Supersonic electroweak baryogenesis

Gláuber Carvalho Dorsch

U F M G

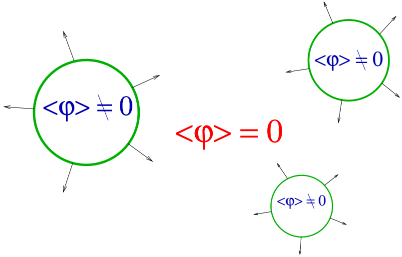
arXiv:2106.06547

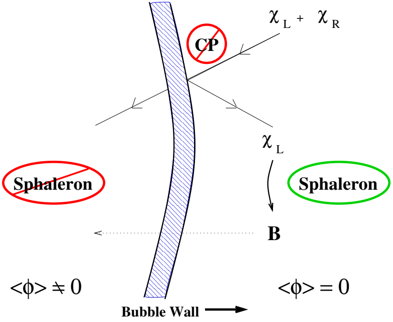
in collaboration with
T. Konstandin and S. Huber

PhenoBR
Natal (Zoom), 24 de Junho de 2021

Electroweak baryogenesis mechanism

- Bubbles nucleate during the EWPT
- Plasma + bubble interaction $\rightarrow$ chiral excess diffuses in front of the wall

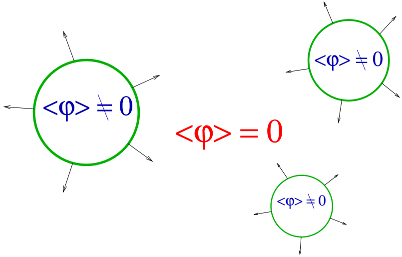


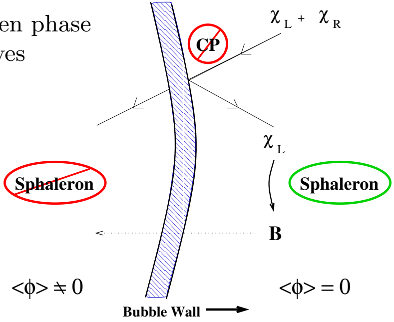


Morrisey and Ramsey-Musolf, New J. Phys. **14** *(2012) 125003*

Electroweak baryogenesis mechanism

- Bubbles nucleate during the EWPT
- Plasma + bubble interaction $\rightarrow$ chiral excess diffuses in front of the wall
- $B + L$ chiral anomaly active in unbroken phase
  Sphalerons: chiral excess $\longrightarrow$ B excess
- Bubble expansion sweeps excess inside broken phase
  Sphalerons inactive $\rightarrow$ B asymmetry survives

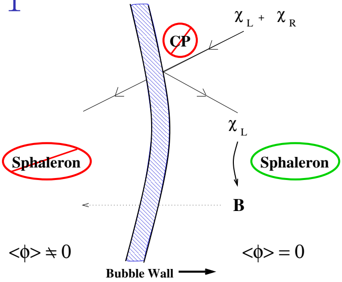




Morrisey and Ramsey-Musolf, New J. Phys. **14** *(2012) 125003*

Supersonic baryogenesis – Round 1

Can fuctuations in the plasma
propagate with speed $> c_s$
and produce a chiral asymmetry
in front of a supersonic wall?



Supersonic baryogenesis – Round 1

*Cline & Kainulainen, PRD **101** 063525 (2020)*

Can fuctuations in the plasma propagate with speed $> c_s$ and produce a chiral asymmetry in front of a supersonic wall?

It turns out...

For BAU one is interested in microscopic transport.
Different than collective macroscopic oscillations (sound)

$$f_i(x,p) = \frac{1}{e^{p^\mu u_\mu/T} \pm 1} + \delta f_i(x,p)$$

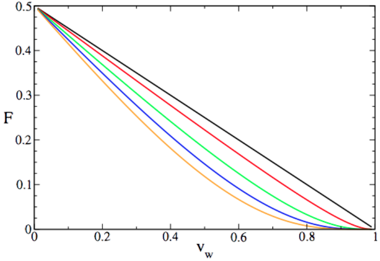


FIG. 1: Fraction of plasma particles that can stay ahead of a bubble wall moving at speed v_w. Different curves are for fermions with $m/T = 0, 1, 2, 3, 4$ (top to bottom).

Supersonic baryogenesis – Round 1

*Cline & Kainulainen, PRD **101** 063525 (2020)*

Can fuctuations in the plasma propagate with speed $> c_s$ and produce a chiral asymmetry in front of a supersonic wall?

It turns out...

