidence in nature?
  [Brunt and Knee, Nature 2001; WMAP 2003; Cobe 1994, M. Szopa and RH 2007; M. Szopa, RH, F. Giacosa, and M. Schwarz 2007]

photons: SU(2) YM ??

- SU(2) YM $\xrightarrow{\text{deconf.}}$ U(1) plus

  – nontrivial ground state
  (topolog. fluctuations: calorons)
  [RH, IJMPA 2005; MPLA 2006]

  – massless γ; massive and very weakly interacting, charged vector excitations $V^{\pm}$ which decouple at phase boundary

  [Herbst, RH, Rohrer, AcPP 2005;
  Schwarz, RH, Giacosa, IJMPA 2007; JHEP 2007]

$\Rightarrow$ postulate: $\mathrm{SU(2)}_{\mathrm{CMB}} \overset{\text{today}}{=} \mathrm{U(1)}_Y$
[RH, PoS (JHW2005)]

phase diagram: SU(2) YM TD

confining

ground state:

Cooper−pair condensate of single center−vortex loops, pressure precisely zero

excitations:

massless (single) and massive (self−intersecting) center−vortex loops (spin−1/2 fermions)

preconfining

ground state:

condensate of magnetic monopoles, collapsing center−vortex loops, negative pressure

excitations:

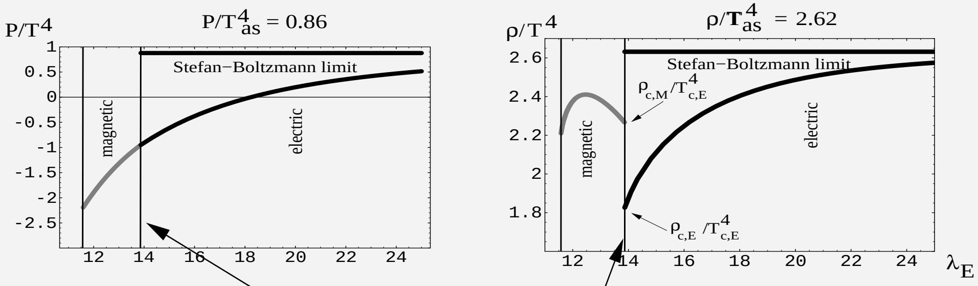
massive dual gauge modes

deconfining

ground state: interacting calorons and anticalorons, negative pressure

excitations: massless and massive gauge modes

power−like approach to Stefan Boltzmann limit



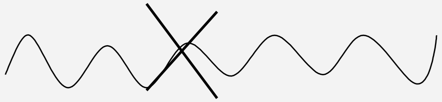
decoupling of V^+, V^-, no (anti) screening

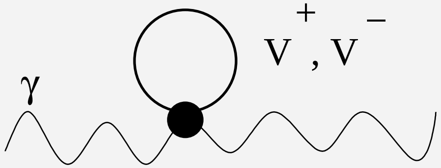
$T_c = 2.73$ K ⟶ $\Lambda \sim 10^{-4}$ eV

