Erbino and his light SUSY partner

Lorenzo Ubaldi
IJS Ljubljana

March 28th, 2023, Herbi fest

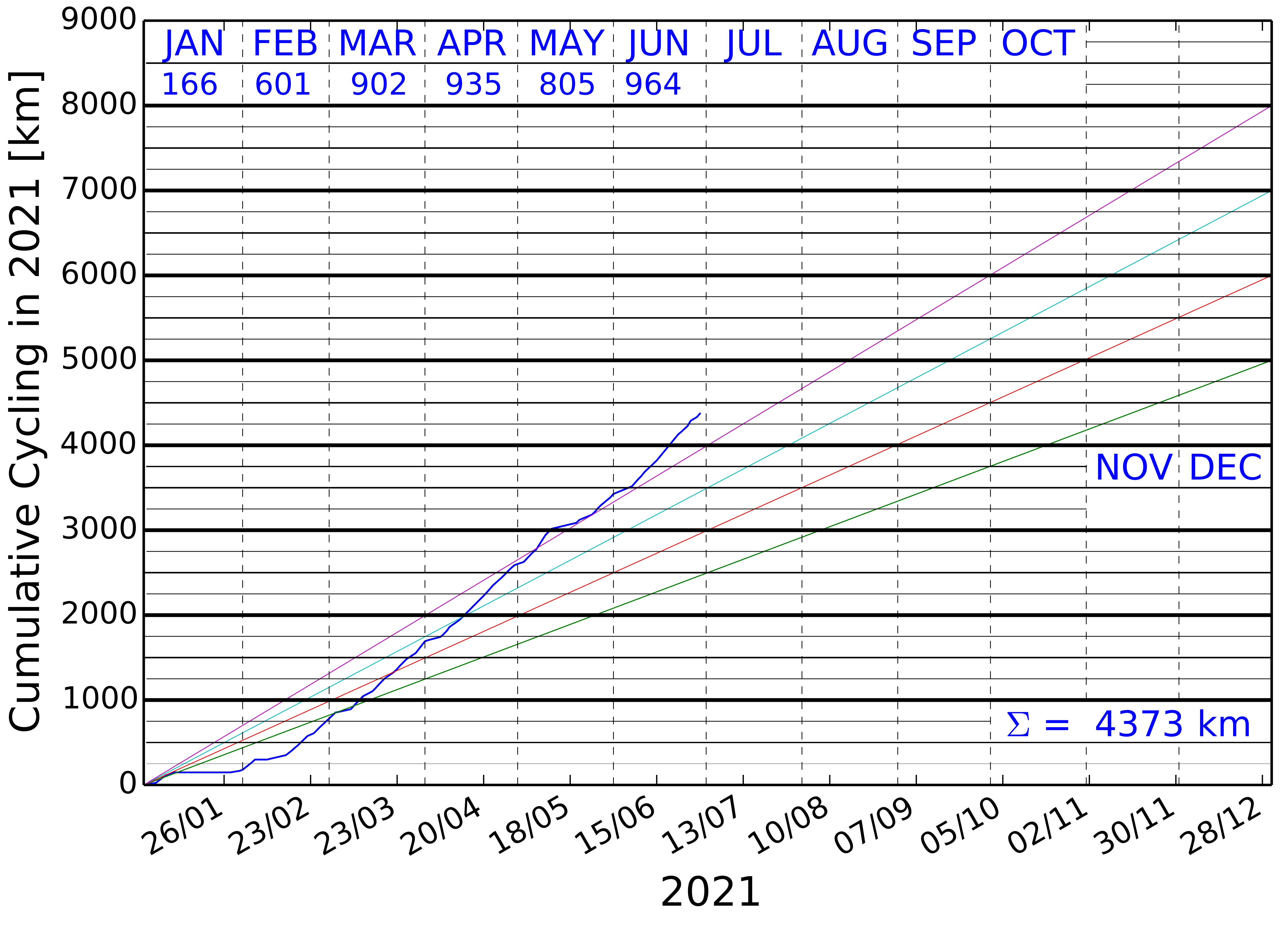
How Herbi met me

Things Herbi tried to teach me but I failed to learn

Take photos for future memory

Make pancakes

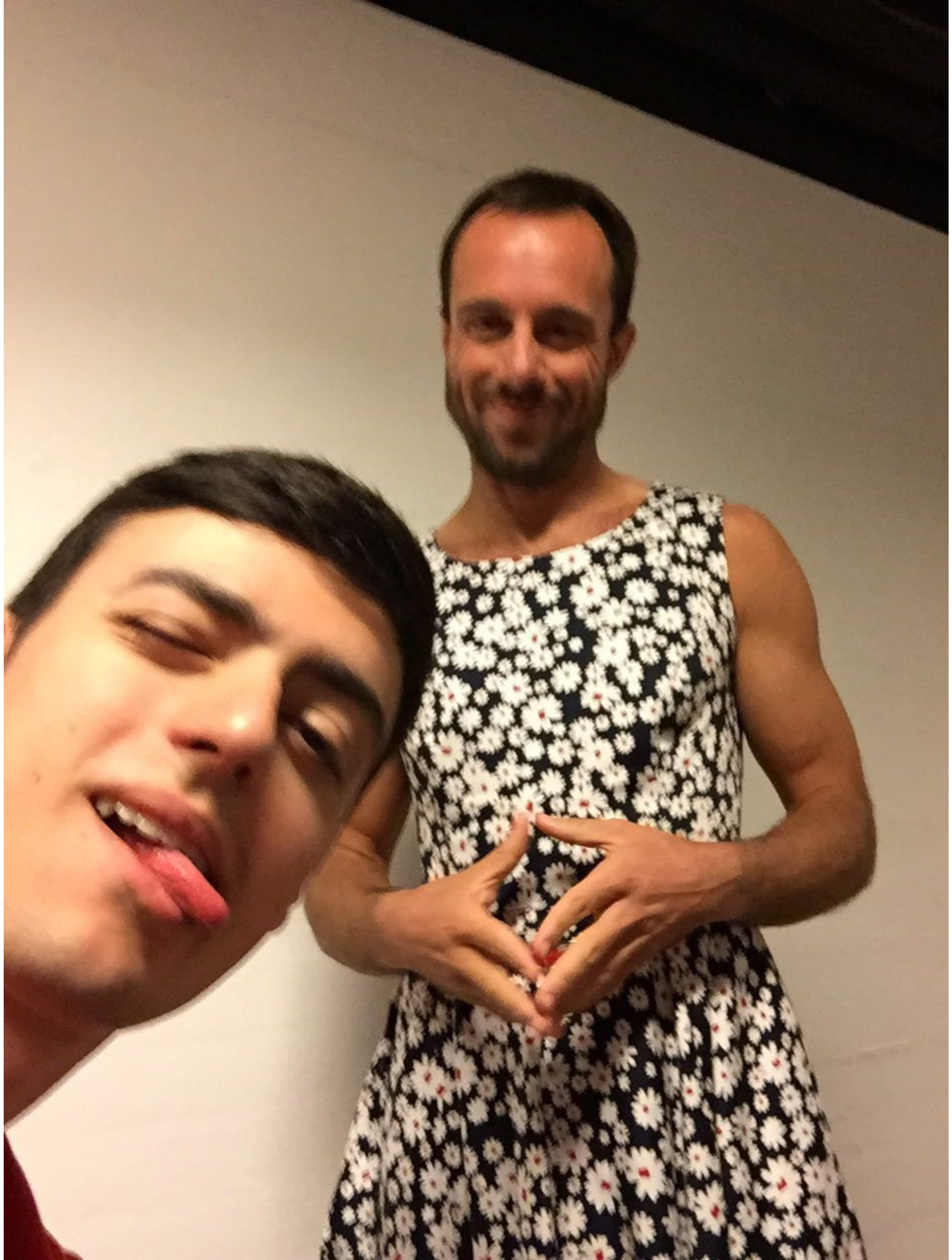
Bike at least 5000 km a year



Cumulative Cycling in 2021 [km]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
166
601
902
935
805
964
NOV DEC
Σ = 4373 km
26/01
23/02
23/03
20/04
18/05
15/06
13/07
10/08
07/09
05/10
02/11
30/11
28/12
2021

Lorenzo Ubaldi

Herbi fest



Lorenzo Ubaldi

Herbi fest

Lorenzo Ubaldi

Herbi fest

Keep in touch with friends regularly

Things I tried to learn from Herbi but he failed to teach me

How to date women successfully

Erbino and his light SUSY partner

Erbino and a light neutralino?

arXiv > hep-ph > arXiv:0707.1425

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High Energy Physics – Phenomenology

[Submitted on 10 Jul 2007 (v1), last revised 12 Jul 2007 (this version, v2)]

How light can the lightest neutralino be?

