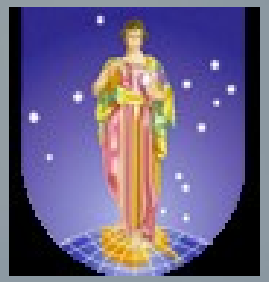

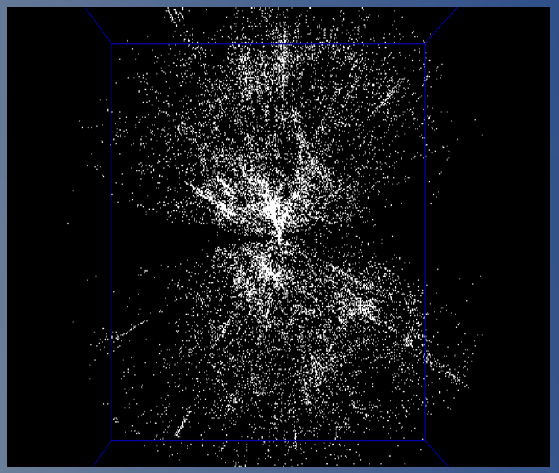

Ciência com grandes levantamentos de galáxias

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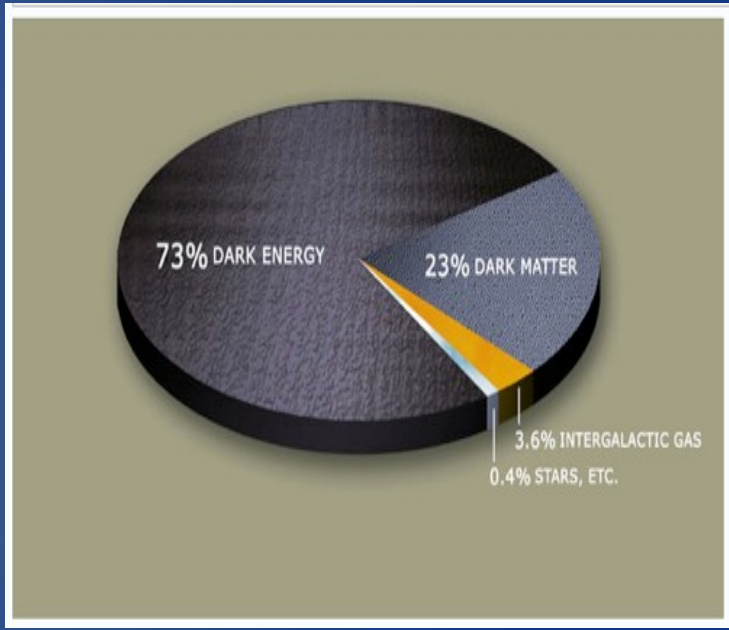
Astronomia ao Meio-Dia
23/05/2013

O paradigma cosmológico: o universo ΛCDM

- Paradigma cosmológico @2013:
- universo descrito pela Teoria da Relatividade Geral com:

- ***curvatura zero***
- dominado por ***energia escura Λ*** ***(74%)***

  universo acelerado!!!
- com ***matéria escura fria CDM*** ***(26%)***
- um pouco de ***bárions*** ***(~4%)***
- ***neutrinos (~0.001%?)***
- ***fótons (~5x10^{-5}%)***
- ***...***



% em unidades da densidade crítica: $3H_0^2/(8\pi G) \sim 10^{-29}$ g/cm^3

The cosmological paradigm in 2012: the ΛCDM universe

- O que é a ***energia escura? (DE)***
- O que é a ***matéria escura? (DM)***

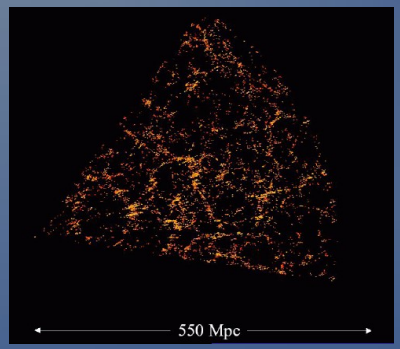
A energia escura é uma *constante cosmológica* ou pode variar com o redshift?

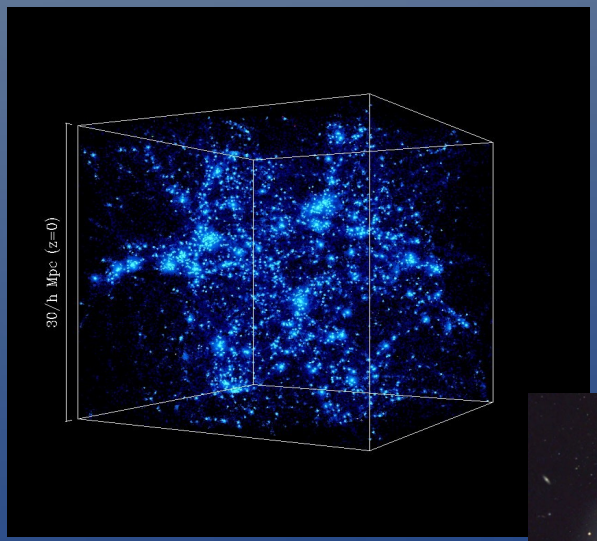
A aceleração cósmica é isotrópica?

- **A assinatura da DE (e da DM)está impressa na distribuição de galáxias**
- **Levantamentos de redshifts de galáxias são as melhores ferramentas para se investigar as propriedades da DE**

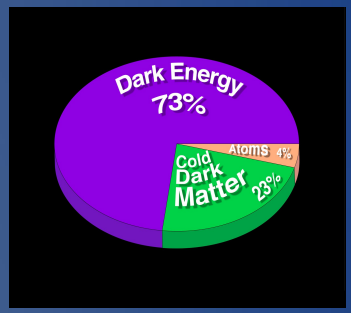
O que é um levantamento de galáxias?

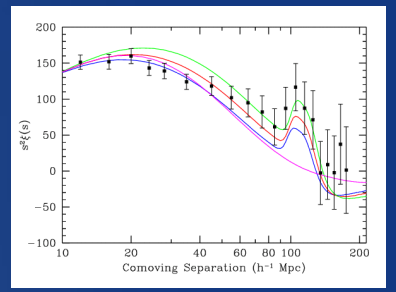
- Objetivo: construir mapas 3-D da distribuição de galáxias
- Para isso são necessários "**espectros**" para se determinar as distâncias das galáxias





- **Os valores dos parâmetros cosmológicos estão "impressos" na distribuição de galáxias**





- **Adicionalmente: o "espectro" necessário para se estimar as distâncias é útil para muitas outras ciências (evolução de galáxias...)**

O que observamos nos levantamentos?

Medimos o desvio espectral z:

- **em geral, redshifts (z > 0)**

$$z \equiv \frac{\lambda_0 - \lambda_e}{\lambda_e}$$

- **z mede a expansão do universo:**

  $1+z = R_0/R$ onde R(z) é o fator de escala

- **distâncias são função de z (e de outros parâmetros cosmológicos): d(z)**

$$D_c = D_H \int_{z_1}^{z_2} \frac{dz'}{E(z')}$$

$$E(z) = \left[\Omega_{m0}(1+z)^3 + \Omega_{k0}(1+z)^2 + \Omega_{\lambda 0} + \ ...\right]^{1/2}$$

- **para z<<1: lei de Hubble: $v = cz = H_0\, d$**

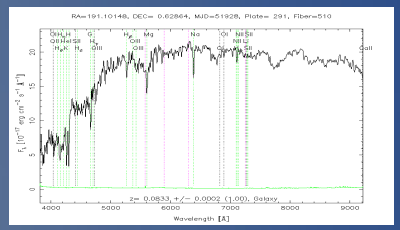
- **mas z é afetado pelas velocidades peculiares:**

  $v = v_H + v_{pec}$

o que observamos nos levantamentos?

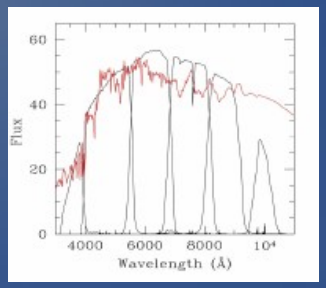
- **Podemos medir o desvio espectral z com um espectrógrafo**

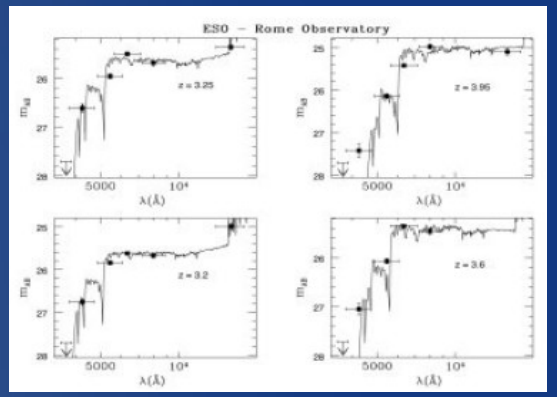
  erro em v: ~100 km/s



- **ou com fotometria multi-bandas: *redshifts fotométricos***
- **SDSS (5 bandas ópticas):**

