

Dark Forces and Dark Matter in a Hidden Sector

Sarah Andreas

DESY

July 19, 2012

Patras 2012



Outline

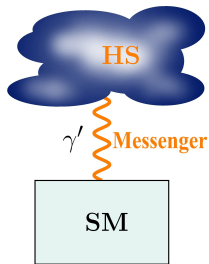
- ① Hidden Photon
- ② Hidden Dark Matter
- ③ Conclusions



Hidden Sector with Hidden Photon

talk R. Essig, B. Batell, D. Hooper

- **Hidden Sectors** often present in
 - ◊ string theories
 - ◊ supersymmetry, e.g. for SUSY
- **HS** with extra U(1)-symmetry
 - ⇒ hidden photon γ' mixes kinetically with γ
- most general Lagrangian



$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} - \frac{\chi}{2}X_{\mu\nu}F^{\mu\nu} + \frac{m_{\gamma'}^2}{2}X_\mu X^\mu + g_Y j_{\text{em}}^\mu A_\mu$$

- γ' couples and can decay to SM fermions through kinetic mixing



Typical values for χ and $m_{\gamma'}$

Kinetic mixing

- from integrating out heavy particles charged under both U(1)s
- χ generated at **loop level**: $\chi \sim \frac{g_Y g_h}{16\pi^2} \times \kappa \sim 10^{-3} - 10^{-4}$ for $\kappa \sim \mathcal{O}(1)$

Higgs mechanism

- masses roughly suppressed by χ : $m_{\gamma'} \simeq \sqrt{g_Y g_h c_{2\beta}} \sqrt{\chi} v$ [Baumgart *et al.* '09, and following papers]

Stückelberg mechanism

- in certain **string compactifications**
mass depends on **volume of extra dimension** i.e. string-scale: $m_{\gamma'} \gtrsim \frac{M_S^2}{M_{Pl}}$
- intermediate string-scale**: $M_S \sim 10^{9-10}$ GeV
gives right regime for axion decay constant and **SUSY** scales [Goodsell *et al.* '09]

$\Rightarrow m_{\gamma'} \sim \text{GeV-scale}$



Constraints: status at Patras'11



7th Patras Workshop on Axions, WIMPs and WISPs

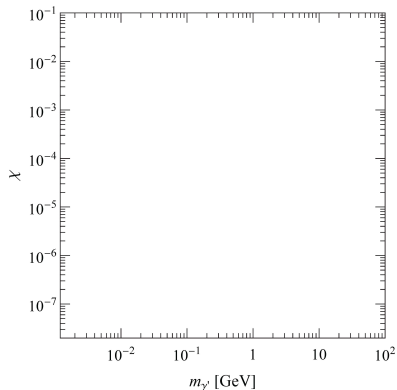
**26 June - 1 July 2011
Mykonos (GR)**

Programme

- The physics case for WIMPs, Axions, WISPs
- Review of collider experiments
- Signals from astrophysical sources
- Direct searches for Dark Matter
- Indirect laboratory searches for Axions, WISPs
- Direct laboratory searches for Axions, WISPs
- New theoretical developments

Organizing committee:
 Yaelle Aouanisopoulos (University of Patras)
 Laura Baudis (University of Zurich)
 Georgios Anagnostou (RWTH Aachen University)
 Axel Lindner (KEK)
 Aristides Arvanitaki (CERN)
 Marc Schumann (University of Zurich)
 Konstantinos Ziogas (University of Patras) (chairman)

<http://axion-wimp.desy.de>

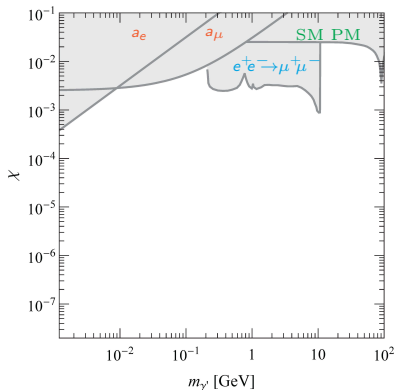


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Precision Measurements

- Muon & Electron $g-2$ [Pospelov '09]
- deviations from SM PM e.g. m_{Z^0} [Hook *et al.* '10]
- reinterpreted BaBar search for $\Upsilon(3S)$ decay into pseudoscalar: $e^+e^- \xrightarrow{\gamma^a/\gamma\gamma'} \gamma\mu^+\mu^-$ [Essig *et al.* '10]