H. K. Dreiner, S. Heinemeyer, O. Kittel, U. Langenfeld, A. M. Weber, G. Weiglein

We show that in the Minimal Supersymmetric Standard Model, the mass of the lightest neutralino is experimentally unconstrained if the GUT relation between the gaugino mass parameters M_1 and M_2 is dropped. We discuss what the impact of light or massless neutralinos would be on their production at LEP, as well as on electroweak precision data and rare decays.

arXiv > hep-ph > arXiv:0901.3485

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High Energy Physics – Phenomenology

[Submitted on 22 Jan 2009 (v1), last revised 1 Sep 2009 (this version, v3)]

Mass Bounds on a Very Light Neutralino

H.K. Dreiner, S. Heinemeyer, O. Kittel, U. Langenfeld, A.M. Weber, G. Weiglein

Within the Minimal Supersymmetric Standard Model (MSSM) we systematically investigate the bounds on the mass of the lightest neutralino. We allow for non-universal gaugino masses and thus even consider massless neutralinos, while assuming in general that R-parity is conserved. Our main focus are laboratory constraints. We consider collider data, precision observables, and also rare meson decays to very light neutralinos. We then discuss the astrophysical and cosmological implications. We find that a massless neutralino is allowed by all existing experimental data and astrophysical and cosmological observations.

High Energy Physics – Phenomenology

[Submitted on 5 Dec 2010 (v1), last revised 4 Jan 2011 (this version, v2)]

Measuring a Light Neutralino Mass at the ILC: Testing the MSSM Neutralino Cold Dark Matter Model

John A. Conley, Herbert K. Dreiner, Peter Wienemann

The LEP experiments give a lower bound on the neutralino mass of about 46 GeV which, however, relies on a supersymmetric grand unification relation. Dropping this assumption, the experimental lower bound on the neutralino mass vanishes completely. Recent analyses suggest, however, that in the minimal supersymmetric standard model (MSSM), a light neutralino dark matter candidate has a lower bound on its mass of about 7 GeV. In light of this, we investigate the mass sensitivity at the ILC for very light neutralinos. We study slepton pair production, followed by the decay of the sleptons to a lepton and the lightest neutralino. We find that the mass measurement accuracy for a few-GeV neutralino is around 2 GeV, or even less if the relevant slepton is sufficiently light. We thus conclude that the ILC can help verify or falsify the MSSM neutralino cold dark matter model even for very light neutralinos.

arXiv > hep-ph > arXiv:1111.5715

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High Energy Physics – Phenomenology

[Submitted on 24 Nov 2011]

Gravitino cosmology with a very light neutralino

Herbi K. Dreiner (Bonn), Marja Hanussek (Bonn), Jong-Soo Kim (Dortmund, Adelaide), Subir Sarkar (Oxford)

It has been shown that very light or even massless neutralinos are consistent with all current experiments, given non-universal gaugino masses. Furthermore, a very light neutralino is consistent with astrophysical bounds from supernovæ and cosmological bounds on dark matter. Here we study the cosmological constraints on this scenario from Big Bang nucleosynthesis taking gravitinos into account and find that a very light neutralino is even favoured by current observations.

arXiv > hep-ph > arXiv:hep-ph/0304289

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High Energy Physics – Phenomenology

[Submitted on 30 Apr 2003]