T_c

Hagedorn

2nd order like

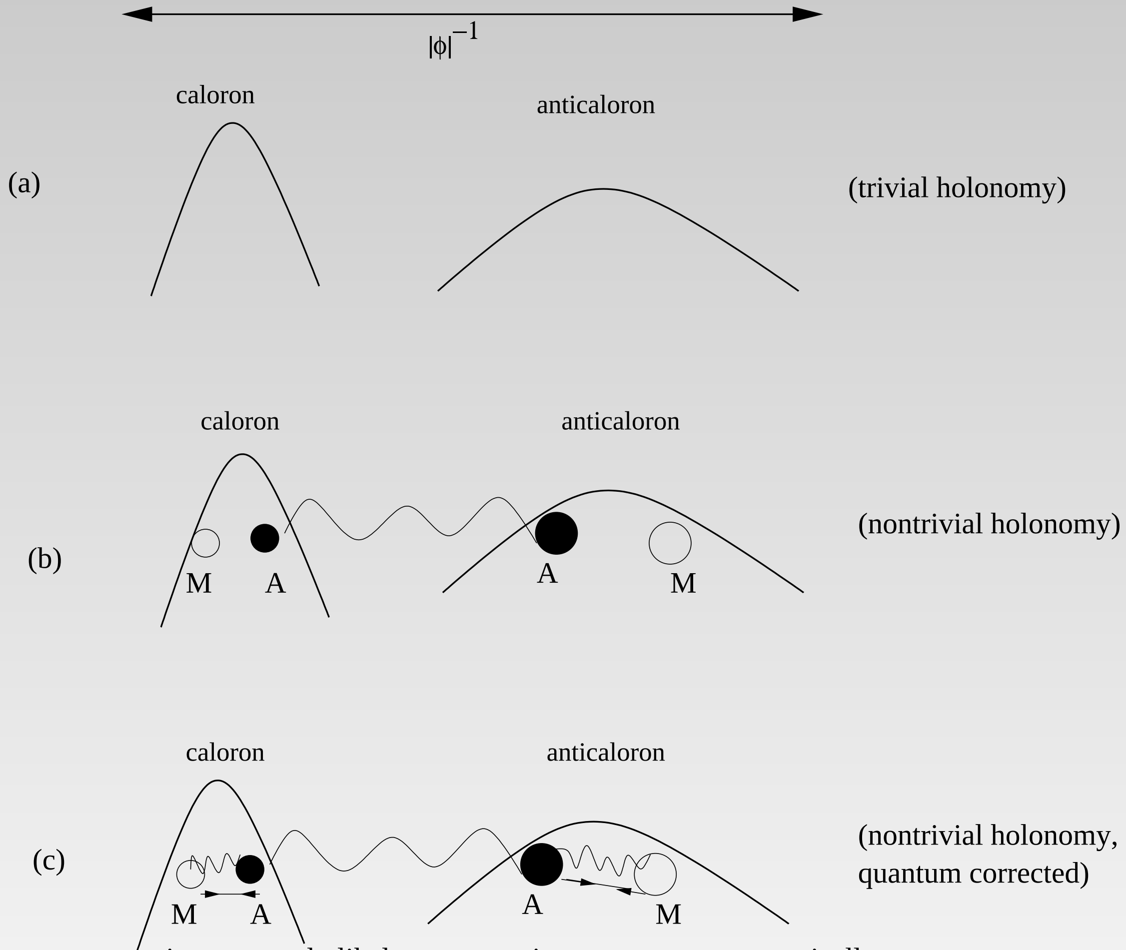




(anti) screening

T

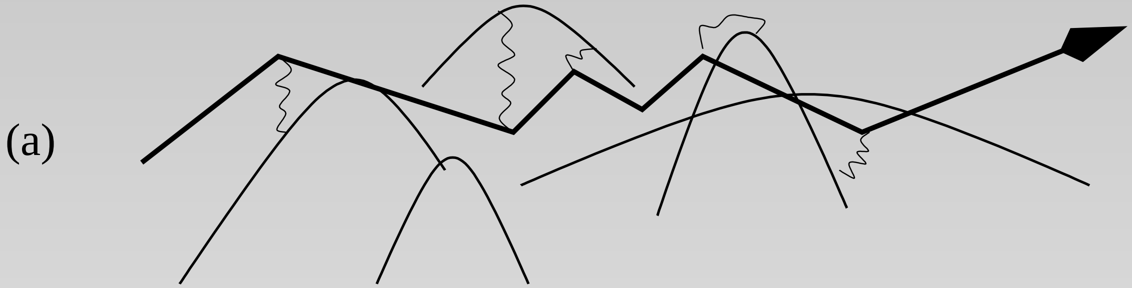
thermal ground state by spatial coarse-graining:



