

# PRIN 2022 E2J4RK "PANTHEON" Stato Unitá INFN

Giovanni Marozzi  
Department of Physics "Enrico Fermi"  
University of Pisa



## Unitá INFN - Composizione

- **Bari:** Eligio Lisi
- **Laboratorio Nazionale Gran Sasso:** Giulia Pagliaroli,  
Francesco Vissani
- **Napoli:** Pasquale Migliozzi, Ninetta Saviano
- **Pisa:** Giovanni Marozzi

## Unitá INFN - Status Economico

Budget complessivo unita' INFN:

- Fondi PRIN non rendicontabili:
  - Assegnazione iniziale: **22.7 kEuro**
  - Residuo attuale: circa **16 kEuro**
- Fondi PRIN rendicontabili:
  - Assegnazione iniziale: **17.3 kEuro**
  - Residuo attuale: circa **5.7 kEuro**

Status Timesheets  $\Rightarrow$  **Molto vario!** Ma tutti hanno piú o meno iniziato e si metteranno in pari presto.

## Sezione di Napoli

- Numero bando: 26226/2023
- Tema attività di ricerca scientifica:  
**Aspetti teorici e osservativi della cosmologia dell'universo primordiale e della materia oscura.**
- Candidato vincitore: **Louis Hamaide** con presa di servizio il 1 ottobre 2024.

## Sezione di Pisa

- Numero bando: 26183/2023
- Tema attività di ricerca scientifica:  
**Cosmologia Teorica nel regime non-lineare**
- Candidato vincitore: **Matheus Rodrigues Medeiros Silva**  
con presa di servizio prevista per il 4 Novembre 2024.

## Articoli pubblicati e preprint

**"Interplay between noninterfering neutrino exchange mechanisms and nuclear matrix elements in  $0\nu\beta\beta$  decay"**, E. Lisi, A. Marrone and N. Nath, e-Print: 2306.07671, Phs. Rev. D 108, 055023.

**"Analysis of  $115\text{-In}$   $\beta$  decay through the spectral moment method"**, J. Kostensalo, E. Lisi, A. Marrone, J. Suhonen, e-Print: 2405.11920 [nucl-th], under review in Phys. Rev. C.

**"Interplay and Correlations Between Quark and Lepton Observables in Modular Symmetry Models"**, G.-J. Ding, E. Lisi, A. Marrone and S. Petcov, e-Print: 2409.15823 [hep-ph], submitted to JHEP.

## Proceedings

**”Neutrinoless double beta decay: interplay between nuclear matrix elements and neutrino exchange mechanisms”**, E. Lisi, A. Marrone and N. Nath, published in the Proceedings of Science for EPS-HEP 2023 and TAUP 2023.

**”Recent topics in the analysis of neutrino mass-mixing parameters”**, E. Lisi, F. Capozzi, E. Di Valentino, A. Marrone, A. Melchiorri, N. Nath and A. Palazzo, published in the Proceedings of Science for CORFU 2023.

## Attivita' in progress

An update of the global analysis of neutrino masses and mixings is in progress, based on data available at (and after) the Neutrino 2024 conference in Milan. This is a joint collaboration between members of four PRIN units: INFN (Lisi) + UniBa (Marrone, Palazzo) + UnivAq (Capozzi) + UniRm1 (Melchiorri et al.).

## Seminari e Talks a Congressi

"Towards a global analysis of absolute neutrino masses", Talk at NeuTel 2023, XX International Workshop on Neutrino Telescopes, Venice, 27/10/2023.

"Unveiling fundamental neutrino properties", Invited Colloquium at INFN Rome Tor Vergata, 12/12/2023.

"Global analysis of neutrino mass-mixing parameters: What Next?", talk at NPB 2024, International Symposium on Neutrino Physics and Beyond, Hong Kong, 19/2/2024.

"Neutrino Theory and Phenomenology", Summary Talk at Neutrino 2024, XXXI International Conference on Neutrino Physics and Astrophysics, Milan, 22/6/2024.