For BAU one is interested in microscopic transport.
Different than collective macroscopic oscillations (sound)

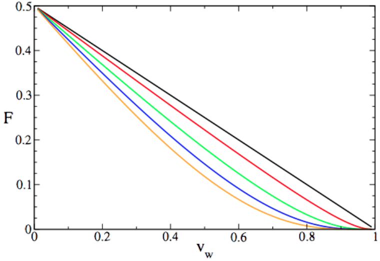


FIG. 1: Fraction of plasma particles that can stay ahead of a bubble wall moving at speed v_w. Different curves are for fermions with $m/T = 0, 1, 2, 3, 4$ (top to bottom).

$$f_i(x,p) = \frac{1}{e^{p^\mu u_\mu/T} \pm 1} + \delta f_i(x,p)$$

Fluid approximation

$$\delta f \simeq -\left(\mu/T + p^\mu \delta u_\mu/T - p^\mu u_\mu \delta T/T^2\right)\times \\ \times f'_{eq}(p^\mu u_\mu/T)$$

$$f_i(x,p) = \frac{1}{e^{\beta(p^\mu u_\mu + \delta)} \pm 1}$$

Supersonic baryogenesis – Round 1

Cline & Kainulainen, PRD **101** 063525 (2020)

Can fuctuations in the plasma propagate with speed $> c_s$ and produce a chiral asymmetry in front of a supersonic wall?

It turns out...

For BAU one is interested in microscopic transport.
Different than collective macroscopic oscillations (sound)

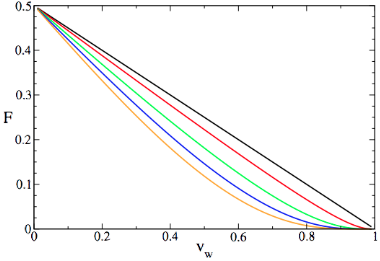
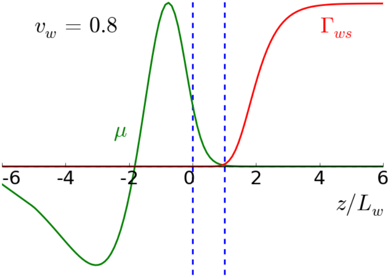


FIG. 1: Fraction of plasma particles that can stay ahead of a bubble wall moving at speed v_w. Different curves are for fermions with $m/T = 0, 1, 2, 3, 4$ (top to bottom).

$$f_i(x,p) = \frac{1}{e^{p^\mu u_\mu/T} \pm 1} + \delta f_i(x,p)$$

Fluid approximation

$$\delta f \simeq -\left(\mu/T + p^\mu \delta u_\mu/T - p^\mu u_\mu \delta T/T^2\right) \times \times f'_{eq}(p^\mu u_\mu/T)$$



Supersonic baryogenesis – Round 1

Cline & Kainulainen, PRD **101** 063525 (2020)

Can fuctuations in the plasma propagate with speed $> c_s$ and produce a chiral asymmetry in front of a supersonic wall?

It turns out...

For BAU one is interested in microscopic transport.
Different than collective macroscopic oscillations (sound)

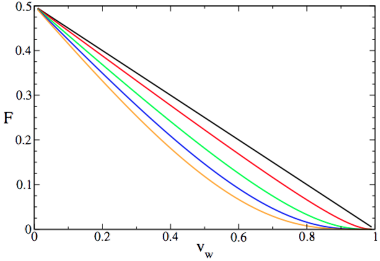
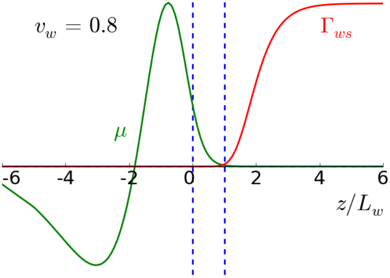


FIG. 1: Fraction of plasma particles that can stay ahead of a bubble wall moving at speed v_w. Different curves are for fermions with $m/T = 0, 1, 2, 3, 4$ (top to bottom).

$$f_i(x,p) = \frac{1}{e^{p^\mu u_\mu/T} \pm 1} + \delta f_i(x,p)$$

Fluid approximation

$$\delta f \simeq -\left(\mu/T + p^\mu \delta u_\mu/T - p^\mu u_\mu \delta T/T^2\right) \times$$
$$\times f'_{eq}(p^\mu u_\mu/T)$$



But how reliable is this Ansatz?
Are three perturbations enough?

Outline

- Modelling charge transport:
  The Boltzmann equation and the need for an Ansatz

- Generalized fluid Ansatz

$$\boxed{f(x,p) \simeq f_{\rm eq}(p) + \left(\underbrace{w^{(0)}}_{-\mu} + p^\mu \underbrace{w^{(1)}_\mu}_{\delta T/T,\ -\delta v} + p^\mu p^\nu w^{(2)}_{\mu\nu} + \cdots \right) f'_{\rm eq}(p)}$$

- Wall velocity dependence of the BAU:
  continuity and convergence

- Conclusions and outlook

Modelling transport: Boltzmann equation

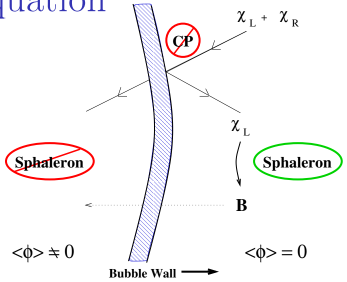
How can we model this complicated process?