Supernovae and Light Neutralinos: SN1987A Bounds on Supersymmetry Revisited

H. K. Dreiner (Bonn U.), C. Hanhart (FZ-Julich), U. Langenfeld (Bonn U.), D. R. Phillips (Ohio U.)

For non-universal gaugino masses, collider experiments do not provide any lower bound on the mass of the lightest neutralino. We review the supersymmetric parameter space which leads to light neutralinos, $M_\lsp \lsim {\cal O}(1\gev)$, and find that such neutralinos are almost pure bino. In light of this, we examine the neutralino lower mass bound obtained from supernova 1987A (SN1987A). We consider the production of binos in both electron-positron annihilation and nucleon-nucleon binostrahlung. For electron-positron annihilation, we take into account the radial and temporal dependence of the temperature and degeneracy of the supernova core. We also separately consider the Raffelt criterion and show that the two lead to consistent results. For the case of bino production in NN collisions, we use the Raffelt criterion and incorporate recent advances in the understanding of the strong-interaction part of the calculation in order to estimate the impact of bino radiation on the SN1987A neutrino signal. Considering these two bino production channels allows us to determine separate and combined limits on the neutralino mass as a function of the selectron and squark masses. For $M_\lsp \sim 100 \mev$ values of the selectron mass between 300 and 900 GeV are inconsistent with the supernova neutrino signal. On the other hand, in contrast to previous works, we find that SN1987A provides almost no bound on the squark masses: only a small window of values around 300 GeV can be excluded, and even then this window closes once $M_\lsp \gsim 20 \mev$.

> hep-ph > arXiv:1310.3826

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High Energy Physics – Phenomenology

[Submitted on 14 Oct 2013]

Supernova Constraints on MeV Dark Sectors from e+ e− Annihilations

Herbert K. Dreiner, Jean-François Fortin, Christoph Hanhart, Lorenzo Ubaldi

Theories with dark forces and dark sectors are of interest for dark matter models. In this paper we find the region in parameter space that is constrained by supernova cooling constraints when the models include dark sector particles with masses around 100 MeV or less. We include only interactions with electrons and positrons. The constraint is important for small mixing parameters.


axino
SOLUTIONS


SOLUTIONS

The Strong CP problem

$$\mathcal{L}_{\mathrm{QCD}} \supset \theta \frac{g_s^2}{32\pi^2} G_a^{\mu\nu} \tilde{G}_{a\mu\nu} + \bar{q}_{Ri} M_{ij} q_{Lj} + \mathrm{h.c.}$$

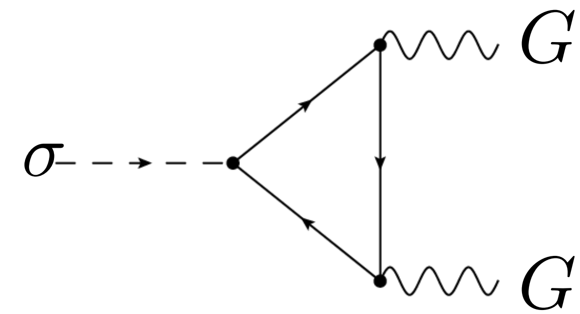
$$\bar{\theta} = \theta + \arg\ \det M$$

The experimental non observation of a neutron EDM implies: $\bar{\theta} < 10^{-10}$

The Axion solution

$$\Phi = \rho e^{i\sigma/f} \xrightarrow[U(1)_{\mathrm{PQ}}]{} \rho e^{i(\sigma/f+\alpha)}$$

PQ = Peccei-Quinn



The anomaly of the $U(1)_{\mathrm{PQ}}$ generates the term $\frac{\sigma}{f}\frac{g_s^2}{32\pi^2}G\tilde{G}$ in the QCD lagrangian.

At scales below confinement, $\Lambda \approx 200 \text{ MeV}$, we get the potential

$$V(\bar{\theta},\sigma) \approx \Lambda^4\left[1-\cos\left(\frac{\sigma}{f}+\bar{\theta}\right)\right]$$

minimized at $\langle\sigma\rangle = -f\bar{\theta}$.

At the minimum of this potential, QCD is CP conserving: strong CP problem solved!

The DFSZ Axion

Dine, Fischler, Srednicki 1981
Zhitnitsky 1980

Two Higgs doublets plus a complex scalar singlet
The SM fermions are also charged under the $U(1)_{PQ}$

$$V = g\Phi^2 H_u^\dagger H_d$$

in SUSY

$$W = c_1 \hat{A}\hat{H}_u\hat{H}_d$$

$$W = g\frac{\hat{A}^2}{M_{Pl}}\hat{H}_u\hat{H}_d$$

Kim, Nilles 1984

Supersymmetric axions

The chiral super field $\hat{A}$ contains not only the axion, but also its two partners:
a CP-even scalar, the saxion,
a fermion, the axino.