"Neutrinos: The Rise of a New Paradigm", talk at the Symposium "The Rise of Particle Physics", Rome, 24/9/2024.



## Lectures

"Neutrino Theory" course at the PhD School "Gran Sasso Hands-On", LNGS, L'Aquila, 26/9/2023 (2h).

"Low-Energy Theory: Neutrinos" course at the GSSI PhD School, L'Aquila, 20-30/11/2023 (15h).

"The Standard Model, Neutrinos, and Oscillations" course at the INSS PhD School 2024, Bologna, 3-5/6/2024.

## Organization and Service Work

GGI, APCG 2024 School "Theoretical Aspects of Astroparticle Physics, Cosmology and Gravitation", 11-22/3/2024.

NOW 2024 "Neutrino Oscillation Workshop", Otranto, Lecce, 2-8/9/2024.

Member of Collegio di Dottorato in Fisica, U. Bari, cicli da 36 a 40.

Member of NEUTEL Conference SAC.

Member of the Editorial Board of PRD.

Local Coordinator of INFN project TASP (Unit of Bari).

## Outreach Activities

Contribution to Asimov Prize 2024 as member of the SC of "Puglia Nord" and reviewer.

Talk entitled: "Fisica dei Neutrini: Nuovi Sviluppi" at Convegno on Bruno Pontecorvo, Pisa, 22/9/2023.

"Phi Talk" entitled "Traiettorie Imprevedibili" at the Bari MS physics student meeting, Dept. of Physics of Bari, 15/5/2024.

## Articoli pubblicati e preprint

**"Observing neutrinos from failed Supernovae at LNGS"**,  
G. Pagliaroli and C. Ternes, JCAP 06 (2024) 022, e-Print: 2403.06678.

**"Invisible neutrino decay at long-baseline neutrino oscillation experiments"**, C. Ternes and G. Pagliaroli, Phys.Rev.D 109 (2024) 7, L071701, e-Print: 2401.14316.

## **Seminari e Talks a Congressi** (Pagliaroli)

Talk su invito al LXV Congresso Nazionale della Società Astronomica Italiana SAI2024, titolo: The high-energy Neutrinos and Gamma-rays from the Galactic Plane.

Talk su invito al GGI, Neutrino Frontiers Program, Firenze, Luglio 2024, titolo: Core-Collapse Supernovae detection with Gravitational Waves and Neutrinos.

Talk parallelo a RICAP 2024, Roma, Settembre 2024, titolo: High-Energy Neutrinos from the Galactic Plane and the Galactic Hadronic sources.

Talk su invito a Conference in memory of Berezhinsky, GSSI, 1-3 October 2024, talk: Core-Collapse Supernovae: Gravitational Waves and Neutrinos.

## **Organization and Service Work** (Pagliaroli)

Membro dell'International Advisory Committee di NEUTRINO 2024, Milano (Italy) - June 16-22, 2024.

Membro del LOC di IDM 2024, Jul 8-12 2024 L'Aquila (Italy).

Coordinatrice gruppo IV INFN-LNGS.

## **Outreach Activities** (Pagliaroli)

PID INFN per Docenti di scuole superiori 2024, Co-chair di tutto il programma insieme a Massimo Mannarelli.

Progetto HOP INFN 2024 per docenti di scuole medie, Tutor formato presso i laboratori nazionali di Frascati.

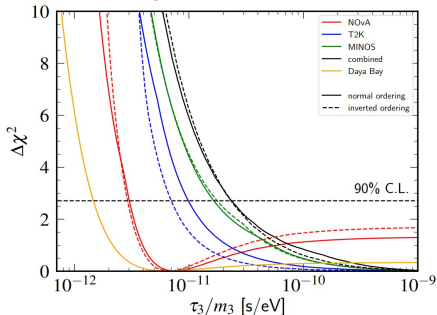
Coordinatrice del programma di PCTO per studenti dell'istituto tecnico Amedeo D'Aosta di L'Aquila.