FROM FIRST PRINCIPLES...

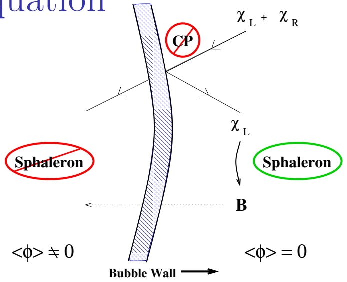
Wightman functions (propagators)

$$\Delta^{>,<} \sim \delta(p^2 - m^2)\, f_i(x,p)$$

satisfy Kadanoff-Baym equations



Modelling transport: Boltzmann equation



How can we model this complicated process?

From first principles...

Wightman functions (propagators)

$\Delta^{>,<} \sim \delta(p^2 - m^2)\, f_i(x,p)$

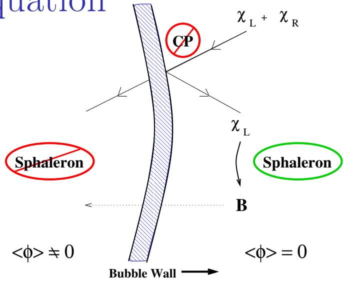
satisfy Kadanoff-Baym equations

Gradient expansion $\left(L_w \gtrsim 1/T \iff \right.$ semiclassical, plasma is on-shell $\left. \right)$

$$\boxed{p^\mu \partial_\mu\, f_i(x^\mu, p^\mu) + m\, F^\mu \partial_{p^\mu}\, f_i(x^\mu, p^\mu) = \mathcal{C}[f_j]}$$

$$\boxed{f_i = f_i^{\rm eq} + \delta f_i}$$

Modelling transport: Boltzmann equation



How can we model this complicated process?

FROM FIRST PRINCIPLES...

Wightman functions (propagators)

$$\Delta^{>,<} \sim \delta(p^2 - m^2)\, f_i(x,p)$$

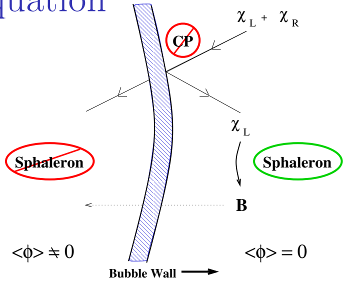
satisfy Kadanoff-Baym equations

GRADIENT EXPANSION $\left(L_w \gtrsim 1/T \Longleftrightarrow \begin{array}{c}\text{SEMICLASSICAL,} \\ \text{PLASMA IS ON-SHELL}\end{array} \right)$

$$\boxed{p^\mu \partial_\mu \, \delta f_i(x^\mu, p^\mu) = \mathcal{S}[f_j] + \mathcal{C}[f_j]}$$

$$\boxed{f_i = f_i^{\text{eq}} + \delta f_i}$$

Modelling transport: Boltzmann equation



How can we model this complicated process?

FROM FIRST PRINCIPLES...

Wightman functions (propagators)

$\Delta^{>,<} \sim \delta(p^2 - m^2)\, f_i(x,p)$

satisfy Kadanoff-Baym equations

GRADIENT EXPANSION $\left(L_w \gtrsim 1/T \iff \right.$ SEMICLASSICAL, PLASMA IS ON-SHELL $\left.\right)$

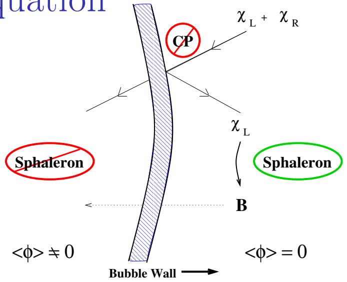
$$\boxed{p^\mu \partial_\mu \, \delta f_i(x^\mu, p^\mu) = \mathcal{S}[f_j] + \mathcal{C}[f_j]}$$

$$\boxed{f_i = f_i^{\text{eq}} + \delta f_i}$$

$$\mathcal{C}[f] = \sum_{\text{processes}} \frac{1}{2} \int_k \int_{p'} \int_{k'} |\mathcal{M}|^2 (2\pi)^4 \delta^4(p + k - p' - k') \mathcal{P}[f]$$

$$\mathcal{P}[f] \equiv \Big[f_p f_k (1 \pm f_{p'})(1 \pm f_{k'}) - f_{p'} f_{k'} (1 \pm f_p)(1 \pm f_k) \Big]$$

Modelling transport: Boltzmann equation



How can we model this complicated process?

FROM FIRST PRINCIPLES...