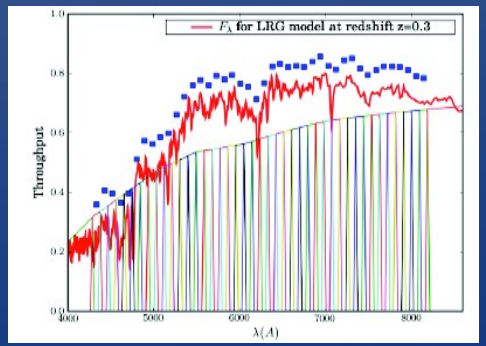
  erro em v: ~10,000 km/s





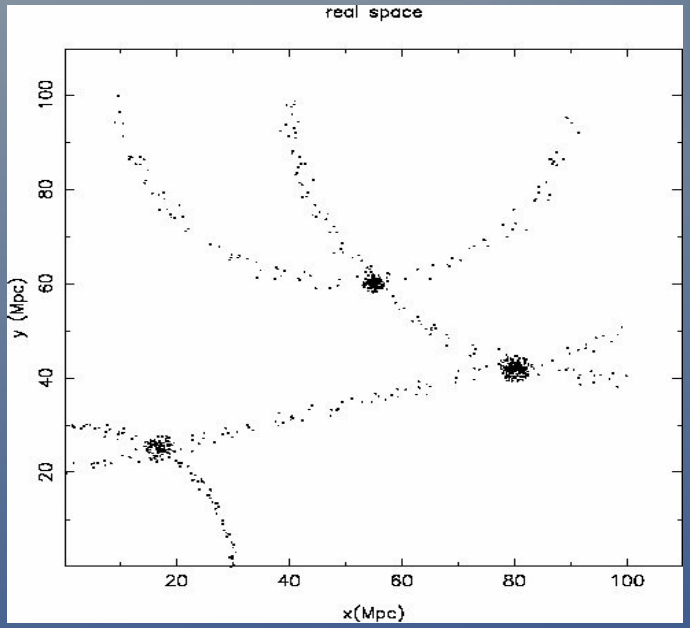
- **JPAS (56 bandas):**

  erro em v: ~1,000 km/s

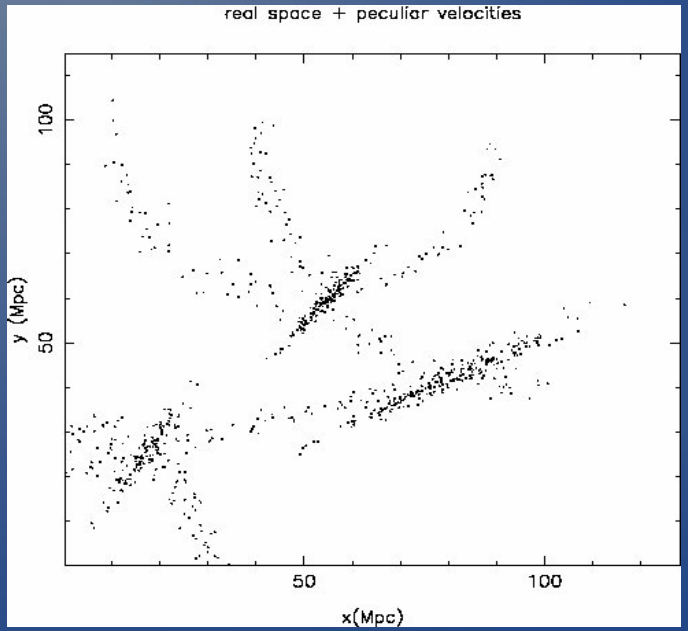


Mas o que observamos?

“simulação 3-D”

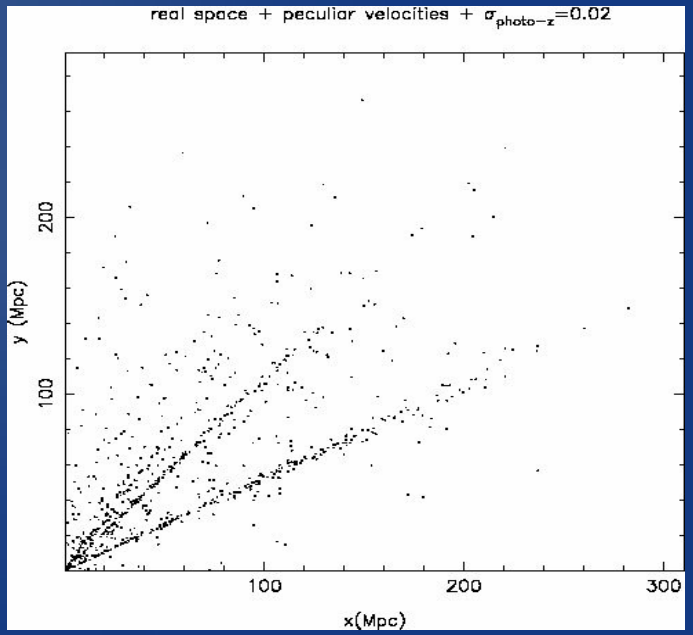


introduzindo velocidades peculiares

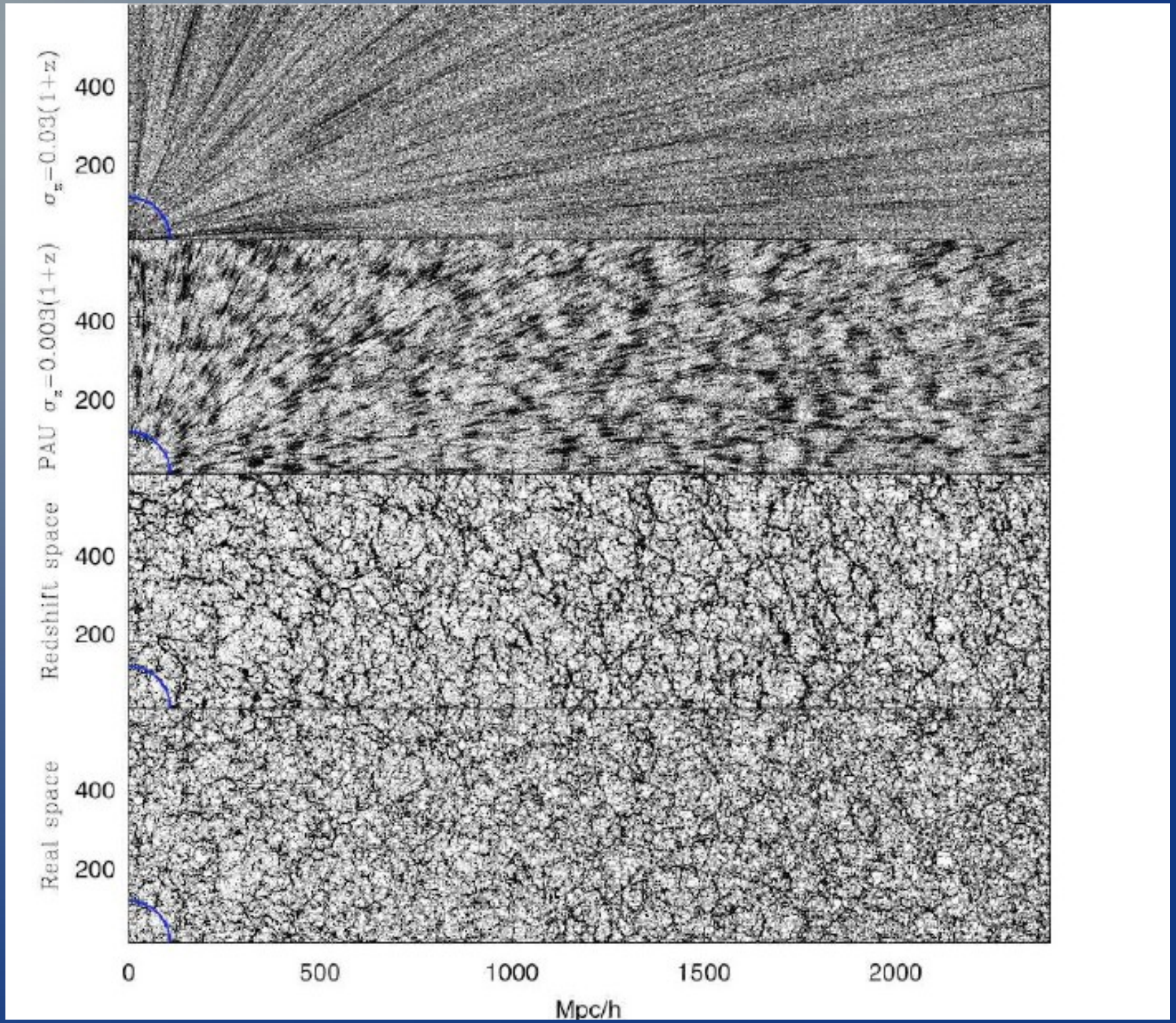


espectroscopia

+ erros nos redshifts fotométricos (0.02)

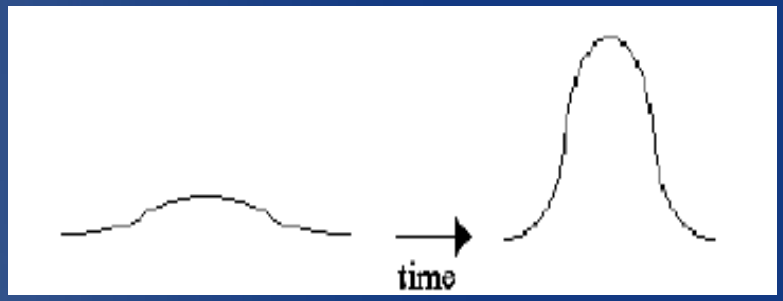


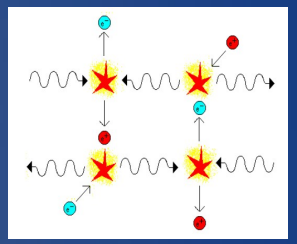
fotometria

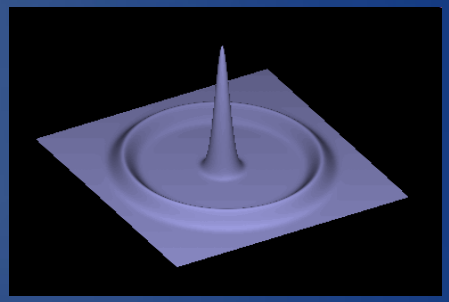

Real space
Redshift space
PAU σ_z=0.003(1+z)
σ_z=0.03(1+z)
400
200
0
500
1000
1500
2000
Mpc/h