Actually, to build a consistent model it is inevitable to introduce more fields

Dreiner, Staub, LU 2014

$$W = \lambda \hat{\chi} \left(\hat{A}\hat{\bar{A}} - \frac{1}{4} f_a^2 \right)$$

$\sqrt{F}$	SUSY breaking scale
f_a	PQ breaking scale
M_{SUSY}	scale of soft SUSY breaking terms

$\sqrt{F} \gg f_a$ saxion and axino are heavy, $m \sim M_{\rm SUSY}$

think gravity mediation

$\sqrt{F} \ll f_a$ axino is light $m_{\tilde{a}} \sim M_{\rm SUSY}^2 / f_a$

think gauge mediation

$$M_{\rm SUSY} = 10^3 \text{ GeV}$$
$$f_a = 10^{10} \text{ GeV}$$

$$m_{\tilde{a}} \sim 100 \text{ keV}$$

The 3.5 keV line

1402.4119

An unidentified line in X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster

A. Boyarsky[1], O. Ruchayskiy[2], D. Iakubovskyi[3,4] and J. Franse[1,5]
[1]Instituut-Lorentz for Theoretical Physics, Universiteit Leiden, Niels Bohrweg 2, Leiden, The Netherlands
[2]Ecole Polytechnique Fédérale de Lausanne, FSB/ITP/LPPC, BSP, CH-1015, Lausanne, Switzerland
[3]Bogolyubov Institute of Theoretical Physics, Metrologichna Str. 14-b, 03680, Kyiv, Ukraine
[4]National University "Kyiv-Mohyla Academy", Skovorody Str. 2, 04070, Kyiv, Ukraine
[5]Leiden Observatory, Leiden University, Niels Bohrweg 2, Leiden, The Netherlands

We report a weak line at 3.52 ± 0.02 keV in X-ray spectra of M31 galaxy and the Perseus galaxy cluster observed by MOS and PN cameras of XMM-Newton telescope. This line is not known as an atomic line in the spectra of galaxies or clusters. It becomes stronger towards the centers of the objects; is stronger for Perseus than for M31; is absent in the spectrum of a deep "blank sky" dataset. Although for each object it is hard to exclude that the feature is due to an instrumental effect or an atomic line, it is consistent with the behavior of a dark matter decay line. Future (non-)detections of this line in multiple objects may help to reveal its nature.

The 3.5 keV line

1402.2301

DETECTION OF AN UNIDENTIFIED EMISSION LINE IN THE STACKED X-RAY SPECTRUM OF GALAXY CLUSTERS

ESRA BULBUL[1,2], MAXIM MARKEVITCH[3], ADAM FOSTER[1], RANDALL K. SMITH[1] MICHAEL LOEWENSTEIN[2,4], AND SCOTT W. RANDALL[1]
[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA, USA
[2] CRESST and X-ray Astrophysics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA
[3] NASA Goddard Space Flight Center, Greenbelt, MD, USA
[4] Department of Astronomy, University of Maryland, College Park, MD, USA

Submitted to ApJ, 2014 February 10, Accepted 2014 April 28

ABSTRACT

We detect a weak unidentified emission line at $E = (3.55-3.57) \pm 0.03$ keV in a stacked *XMM-Newton* spectrum of 73 galaxy clusters spanning a redshift range 0.01 – 0.35. MOS and PN observations independently show the presence of the line at consistent energies. When the full sample is divided into three subsamples (Perseus, Centaurus+Ophiuchus+Coma, and all others), the line is seen at $> 3\sigma$ statistical significance in all three independent MOS spectra and the PN "all others" spectrum. The line is also detected at the same energy in the *Chandra* ACIS-S and ACIS-I spectra of the Perseus cluster, with a flux consistent with *XMM-Newton* (however, it is not seen in the ACIS-I spectrum of Virgo). The line is present even if we allow maximum freedom for all the known thermal emission lines. However, it is very weak (with an equivalent width in the full sample of only ~ 1 eV) and located within 50–110 eV of several known faint lines; the detection is at the limit of the current instrument capabilities and subject to significant modeling uncertainties. On the origin of this line, we argue that there should be no atomic transitions in thermal plasma at this energy. An intriguing possibility is the decay of sterile neutrino, a long-sought dark matter particle candidate. Assuming that all dark matter is in sterile neutrinos with $m_s = 2E = 7.1$ keV, our detection in the full sample corresponds to a neutrino decay mixing angle $\sin^2(2\theta) \approx 7 \times 10^{-11}$, below the previous upper limits. However, based on the cluster masses and distances, the line in Perseus is much brighter than expected in this model, significantly deviating from other subsamples. This appears to be because of an anomalously bright line at $E = 3.62$ keV in Perseus, which could be an Ar XVII dielectronic recombination line, although its emissivity would have to be 30 times the expected value and physically difficult to understand. In principle, such an anomaly might explain our line detection in other subsamples as well, though it would stretch the line energy uncertainties. Another alternative is the above anomaly in the Ar line combined with the nearby 3.51 keV K line also exceeding expectation by a factor 10–20. Confirmation with *Chandra* and *Suzaku*, and eventually *Astro-H*, are required to determine the nature of this new line. (APJ HAS THE ABRIDGED ABSTRACT)