Wightman functions (propagators)

$$\Delta^{>,<} \sim \delta(p^2 - m^2)\, f_i(x,p)$$

satisfy Kadanoff-Baym equations

GRADIENT EXPANSION $\left(L_w \gtrsim 1/T \Longleftrightarrow \right.$ SEMICLASSICAL, PLASMA IS ON-SHELL $\left. \right)$

$$\boxed{p^\mu \partial_\mu \, \delta f_i(x^\mu, p^\mu) = \mathcal{S}[f_j] + \mathcal{C}[f_j]}$$

$$\boxed{f_i = f_i^{\text{eq}} + \delta f_i}$$

$$\mathcal{C}[f] = \sum_{\text{processes}} \frac{1}{2} \int_k \int_{p'} \int_{k'} |\mathcal{M}|^2 (2\pi)^4 \delta^4(p + k - p' - k') \mathcal{P}[f]$$

$$\mathcal{P}[f] \equiv \Big[f_p f_k (1 \pm f_{p'})(1 \pm f_{k'}) - f_{p'} f_{k'} (1 \pm f_p)(1 \pm f_k) \Big]$$

We need an Ansatz!

The fluid Ansatz

$$\boxed{f_i(x,p) = \frac{1}{e^{\beta(p^\mu u_\mu + \delta)} \pm 1}}$$

$$\boxed{\delta = -\left(\mu - p^\mu u_\mu \delta T/T + p^\mu \delta u_\mu + \ldots\right)}$$

Steady planar wall

3 fluctuations

$$q = (\mu, -\delta T/T, \delta v)^T$$

The fluid Ansatz

$$f_i(x,p) = \frac{1}{e^{\beta(p^\mu u_\mu + \delta)} \pm 1}$$

$$\delta = -\left(\mu - p^\mu u_\mu \delta T/T + p^\mu \delta u_\mu + \dots\right)$$

Steady planar wall

3 fluctuations

$$q = (\mu, -\delta T/T, \delta v)^T$$

Get rid of p^μ dependence $\Longrightarrow$ take moments!

$$\partial_\mu J^\mu = \int \frac{d^3p}{E_p} p^\mu \partial_\mu f = \int \frac{d^3p}{E_p} p^\mu \mathcal{C} + \text{source}$$

$$\partial_\mu T^{\mu\nu} = \int \frac{d^3p}{E_p} p^\mu p^\nu \partial_\mu f = \int \frac{d^3p}{E_p} p^\mu p^\nu \mathcal{C} + \text{source}$$

The fluid Ansatz

$$\boxed{f_i(x,p) = \frac{1}{e^{\beta(p^\mu u_\mu + \delta)} \pm 1}}$$

$$\boxed{\delta = -\left(\mu - p^\mu u_\mu \delta T/T + p^\mu \delta u_\mu + \ldots\right)}$$

Steady planar wall

3 fluctuations

$$q = (\mu, -\delta T/T, \delta v)^T$$

Get rid of p^μ dependence $\Longrightarrow$ take moments!

$$\partial_\mu J^\mu = \int \frac{d^3p}{E_p} p^\mu \partial_\mu f = \int \frac{d^3p}{E_p} p^\mu \mathcal{C} + \text{source}$$

$$\partial_\mu T^{\mu\nu} = \int \frac{d^3p}{E_p} p^\mu p^\nu \partial_\mu f = \int \frac{d^3p}{E_p} p^\mu p^\nu \mathcal{C} + \text{source}$$

Linearizing in perturbations, collision terms become tractable

(even analytically at leading-log)

$$\int_p p^\mu \ldots p^\nu \mathcal{C}[f] = \int_p \int_k \int_{p'} \int_{k'} |\mathcal{M}|^2 (2\pi)^4 \delta^4(p+k-p'-k') f_p^{\text{eq}} f_k^{\text{eq}} (1 \pm f_{p'}^{\text{eq}})(1 \pm f_{k'}^{\text{eq}}) \times$$
$$\times p^\mu \ldots p^\nu (\delta_p + \delta_k - \delta_{p'} - \delta_{k'})$$

The linearized system

$$\boxed{A \cdot q' + \Gamma \cdot q = S} \quad A = \begin{pmatrix} v_w c_2 & v_w c_3 & c_3/3 \\ v_w c_3 & v_w c_4 & c_4/3 \\ c_3/3 & c_4/3 & v_w c_4/3 \end{pmatrix}$$

Γ calculated since the 90s

Moore & Prokopec, PRD ***52****, n. 12 (1995) 7182*

$$q(z) = \int_z^\infty dz' \sum_{\lambda_i > 0} (\chi_i^{-1} \cdot A^{-1} \cdot S)(z')\, \chi_i \, \exp\left[-\lambda_i \,(z' - z)\right]$$

$$- \int_{-\infty}^z dz' \sum_{\lambda_i < 0} (\chi_i^{-1} \cdot A^{-1} \cdot S)(z')\, \chi_i \, \exp\left[-\lambda_i \,(z' - z)\right]$$

