

HOPES IN THE DARK

MARTÍN MAKLER



The Dark Energy Revolution in Cosmology
Celebrating Ioav Waga's Career

MMC

#VoltaMCTI

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MIC

Fora Temer!

TI

Morpho-z: improving photometric redshifts with galaxy morphology

John Y. H. Soo^{1*}, Bruno Moraes¹, Benjamin Joachimi¹, William Hartley¹, Ofer Lahav¹, Aldée Charbonnier², Martín Makler³, Maria E. S. Pereira³, Johan Comparat⁴, Thomas Erben⁵, Alexie Leauthaud⁶, Huanyuan Shan⁷ and Ludovic Van Waerbeke⁸.

ACKNOWLEDGEMENTS

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National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. The Brazilian partnership on CFHT is managed by the Laboratório Nacional de Astrofísica (LNA). We thank the support of the Laboratório Interinstitucional de e-Astronomia (LineA). We thank the CFHTLenS team.

On mass concentrations and magnitude gaps of galaxy systems in the CS82 survey

André Z. Vitorelli,^{1*} Eduardo S. Cypriano,¹ Martín Makler,² Maria E. S. Pereira,² Thomas Erben³ and Bruno Moraes⁴

MegaPrime/MegaCam, a joint project of CFHT and CEA/DAPNIA, at the Canada-France-Hawaii Telescope

ACKNOWLEDGEMENTS

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Do satellite galaxies trace matter in galaxy clusters?

Chunxiang Wang,^{1,2★} Ran Li,^{1,3★} Liang Gao,^{1,3,4} Huanyuan Shan,^{5,6}
Jean-Paul Kneib,^{5,7} Wenting Wang,⁸ Gang Chen,² Martin Makler,⁹
Maria E. S. Pereira,^{9,10} Lin Wang,^{1,3} Marcio A. G. Maia¹¹ and Thomas Erben⁶

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Compact Groups analysis using weak gravitational lensing II: CFHT Stripe 82 data

Martín Chalela,^{1,2} Elizabeth Johana Gonzalez,^{1,2★} Martín Makler,³
Diego García Lambas,^{1,2} Maria E. S. Pereira,⁴ Ana Laura O’Mill^{1,2} and
HuanYuan Shan⁵

by CNPq (grant 312353/2015-4) and FAPERJ. **FORA TEMER**. We acknowledge the PCI BEV fellowship program from MCTI and CBPF.

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Ioav Waga: pioneiro da energia escura no Brasil

THE ASTROPHYSICAL JOURNAL, 414:436–448, 1993 September 10

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DECAYING VACUUM FLAT COSMOLOGICAL MODELS: EXPRESSIONS FOR SOME OBSERVABLE QUANTITIES AND THEIR PROPERTIES

I. WAGA

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Received 1992 November 25; accepted 1993 March 18

ABSTRACT

Flat cosmological models with a cosmological term varying as $\Lambda = \alpha R^{-2} + \beta H^2 + \gamma$ are investigated. Exact expressions for observable quantities are obtained and some of their properties discussed. The lookback time–redshift, the luminosity distance–redshift, the angular diameter distance–redshift and the comoving volume derivative–redshift diagrams for some selected world models are also presented.

Subject heading: cosmology: theory

Antes das Supernovas do tipo Ia (1998)....

Ioav Waga: pioneiro de lentes no Brasil

Mon. Not. R. Astron. Soc. **279**, 712–726 (1996)

Decaying Λ cosmologies and statistical properties of gravitational lenses

L. F. Bloomfield Torres¹ and I. Waga^{1,2}

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Accepted 1995 October 12. Received 1995 September 25; in original form 1995 April 18

ABSTRACT

In this paper we investigate the statistical properties of gravitational lenses for models in which a cosmological term decreases with time as $\Lambda \propto a^{-m}$, where a is the scale factor, and m is a parameter ($0 \leq m < 3$). We show that for given low values of the present matter density parameter Ω_{m0} , there is a wide range of values for m for which the lensing rate is significantly smaller than that in cosmological constant (Λ) models. We also show that models with low Ω_{m0} and $m \gtrsim 1$ have a high likelihood of reproducing the observed lens statistics in the *Hubble Space Telescope* Snapshot Survey (HSTSS).

Key words: cosmology: theory – gravitational lensing.

Ioav Waga: pioneiro de lentes no Brasil

Mon. Not. R. Astron. Soc. **309**, 465–473 (1999)

Weak gravitational lensing by voids

Luca Amendola,^{1,2} Joshua A. Frieman^{1,3} and Ioav Waga^{1,4}

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Accepted 1999 June 2. Received 1999 April 12; in original form 1998 December 3

ABSTRACT

We consider the prospects for detecting weak gravitational lensing by underdensities (voids) in the large-scale matter distribution. We derive the basic expressions for magnification and distortion by spherical voids. Clustering of the background sources and cosmic variance are the main factors that limit in principle the detection of lensing by voids. We conclude that only voids with radii larger than $\sim 100 h^{-1}$ Mpc have lensing signal-to-noise ratio larger than unity.

Key words: cosmology: theory – gravitational lensing.

Ioav Waga: pioneiro de supernovas no Brasil

PHYSICAL REVIEW D

VOLUME 57, NUMBER 8

15 APRIL 1998

Constraints from high redshift supernovae upon scalar field cosmologies

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and Department of Astronomy and Astrophysics, University of Chicago, Chicago, Illinois 60637*

Ioav Waga

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(Received 8 September 1997; published 27 February 1998)

Recent observations of high-redshift type Ia supernovae have placed stringent constraints on the cosmological constant Λ . We explore the implications of these SNe observations for cosmological models in which a classically evolving scalar field currently dominates the energy density of the Universe. Such models have been shown to share the advantages of Λ models: compatibility with the spatial flatness predicted by inflation; a Universe older than the standard Einstein–de Sitter model; and, combined with cold dark matter, predictions for large-scale structure formation in good agreement with data from galaxy surveys. Compared to the cosmological constant, these scalar field models are consistent with the SNe observations for a lower matter density, $\Omega_{m0} \sim 0.2$, and a higher age, $H_0 t_0 \gtrsim 1$. Combined with the fact that scalar field models imprint a distinctive signature on the cosmic microwave background anisotropy, they remain currently viable and should be testable in the near future. [S0556-2821(98)03106-3]

PACS number(s): 98.80.Cq

Conselhos de Ioav

- 1996: curso de cosmologia
- 2001: 2dF ou SDSS?
- 2002: volta do Fermilab
 - Início da colaboração

Unificação Matéria - Energia Escuras

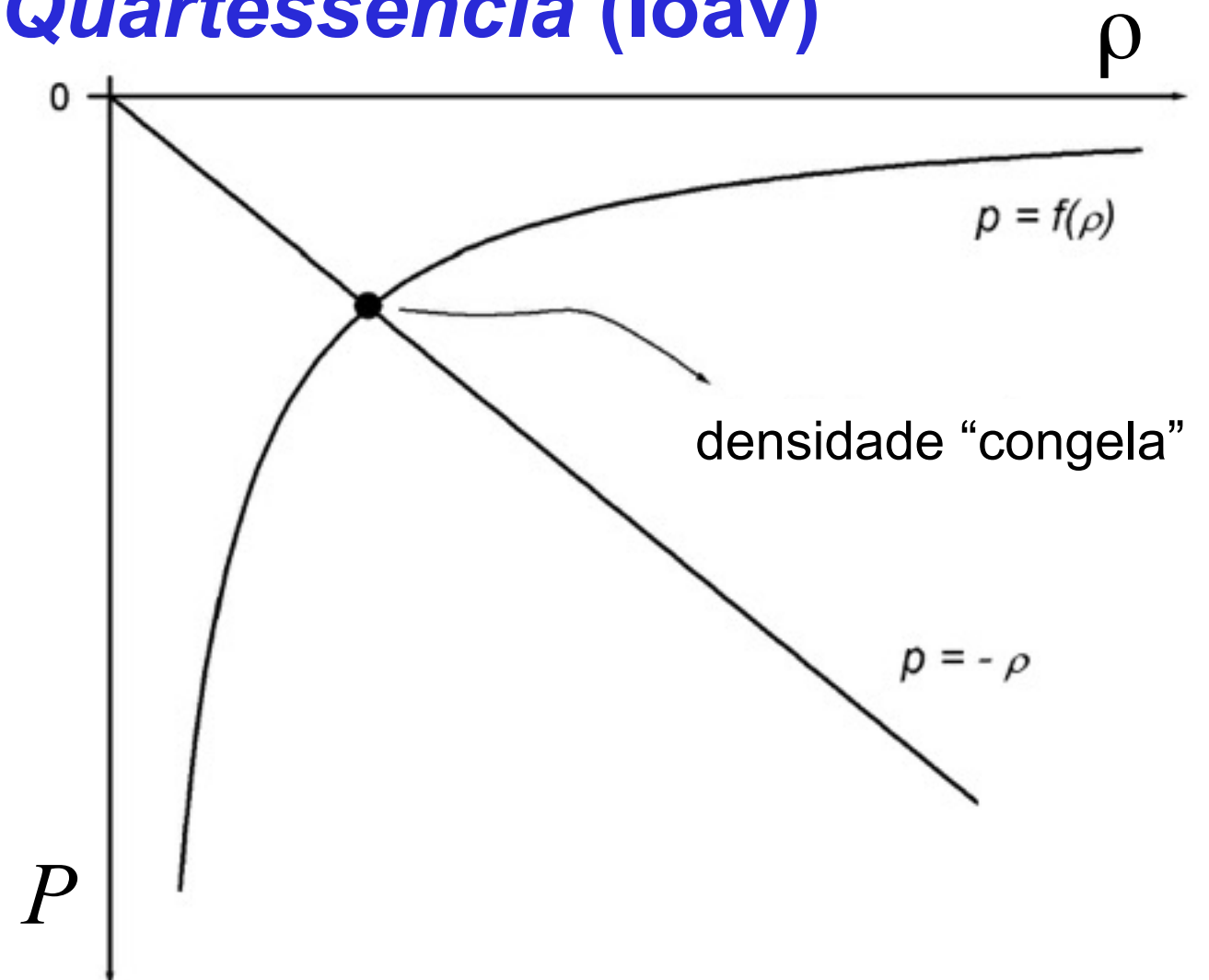
- Muitos candidatos, mas nenhuma detecção no laboratório (evidências apenas astrofísicas)
- Porque duas componentes desconhecidas?
Unificação da matéria e energia escuras
 $\Rightarrow$ *Unifying Dark Matter* ou **Quartessência (loav)**

- $p < 0$ e aumentando com a densidade $\Rightarrow$ estabilidade

$$(c_s^2 = dp/d\rho > 0)$$

- Conservação da Energia

$$(\rho + p)\theta = \dot{\rho}$$



Unificação Matéria - Energia Escuras

- Energia Escura + Matéria Escura: modelo “de concordância” mais simples
- Unificação ME + EE: *Quartessência*

$P(\rho)$	$\longleftrightarrow$ adiabático	$L = L(\partial_\mu \phi \partial^\mu \phi)$
Fluido efetivo		K-essence
$p = -\frac{M^{4(\alpha+1)}}{\rho^\alpha}$		$L = -\sqrt{1 - \partial_\mu \phi \partial^\mu \phi} \quad (\text{para } \alpha = 1)$

- Modelos são consistentes com os dados?
- Que valores dos seus parâmetros são permitidos pelas observações?
- Obter resultados o mais genérico e abrangentes possíveis

Unificação Matéria - Energia Escuras

- Energia Escura + Matéria Escura: modelo “de concordância” mais simples
- Unificação ME + EE: *Quartessência*

$$P(\rho)$$

Fluido efetivo



$$L = L(\partial_\mu \phi \partial^\mu \phi)$$

K-essence

convexa

$$\left\{ \begin{array}{l} p = -\frac{M^{4(\alpha+1)}}{\rho^\alpha} \\ p = \frac{-M^4}{[\log(\rho/M^4)]^\alpha} \\ p = -M^4 \exp\left(-\frac{\alpha\rho}{M^4}\right) \end{array} \right.$$

$$L = -\sqrt{1 - \partial_\mu \phi \partial^\mu \phi} \quad (\text{para } \alpha = 1)$$