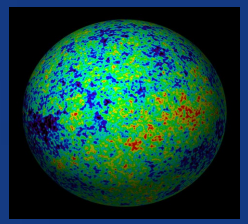
Probes of Dark Energy: Baryonic Accustic Oscilations (BAOs)

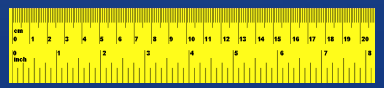
- structures evolve by gravity from small density fluctuations
- just after the Big-Bang: the universe is hot and photons and baryons are strongly coupled: the photon-baryon plama
- however, Dark Matter fluctuations can collapse and attract photon-baryon fluctuations, but the radiation pressure prevent their collapse: they oscilate and propagate like sound waves in the plasma: the BAOs
- these waves propagate up to the recombination epoch, and its size, $\sim c/3^{1/2}\ t \sim 150$ Mpc, is a ***standard rule!***



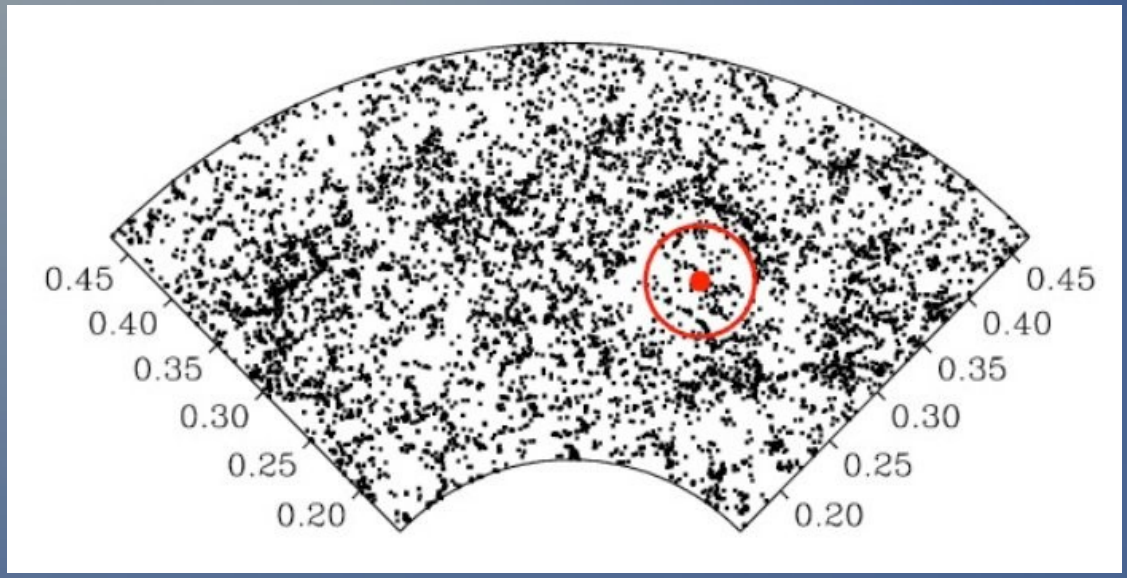


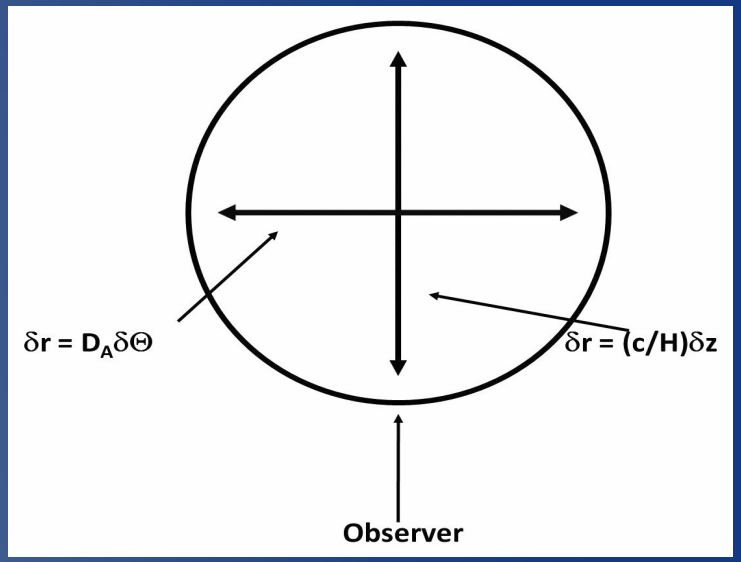




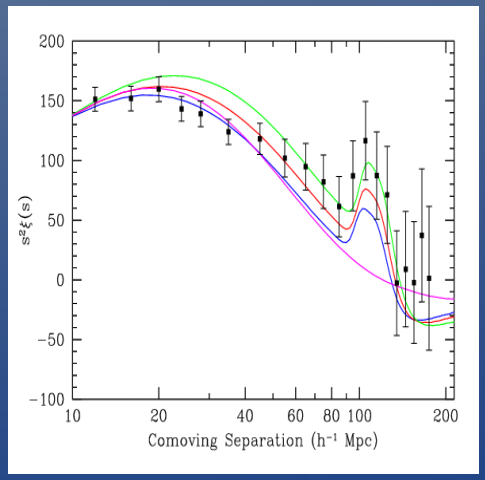


Probes of Dark Energy: the BAO scale is imprinted in the galaxy distribution

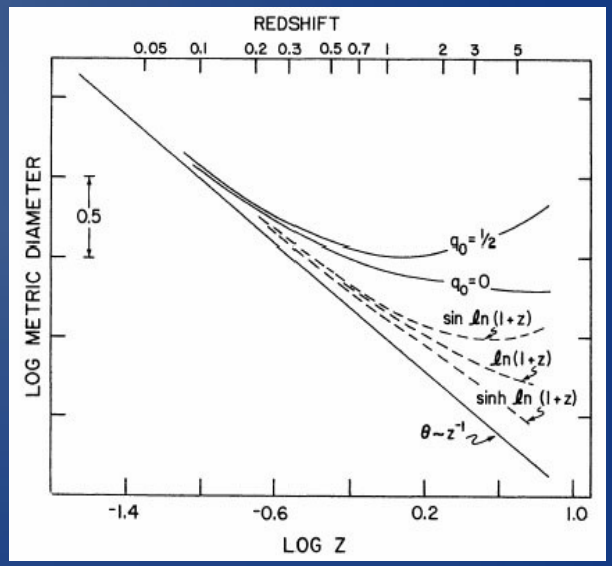




Radial and transversal BAOs



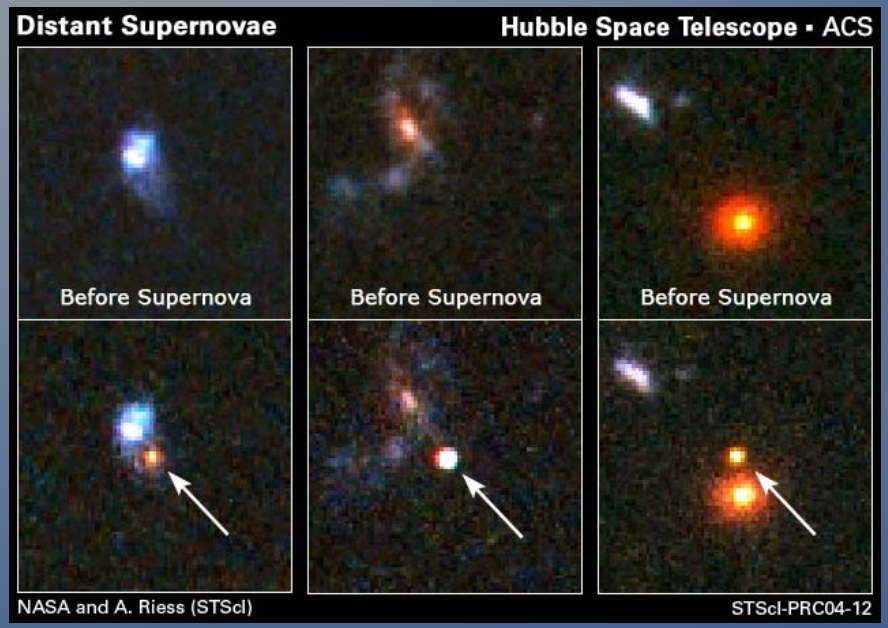
detection of transversal BAOs in the SDSS survey (Eisenstein et al. 2005)