The linearized system

$$\boxed{A \cdot q' + \Gamma \cdot q = S} \qquad A = \begin{pmatrix} v_w c_2 & v_w c_3 & c_3/3 \\ v_w c_3 & v_w c_4 & c_4/3 \\ c_3/3 & c_4/3 & v_w c_4/3 \end{pmatrix}$$

Γ calculated since the 90s

*Moore & Prokopec, PRD **52**, n. 12 (1995) 7182*

$$q(z) = \int_z^\infty dz' \sum_{\lambda_i > 0} (\chi_i^{-1} \cdot A^{-1} \cdot S)(z')\, \chi_i \exp\left[-\lambda_i\,(z' - z)\right]$$
$$- \int_{-\infty}^z dz' \sum_{\lambda_i < 0} (\chi_i^{-1} \cdot A^{-1} \cdot S)(z')\, \chi_i \exp\left[-\lambda_i\,(z' - z)\right]$$

$$\boxed{\lambda_i = \mathrm{eig}(A^{-1} \cdot \Gamma)}$$

$v_w < c_s$

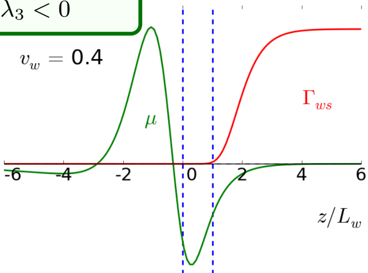
$\lambda_1, \lambda_2 > 0$
$\lambda_3 < 0$

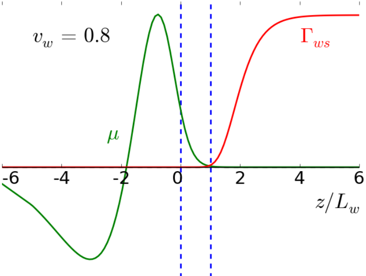
$v_w = c_s = 1/\sqrt{3}$

$\det A = 0$

$v_w > c_s$

$\lambda_{1,2,3} > 0$



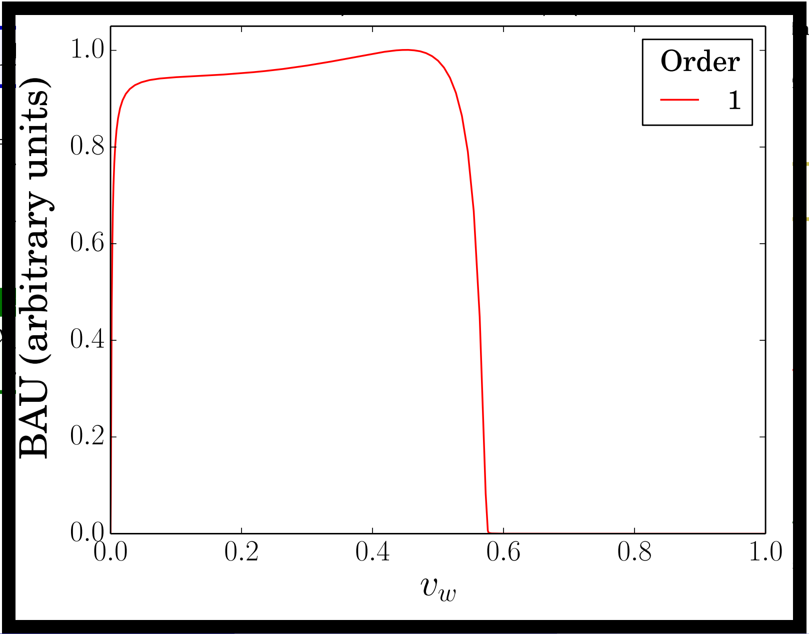


The linearized system

he 90s

7182

$q(z) =$



The need for higher orders

The eigenvalue sign flip is associated to the mode $v_w \delta v = -\delta T/T$

$$\boxed{\begin{aligned} \delta f &= (p_z \delta v - E_p \delta T/T)\, f'(E_p/T)/T \\ &\simeq \left(p_z + v_w E_p\right) \delta v\, f'(E_p/T)/T \end{aligned}}$$

$\xi \equiv z + v_w t$

$$p^\mu \partial_\mu = (v_w E_p - p_z)\partial_\xi$$

$$\boxed{p^\mu \partial_\mu \delta f = \left(v_w^2 E_p^2 - p_z^2\right)(\partial_\xi \delta v)\frac{f'(E_p/T)}{T}}$$

The need for higher orders

The eigenvalue sign flip is associated to the mode $v_w \delta v = -\delta T/T$

$$\boxed{\begin{aligned} \delta f &= (p_z \delta v - E_p \delta T/T)\, f'(E_p/T)/T \\ &\simeq \left(p_z + v_w E_p\right) \delta v\, f'(E_p/T)/T \end{aligned}}$$

$\xi \equiv z + v_w t$

$$p^\mu \partial_\mu = (v_w E_p - p_z)\partial_\xi$$

$$\boxed{p^\mu \partial_\mu \delta f = \left(v_w^2 E_p^2 - p_z^2\right)(\partial_\xi \delta v)\frac{f'(E_p/T)}{T}}$$

But

$$\langle E_p^n\, p_z^2\, f'\rangle = \frac{\langle E_p^{n+2}\, f'\rangle}{3}$$

At $c_s = 1/\sqrt{3}$

$$p_\mu \partial_\mu \delta f \simeq 0$$

unless terms p_z^4 (or higher) appear!