- **Modelo de Born-Infeld extendido**

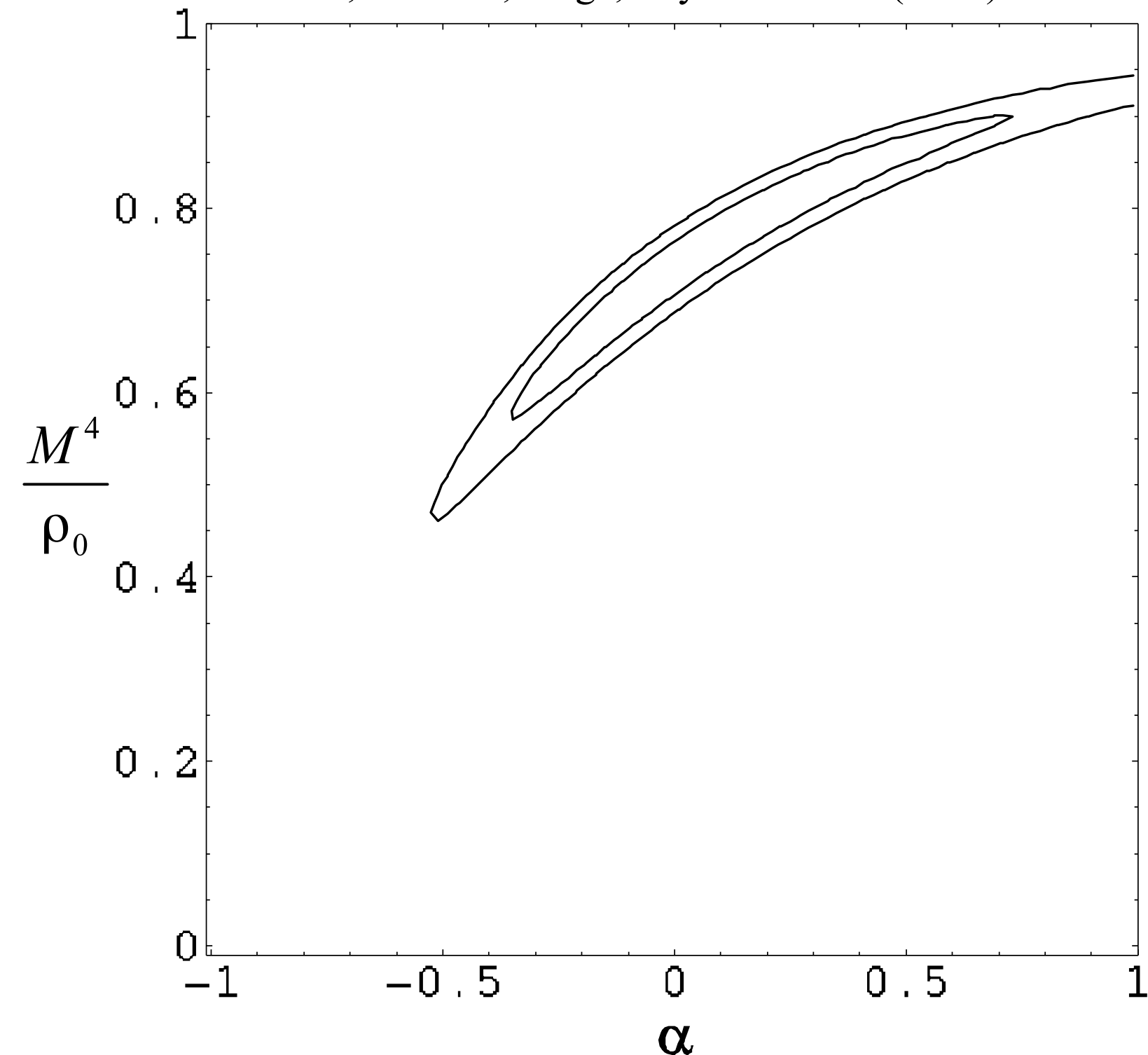
$$\mathcal{L} = -\sqrt{\alpha X^2 + \beta X + \gamma}$$

$$X = \frac{1}{2} g^{\alpha\beta} \phi_{;\alpha} \phi_{;\beta}$$

Primeiro trabalho com Ioav:

Primeiros Limites Observacionais em Quatresência

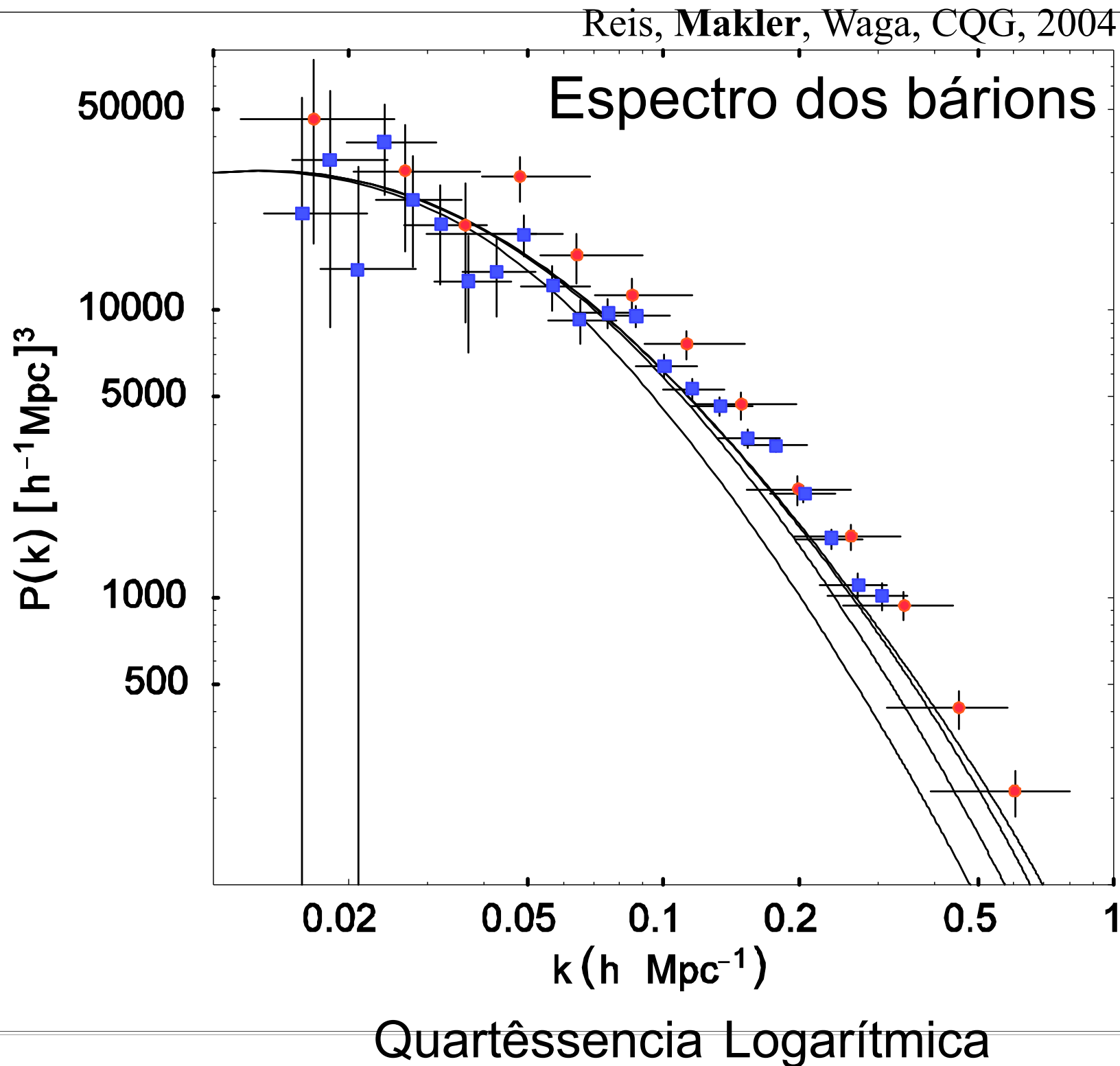
Makler, Oliveira, Waga, Phys.Rev. D68 (2003) 123521



Análise Combinada:

- Dados de SNIa, lentes, galáxias FR IIb e raios-X
- Limites mais fortes a partir da métrica de fundo
- GCG consistente com os dados, incluindo “gás Chaplygin” e Λ CDM
- Parâmetros do modelo no intervalo esperado

Regime Linear: Espectro de Potência



Característica geral de modelos de convexos:

- Supressão (e oscilações) na componente de quartessência para perturbações adiabáticas
- Inconsistente com dados de: $\sigma_8 + P(k)$

Sandvik et al., Phys. Rev. D **69**, 123524 (2004)

Beca et al., Phys. Rev. D **67**, 101301 (2003)

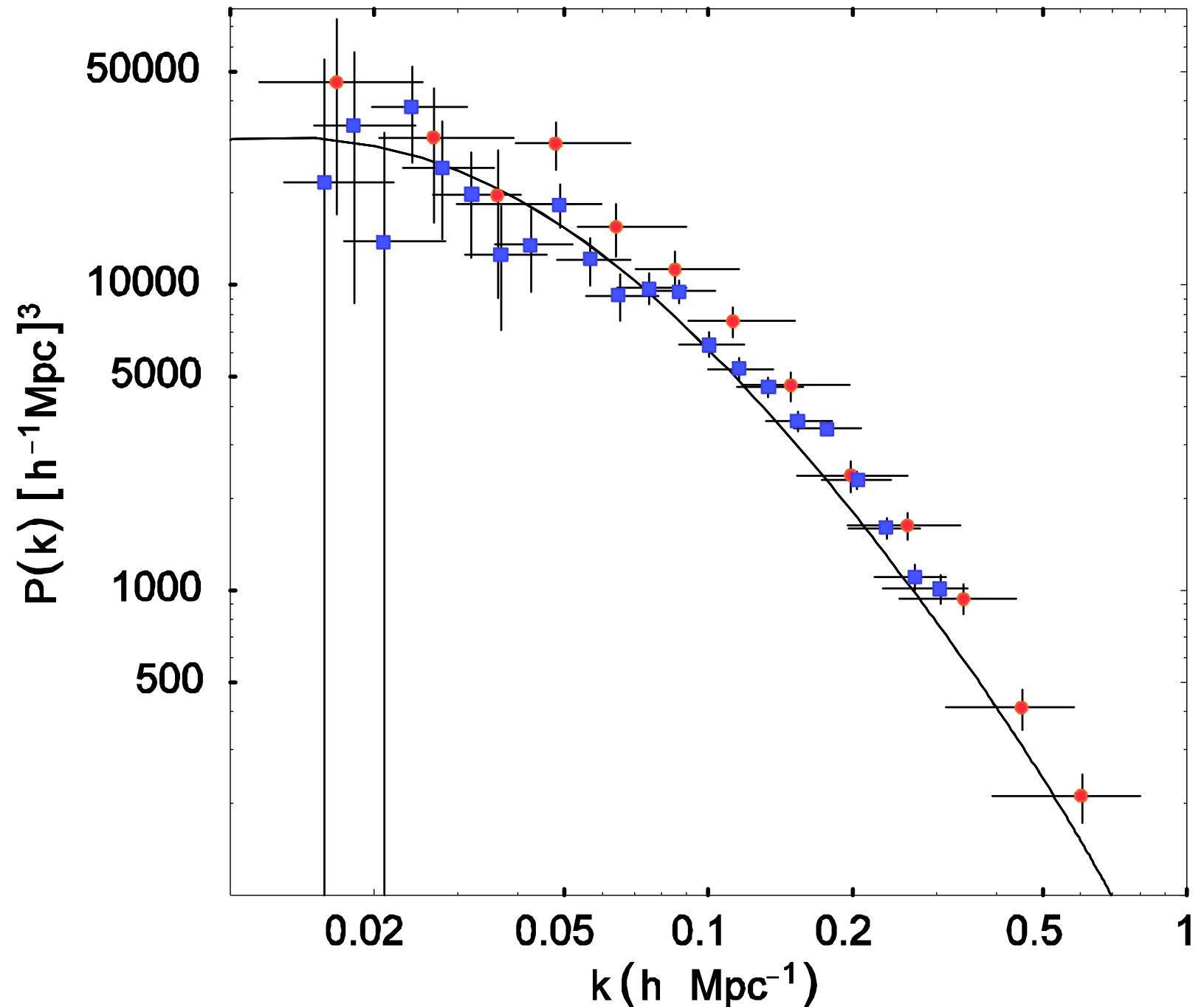
Reis et al., Phys. Rev. D **68**, 061302 (2003)

Quartêssencia não adiabática

Reis, Waga, Calvão, & Jorás,
Phys.Rev. D**68** (2003) 061302

- Flutuações intrínsecas de entropia tal que $c_s^{eff} = 0$
- Consistentes com dados do SDSS e 2dF
- Outra solução: função degrau

Reis, Makler, Waga, CQG, 2004



Quartêssencia Logarítmica

Aglomeraco no linear

o Regime linear ok para $c_s^{eff} = 0$

o Assimetria (regime no linear) $S_3 = \langle \delta^3 \rangle / \langle \delta^2 \rangle^2$

o Parmetros da quartessncia em acordo com outros dados levam a

$$S_3 \sim 15 - 20$$

o O modelo Λ CDM prediz (em acordo com as observaes):