talk B. Echenard



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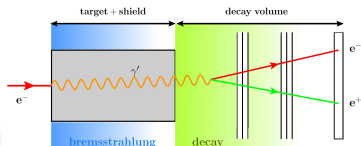
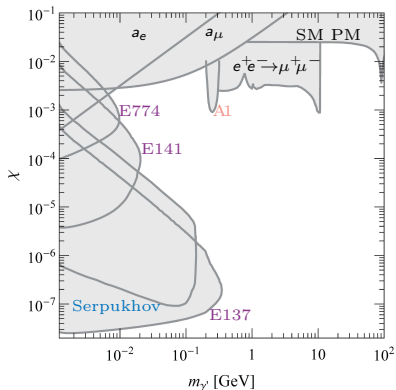
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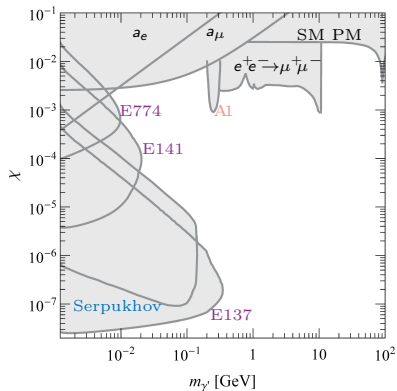
Fixed-target Experiments

γ' Bremsstrahlung off e/p -beam
followed by decay $\gamma' \rightarrow e^+e^-$

- e -beam dump experiments [Bjorken et al. '09]
- e -thin target search A1 at MAMI [Merkel et al. '11]
- p -beam dump at Serpukhov [Blümlein, Brunner '11]



Constraints: status quo & outlook

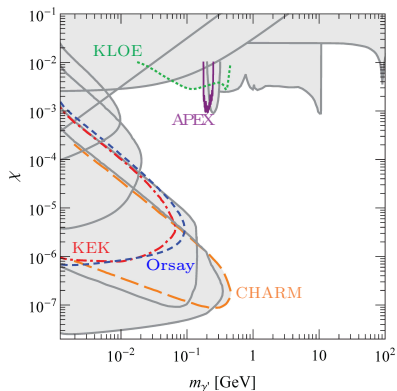


Constraints: status quo & outlook

New Limits

talk J. Beacham

- thin target experiment **APEX** at JLab [Abrahamyan *et al.* '11]
- search in ϕ decays with **KLOE** at Frascati e^+e^- collider [Archilli *et al.* '11]
- search in η decays with **CHARM** neutrino experiment using a p -beam at CERN [Gninenko *et al.* '12]
- rediscovered e -beam dump experiments:
 search for axion-like particles at **KEK** [SA, Niebuhr, Jacobsohn, Ringwald *in prep.*]
 search for light Higgs boson in **Orsay**

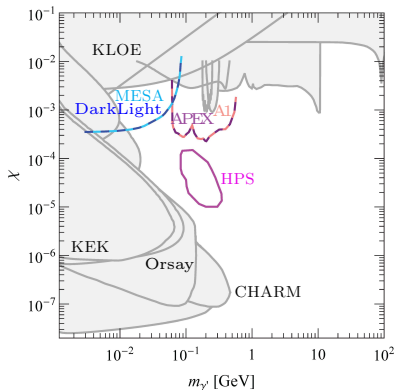


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Future Sensitivities

talk P. Hansson

- JLab: **APEX**, **DarkLight**, **HPS**
- Mainz: **A1**, **MESA**

talk J. Boyce



Outline

- 1 Hidden Photon
- 2 Hidden Dark Matter
 - Toy Model
 - Supersymmetric Model
- 3 Conclusions



Toy-Model: Fermionic DM

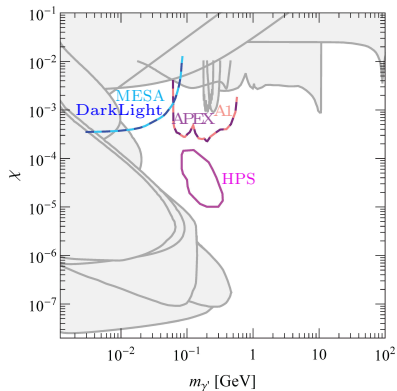
Simplest hidden sector with DF & DM

talk D. Hooper

Hidden Photon with mass $m_{\gamma'}$ and mixing χ

Additional Dirac fermion ψ

- ▶ one extra mass parameter m_ψ



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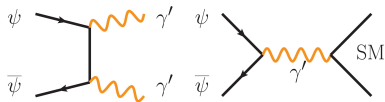
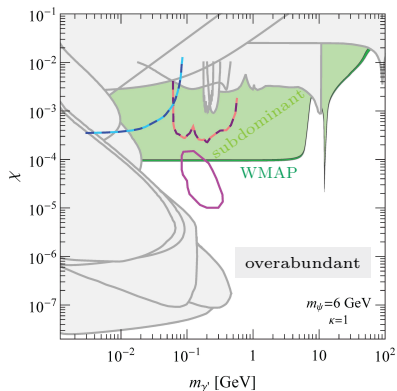
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Relic abundance Ωh^2