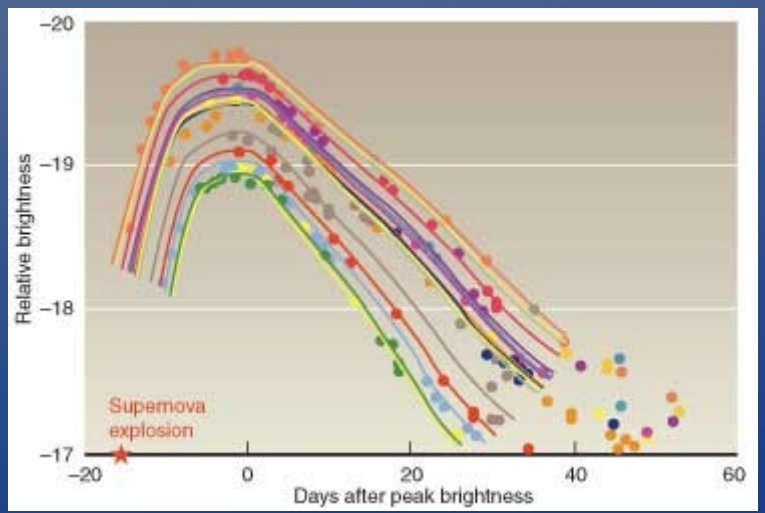


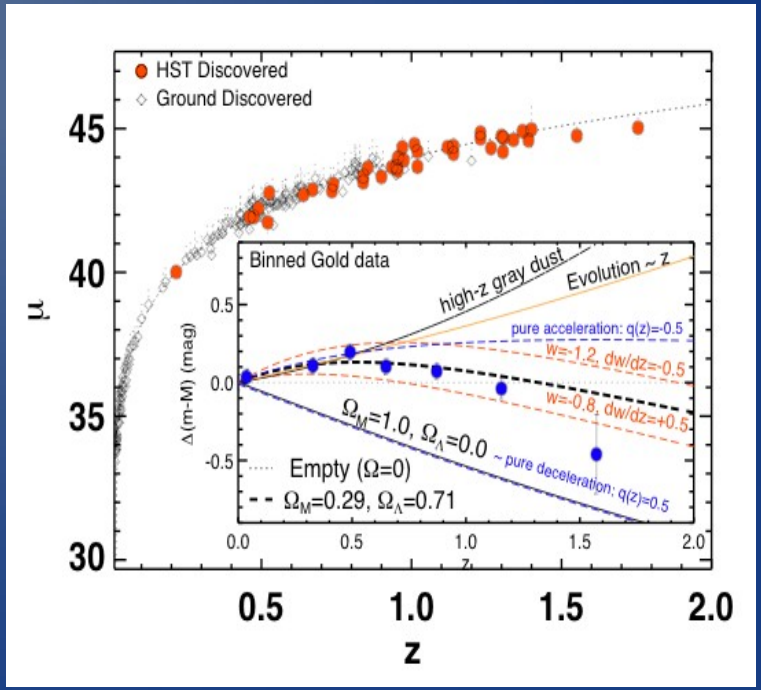
The BAO size-redshift relation depends on the properties of DM and DE

Probes of Dark Energy

- SN Ia: standard candles



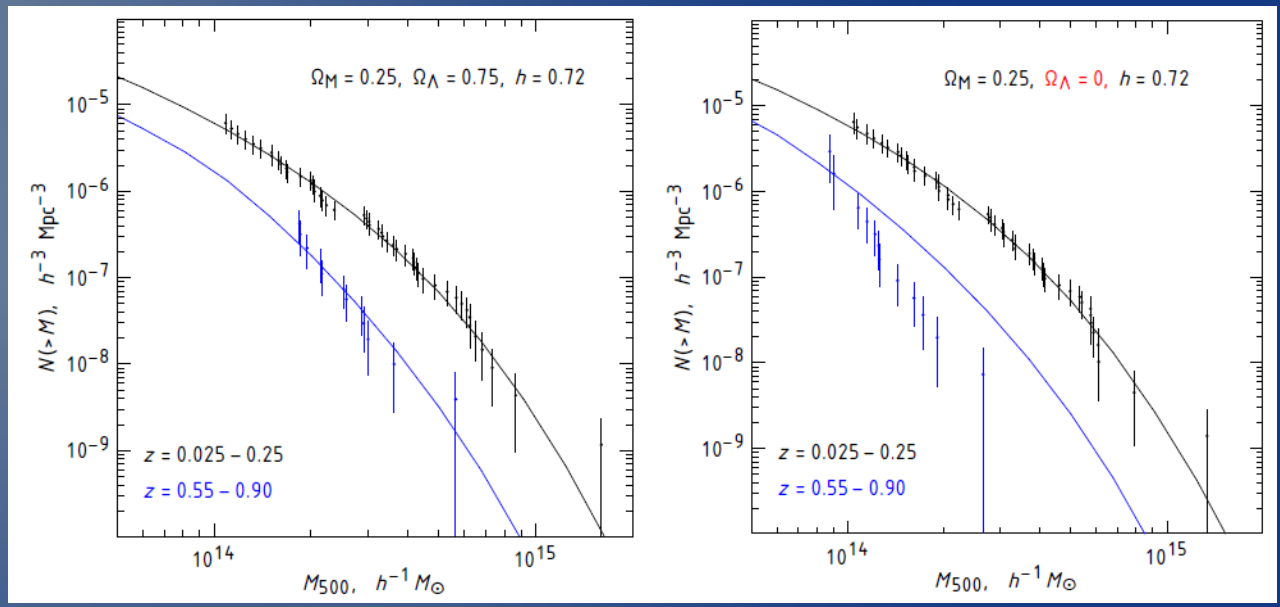


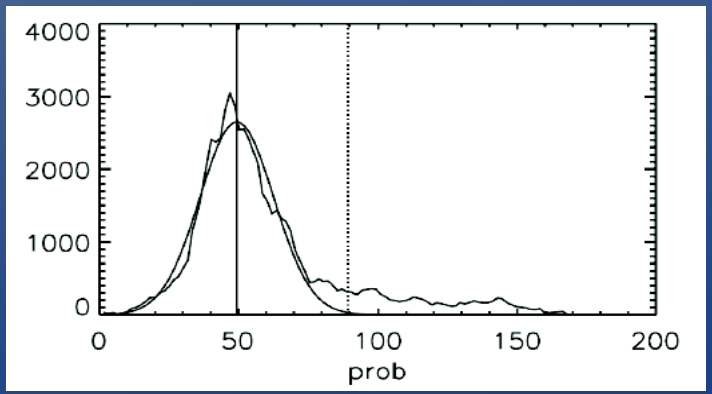


JPAS: 10^3 – 10^4 SNe!