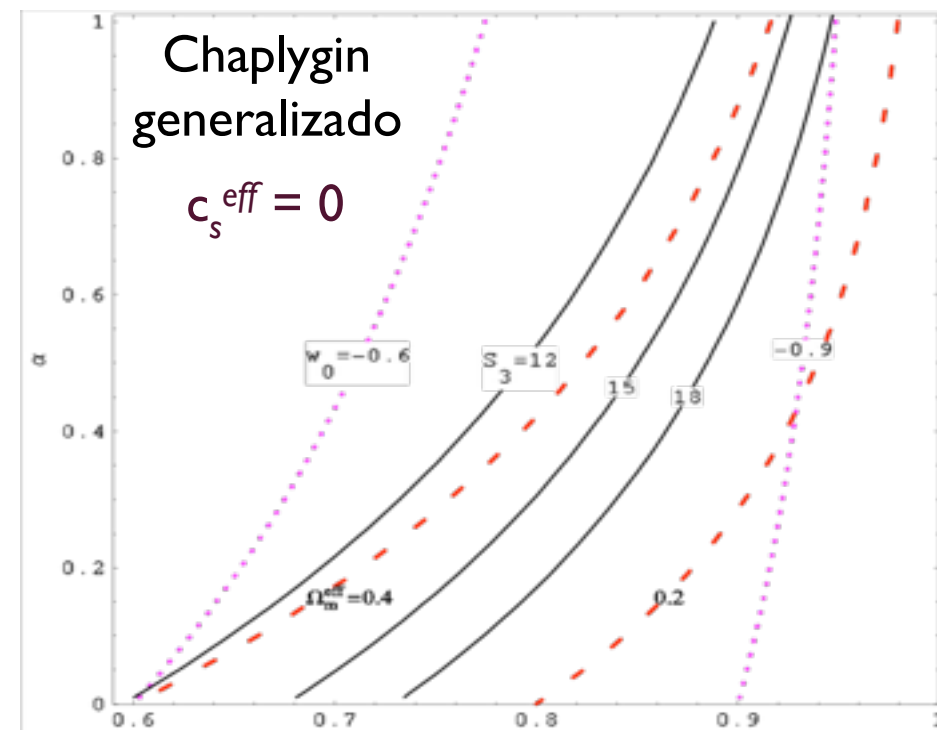
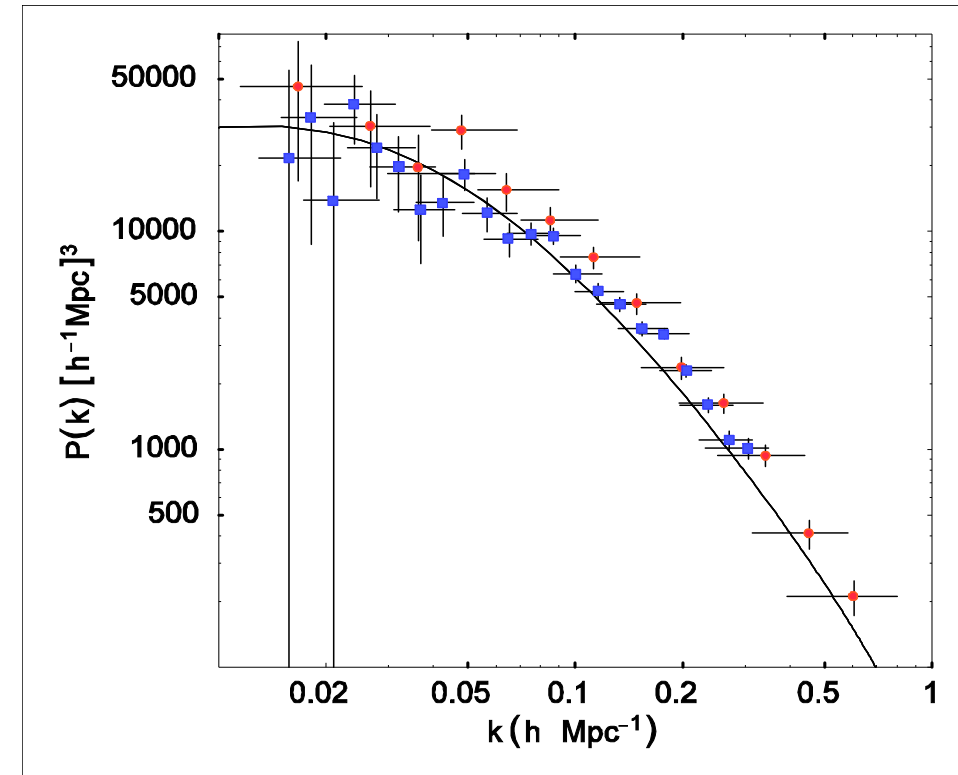
$$S_3 \sim 5$$

o Assimetria na componente barinica: $S_{3b} \sim 5$

► Deveramos olhar a distribuio de matria total

➔ Lentes gravitacionais

Teste “definitivo” para a quartessncia



Estruturas no lineares + lensing ➔ strong lensing ➔ arcos

Constraints on the generalized Chaplygin gas from supernovae observations

Martín Makler^{a,b}, Sérgio Quinet de Oliveira^b, Ioav Waga^b

Ou
 $c_s^{\text{eff}} = 0$
(não adiabático)
ou indistinguível
de Λ CDM

PHYSICAL REVIEW D 68, 123521 (2003)

Observational constraints on Chaplygin quartessence: Background results

Martín Makler, Sérgio

INSTITUTE OF PHYSICS PUBLISHING

Class. Quantum Grav. 22 (2005) 353–362

CLASSICAL AND QUANTUM GRAVITY

[doi:10.1088/0264-9381/22/2/008](https://doi.org/10.1088/0264-9381/22/2/008)

Matter power spectrum for convex quartessence

R R R Reis¹, M Makler^{1,2}

PHYSICAL REVIEW D 69, 101301(R) (2004)

Skewness as a test for quartessence

R. R. R. Reis, M. Makler, and I. Waga

PHYSICAL REVIEW D 71, 043515 (2005)

Extended Born-Infeld dynamics and cosmology

M. Novello,¹ M. Makler,^{1,2,3} L. S. Werneck,⁴ and C. A. Romero⁵

PHYSICAL REVIEW D 74, 063524 (2006)

Is it possible to observationally distinguish adiabatic quartessence from Λ CDM?

L. Amendola,¹ M. Makler,² R. R. R. Reis,³ and I. Waga³

Navalha de Ockham
Falseabilidade

A new hope in the Dark

arXiv:1809.07409

New Scalar Field Quartessence

Robert Brandenberger,^{1,*} Rodrigo R. Cuzinatto,^{2,1,†} Jürg Fröhlich,^{3,‡} and Ryo Namba^{1,§}

¹*Department of Physics, McGill University, Montréal, QC, H3A 2T8, Canada*

²*Instituto de Ciência e Tecnologia, Universidade Federal de Alfenas, Rodovia José Aurélio Vilela, 11999, Cidade Universitária, CEP 37715-400, Poços de Caldas, MG, Brazil*

³*Institute of Theoretical Physics, ETH Zürich, CH-8093 Zürich, Switzerland*

(Dated: September 21, 2018)

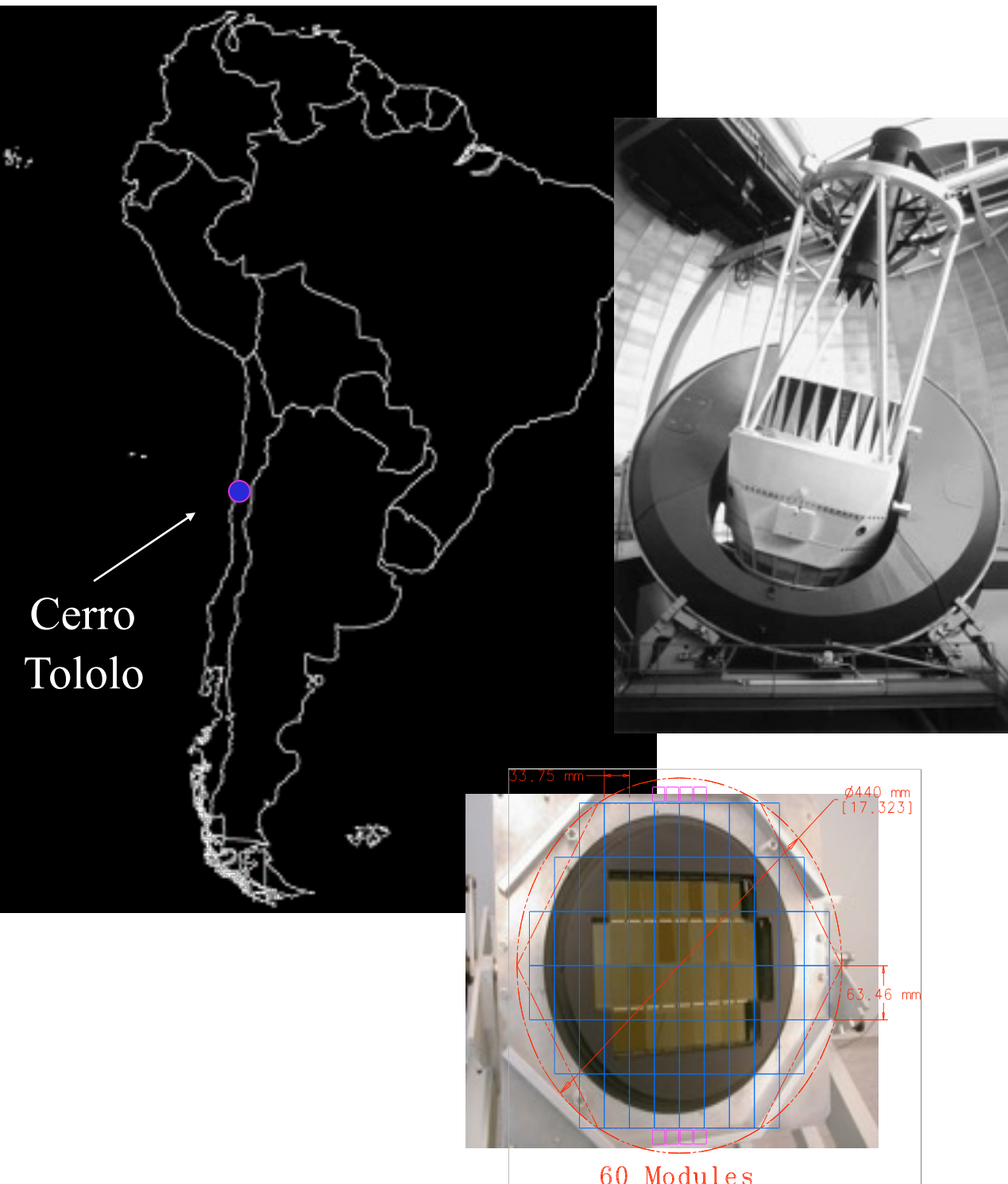
We propose a cosmological scenario involving a single scalar field, φ , that is a source of Dark Matter as well as Dark Energy. The Lagrangian density of φ contains a second field χ , for simplicity assumed to be a scalar. For fixed values of χ , the potential of φ decays exponentially at large positive φ -values. While φ is not coupled to Standard Model fields, χ is assumed to couple to them. Hence, the Green functions of χ depend on the temperature of the local equilibrium in the expanding universe. We assume that the coupling of χ to φ is such that, at temperatures larger than some critical temperature T_c , φ is trapped near the origin, and excitations of φ about the origin form Dark Matter. After a phase transition at the temperature T_c , the trapping force disappears and φ rolls towards large field values. A homogenous component of φ appears and acts as Dark Energy. Within overdense regions, such as galaxies and galaxy clusters, the kinetic temperature is sufficiently high such that the phase transition does not occur. Thus, at the present time, φ can describe both Dark Energy and Dark Matter.



Participação Brasileira no DES

Por que o DES?