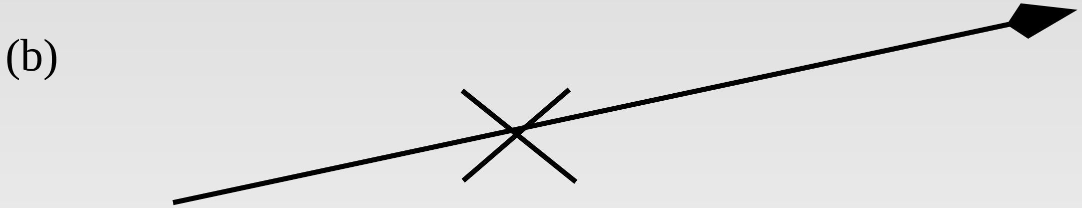
attraction extremely likely => negative pressure macroscopically
repulsion extremely unlikely => isolated and screened magnetic monopoles

[Nahm 1981; Kraan and van Baal 1998; Lee and Lu 1998, Diakonov 2004; U. Herbst and RH 2004; RH 2005]

emergence of mass:



microscopic situation



after spatial coarse−graining

in admissible unitary gauge:

$$m_{1,2} = 2e|\phi| = 2e\sqrt{\frac{\Lambda^3}{2\pi T}}\,, \quad m_3 = 0\,.$$

evolution of coupling e:

– invariance of Legendre trafos under spatial coarse-graining $\Rightarrow$

$$\partial_a \lambda = -\frac{24\lambda^4 a}{(2\pi)^6} \frac{D(2a)}{1+\frac{24\lambda^3 a^2}{(2\pi)^6} D(2a)}$$

– possesses attractor with plateau $e = \sqrt{8}\pi$

and singularity $e \propto -\log(\lambda - \lambda_c)$.

– charged vector excitations $V^{\pm}$ decouple at $\lambda_c \Rightarrow$

no screening $\Rightarrow \lambda_c \leftrightarrow T_{\text{CMB}} \sim 2.73\,\text{K} \Rightarrow$

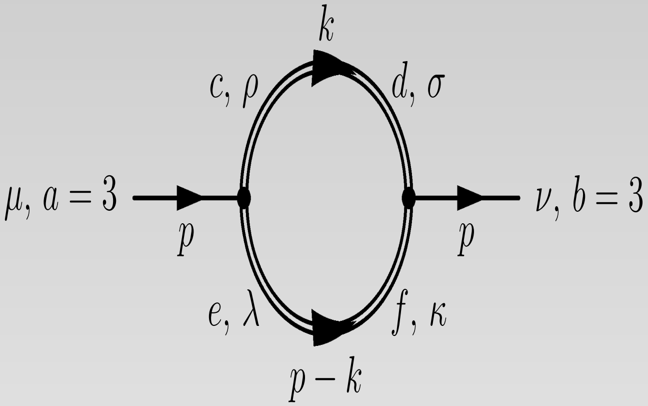
postulate:

$\text{SU(2)}_{\text{CMB}} \overset{\text{today}}{=} \text{U(1)}_Y$

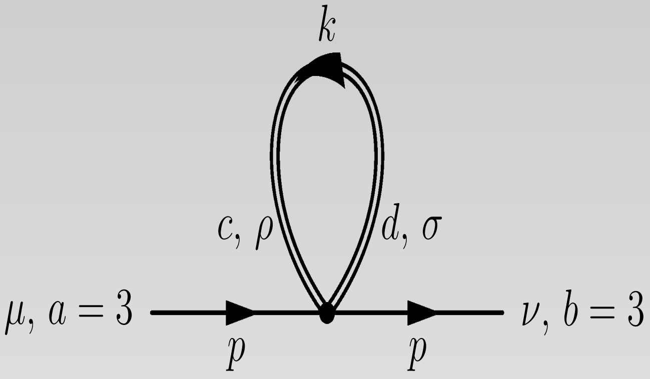
[RH, PoS (JHW2005)]

modified photon dispersion law:

– in effective theory compute one-loop polarization

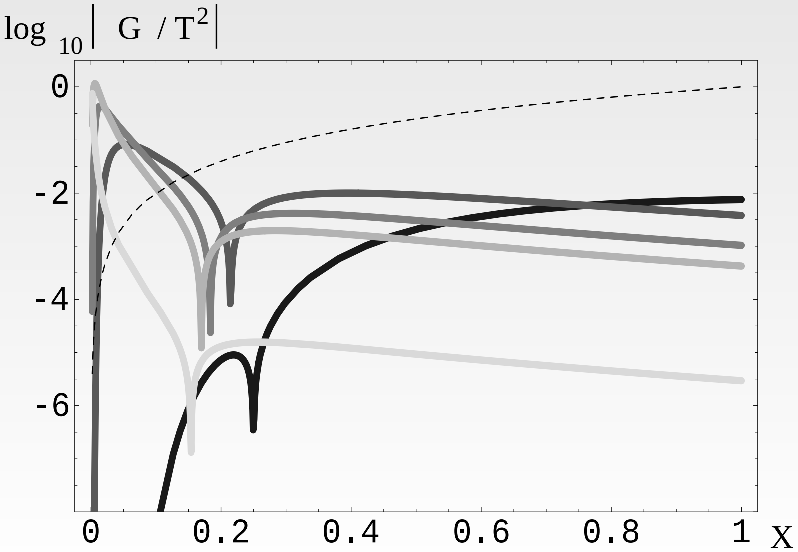


A



B

$\Rightarrow$ modified dispersion: $\omega^2 = \vec{p}^2 + G(T, |\vec{p}|)$



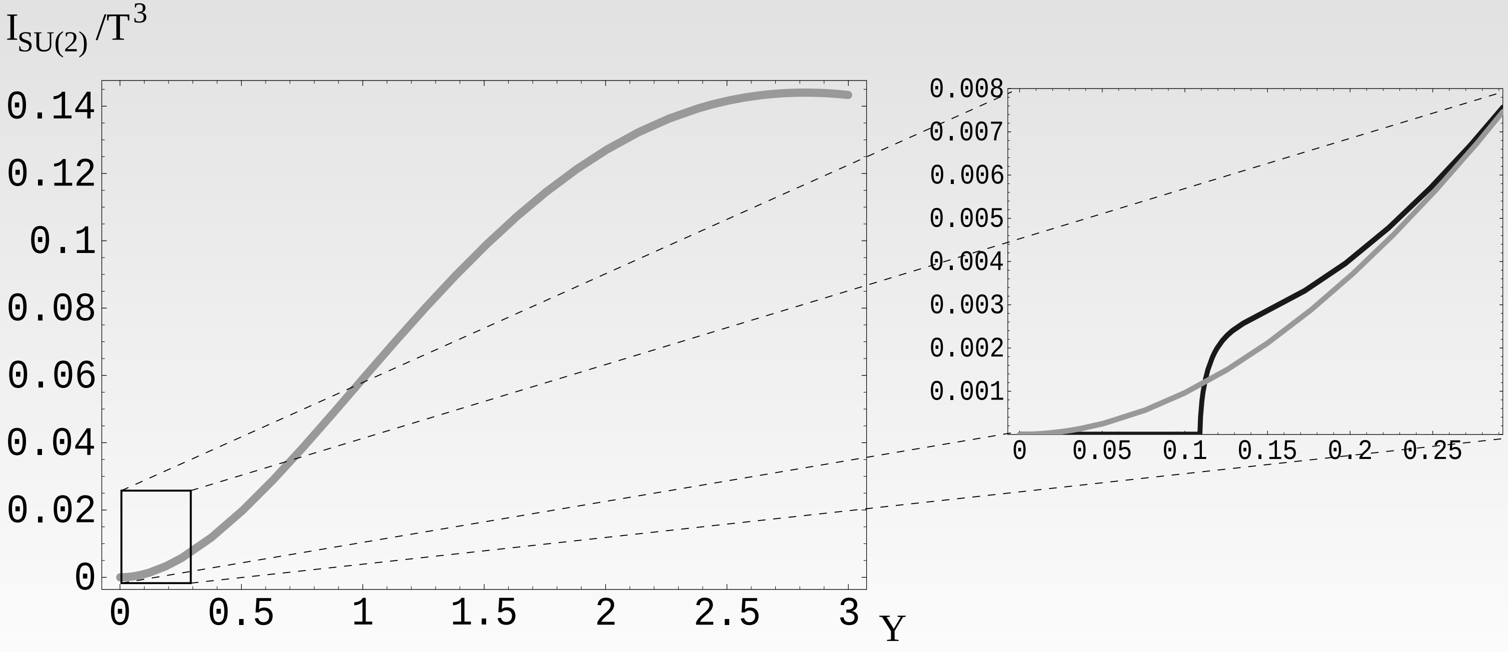
modified black-body spectra:

– $G \neq 0 \Rightarrow$

$$I_{\mathrm{U(1)}} = \frac{1}{\pi^2}\frac{\omega^3}{\exp\left[\frac{\omega}{T}\right]-1} \longrightarrow$$

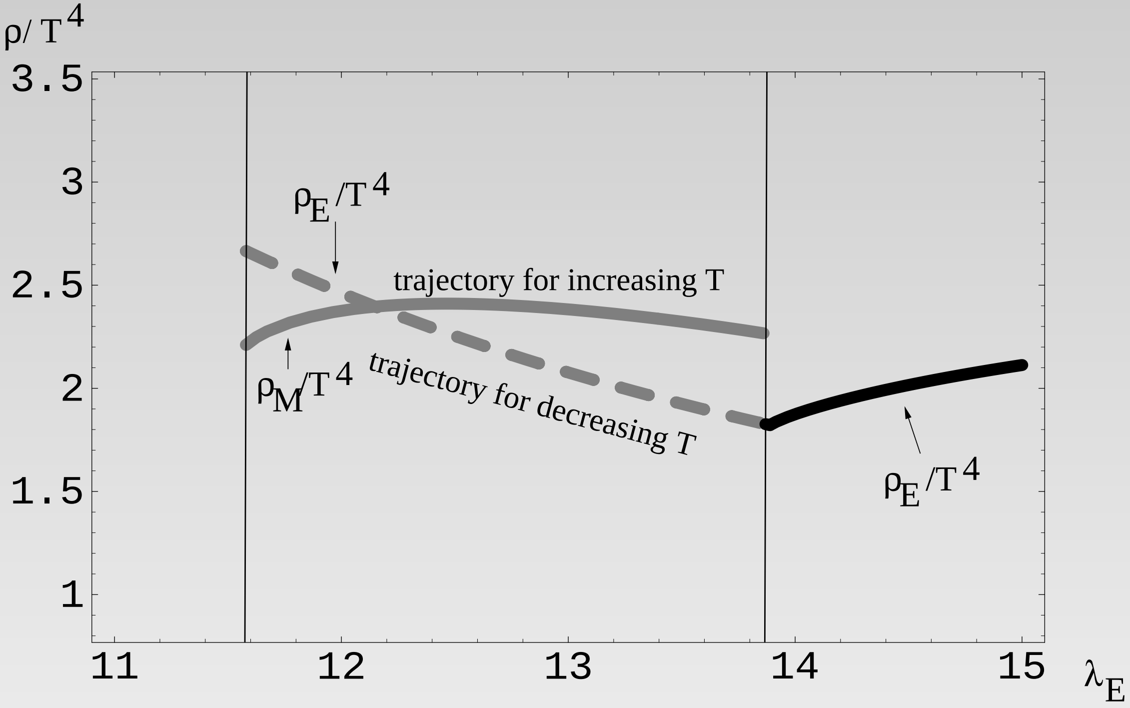
$$I_{\mathrm{SU(2)}} = I_{\mathrm{U(1)}} \times \frac{(\omega-\frac{1}{2}\frac{d}{d\omega}G)\sqrt{\omega^2-G}}{\omega^2}\,\theta(\omega-\omega^*)$$

where ω^* root of $\omega^2 = G$. For $T = 10\,\mathrm{K}$:



supercooling:

– energy density near phase boundary:



– duration of supercooling from H_0:

$$\Delta t_{m_\gamma=0} = (2.2 \pm 0.15)\,\mathrm{Gy}$$

– tunneling between two trajectories ⇒
increase of effective number of photon polarizations

(droplet model [RH, 2007])

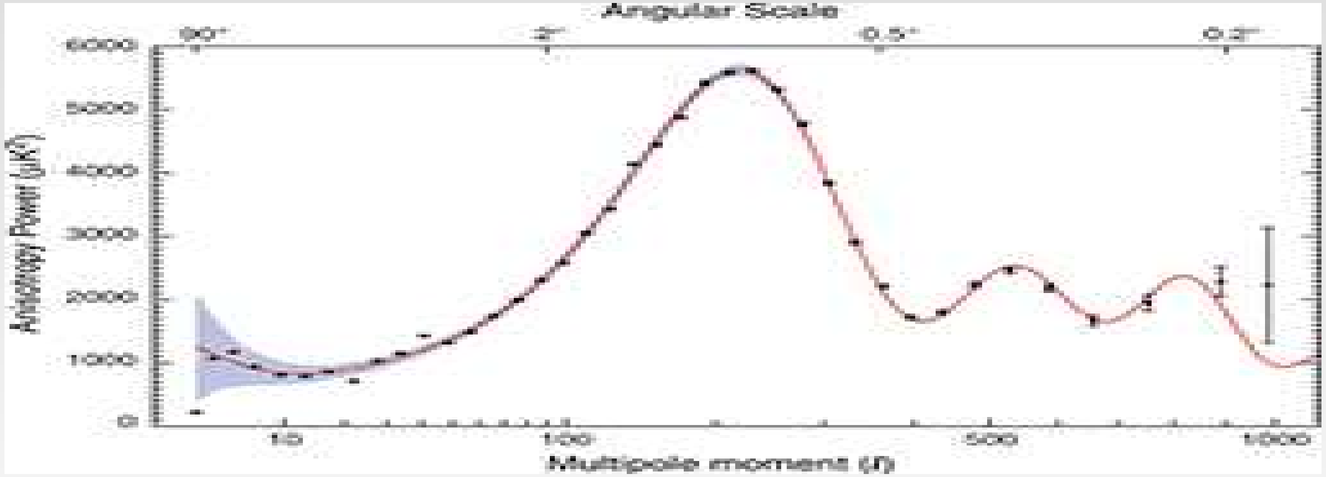
evidence in nature?:

low multipoles in CMB:

[Copi et al. 2007]

– strongly suppressed TT correlations for $\theta > 60$ degrees

– low multipoles statistically correlated



$\overset{?}{\Rightarrow}$ strong dynamic component in CMB dipole

[M. Szopa and RH 2007]

temperature offsets in FIRAS calibration:

[COBE 1994]

– errors in fit to ideal BB too large

[M. Szopa, RH, F. Giacosa, and M. Schwarz 2007]

however: conspicuous peak at $T = 2.2\,\mathrm{K}$

extreme supercooling

(increase of effective number of photon polarizations?)