Coordinatrice del programma di outreach "Spieghiamo insieme la Materia Oscura" dedicato a studenti del quarto anno delle scuole superiori di tutto l'Abruzzo e legato alla conferenza internazionale IDM 2024.

Seminario divulgativo aperto a tutti in ambito del progetto Pint of Science con seminario dal titolo "La materia oscura", L'Aquila.

## Invisible neutrino decay at long baseline experiments

Termes, Pagliaroli, 2401.14316, PRD 2024



Some BSM models allow for non-radiative neutrino decay into invisible daughter particles, i.e.

$$\nu_i \rightarrow \nu + X$$

We compute updated bounds from a combined analysis of data from NOvA, T2K and MINOS, finding

$$\tau_3/m_3 \geq 2.4 \times 10^{-11} \text{ s/eV at 90\% CL}$$

Our analysis improves the previous bound from long-baseline accelerator data by one order of magnitude



# Failed SN@LNGS

Pagliaroli and Ternes, *JCAP* 06 (2024) 022

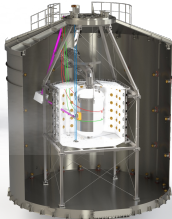
- Veto regions of detectors dedicated to other topics as DM or  $0\nu\beta\beta$  decay can be a network sensitive to SN neutrinos
- For BH forming SN the neutrino and GW emissions end abruptly at the time of the Black Hole formation.
- The LNGS infrastructure can identify the time of the BH formation for the Virgo interferometer

LEGEND-200

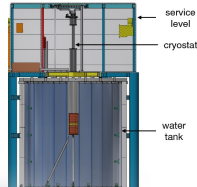


SN@10 kpc  $\rightarrow$  H<sub>2</sub>O IBD and NO  
 XENONnT (700 ton) = 167  
 LEGEND 200 (590 ton) = 140  
 COSINUS (270 ton) = 64

XENONnT



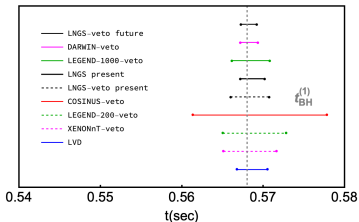
COSINUS



Combined Horizon: LMC. Very high duty cycle and fast coincidences in time (ms). The time of the BH formation in the Virgo det. can be identified within

$$\delta T_{\text{BH}}^{\text{GW}} = \delta T_{\text{BH}}^{\text{LNGS}} + \delta t_{\text{fly}} = 4 \text{ ms.}$$

LNGS - VIRGO



## PAPERS

- [1] **F. Vissani**, “1930-1937: the first  $\beta$ -rays and neutrino theories,” Atti del XLIII Congresso annuale degli Storici Italiani della Fisica e dell’Astronomia (SISFA), pp. 287-294 (2024) [arXiv:2409.17824].
- [2] **F. Vissani**, “Majorana and the bridge between matter and anti-matter,” Il Nuovo Cimento 47 C6 article 351 (2024) doi:10.1393/ncc/i2024-24351-1 [arXiv:2409.17826].
- [3] **G. Ricciardi, N. Vignaroli, F. Vissani**, “A discussion of the cross section  $\bar{\nu}_e + p \rightarrow e^+ + n$ ,” Il Nuovo Cimento 47 C6 article 379 (2024) doi:10.1393/ncc/i2024-24379-1 [arXiv:2311.16730].
- [4] **F. Vissani**, “First steps towards understanding neutrinos,” Quaderni di Storia della Fisica, issue 1, 109-143 (2024) doi:10.1393/qsf/i2024-10128-8 [arXiv:2310.07834].