- Projeto em fase inicial
 - Envolver pessoas
- Histórico de colaboração com Fermilab
 - CBPF
 - pessoal
- Médio porte
- Instrumento versátil:
 - Outros interesses astrofísica brasileira



II Workshop Dark Energy Survey - Brazil

27-29 Fevereiro de 2008, ICRA/CBPF, Rio de Janeiro, RJ



WWW.DES-BRAZIL.ORG

II Workshop do Dark Energy Survey - Brazil

27/02: Parte I: Ciência e Desafios do DES

28-29/02: Parte II: Reunião de trabalho do DES-Brazil

Para mais informações e inscrições para a parte I: www.des-brazil.org (no menu reuniões)
Local: Auditório Min. João Alberto Lins de Barros, Centro Brasileiro de Pesquisas Físicas

Comitê organizador: Martín Makler (CBPF), Paulo Pellegrini (ON), Ioav Waga (UFRJ), Basílio Santiago (UFRGS), Thyrso Villela (INPE)

Apoio:



Ministério da
Ciência e Tecnologia





UNIVERSIDADE FEDERAL DO RIO DE JANEIRO
CENTRO DE CIÊNCIAS MATEMÁTICAS E DA NATUREZA
INSTITUTO DE FÍSICA
<http://www.if.ufrj.br>

Aos membros do consórcio
(DES-Brazil),

antecipação de problemas na governança

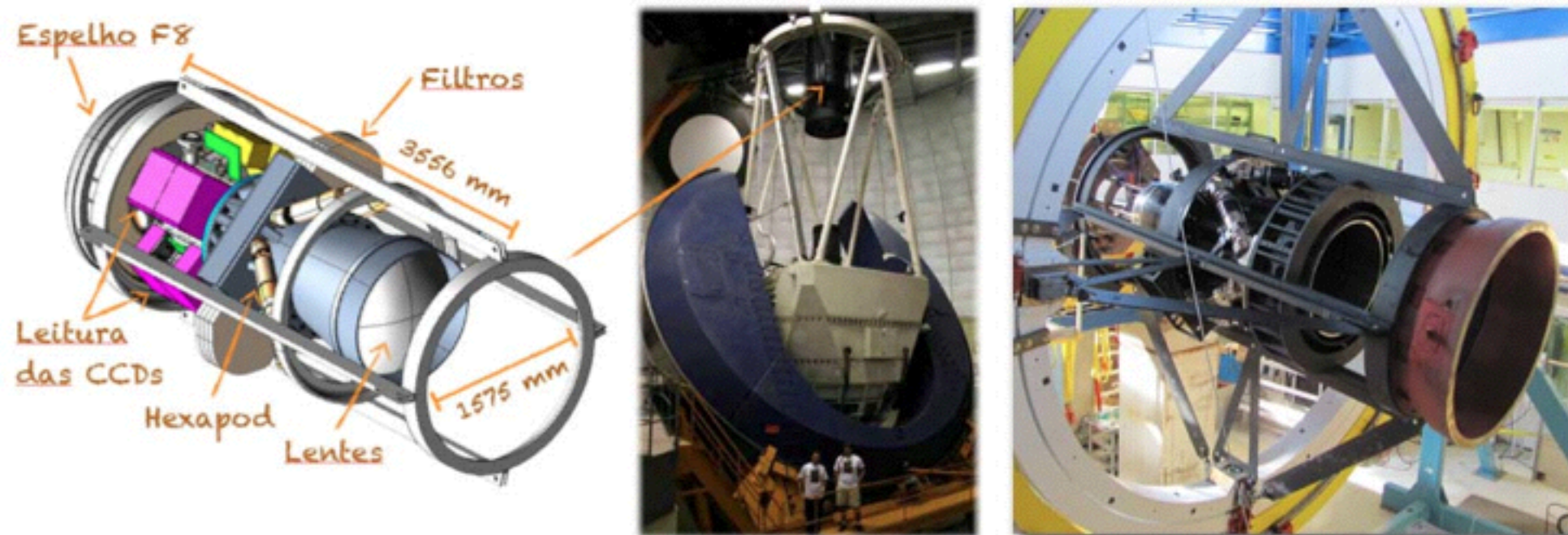
Comunicamos que condições estabelecidas nos documentos (MoU) estabelecidas pelo coordenador do projeto DES-Brazil, não nos permitem assiná-lo. A proposta de MoU apresentada não tem como base nenhum critério científico, centrando-se em decisões de formação política para nós. Supostamente alguns desses assuntos poderiam ser negociados e modificados, conforme já sugerido por um dos atuais membros. Entretanto, o simples fato de considerarmos ter submetido à nossa apreciação uma proposta com tais características suscitou um sentimento de desconfiança e confirma nossa suspeita de que isso foi o ápice de um processo recorrente para burlar nossa saída. Infelizmente, com a assinatura desse MoU, está criada para nós uma atmosfera de colaboração que não nos permite continuar realizando nosso trabalho de forma adequada. Sendo assim, entendemos que a melhor solução é sairmos do DES-Brazil.

Maurício O. Calvão
Ioav Waga



Centro Brasileiro de Pesquisas Físicas

DARK ENERGY SURVEY



Plano Diretor do CBPF

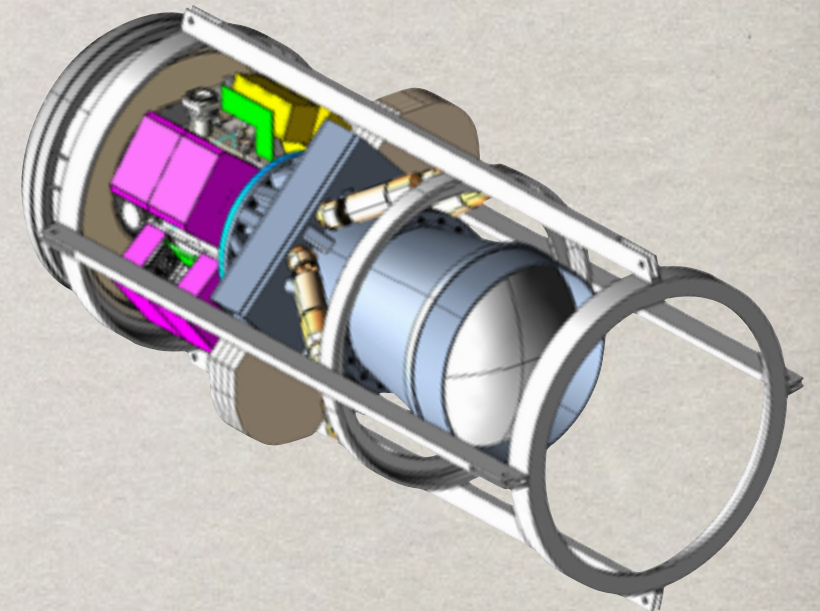
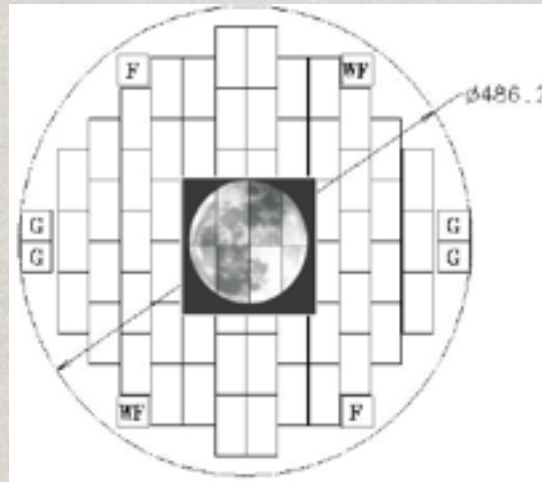
2011-2015



DARK ENERGY
SURVEY

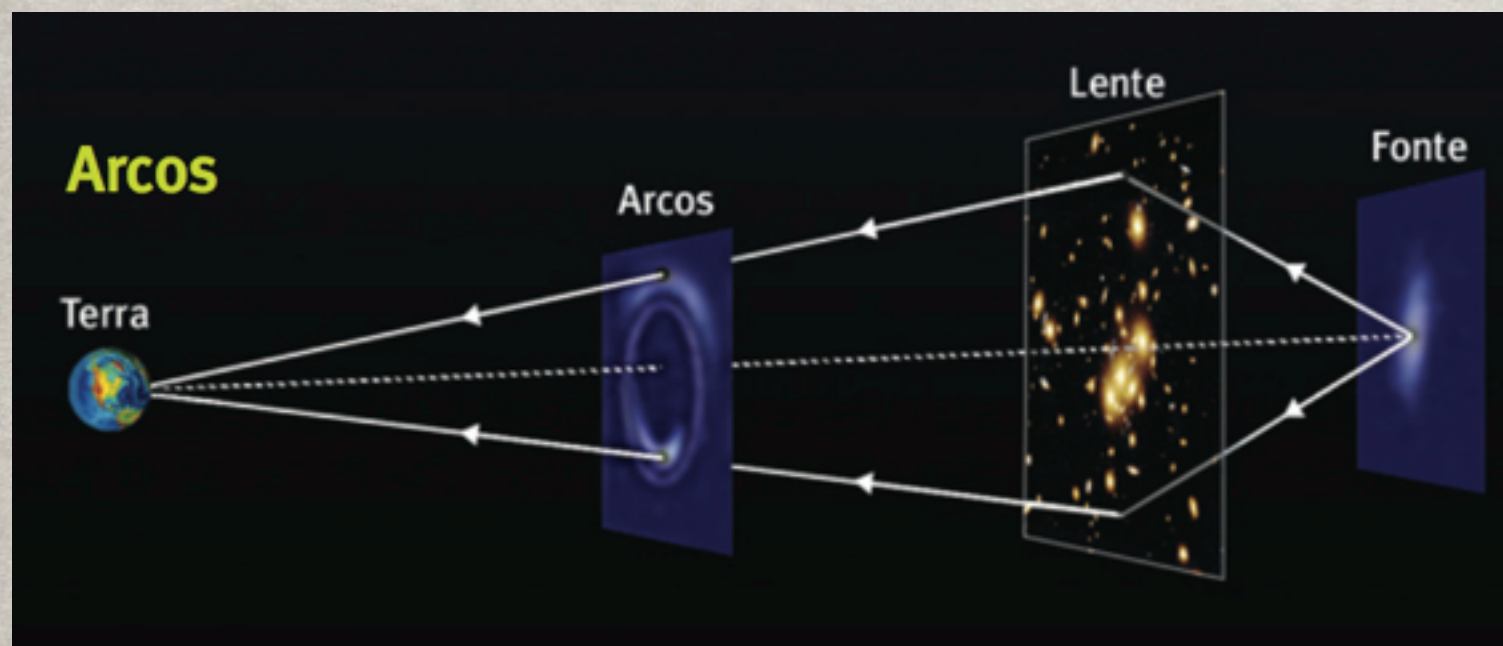
DARK ENERGY CAMERA AND SURVEY

- Plano Focal
 - 500 Megapixels,
 - Field: $\sim 3 \text{ deg}^2$
 - $0.27''/\text{pixel}$
 - Red sensitive CCDs
 - $\sim 1.8 \text{ Tb/night}$
- Blanco 4m telescope
- 30% of CTIO in 5 yrs (525 nights)
- $g, r, i, Z, Y = 24.6, 24.1, 24.4, 23.8, 21.3$
 - photometric redshifts
 - accuracy: $dz < 0.02$ to $z = 1$
- Coverage: 5000 deg^2
- Current median seeing $\leq 0.9''$
- Survey started November 2012



EFEITO FORTE DE LENTE

- Imagens múltiplas, grandes deformações, magnificação, atraso temporal
 - Geodésicas nulas
 - brilho superficial conservado
 - acromático
 - estrutura de galáxias e aglomerados → matéria escura e bárions
 - informações complementares sobre a cosmologia e testes da gravidade
- } → Telescópios gravitacionais



efeito forte de lentes, gravidade fraca



arcos gravitacionais



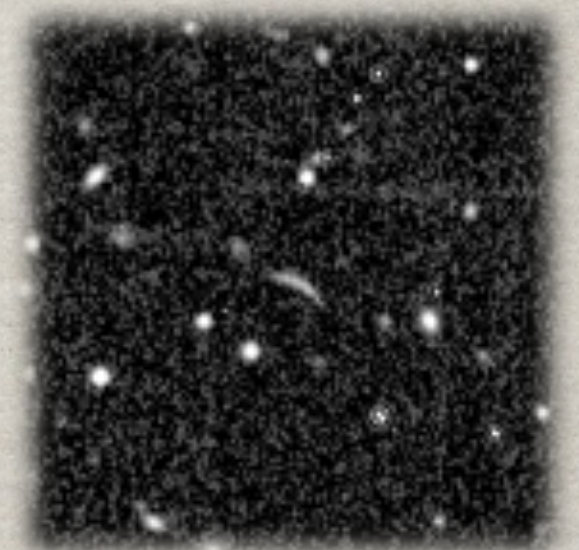
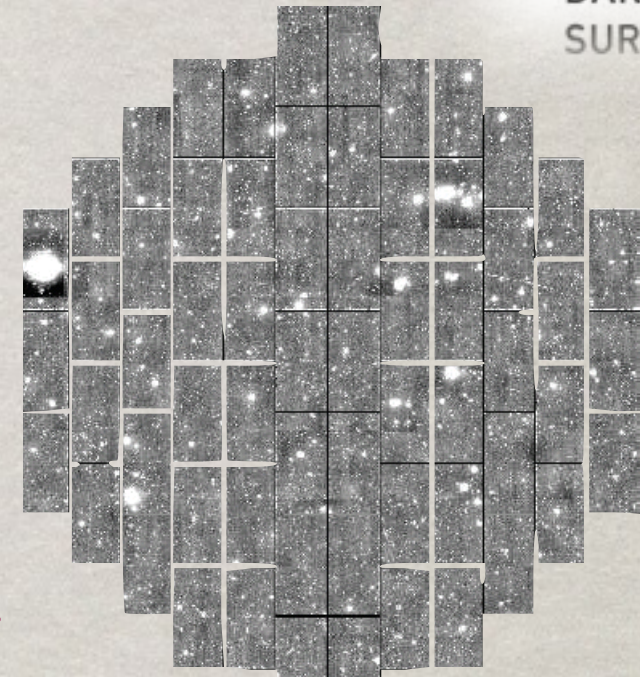
DARK ENERGY
SURVEY

ARCOS NO DES



DARK ENERGY
SURVEY

- Esperamos $\sim 10^3$ arcos no DES
(a partir de simulações e dados atuais)
 - Propriedades médias das lentes
 - Follow-up
- DES utiliza simulações no nível das imagens:
 - galáxias + estrelas, absorção, atmosfera, instrumento, etc.
 - teste do processamento + análise científica
 - Data-Challenges (2011/12: DC6)
- Arcos simulados
- Testes extensivos nas áreas com arcos simulados
- Arcfinders conseguem rodar com o volume de dados do DES!