- annihilation of ψ through and into γ'
 - t-channel only when $m_{\gamma'} < m_\psi$
 - s-channel: **resonance** for $m_{\gamma'} = 2 m_\psi$
- ⇒ ψ **total DM** or **subdominant component**



[Pospelov *et al.* '08; Chun *et al.* '10; Mambrini '10; SA, Goodsell, Ringwald '11]

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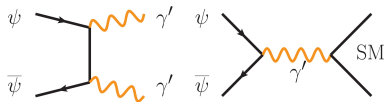
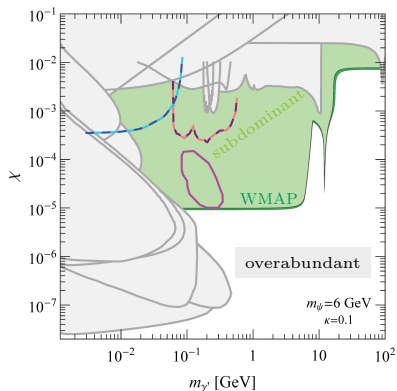
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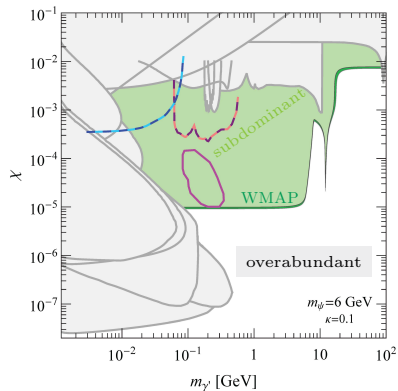
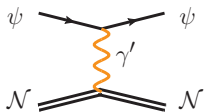
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Toy-Model: Fermionic DM

talk P. Gondolo

Direct Detection

- elastic scattering on nuclei
- mediated by γ'
- **spin-independent** vector-like interaction

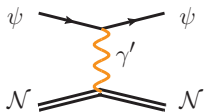


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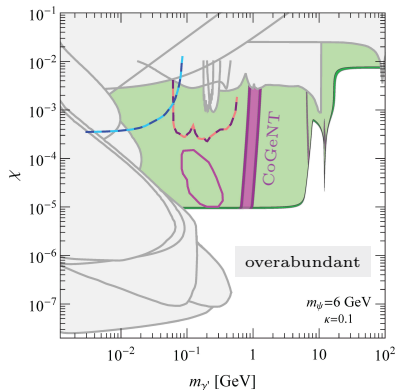


Comparison with experiments

- limits on σ_{SI} from CDMS & XENON
- potential signature in DAMA & **CoGeNT**

talk J. Collar

[SA, Goodsell, Ringwald '11]

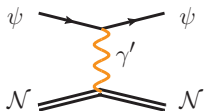


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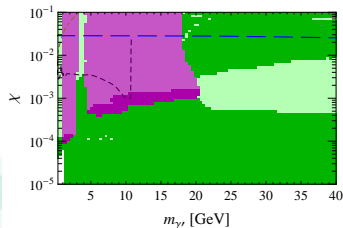
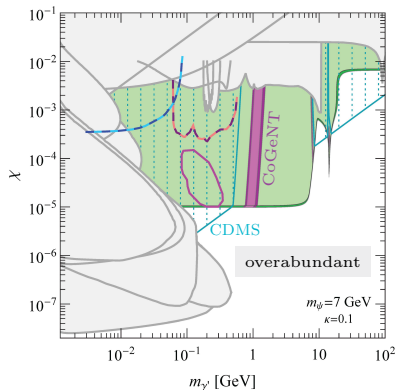


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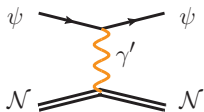


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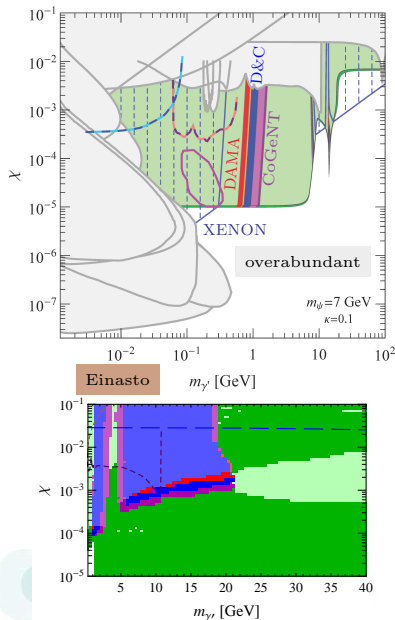
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talk M. Schumann