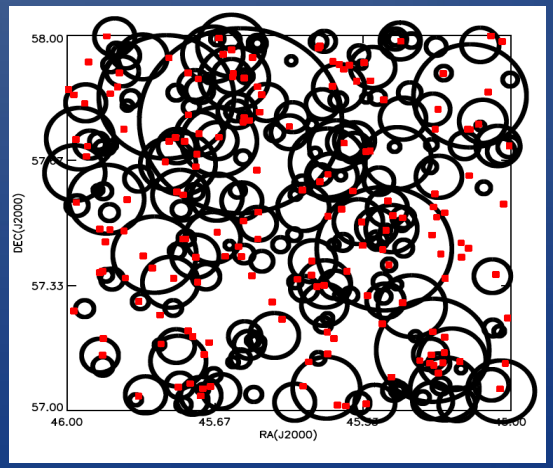
Probes of Dark Energy

- **Counting of galaxy clusters:**
  10^5 - 10^6 aglomerados





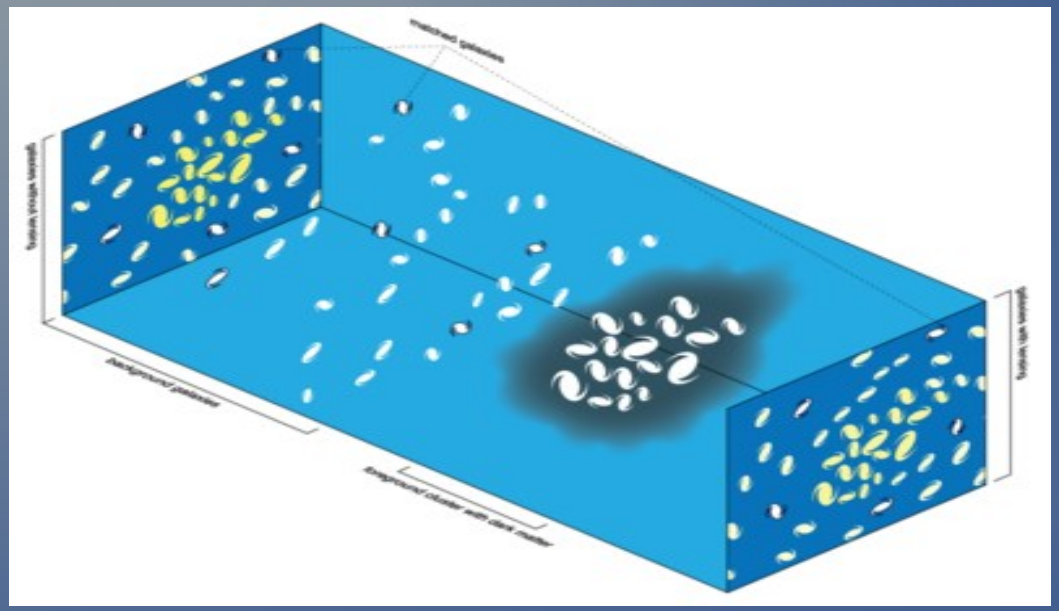
Probabilistic detection of clusters

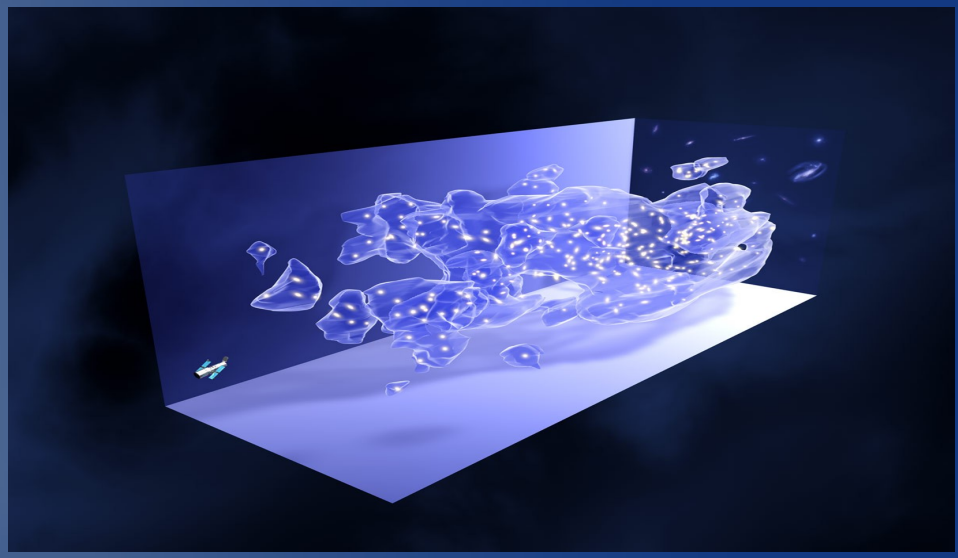


Probes of Dark Energy

- Cosmic shear

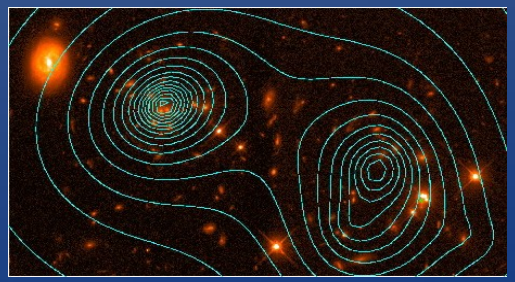
Seeing @ OAJ ~0.7”





Dark matter:

- Distribution
- Profiles



$$\rho(r) = \frac{\rho_c \cdot \delta_c}{\frac{r}{r_s} \cdot \left(1 + \frac{r}{r_s}\right)^2}$$

Testing the gravitation theory

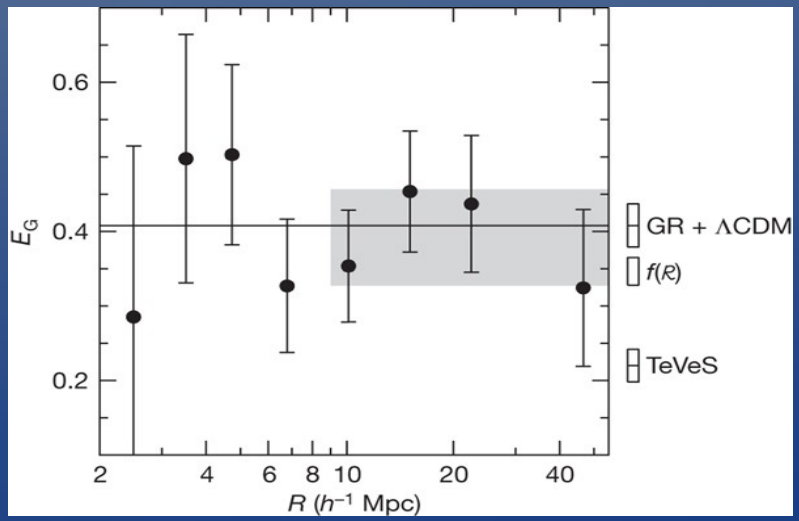
- Gravity affects the expantion of the universe

  $H(z)=H_0[\Omega_m(1+z)^3+\Omega_\lambda+\Omega_k(1+z)^2]^{1/2}$ (ΛCDM)

- Gravity affects the formation and evolution of structures

$$\ddot{\delta}_k + 2\frac{\dot{a}}{a}\dot{\delta}_k = 4\pi G\bar{\rho}\delta_k$$

- *The joint study of these effects allows to study the nature of dark energy and to test the theory of gravitation*

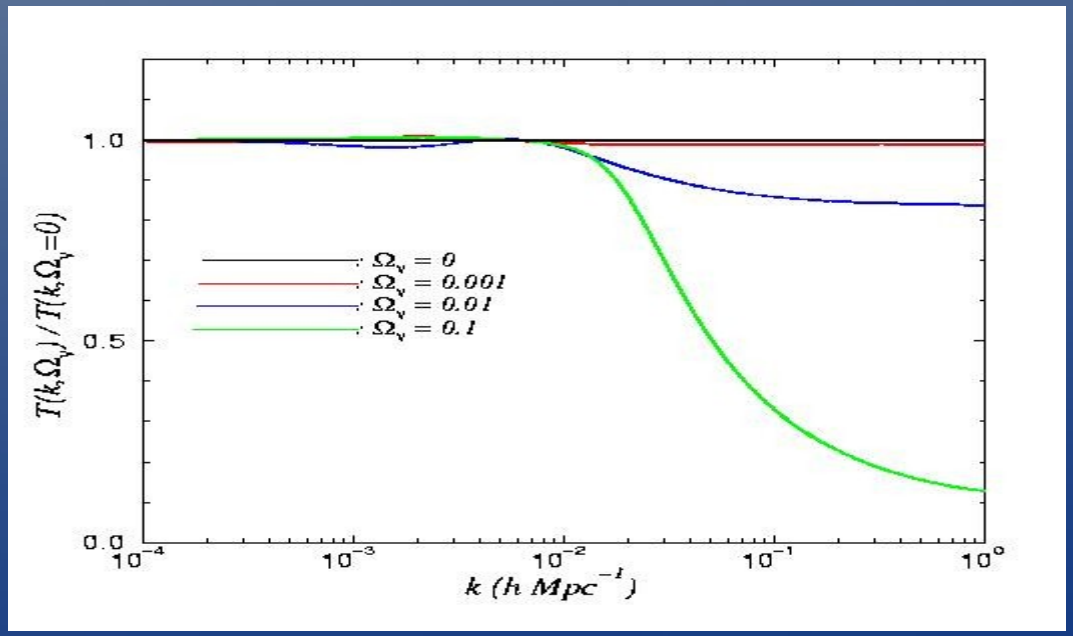


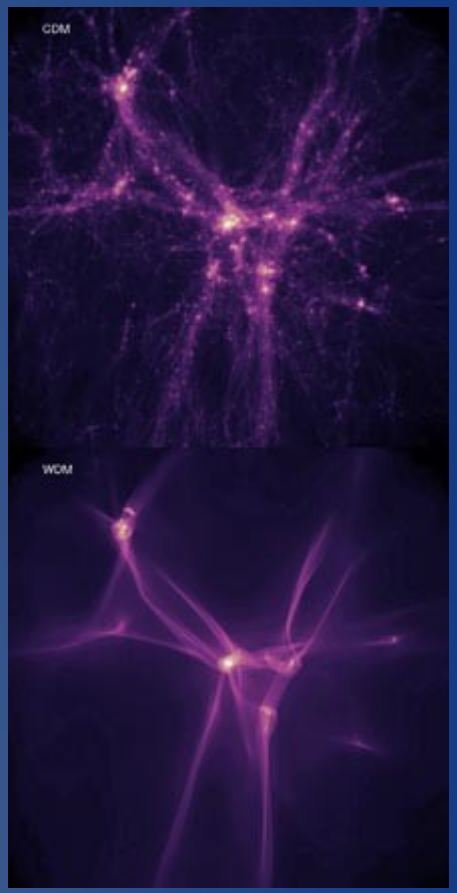
R Reyes *et al. Nature* **464**, 256-258 (2010) doi:10.1038/nature08857

Neutrino mass

- Neutrinos: hot dark matter – they are relativistic when they decouple
- As a consequence, their propagation destroys small density fluctuations ("free streaming"):

$$P(k)=A\,k^{n}\,T^{2}(k)$$





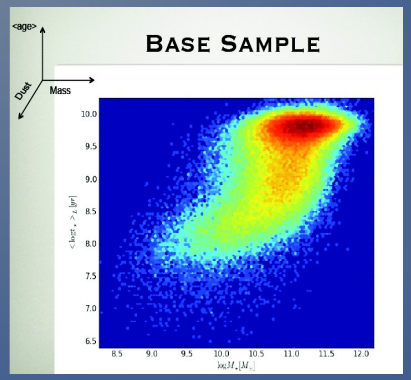
$\Delta P(k)/P(k) = -8\ \Omega_\nu / \Omega_m$ (Hu et al. 1998)

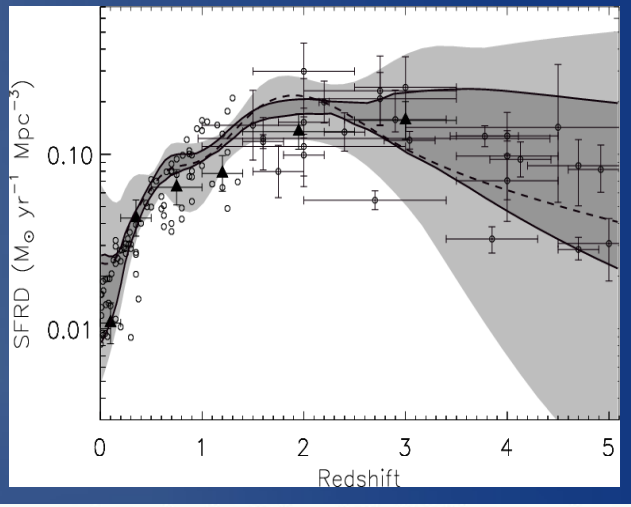
Redshift surveys (+ CMB) $M_\nu < 0.7\text{-}1.8$ eV

Ly-α (+ CMB+LSS) $M_\nu < 0.17$ eV

Galaxy evolution

- How galaxies form and evolve?
- What is the role of environment?
- How supermassive black holes form, evolve and affect the evolution of their host galaxies?