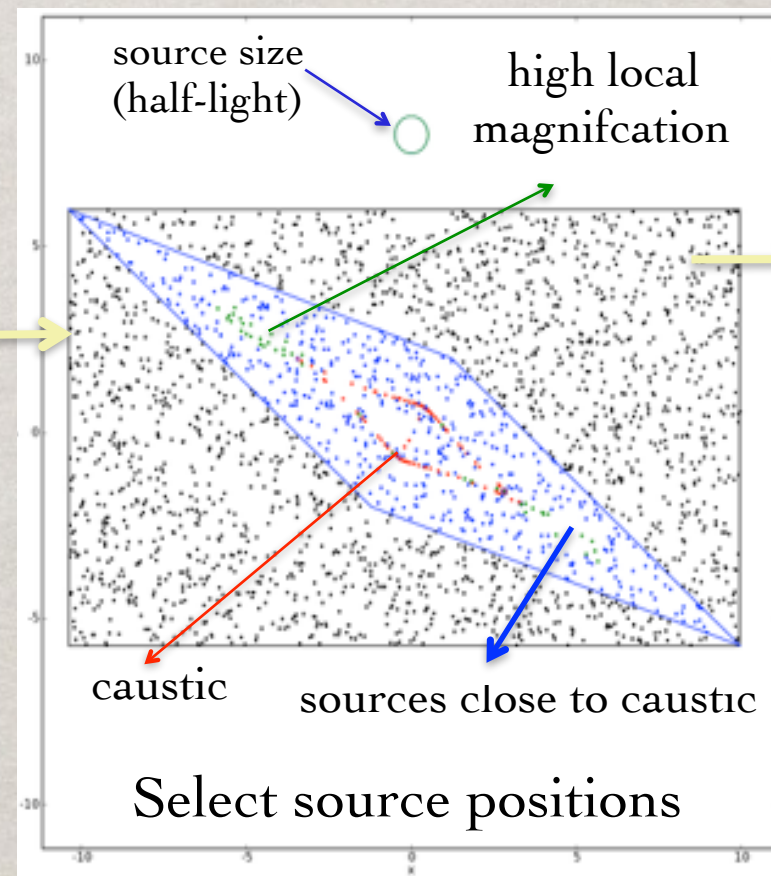


ADDARCS

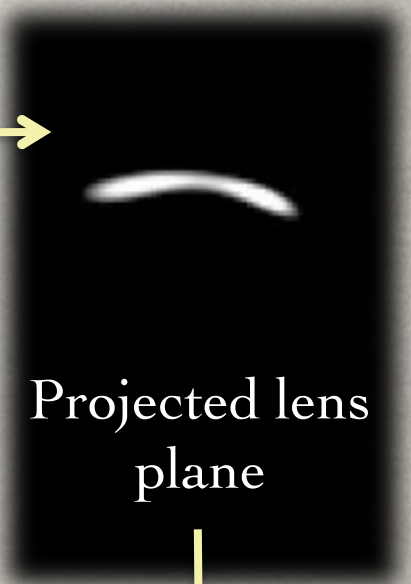


DARK ENERGY
SURVEY

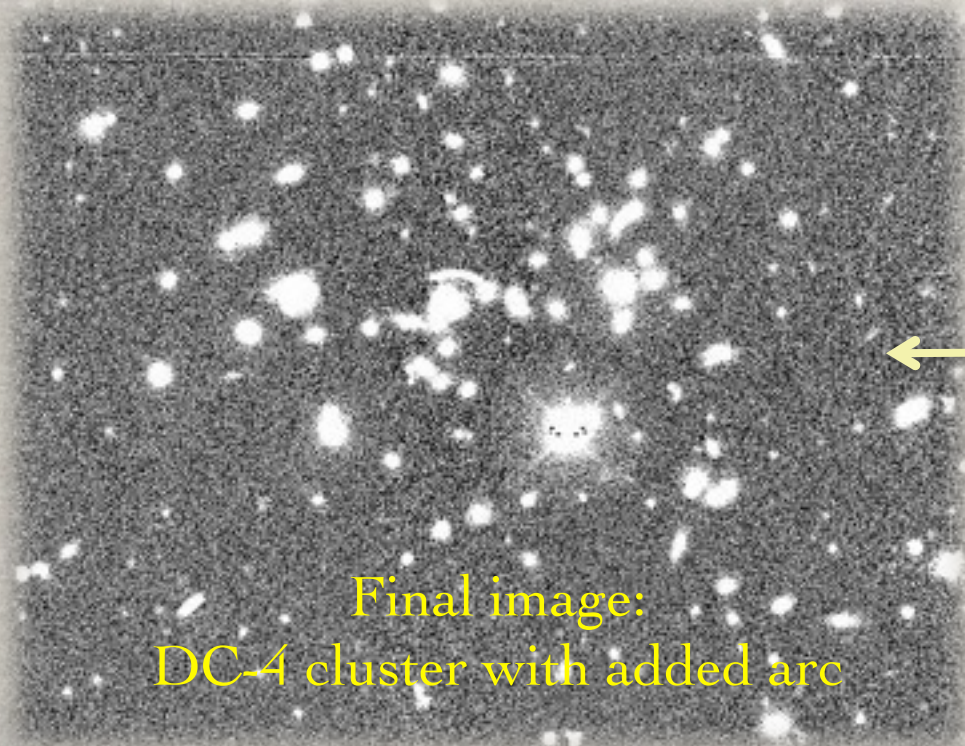
- Selecciona halos de catálogo
- Fatia plano das fontes em *bins* de z
- Selecciona posições e “lenteia” fontes finitas
- Identifica os arcos
- Adiciona arco à imagem e cria tabela



Lens Sersic
source from
UDF catalog

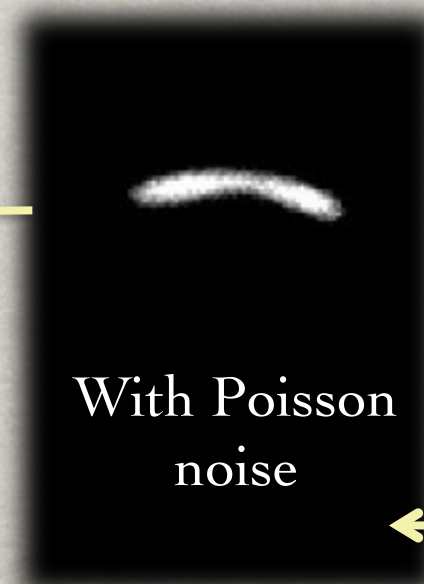


Projected lens
plane



Final image:
DC-4 cluster with added arc

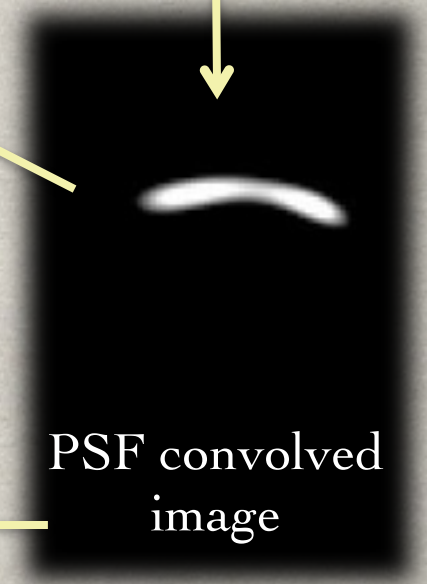
WCS



With Poisson
noise



“Sextracted” arc
“postage stamp”
→ arc parameters →
“truth table”