A light axino and the 3.5 keV line

$$C_{aB}\frac{a}{32\pi^2 f_a}g_1^2 B_{\mu\nu}\tilde{B}^{\mu\nu} + C_{\tilde{a}B}\frac{\tilde{a}}{16\pi^2 f_a}\sigma_{\mu\nu}g_1^2\tilde{B}B^{\mu\nu}$$

R-parity conserving with a massless bino $\tilde{a} \to \tilde{B} + \gamma$

R-parity violating $\tilde{a} \to \nu + \gamma$

Needed a decay rate $\Gamma \sim (10^{28}\ s)^{-1}$ Boyarsky et al., Bulbul et al. 2014

Physics Letters B 750 (2015) 107–111

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Heavy concerns about the light axino explanation of the 3.5 keV X-ray line

Stefano Colucci [a], Herbi K. Dreiner [a], Florian Staub [b], Lorenzo Ubaldi [c,*]

[a] *Physikalisches Institut der Universität Bonn, Bethe Center for Theoretical Physics, Nußallee 12, 53115 Bonn, Germany*
[b] *Theory Division, CERN, 1211 Geneva 23, Switzerland*
[c] *Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv 69978, Israel*

A R T I C L E   I N F O

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A B S T R A C T

An unidentified 3.5 keV line from X-ray observations of galaxy clusters has been reported recently. Although still under scrutiny, decaying dark matter could be responsible for this signal. We investigate whether an axino with a mass of 7 keV could explain the line, keeping the discussion as model independent as possible. We point out several obstacles, which were overlooked in the literature, and which make the axino an unlikely candidate. The only viable scenario predicts a light metastable neutralino, with a mass between 0.1 and 10 GeV and a lifetime between 10^{-3} and 10^{4} s.

arXiv > astro-ph > arXiv:1812.06976

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Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 17 Dec 2018 (v1), last revised 1 Mar 2021 (this version, v3)]

The dark matter interpretation of the 3.5-keV line is inconsistent with blank-sky observations

Christopher Dessert, Nicholas L. Rodd, Benjamin R. Safdi

Observations of nearby galaxies and galaxy clusters have reported an unexpected X-ray emission line around 3.5 kilo-electron volts (keV). Proposals to explain this line include decaying dark matter—in particular, that the decay of sterile neutrinos with a mass around 7 keV could match the available data. If this interpretation is correct, the 3.5 keV line should also be emitted by dark matter in the halo of the Milky Way. We used more than 30 megaseconds of XMM-Newton (X-ray Multi-Mirror Mission) blank-sky observations to test this hypothesis, finding no evidence of the 3.5-keV line emission from the Milky Way halo. We set an upper limit on the decay rate of dark matter in this mass range, which is inconsistent with the possibility that the 3.5-keV line originates from dark matter decay.

arXiv > astro-ph > arXiv:2004.06601

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Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 14 Apr 2020 (v1), last revised 24 Feb 2021 (this version, v2)]

Technical comment on the paper of Dessert et al. "The dark matter interpretation of the 3.5 keV line is inconsistent with blank-sky observations"

Alexey Boyarsky, Denys Malyshev, Oleg Ruchayskiy, Denys Savchenko

An unidentified line at energy around 3.5 keV was detected in the spectra of dark matter-dominated objects. Recent work of Dessert et al. [1812.06976] used 30 Msec of XMM-Newton blank-sky observations to constrain the admissible line flux, challenging its dark matter decay origin. We demonstrate that these bounds are overestimated by more than an order of magnitude due to improper background modeling. Therefore the dark matter interpretation of the 3.5 keV signal remains viable.