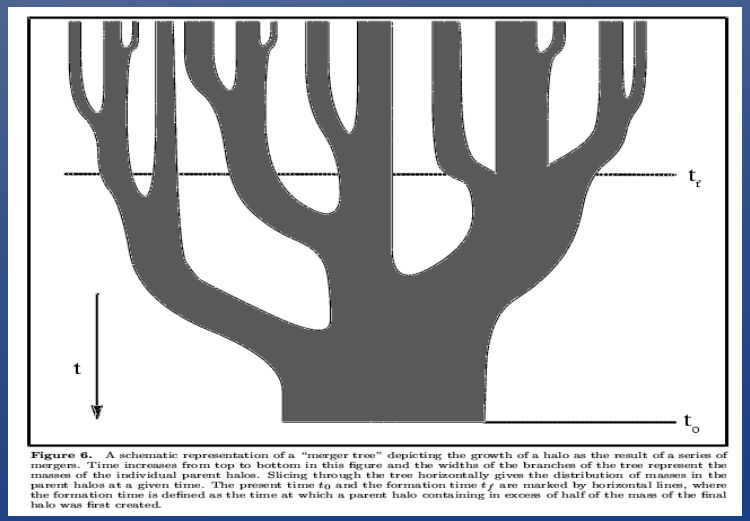
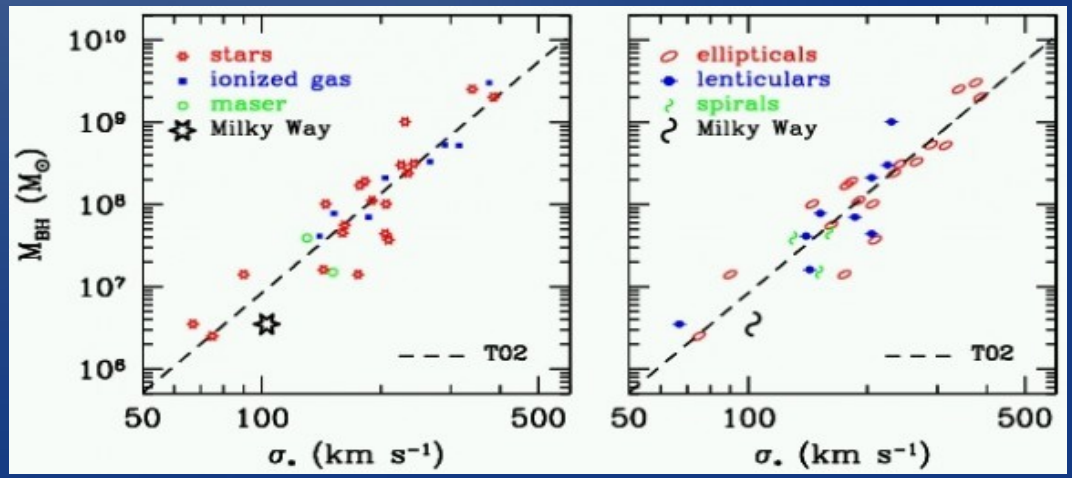
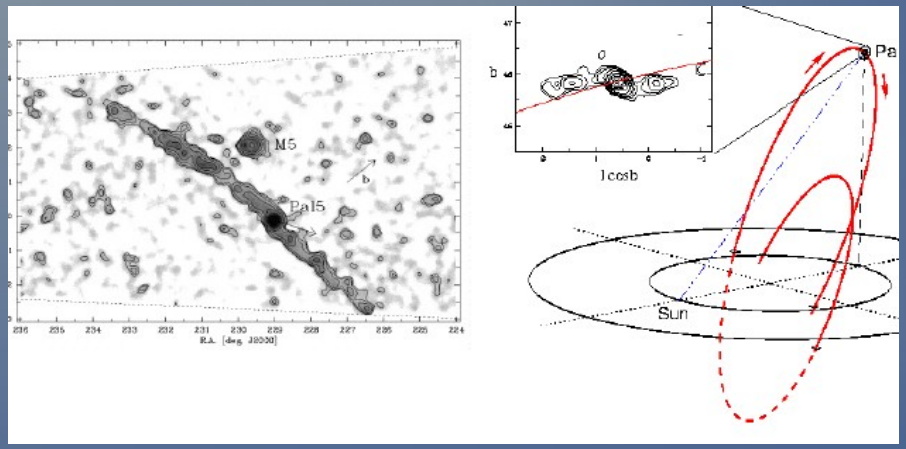


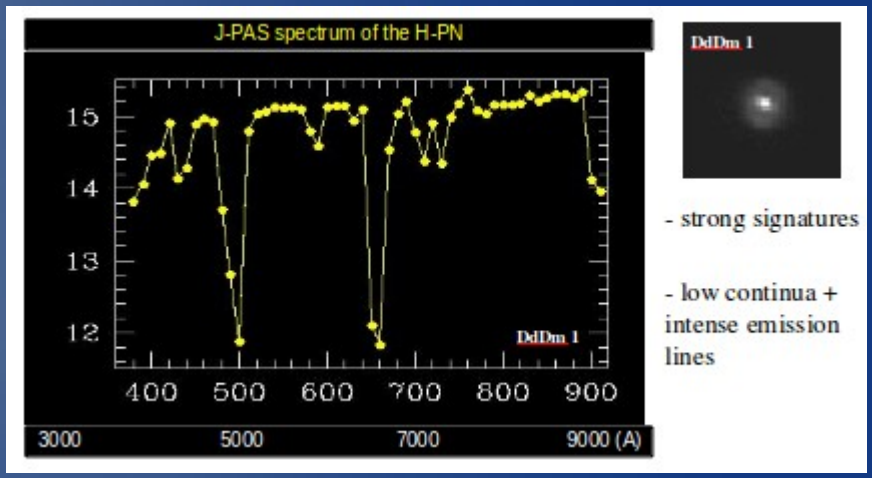
Figure 6. A schematic representation of a "merger tree" depicting the growth of a halo as the result of a series of mergers. Time increases from top to bottom in this figure and the widths of the branches of the tree represent the masses of the individual parent halos. Slicing through the tree horizontally gives the distribution of masses in the parent halos at a given time. The present time t_0 and the formation time t_f are marked by horizontal lines, where the formation time is defined as the time at which a parent halo containing in excess of half of the mass of the final halo was first created.

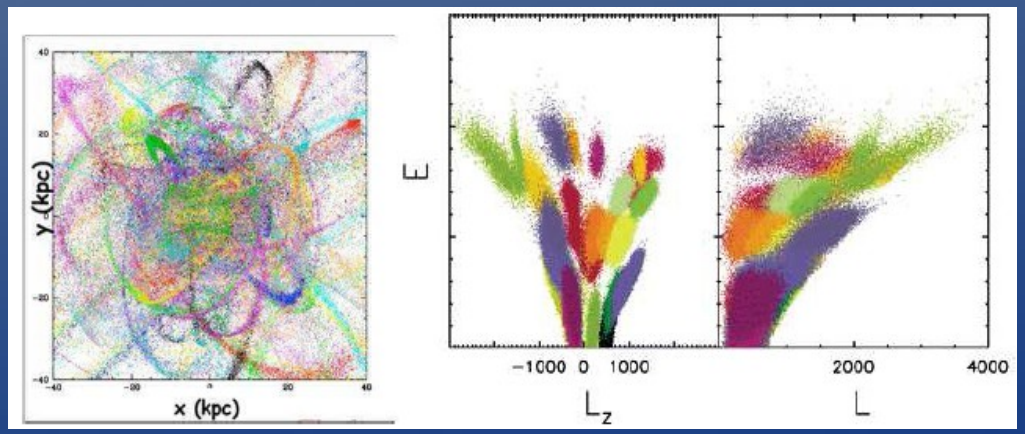


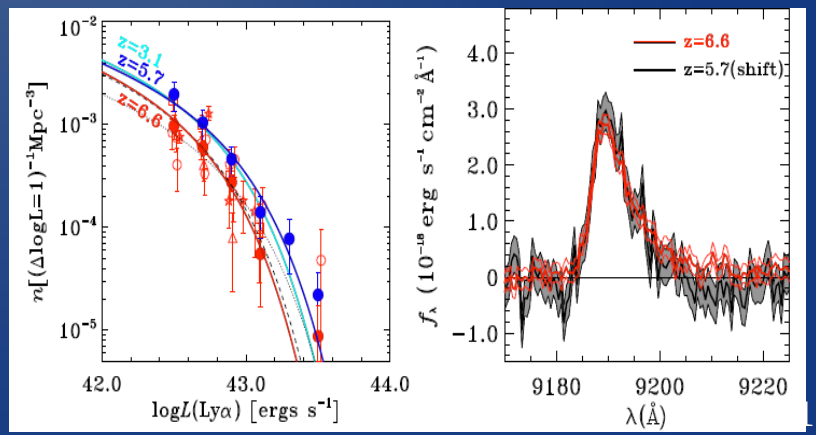
Local cosmology: formation and evolution of Milky Way

- ~10^9 stars!