PSF convolved
image



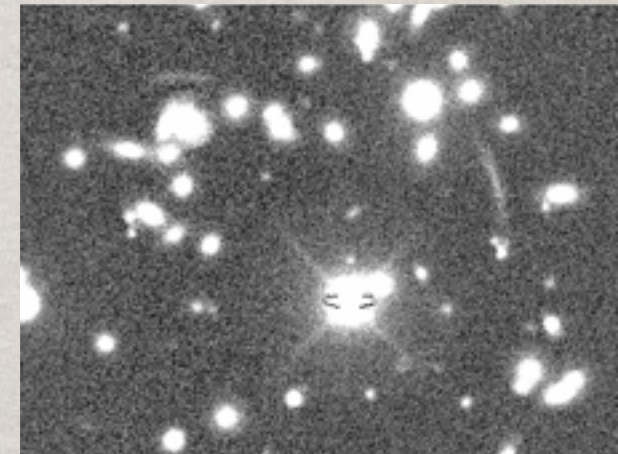
DARK ENERGY
SURVEY

DARK ENERGY SURVEY

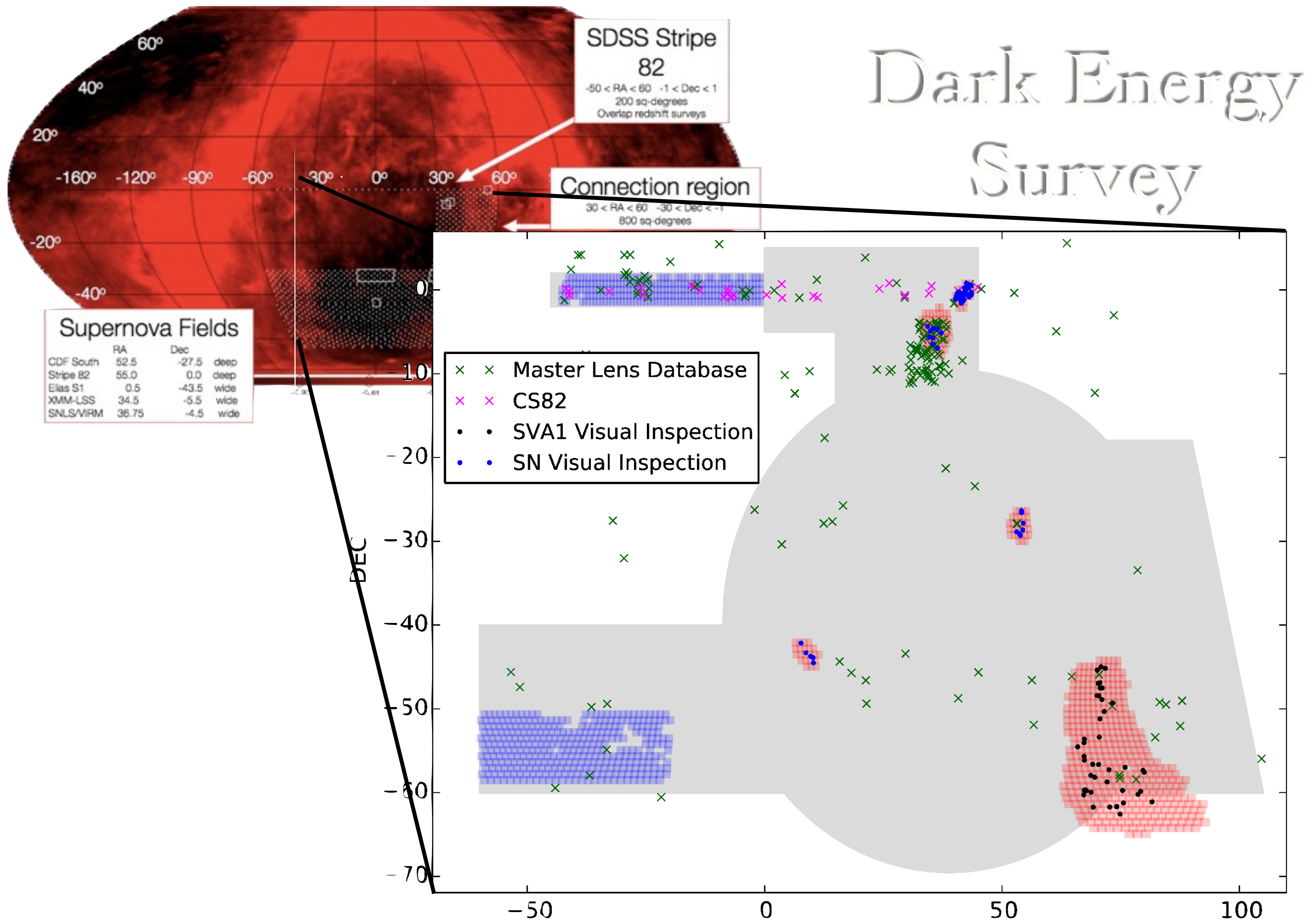


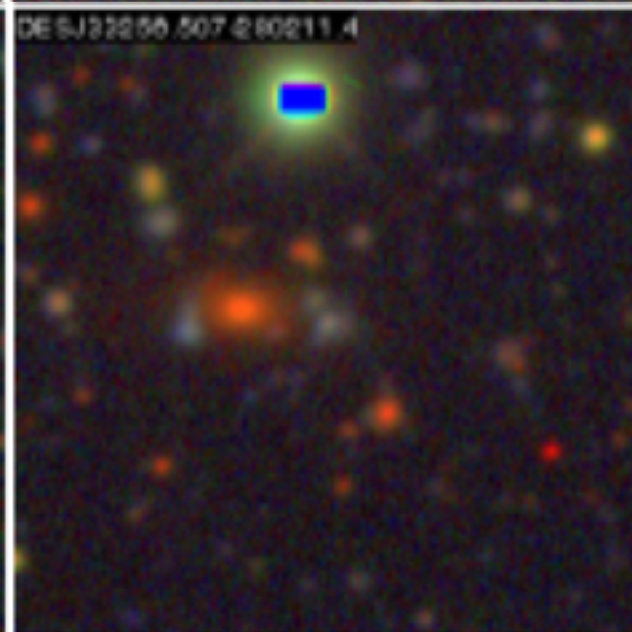
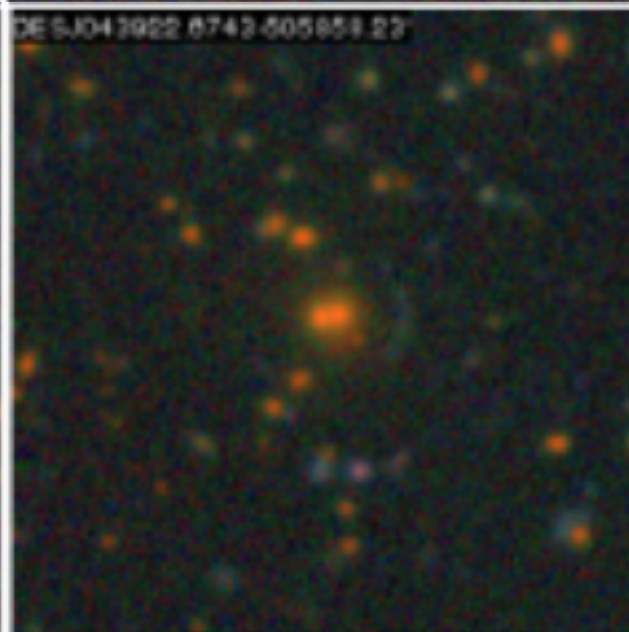
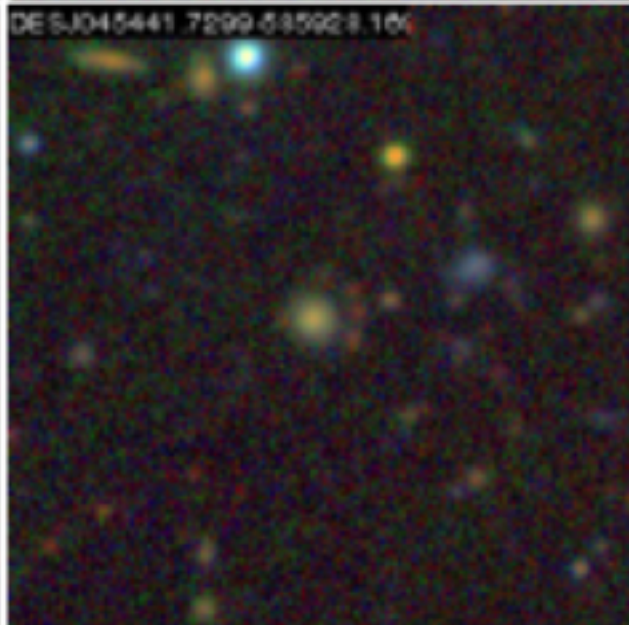
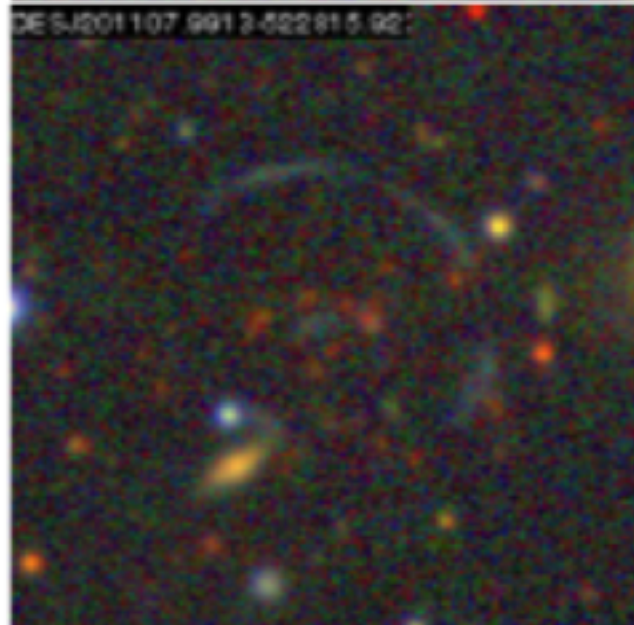
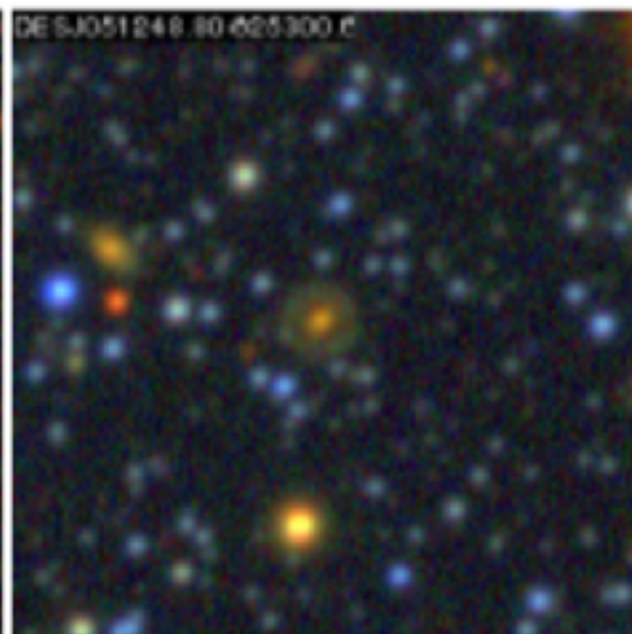
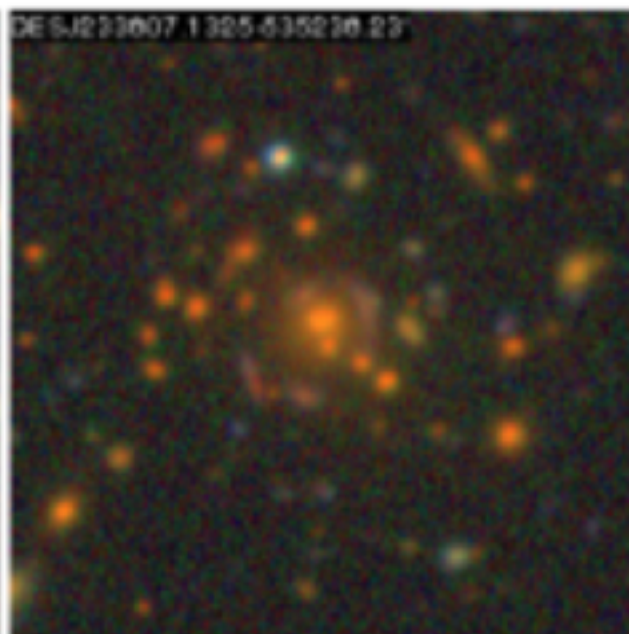
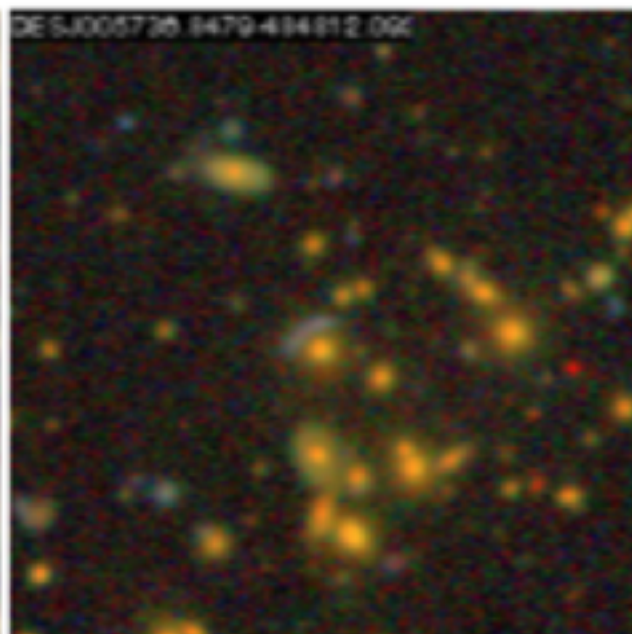
DARK ENERGY
SURVEY

- Criação e co-coordenação do Strong Lensing Working Group
- Previsões estatísticas para o DES
- Simulações de arcos para o DES:
AddArcs + PaintArcs/Arcfitting
- Caracterização e compração de buscadores automáticos de arcos
- Modelagem inversa
- Descoberta e modelamento de sistemas de arcos no DES (dezenas de sistemas encontrados nos dados de *Science Verification*)



Área do DES e sistemas com arcos







Welcome to the Fermilab Center for Particle Astrophysics.

News & Events

Astro Seminar : Joseph Lazio (JPL)

"Title: Rediscovering the Radio Transient Sky"

Monday, December 9, 2:30PM, Dark Side 6W, Wilson Hall

Munch

Every Monday, at 12:30PM, DEC 9 ONLY in Dark Side 6W, Wilson Hall, NOTE SPECIAL LOCATION

Monthly Highlights

Through a lens darkly (and strongly)



Photo: Courtesy of DES. Examples of strong lensing systems imaged in the DES science verification (SV) data. Previously known strongly lensed, bluish-colored arcs are visible in the DES Images of three rich galaxy clusters. Top row, from left: Bullet Cluster, RXC J2248.7-4431 and El Gordo. A nearly complete Einstein ring is visible in another cluster lensing system (bottom left), which was previously found by Fermilab scientists. Finally, two new candidate systems discovered in the DES SV data are also shown: one with a giant blue arc (bottom middle) and one with multiple blue images (bottom right).

The Dark Energy Survey collected more than 34,000 exposures during its science verification (SV) phase, from November 2012 to February 2013. It also began its first official season of observations on Aug. 31. Among the millions of astronomical objects imaged by DES so far, there are rare instances of "strong lensing" systems, where the effects of general relativity, Einstein's theory of gravity, are demonstrated in visually striking fashion.

When a foreground "lens" object is by chance very closely aligned on the sky with a much more distant background "source" object, the light from the source may be significantly deflected as it passes by the lens, due to the gravity of the lensing object's mass. This strong lensing effect leads to big

PROBING COSMOLOGY WITH SL SYSTEMS!

Sources at different redshifts

☑ constrain not only the mass distribution but also the cosmology.