arXiv > astro-ph > arXiv:2006.03974

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Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 6 Jun 2020 (v1), last revised 1 Mar 2021 (this version, v2)]

Response to a comment on Dessert et al. "The dark matter interpretation of the 3.5 keV line is inconsistent with blank-sky observations"

Christopher Dessert, Nicholas L. Rodd, Benjamin R. Safdi

The dark matter explanation of the 3.5 keV line is strongly disfavored by our work in Dessert et al. 2020. Boyarsky et al. 2020 questions that conclusion: modeling additional background lines is claimed to weaken the limit sufficiently to re-allow a dark matter interpretation. We respond as follows. 1) A more conservative limit is obtained by modeling additional lines; this point appeared in its entirety in our work in Dessert et al., though we also showed that the inclusion of such lines is not necessary. 2) Despite suggestions in Boyarsky et al., even the more conservative limits strongly disfavor a decaying dark matter origin of the 3.5 keV line.

Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 3 Feb 2021 (v1), last revised 4 May 2021 (this version, v2)]

A deep search for decaying dark matter with XMM-Newton blank-sky observations

Joshua W. Foster, Marius Kongsore, Christopher Dessert, Yujin Park, Nicholas L. Rodd, Kyle Cranmer, Benjamin R. Safdi

Sterile neutrinos with masses in the keV range are well-motivated extensions to the Standard Model that could explain the observed neutrino masses while also making up the dark matter (DM) of the Universe. If sterile neutrinos are DM then they may slowly decay into active neutrinos and photons, giving rise to the possibility of their detection through narrow spectral features in astrophysical X-ray data sets. In this work, we perform the most sensitive search to date for this and other decaying DM scenarios across the mass range from 5 to 16 keV using archival XMM-Newton data. We reduce 547 Ms of data from both the MOS and PN instruments using observations taken across the full sky and then use this data to search for evidence of DM decay in the ambient halo of the Milky Way. We determine the instrumental and astrophysical baselines with data taken far away from the Galactic Center, and use Gaussian Process modeling to capture additional continuum background contributions. No evidence is found for unassociated X-ray lines, leading us to produce the strongest constraints to date on decaying DM in this mass range.

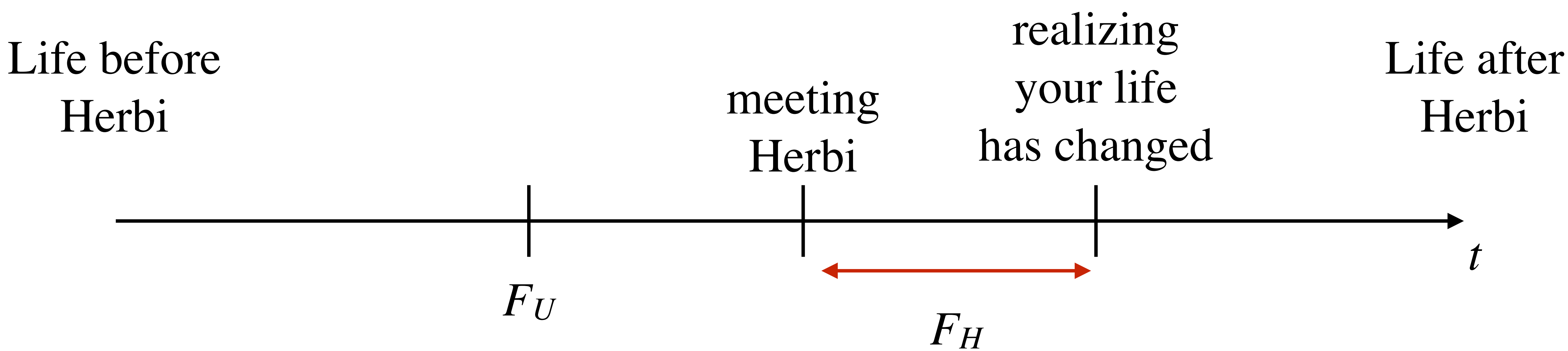
Take home

Wagner's theorem seems to hold: if you try to explain a possible new physics signal (also in astrophysics) with RPV SUSY, the signal will go away.

Careful with the look elsewhere effect

Keep in touch with your friends!

Measuring friendship with Herbi



Expectation: $F_H > 0$

Only one known exception: $F_U < 0$