### - CONFERENCE ORGANIZED

Neutrino Frontiers: Neutrinos in cosmology, non-standard neutrino physics and neutrino anomalies  
lecture on "Neutrino Astrophysics"; june-july 2024, GGI, Florence

### - CONFERENCES INVITED

NOW 2024

"Neutrino: Opening New Doors. The strengths of neutrino physics discussed via its results"; september 2024, Otranto

Neutrino mass,

"History of neutrino & its mass. Focusing on earliest theoretical approaches and their enduring legacy"; february 2024, Genua

#### ◦ LECTURES

Lezioni di dottorato su "Neutrini" presso l'universita' di Milano (10 ore) september

Lecture at EPIC 2024 for PhD students, "Neutrinos. 1. History and relevance 2. Selected results 3. Prospects", Cagliari september

Lecture at Neutrino 2024 for PhD students, "Genesis of the neutrino concept. How current theoretical frameworks were developed", june

Lecture for the LNGS colleagues A" history of some recent attempts to go beyond the standard model", april

#### ◦ STUDENTS

Simone Boscolo, Universita' di Milano, laurea magistrale/MSc

"Ultra-high energy neutrinos from cosmic sources", settembre 2024

other advisors: Alessandra Re (UniMI), Fabrizio Tavecchio & Chiara Righi (INAF Merate)

#### ◦ POPULAR TALK

"Viaggio al centro del sole" dato nel corso dell'anno presso l' Universita' di Macerata, Arcetri (FI), SHARPER-L'Aquila

#### ◦ HIGH SCHOOL

Corso di introduzione alla fisica moderna al Liceo D'Ascanio, Montesilvano (PE) primavera 2024

1 Perché il sole brilla? 2 Alle radici dell'idea moderna di atomo 3 Dal paradosso di Bentley alla fisica moderna

Intervento "Un ricordo degli anni al Galilei e di cosa mi hanno lasciato" in occasione dei 100 anni del Liceo Galilei, pubblicato sugli Annali del Liceo Galilei, Macerata



# PREMIO ASIMOV

NONA EDIZIONE

PER L'EDITORIA SCIENTIFICA

2024



**Covone vince la decima edizione  
(Salone del Libro)**



**Malvaldi vince la seconda edizione  
del premio ASIMOV Junior**

## Articoli pubblicati e preprint

**"Impact of primordial black holes on heavy neutral leptons searches in the framework of resonant leptogenesis"**, R. Calabrese, M. Chianese, J. Gunn, G. Miele, S. Morisi and N. Saviano, Phys. Rev. D **109** (2024), 10.

**"Tomography of flavoured leptogenesis with primordial blue gravitational waves"**, M. Chianese, S. Datta, R. Samanta and N. Saviano, [arXiv:2405.00641 [hep-ph]].

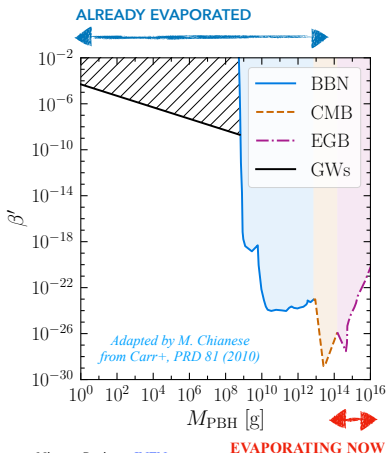
**"Probing flavored regimes of leptogenesis with gravitational waves from cosmic strings"**, M. Chianese, S. Datta, G. Miele, R. Samanta and N. Saviano, [arXiv:2406.01231 [hep-ph]].

## **Seminari e Talks a Congressi (Saviano)**

GGI workshop Neutrino Frontiers, Focus week (01/07-05/07/2024), "Neutrinos in cosmology, non-standard neutrino physics and neutrino anomalies". Partecipazione e relazione su invito.

Invisibles24 Workshop 5 luglio 2024 Partecipazione e relazione su invito.