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Supersymmetric Dark Force models

- most simple anomaly-free HS:
 - ◇ three chiral superfields S , H_+ , H_- charged under $U(1)_h$
 - ◇ superpotential: $W \supset \lambda_S SH_+H_-$
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 - ⇒ gravitino is not the LSP
 - ⇒ DM can consist of stable hidden sector particle
is either Majorana or Dirac fermion



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is either **Majorana** or **Dirac** fermion
- hidden gauge symmetry breaking:
 - ◇ radiatively through running
 - ◇ induced by visible sector



Radiative breaking

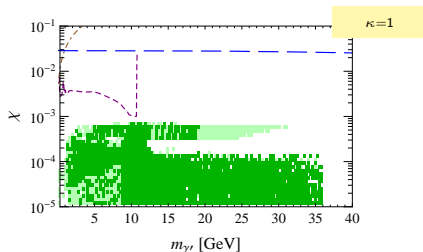
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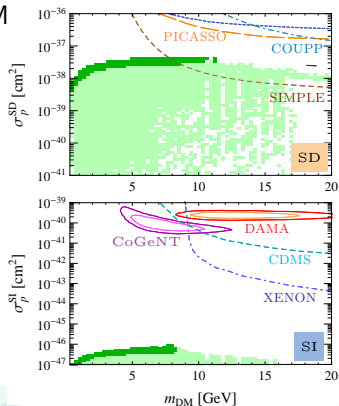
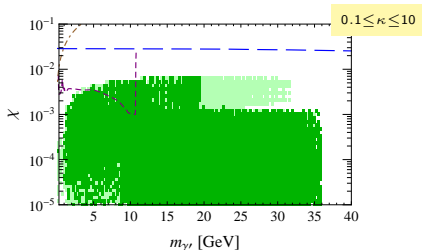
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- Majorana fermion Ψ_M : total & subdominant DM
 - ◊ axial coupling generates SD scattering
 - ◊ minor SI scattering (Higgs Portal $\sim 10^{-46} \text{cm}^{-2}$)



⇒ SD in reach of experiments SI beyond reach

[SA, Goodsell, Ringwald '11]

Visible sector induced breaking

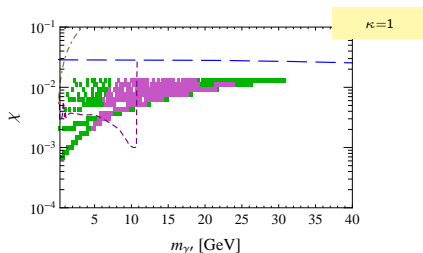
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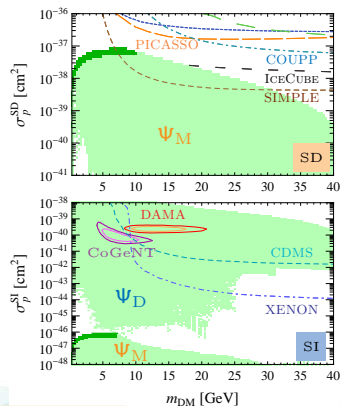
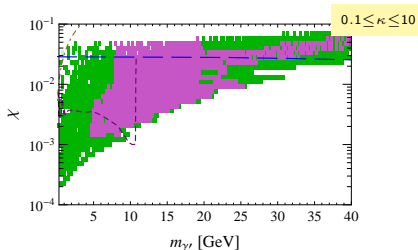
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⇒ SI fits DAMA & CoGeNT SD in reach of experiments

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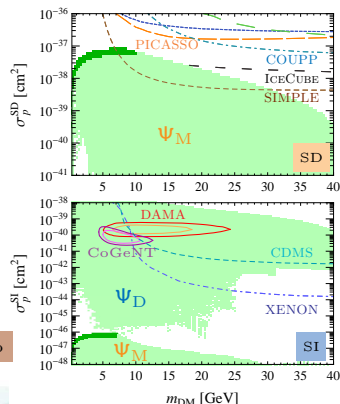
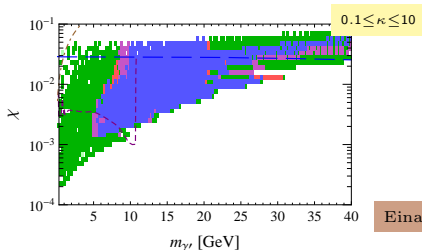
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Conclusions

- hidden sector
 - ◇ well motivated
 - ◇ rich content & interesting phenomenology: dark force and dark matter
- hidden photons as dark force
 - ◇ constrained and currently further explored
- dark matter in HS
 - ◇ viable as total & subdominant DM with interesting DD potential
- SUSY models with gravity mediation
 - ◇ yield viable Majorana or Dirac fermion as DM with different features