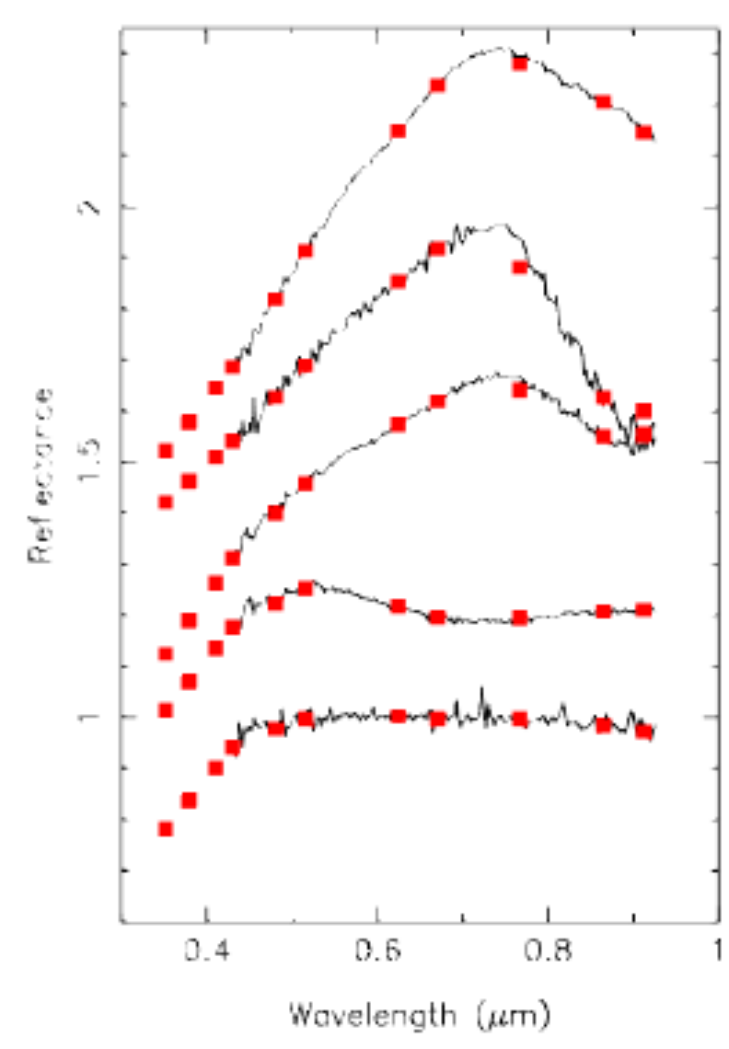






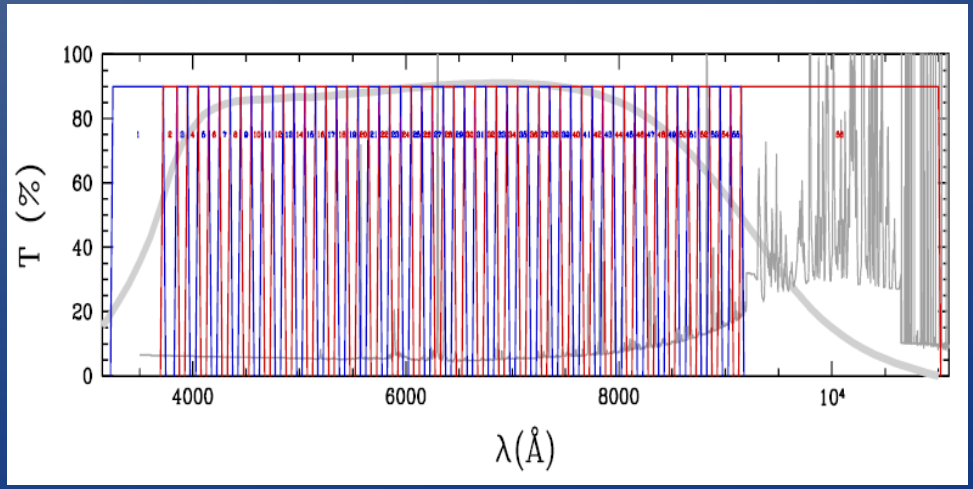
Solar system objects

Small bodies in the solar system



JPAS
Javalambre Physics of the Accelerating Universe Astrophysical Survey

- Um novo conceito de levantamento:
- vamos observar ~8000 graus quadrados em 56 filtros estreitos (I < 22.5) a fotometria corresponde a um espectro de baixa resolução!
- poderemos medir redshifts fotométricos para mais de 100 milhões de galáxias com precisão ~0.003(1+z)
- Vai medir BAO radial e tranversal
- Aglomerados, SN, lentes fracas, quasares, evolução de galáxias,estrelas, asteróides...



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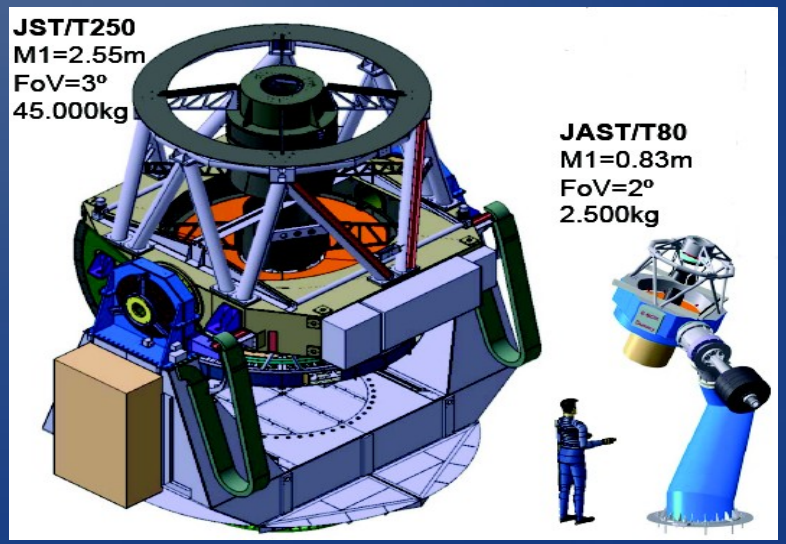
Javalambre Physics of the Accelerating Universe Astrophysical Survey

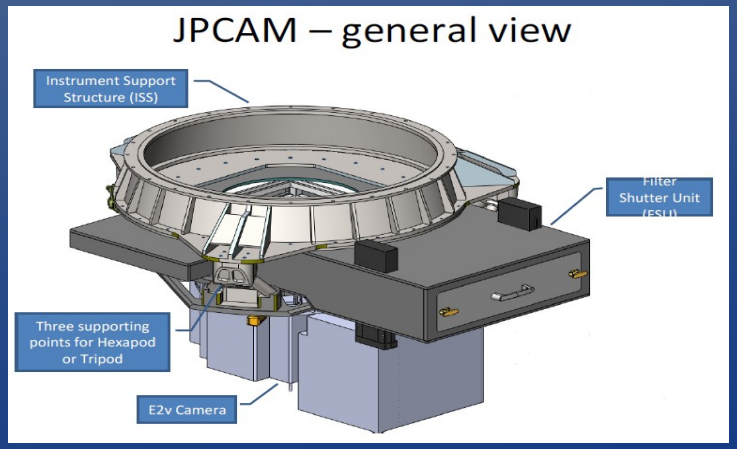
- Colaboração entre Brasil e Espanha:
- Brasil: ON, CBPF, UFRJ, IAG, IF, INPE, UFRGS, UFSC,...
- Espanha: IAA, CEFCA, IAC, UCM,...

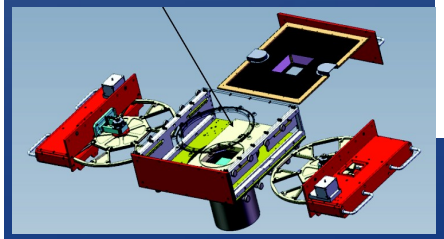
- JAO: Javalambre Astrophysical Observatory, Teruel, Aragón