# PBH Searches



- ◆ Formed at  $T_{\text{form}}$  after inflation with an abundance

$$\beta'(M_{\text{PBH}}) = \gamma^{1/2} \frac{\rho_{\text{PBH}}(T_{\text{form}})}{\rho_R(T_{\text{form}})}$$

- ◆ Hawking radiation: emission of particles with a mass  $m \leq T_{\text{PBH}} \simeq 10 (10^{15} \text{ g}/M_{\text{PBH}}) \text{ MeV}$

- ◆ The evaporation lifetime is  $\simeq 4 \times 10^{17} (M_{\text{PBH}}/10^{15} \text{ g})^3 \text{ s}$

## PBH PAPERS

- ◆ Light PBHs ( $M_{\text{PBH}} \lesssim 10^9 \text{ g}$ ) strongly modify the parameter space of leptogenesis

*Calabrese, Chianese, Gunn, Miele, Morisi, Saviano, PRD 109.103001 (2024), PRD 107.123537 (2023)*

## Imprints on the GW spectrum

**GOAL:** probing high-energy models with specific spectral features in the GWs today

**Example 1:** Characteristic spectral features, induced by different flavour regimes of leptogenesis, are detectable in multiple frequency bands with current and future GW experiments in case of Blue GWs (BGWs) described by a power-law with a positive spectral index ( $n_T > 0$ )

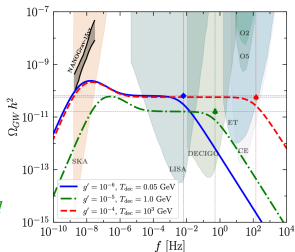
*Chianese, Datta, Samanta and Saviano, arXiv:2405.00641*

**Example 2:** Cosmic strings radiate detectable Gravitational Waves in models featuring high-scale symmetry breaking, e.g., high-scale leptogenesis.

We show that different flavored regimes of high-scale leptogenesis can be tested distinctly with the spectral features in cosmic string-radiated gravitational waves.

*Chianese, Datta, Miele, Samanta and Saviano, arXiv:2406.01231*

Ninetta Saviano, [INFN](#)







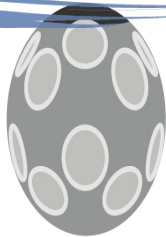
# Attività PANTHEON @INFN- Napoli

Pasquale Migliozzi

INFN - Napoli

**KM3NeT**

arca&orca



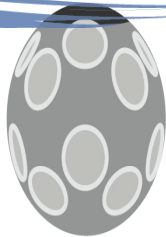
## Articoli pubblicati 2024

- Measurement of neutrino oscillation parameters with the first six detection units of KM3NeT/ORCA
- [Search for neutrino emission from GRB 221009A using the KM3NeT ARCA and ORCA detectors](#) (Published in: *JCAP* 08 (2024) 006)
- [Atmospheric muons measured with the KM3NeT detectors in comparison with updated numeric predictions](#) (Published in: *Eur.Phys.J.C* 84 (2024) 7, 696)
- [Differential Sensitivity of the KM3NeT/ARCA detector to a diffuse neutrino flux and to point-like source emission: Exploring the case of the Starburst Galaxies](#) (Published in: *Astropart.Phys.* 162 (2024) 102990)
- [Astronomy potential of KM3NeT/ARCA](#) (Published in: *Eur.Phys.J.C* 84 (2024) 9, 885)
- [The Power Board of the KM3NeT Digital Optical Module: design, upgrade, and production](#) (Published in: *Electronics* 13 (2024) 11, 2044)