Extended fluid Ansatz

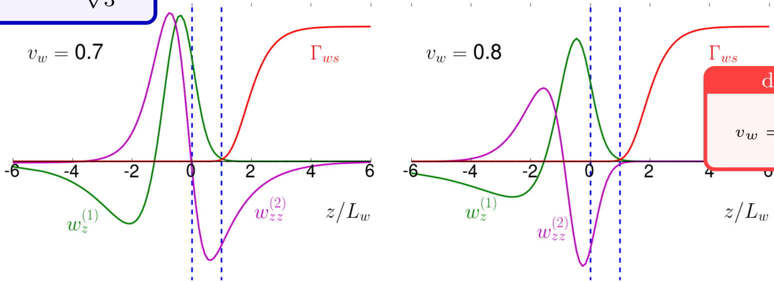
$$\delta f = \left(w^{(0)} + p^\mu w_\mu^{(1)} + p^\mu p^\nu w_{\mu\nu}^{(2)} + \cdots \right) f'_{\rm eq}(p^\mu u_\mu / T)$$

To 2^{nd} order

$$A = \begin{pmatrix} v_w c_2 & v_w c_3 & c_3/3 & v_w c_4 & c_4/3 & v_w c_4/3 \\ v_w c_3 & v_w c_4 & c_4/3 & v_w c_5 & c_5/3 & v_w c_5/3 \\ c_3/3 & c_4/3 & v_w c_4/3 & c_5/3 & v_w c_5/3 & c_5/5 \\ v_w c_4 & v_w c_5 & c_5/3 & v_w c_6 & c_6/3 & v_w c_6/3 \\ c_4/3 & c_5/3 & v_w c_5/3 & c_6/3 & v_w c_6/3 & c_6/5 \\ v_w c_4/3 & v_w c_5/3 & c_5/5 & v_w c_6/3 & c_6/5 & v_w c_6/5 \end{pmatrix}$$

det $A = 0$

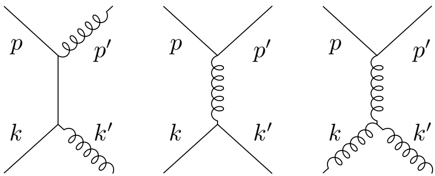
$$v_w = \frac{1}{\sqrt{3}}$$



det $A = 0$

$$v_w = \sqrt{\frac{3}{5}} \approx 0.77$$

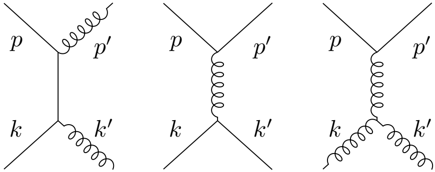
Collision terms



Singular behaviour $\longleftarrow$ kinetic term
but
collisions important for convergence

We consider a “network” of tops only
Other particles treated as background

Collision terms



Singular behaviour $\longleftarrow$ kinetic term
but
collisions important for convergence

We consider a "network" of tops only
Other particles treated as background

$$\boxed{\text{coll.} \sim \delta_p + \delta_k - \delta_{p'} - \delta_{k'}}$$

Annihilations

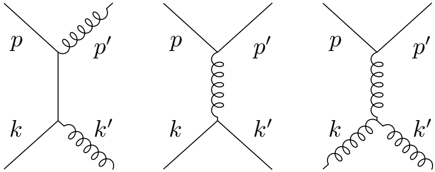
$$|\mathcal{M}|^2 \sim -g_s^4 \frac{st}{(t-m_q^2)^2}$$

$$t = -2p\cdot p' = -2|\mathbf{p}||\mathbf{p}'|\cos\theta_{pp'}$$

$$\int_p p^\mu \ldots p^\nu \mathcal{C}[f] \simeq \int_p \int_k \int_{p'} \int_{k'} \frac{st}{(t-m_q^2)^2} \delta^4(\ldots) p^\mu \ldots p^\nu f_p f_k (1 \pm f_{p'})(1 \pm f_{k'}) \times$$

$$\times \left[\ldots + w^{(2)}_{\rho\sigma}(p^\rho p^\sigma + k^\rho k^\sigma) + \ldots \right]$$

Collision terms



Singular behaviour $\longleftarrow$ kinetic term
but
collisions important for convergence