The angular diameter distance ratio for 2 (or more) images from different sources defines the 'family ratio'

$$\Xi(z_1, z_{s1}, z_{s2}; \Omega_M, \Omega_X, w_X) = \frac{D(z_1, z_{s1})}{D(0, z_{s1})} \frac{D(0, z_{s2})}{D(z_1, z_{s2})}$$

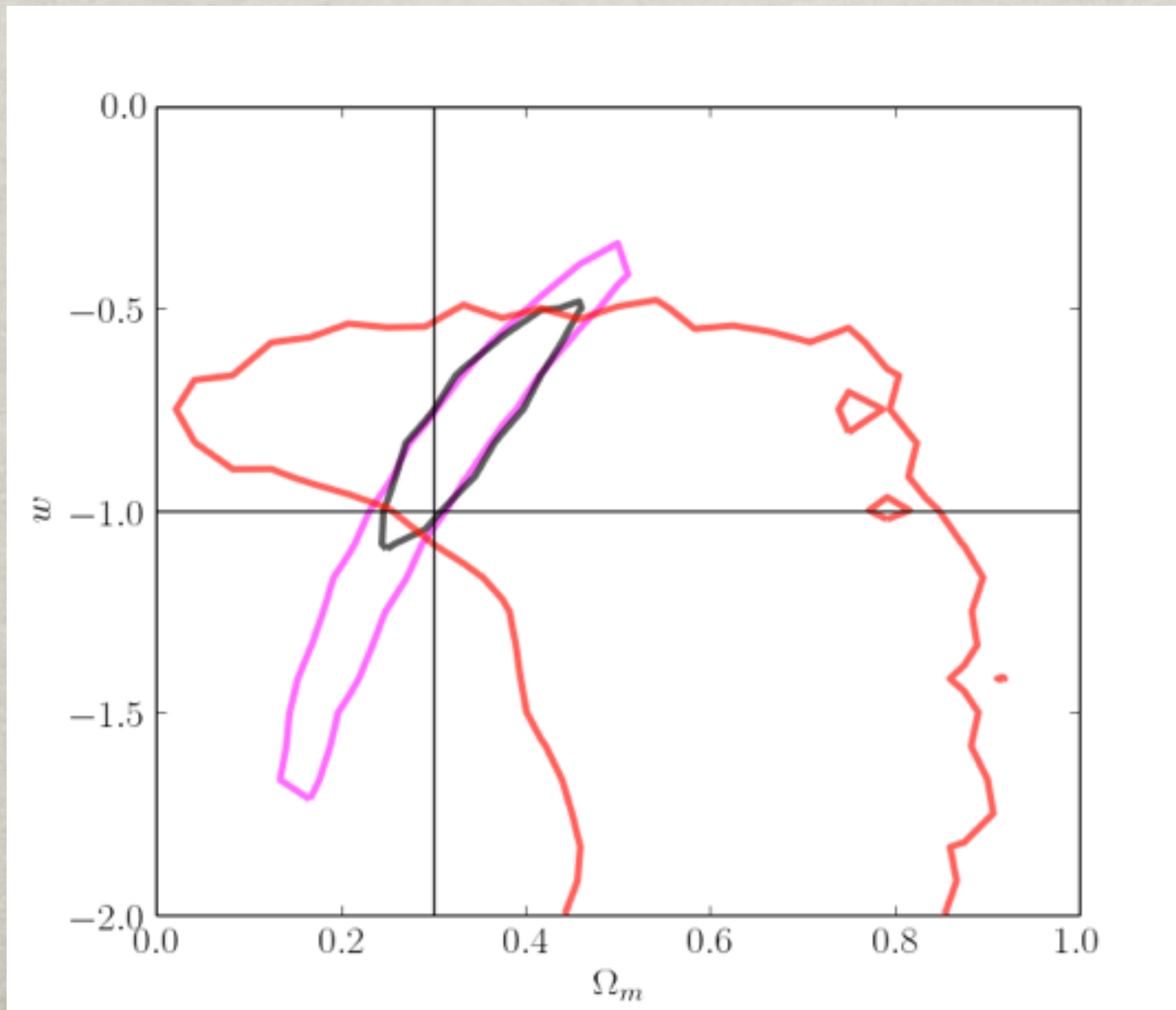
Jullo et al., Science (2010) showed that is possible to constrain Cosmology with Strong Lens systems, in a competitive way, applying this method to the cluster Abell 1689

- 8 different source families with redshifts from 1.15 to 4.86
- ~ 1/40 - 1/80 systems expected to be double source plane strong lenses

☑ ~20 in DES!!

SIMULATIONS

- 5 Abell 1689-like clusters at redshifts 0.2 to 0.6 with two multiple image families at redshift 1.5 and 2.0
- modelled the mass distribution and the cosmology “all together”.
- Flat LCDM cosmology, and free w (DE equation of state parameter)
- Conservative error on the multiple image positions of $0''.5$





Feb. 10, 2015

Dr. Martin Makler
Centro Brasileiro de Pesquisas Fisicas
Rio de Janeiro, Brasil

Dear Martin,

I am writing to regretfully inform you that the Dark Energy Survey (DES) Management Committee has not approved your application for Associate Membership in the DES Collaboration. This decision, which comes after an extended period of discussion and examination, has not been an easy one to reach. The primary considerations were two-fold, namely that (1) you and your group did not actively contribute to the infrastructure tasks taken on by DES-Brazil when it joined DES, including the Science Portal, Quick Reduce, and Quality Assurance pipelines, and (2) your participation level in DES has fallen off substantially over the last several years, while Associate Members are expected to be active participants in and contributors to the collaboration.

According to the DES policies, your access to DES data and your Builder status are both contingent upon your membership status. Therefore, with the termination of your membership in DES, your data access and Builder status will end as well. Any students or postdocs of yours will also no longer have access or be able to participate in the project. In order to enable you and them to wrap up any current DES activities, your membership end date has been set as March 31, 2015.

I note that if you wish to continue participating in any DES activities beyond that date, or you wish to have any of your students or postdocs participate, you will need to have someone in DES sponsor you or them as an External Collaborator on a specific project or projects.

Again, this has been a difficult process, and I am sorry it did not turn out differently. I wish you all the best in your research career.

Yours Sincerely,

Joshua A. Frieman
Director of the Dark Energy Survey
Fermilab Center for Particle Astrophysics
Professor of Astronomy & Astrophysics
Kavli Institute for Cosmological Physics
The University of Chicago

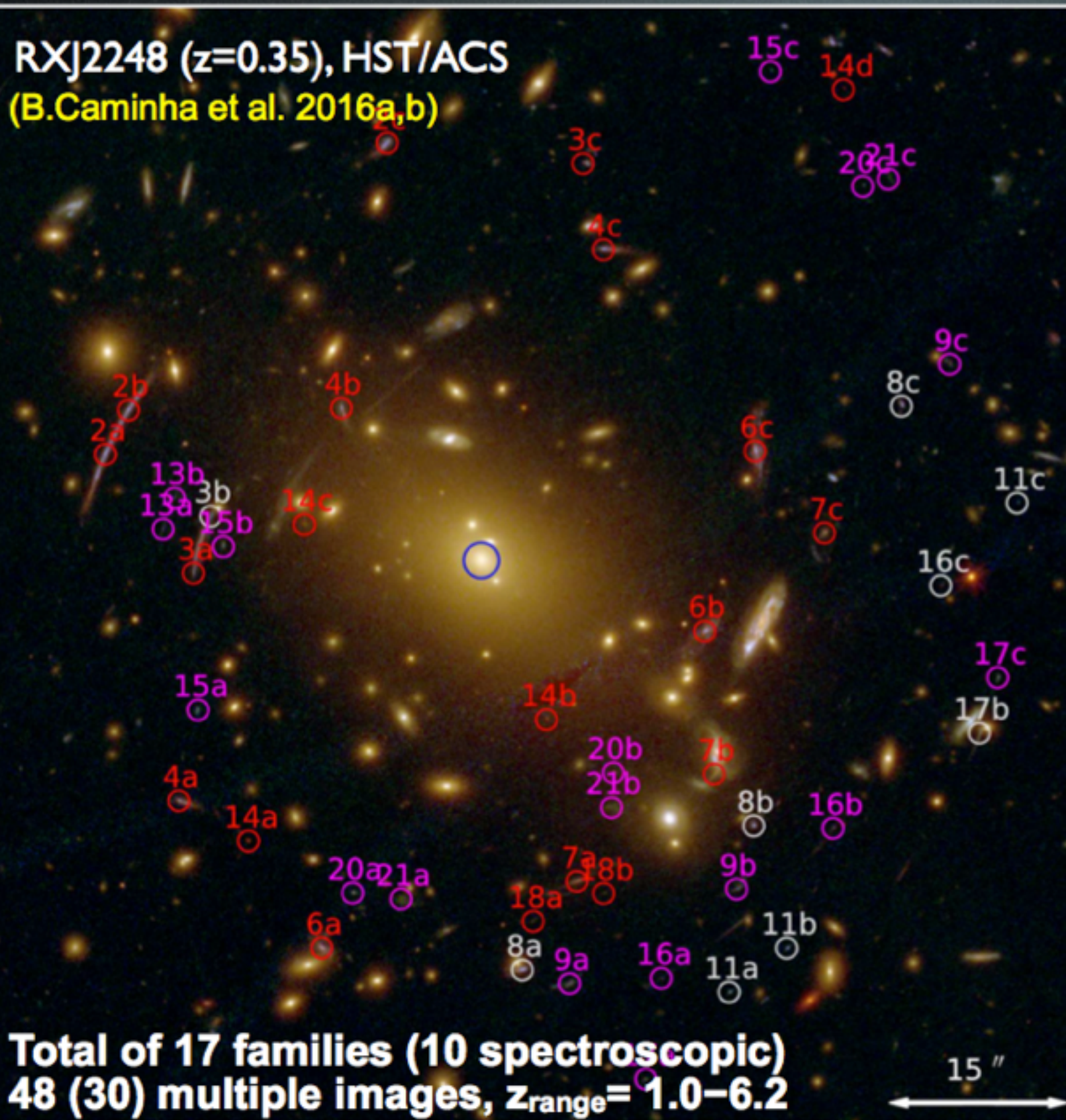
Luiz Inácio falou
Luiz inácio avisou

...

COSMOLOGICAL CONSTRAINTS

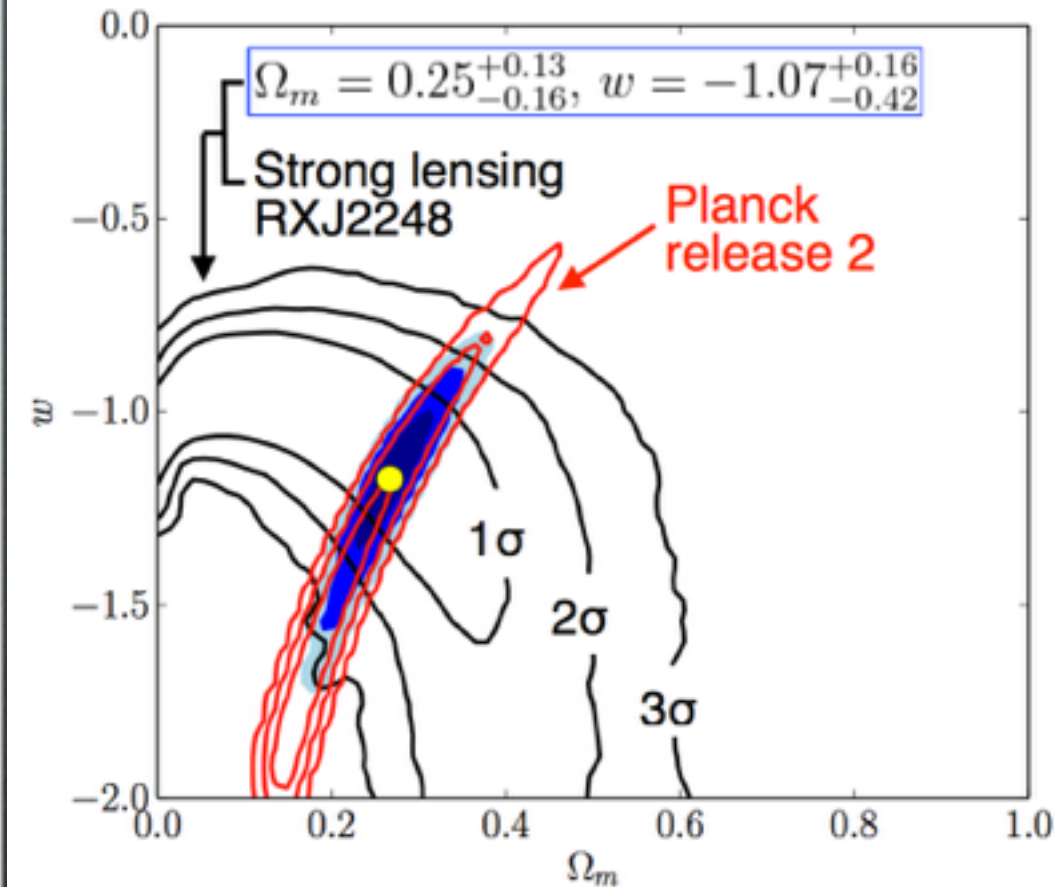
Frontier Field Cluster AS1063 (aka RXJ2248)