## Conferenze 2024

- NOW 2024 - KM3NeT: status and perspectives P. Migliozzi

**KM3NeT**  
arca&orca



# Analysis in progress @INFN-Napoli

- Analisi di tipo Stacking con i dati di ARCA21/28 su un catalogo di galassie di tipo Seyfert
- Analisi di tipo Staking con i dati di ARCA21/28 su un catalogo di galassie di tipo Starforming
- Studio della emissione di neutrini da sorgenti Galattiche estese (Central Molecular Zone, Cygnus region, low latitude Fermi Bubbles)
- Analisi temporale di massima verosimiglianza fra la emissione X di Blazars di tipo "Extreme" e il flusso misurato da ARCA 21/28 correlato direzionalmente.
- Studio di osservabilità delle supernovae di tipo "core collapse" nella regione delle alte energie con i dati di ARCA.
- Studio di tipo template fitting fra i dati di ARCA e le osservazioni di raggi gamma di provenienza Galattica osservati da LHAASO

**KM3Net**  
arca&orca



## Articoli pubblicati e preprint

### **“On the stability of string-hole gas”**

D. Bitnaya, P. Conzino e G. Marozzi.

Publicato in Journal of Cosmology and Astroparticle Physics 01 (2024) 025.

e-Print: arXiv:2308.16764 [hep-th].

### **“ $\delta\mathcal{N}$ formalism on the past light-cone”**

G. Fanizza, G. Marozzi e M. Medeiros.

Publicato in General Relativity and Gravitation 56, 53 (2024).

e-Print: arXiv:2311.08073 [gr-qc].

### **“Gauge invariant quantum backreaction in U(1) axion inflation”**

D. C. Galanti, P. Conzino, G. Marozzi and S. Santos da Costa.

Sottomesso per la pubblicazione a Phys. Rev. D.

e-Print: arXiv:2406.19960 [gr-qc].

## $\delta N$ formalism

- *Expansion rate*

$$\Theta_u := \frac{1}{\sqrt{-g}} \partial_\mu (\sqrt{-g} u^\mu) = \frac{1}{\sqrt{\gamma} \Upsilon} \frac{d}{d\lambda} (\sqrt{\gamma} \Upsilon) + \partial_\mu u^\mu \quad u^\mu \partial_\mu := \frac{d}{d\lambda}$$

This is a completely non-linear expression for the expansion rate, obtained through a covariant approach. In the following we neglect the last term which is second order in the gradient expansion.

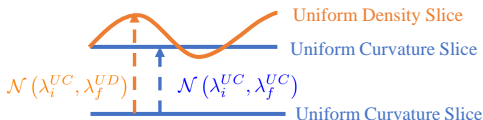
- *Curvature perturbation on the LC*

$$\zeta = -\frac{1}{3} \ln \left( \frac{\Upsilon \sqrt{\gamma}}{\bar{\Upsilon} \sqrt{\bar{\gamma}}} \right) - \frac{1}{3} \int_{\bar{\rho}(t)}^{\rho(x^i, t)} \frac{d\rho}{\rho + P(\rho)} + \mathcal{O}(\epsilon^2)$$

- *Delta N formalism*

Computing the number of e-folds between the uniform density and uniform curvature slices we obtain the  $\delta N$  formalism on the light-cone.

$$\delta^{(n)} \mathcal{N} = \frac{1}{3} \ln \left[ \frac{(\Upsilon \sqrt{\gamma})_{UDLC}}{(\Upsilon \sqrt{\gamma})_{UCLC}} \right] = -\zeta$$



# Gauge invariant quantum backreaction in U(1) axion inflation

2406.19960

D. Campanella Galanti (INFN, Pisa), P. Conzino (INFN, Pisa and CERN), G. Marozzi (INFN, Pisa), S. Santos da Costa (INFN, Pisa and Trento U. and TIFPA-INFN)

$$S = \int d^4x \sqrt{-g} \left[ -\frac{1}{2} \partial_\mu \phi \partial^\mu \phi - V(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} - \frac{g\phi}{4} F^{\mu\nu} \tilde{F}_{\mu\nu} \right], \quad (1)$$

Axion-like field

Gauge-fields

Interaction term

A physical gauge invariant observable

$$\langle S \rangle_{A_0} = \frac{\langle \sqrt{|\bar{\gamma}(t_0, \mathbf{x})|} \bar{S}(t_0, \mathbf{x}) \rangle}{\langle \sqrt{|\bar{\gamma}(t_0, \mathbf{x})|} \rangle},$$