We consider a "network" of tops only
Other particles treated as background

$$\boxed{\text{coll.} \sim \delta_p + \delta_k - \delta_{p'} - \delta_{k'}}$$

Scatterings

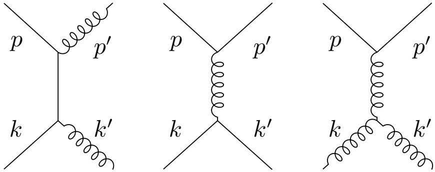
$$|\mathcal{M}|^2 \sim -g_s^4 \frac{s^2}{(t - m_q^2)^2}$$

Much more complicated

Can be done analytically to leading-log!

$$\int_p p^\mu \dots p^\nu \mathcal{C}[f] \simeq \int_p \int_k \int_{p'} \int_{k'} \frac{s^2}{(t - m_q^2)^2} \delta^4(\dots) p^\mu \dots p^\nu f_p f_k (1 \pm f_{p'})(1 \pm f_{k'}) \times$$
$$\times \left[\dots + w^{(2)}_{\rho\sigma} (p^\rho p^\sigma - p'^\rho p'^\sigma) + \dots \right]$$

Collision terms



Calculated analytically to leading-log!

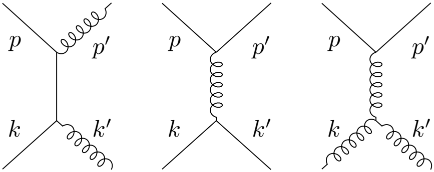
Singular behaviour $\longleftarrow$ kinetic term
but
collisions important for convergence

We consider a "network" of tops only
Other particles treated as background

QCD processes

$\Gamma \sim \alpha_s^2 \log \alpha_s$
Transport regulated by α_s

Collision terms



Singular behaviour $\longleftarrow$ kinetic term
but
collisions important for convergence

We consider a "network" of tops only
Other particles treated as background

QCD processes

$\Gamma \sim \alpha_s^2 \log \alpha_s$
Transport regulated by α_s

Calculated analytically to leading-log!

Source

CPV obviously important for BAU

But...

v_w dependence dominated by kinetic term
Collisions set the convergence behaviour
Details of the source not so important

CP-even source!

$$mF_\mu \equiv \frac{\partial_\mu m^2}{2}$$

Ignore strong sphalerons,
chirality flips
These affect BAU magnitude
but not v_w dependence

Weak sphalerons

Sphaleron rate is known

$$\Gamma_{ws} \simeq 10^{-6} T \exp(-a\phi(z)/T)$$

But how does it couple to the fluid fluctuations?

Weak sphalerons

Sphaleron rate is known

$$\Gamma_{ws} \simeq 10^{-6} T \exp(-a\phi(z)/T)$$

But how does it couple to the fluid fluctuations?

Typically

$$\partial_z n_B \sim \Gamma_{ws} \frac{\mu}{T}$$

Weak sphalerons

Sphaleron rate is known

$$\Gamma_{ws} \simeq 10^{-6} T \exp(-a\phi(z)/T)$$

Typically

$$\partial_z n_B \sim \Gamma_{ws} \frac{\mu}{T}$$

But how does it couple to the fluid fluctuations?

Merely zeroth-order term of a long expansion!

Strongly dependent on basis choice for fluctuations

This Ansatz seems inadequate here!

Weak sphalerons

Sphaleron rate is known

$\Gamma_{ws} \simeq 10^{-6} T \exp(-a\phi(z)/T)$

Typically

$$\partial_z n_B \sim \Gamma_{ws} \frac{\mu}{T}$$

Our Ansatz

Couple sphaleron to particle number current density

$$J^\mu = \int_p p^\mu f$$

At 0-th order, $J^\mu \sim \mu$

Full computation requires solving the full collision integral for sphaleron multi-fermionic operator!

But how does it couple to the fluid fluctuations?

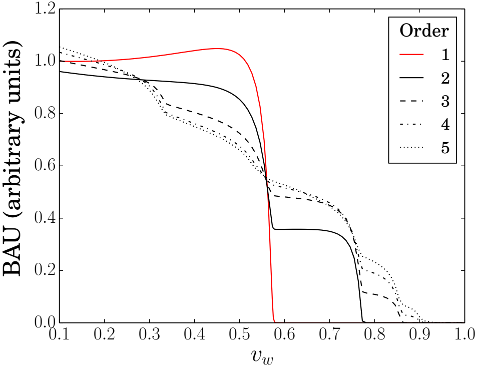
Merely zeroth-order term of a long expansion!