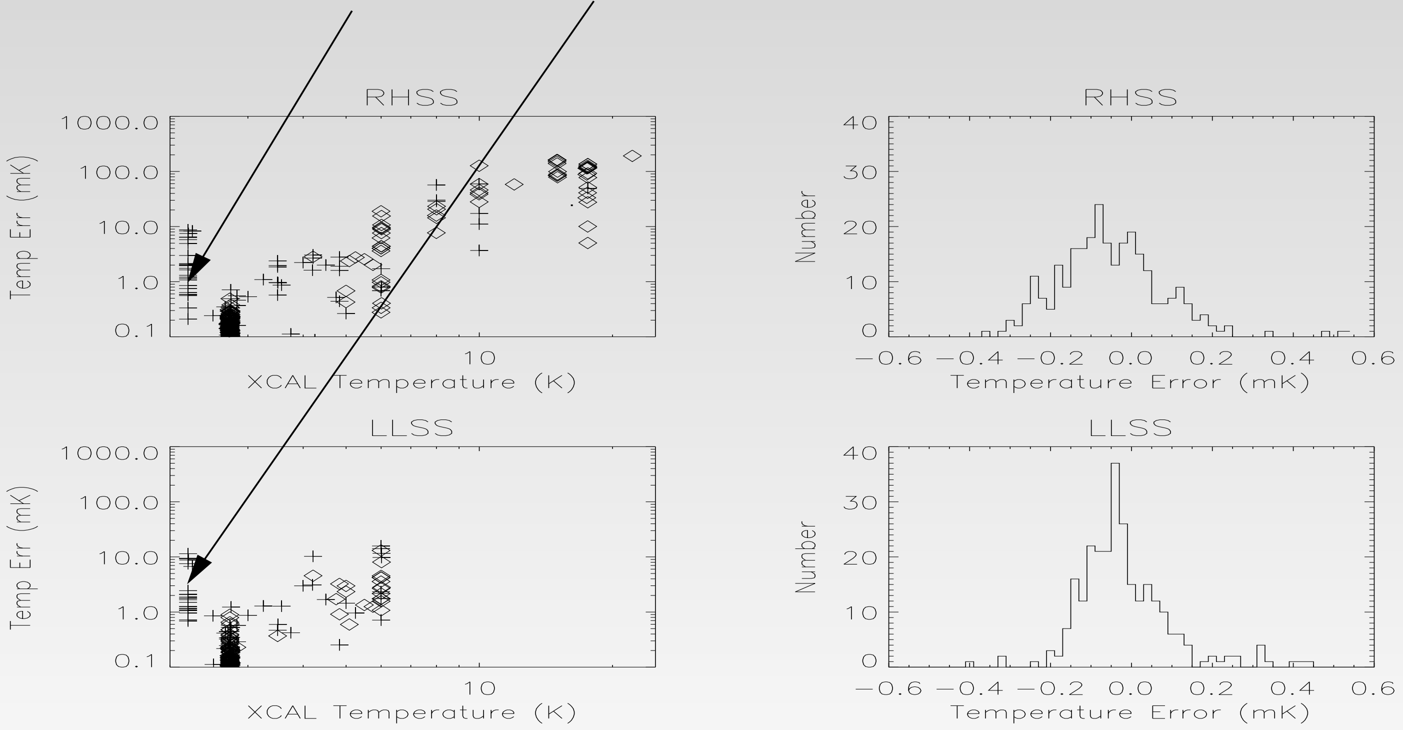
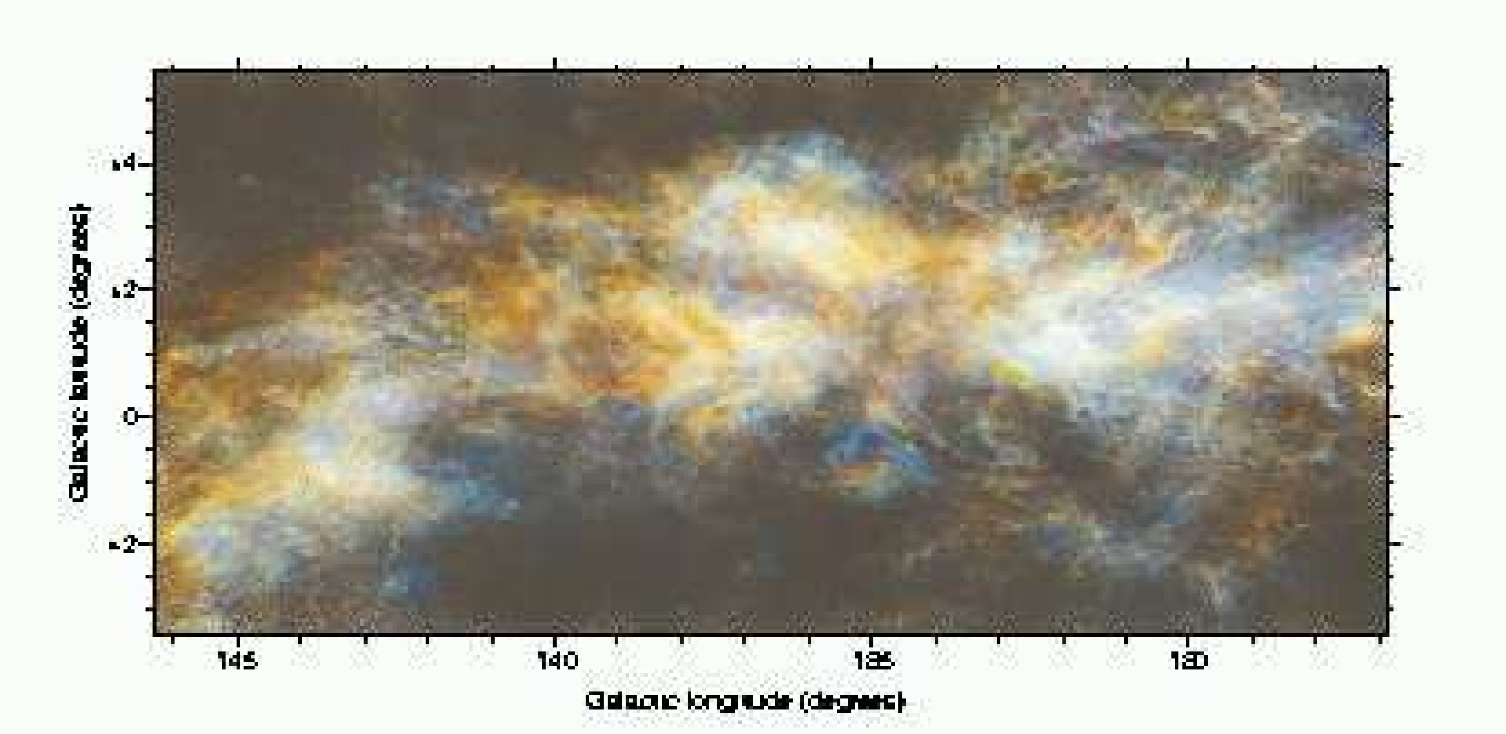


Fig. 5.3.— Photometric XCAL temperature adjustments — The values for RHSS (top plots) and LLSS (bottom plots) calibrations are shown here. The left hand plots are the adjustments (in mK), plotted as a function of XCAL temperature (in K). The symbol + indicates a positive correction, and the symbol ◇ indicates a negative correction. Temperatures greater than 7K are not used in LLSS. On the right are histograms of temperature adjustments for cold nulls (i.e. all controllables $\sim$2.7K).

cold, dilute, and old H1 clouds:

[Brunt and Knee, Nature 412, 308 (2001)]

– observations suggest:
age $5 \times 10^7\,y$, temperature 5 K-10 K, density 1 cm^{-3}



– simulations predict: age $\sim 1 \times 10^6\,y$

– wavelength 1cm in screening regime (BB anomaly)

[J. Keller and RH, work in progress]

conclusions

- SU(2) YMTD suggests modified photon propagation
- some evidence in favor, but not yet conclusive
- direct falsification/verification by terrestial low-T, low-ω BB experiment

Thank you.