Going up to second order in the field and scalar metric perturbations\*\*\*

- The uniform curvature gauge (UCG)  $\Rightarrow \psi = E = 0$
- The Einstein tensor terms remain the usual ones, while the energy-momentum tensor is modified by the presence of the gauge fields.
- We consider the weak backreaction regime and neglect the background contribution of the gauge fields  $\Rightarrow$  we will treat expressions like  $\mathbf{E}^2$ ,  $\mathbf{B}^2$ ,  $\mathbf{E} \cdot \mathbf{B}$  as second order perturbations.
- Comoving observer: homogeneous inflaton field for which  $\Rightarrow \varphi = \varphi^{(2)} = 0$

To finally obtain

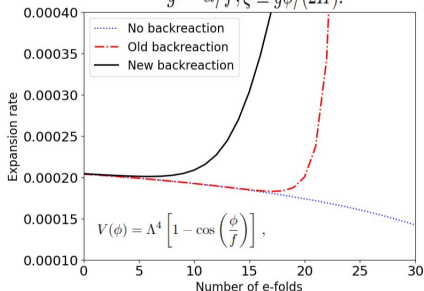
$$H_{\text{eff}}^2 = H^2 \left[ 1 + \frac{1}{3H^2} \left( \frac{1}{M_{\text{Pl}}^2} \frac{\langle \mathbf{E}^2 + \mathbf{B}^2 \rangle}{2} - \frac{g^2}{\xi} \langle \mathbf{E} \cdot \mathbf{B} \rangle \right) \right]$$

Renormalization procedure [Animali et al. 2022]

$$\xi' + \left( \frac{H'}{H} + 3 \frac{H}{H_{\text{eff}}} \right) \xi + \frac{g}{2} \frac{V_{,\phi}}{H H_{\text{eff}}} = 0,$$

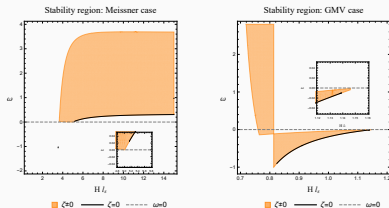
$$\phi' = \frac{2}{g} \frac{H}{H_{\text{eff}}} \xi, \quad dN_{\text{eff}} \equiv H_{\text{eff}} dt,$$

$$g = \alpha/f, \xi \equiv g\dot{\phi}/(2H).$$



# Bulk viscosity and stability

- $\alpha'$  corrected  $S_{EH}$  with  $\dot{\phi} = dH$  and string-holes matter ( $\rho = Cl_s^{-1-d} e^{-\phi}$ )  $\rightarrow$  unstable fixed point
- Bulk viscosity:  $T_{ab} = \rho u_a u_b + (p - \zeta\Theta)h_{ab} - 2\eta\sigma_{ab} \rightarrow$  stable fixed point



Non perturbative case: O. Hohm and B. Zwiebach and H. Bernardo and G. Franzmann

$$\dot{\Phi}^2 + HF'(H) - F(H) = 2k^2 e^\Phi \bar{\rho},$$

$$\dot{H}F''(H) - \dot{\Phi}F'(H) = -2dk^2 e^\Phi \bar{\rho}, \rightarrow \text{Fixed point: } F = -Yd\bar{\zeta}H, F' = \frac{Y}{H}(\bar{\rho} - d\bar{\zeta}H)$$

$$2\ddot{\Phi} - \dot{\Phi}^2 + F(H) = k^2 e^\Phi \bar{\sigma}.$$

Orbits with constraints in the case of the viscosity presence:

$$F'' > 0, -1 < \omega < -1 + \frac{d\zeta H}{\rho}, F'' < 0, \omega < -1 \vee \omega > -1 + \frac{d\zeta H}{\rho}.$$

THANKS FOR THE ATTENTION!