Strongly dependent on basis choice for fluctuations

This Ansatz seems inadequate here!

$$\partial_z n_B = \frac{3}{2v_w} \Gamma_{ws} \left(\kappa \, u_\mu J^\mu - \frac{15}{2} n_B \right)$$

Results: Supersonic baryogenesis – Round 2

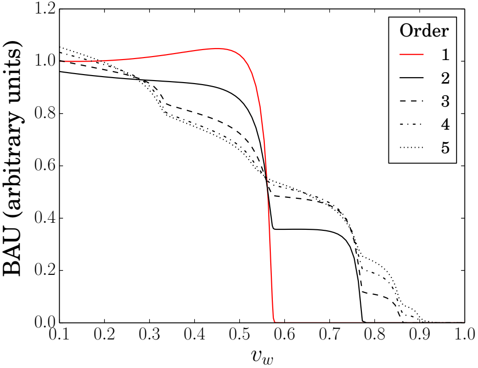


$\alpha_s = 0.01$

BAU suppressed for $v_w > c_s$, but
not prohibitively small!
(except for $v_w \to 1$)

Continuous along v_w
similar to found recently in
Cline & Kainulainen
PRD ***101*** *(2020) no. 6, 063525*

Results: Supersonic baryogenesis – Round 2

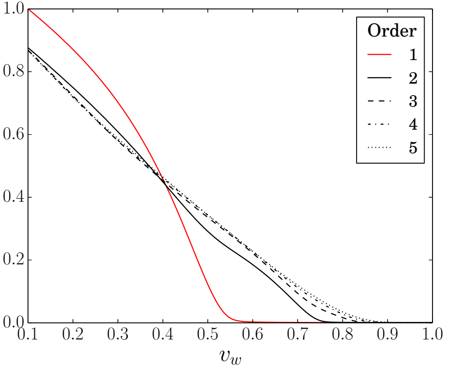


$\alpha_s = 0.01$

BAU suppressed for $v_w > c_s$, but
not prohibitively small!
(except for $v_w \to 1$)

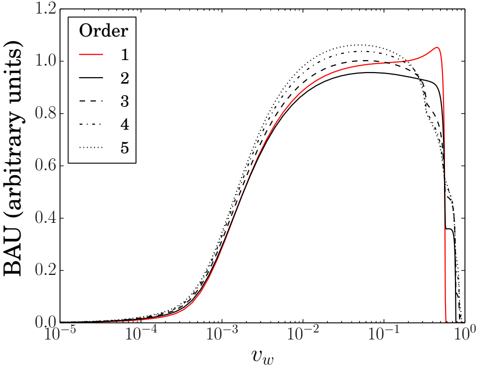
convergence parameter $\sim \dfrac{T}{\Gamma} \sim D\,T$

$\alpha_s = 0.06$



Continuous along v_w
similar to found recently in
Cline & Kainulainen
PRD ***101*** *(2020) no. 6, 063525*

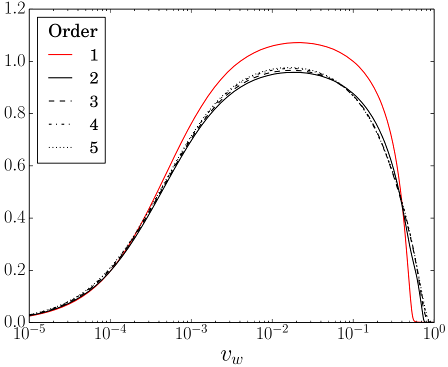
Results: small v_w



$\alpha_s = 0.01$

BAU can be either enhanced or suppressed relative to 1st order

$\alpha_s = 0.06$

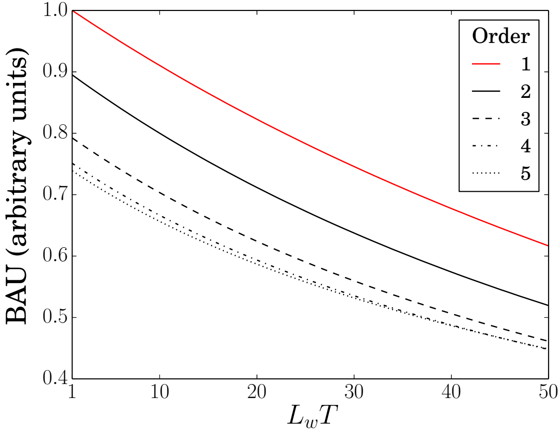


Either way the discrepancy is $\sim \mathcal{O}(20\%)$ for subsonic walls

$\Downarrow$

3-fluid reasonably reliable in this regime

Results: L_w dependence



$\alpha_s = 0.01$
$v_w = 0.4$

Convergence apparent
Dependence on L_w unaffected

Conclusions

- Supersonic baryogenesis is **not necessarily** impossible (though suppressed)
- We need an Ansatz to solve transport problem
  Fluid-like Ansatz adequate, but
  extension beyond 3 fluctuations may be (very) relevant

Outlook

- Full evaluation of coupling sphaleron–fluctuations still missing
- Systematics of series convergence
  When to truncate the momentum expansion?
- Supersonic walls enhance GW production
  Baryogenesis $\longleftrightarrow$ Gravitational Waves interplay

THANK YOU!