RXJ2248 ($z=0.35$), HST/ACS
(B.Caminha et al. 2016a,b)



Caminha et al., 2016

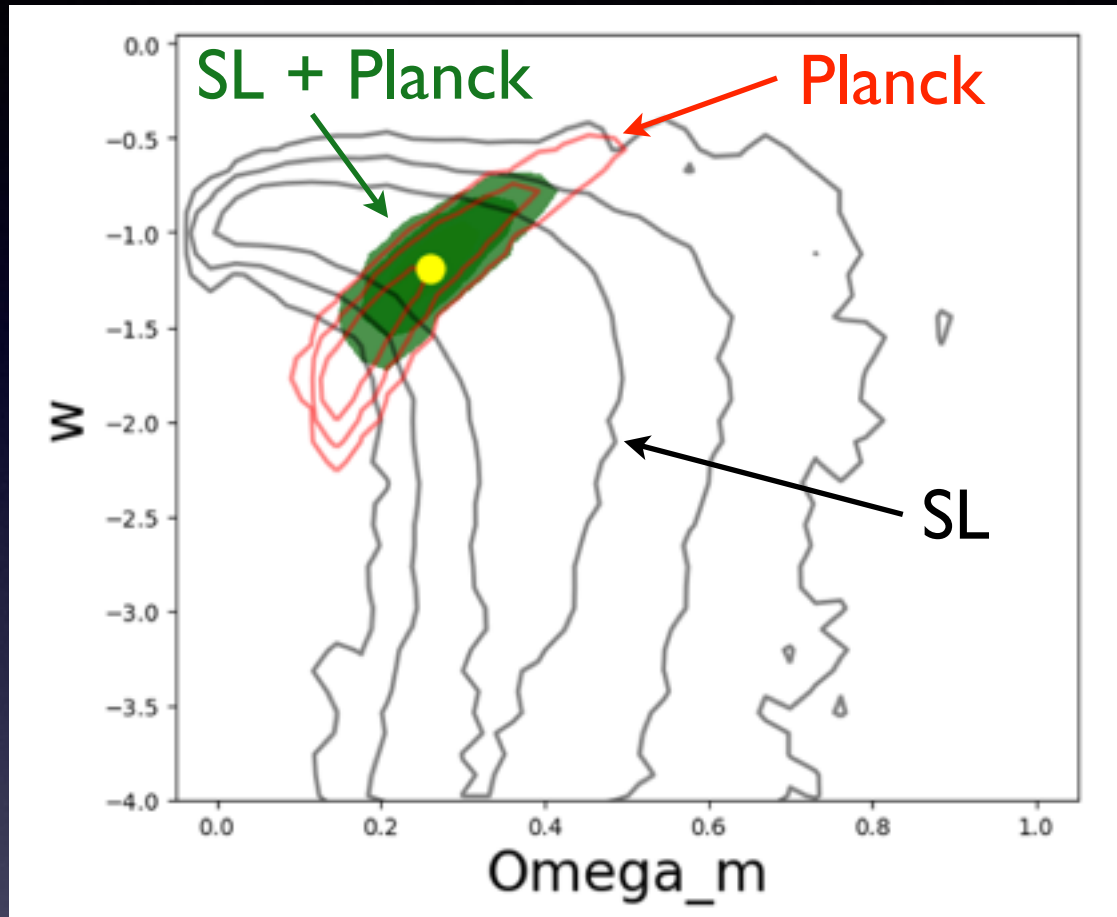
MUSE SV programme + GO (PI: K.Caputi)
(Karman et al. 2015)
(W.Karman et al. 2016, arXiv/160601471)



1 arcmin² FoV
2.6 Å resolution (4800-9300 Å)
0.2 arcsec/pxl
Exp. = 5 hrs

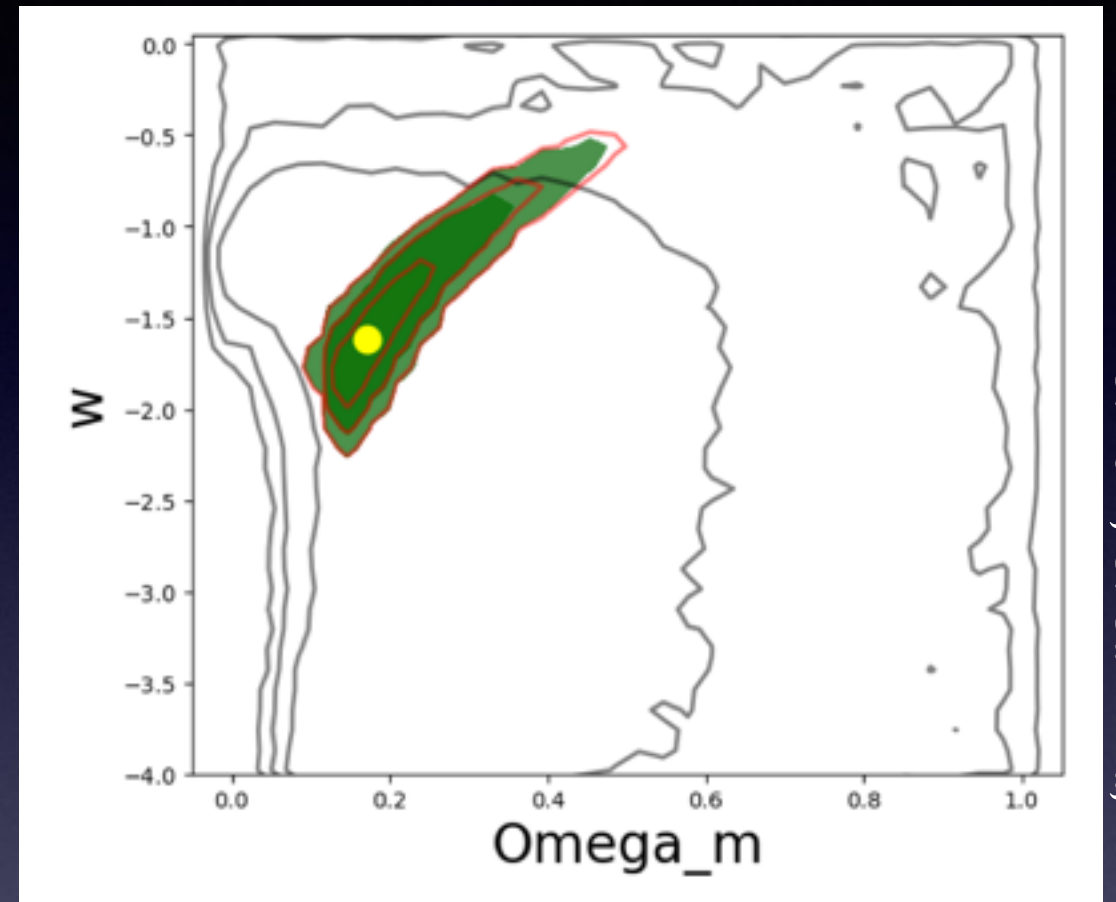
Distance ratios from the ground?

Example: RXC J2248.7–443 I



C. Bom, G. Caminha, MM, 2017

HFF: magAB ~ 29 , 7 filters + MUSE
(including 5 new families)



C. Bom, G. Caminha, MM

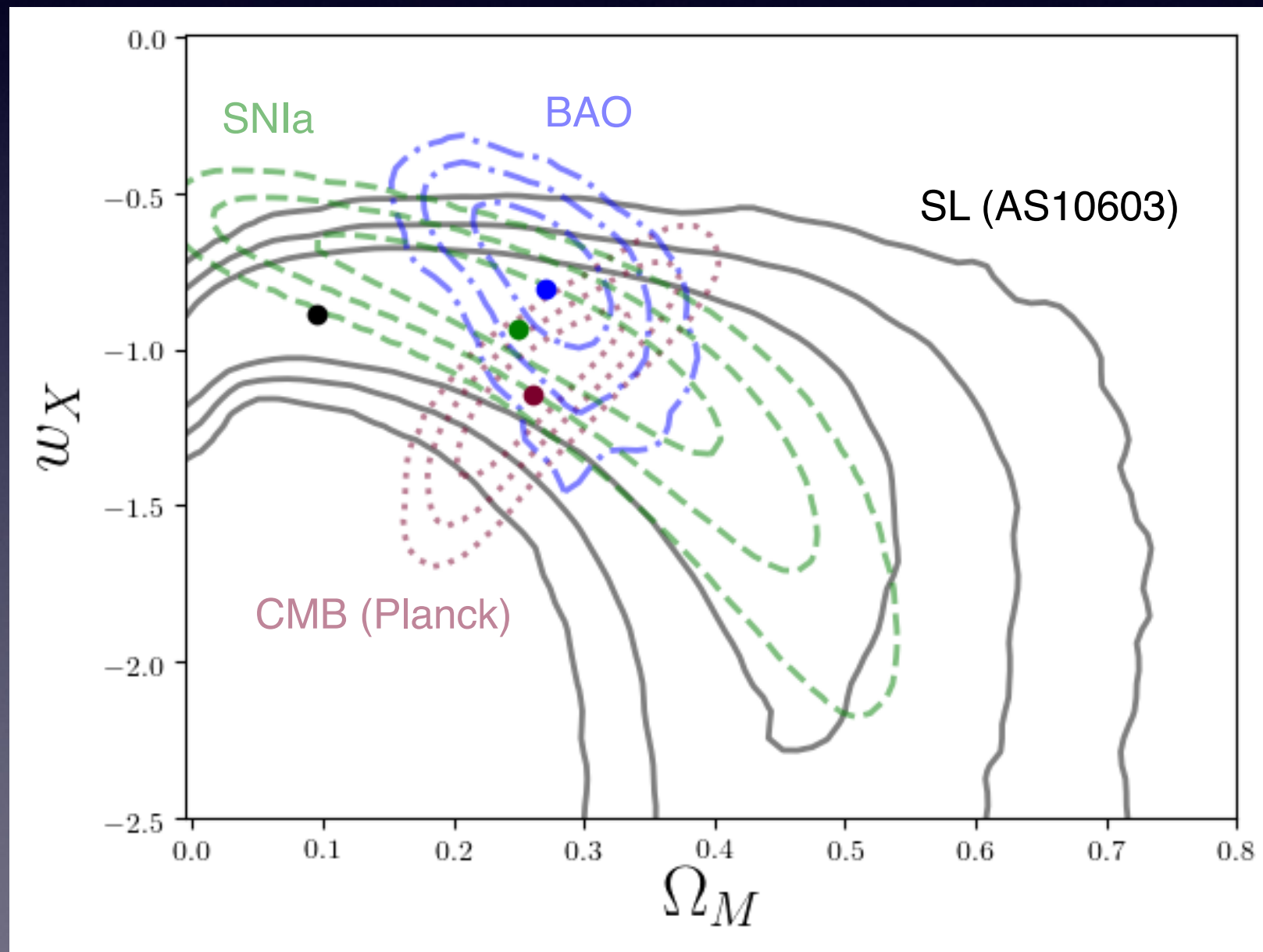
HFF degraded to FWHM = 0.6",
mag = 25 (7 families, 17 multiple
images), assuming known redshifts

- ~ 20 systems would yield the same constraints
- Better for systematics and comparison to simulations

Novos limites com Abel S1063

- Dobro de famílias de imagens múltiplas
- Comparação e combinação com outros observáveis

Bom, Makler, Caminha, Vitenti, Penna-Lima (2018, in prep.)



Limites exclusivamente de Strong Lensing:

$$\Omega_M = 0.422^{+0.062}_{-0.274}$$

$$w = -0.911^{+0.030}_{-1.356}$$

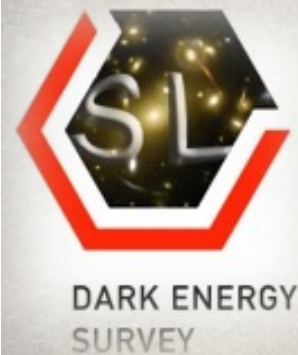
Único sistema!

Teste de consistência

Refsdal

Futuro promissor,
especialmente para DM

RESUMO



- Energia Escura e Quartessência (de cabo a rabo)
- DES e Lentes Gravitacionais
- Em tempos tão sombrios, sabedoria, serenidade, equilíbrio e realismo otimista em política global e científica
- Grande impacto em diversos momentos da carreira e da vida
- Obrigado e um forte abraço!!!