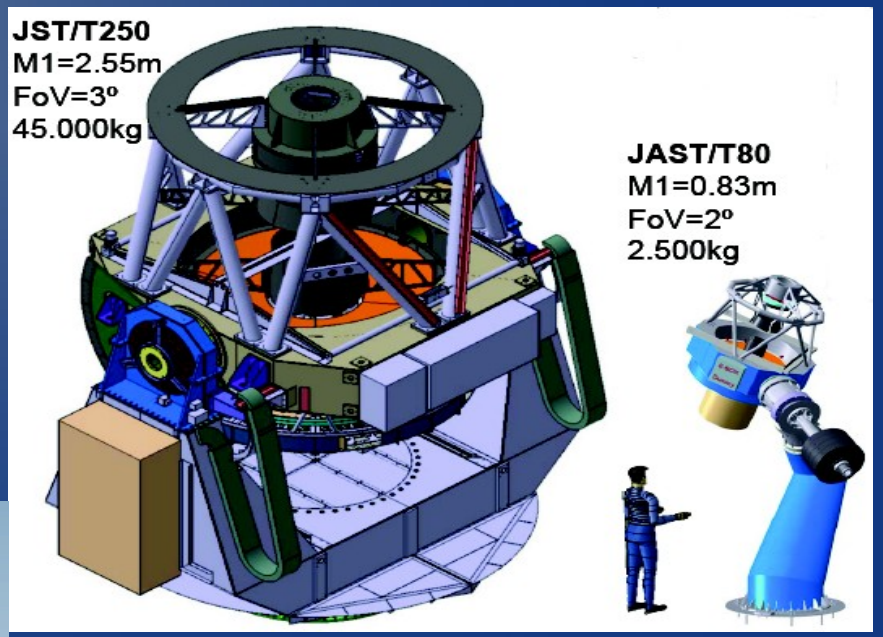


JPAS
Javalambre Physics of the Accelerating Universe Astrophysical Survey

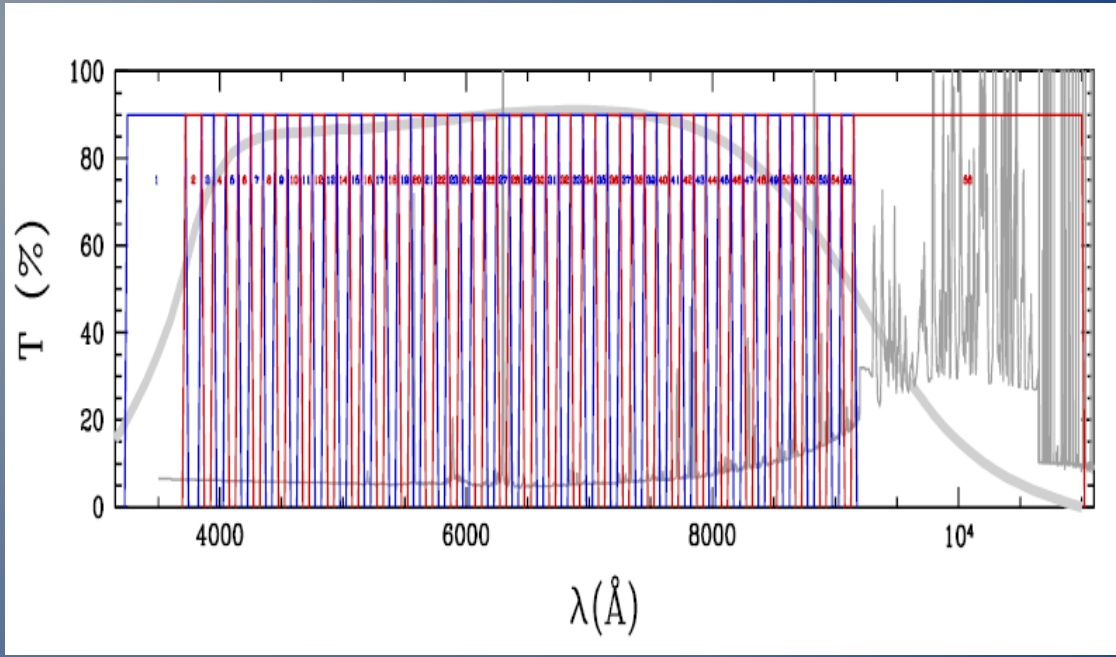
- Levantamento de 8000 graus quadrados em 56 filtros estreitos
- Telescópio de 2.5m de diâmetro+ câmera de 5 graus quadrados com 1.2 Gpixel
- Telescópio de 80cm + câmera de 2 graus quadrados para calibração



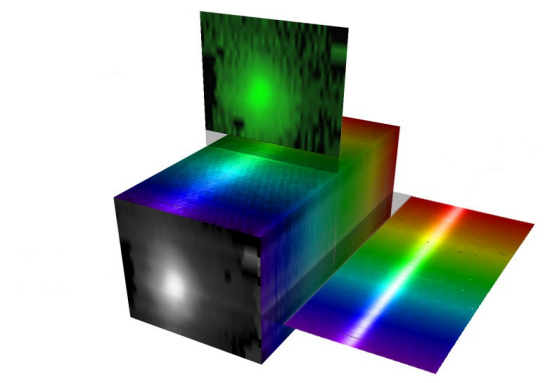


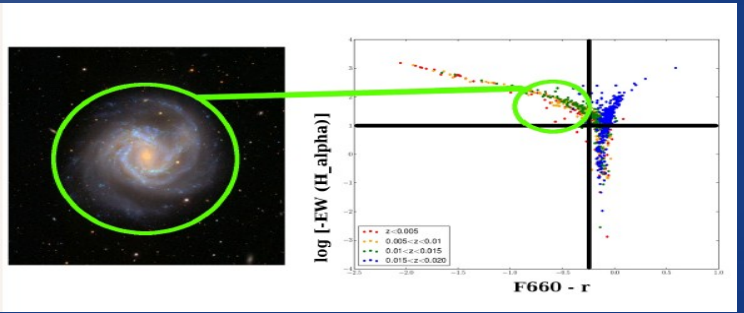


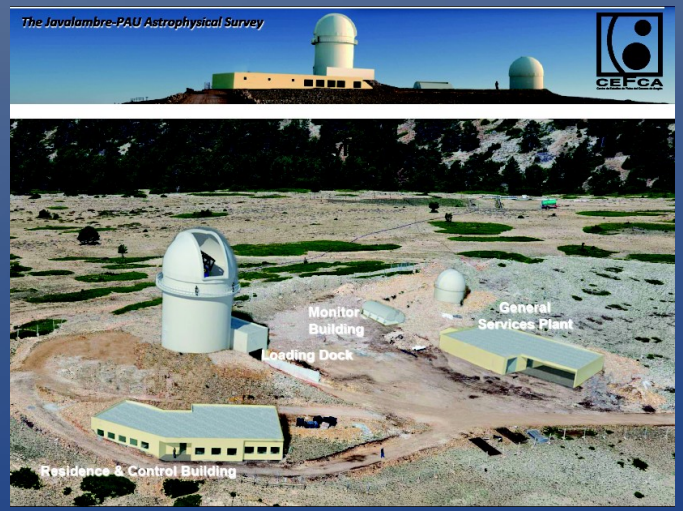
56 filtros- precisão em photo-z: ~0.003(1+z)



- **JPAS: vai produzir um espectro de baixa resolução para todos os pixels de uma imagem!!!**
- **Vai permitir *IFU science* de todo o céu!**







Quando?

- T80 – setembro 2012

  J-PLUS: dezembro 2013

- T250 – novembro 2013

  JCam: dezembro 2014

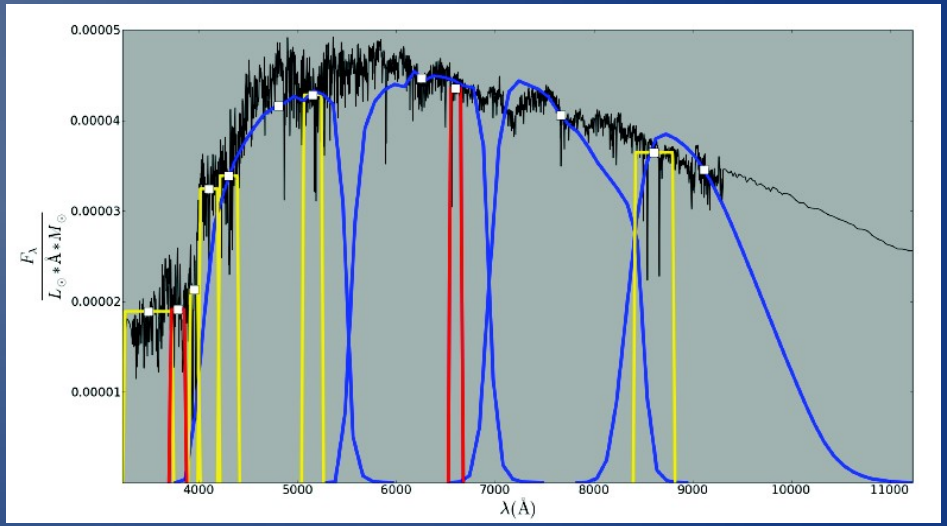
J-PLUS/T80

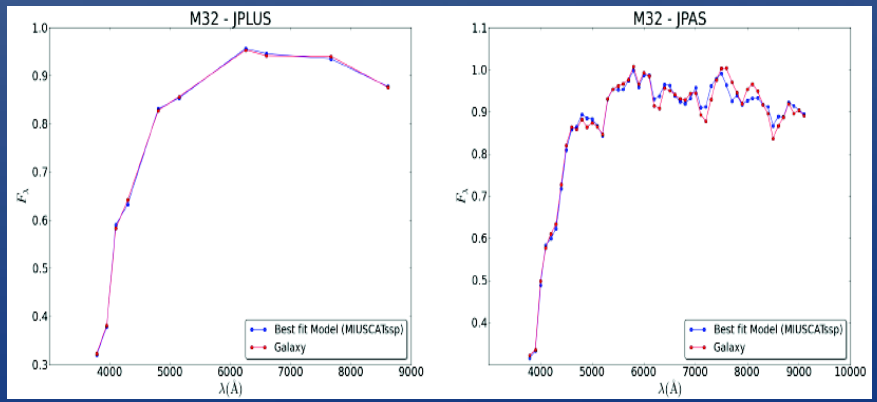
The Javalambre Photometric Local Universe Survey

- Motivação:
- Prover a calibração fotométrica para o JPAS
- Testar o sistema científico, tecnológico e gerencial do JPAS

- Início: dezembro 2013
- Tempo de execução: 2-2,5 anos

- 12 filtros: 4 do SDSS + 8 estreitos/intermediários
- 5000 graus quadrados, AB~22-23 (S/N >5)





J-PLUS/T80

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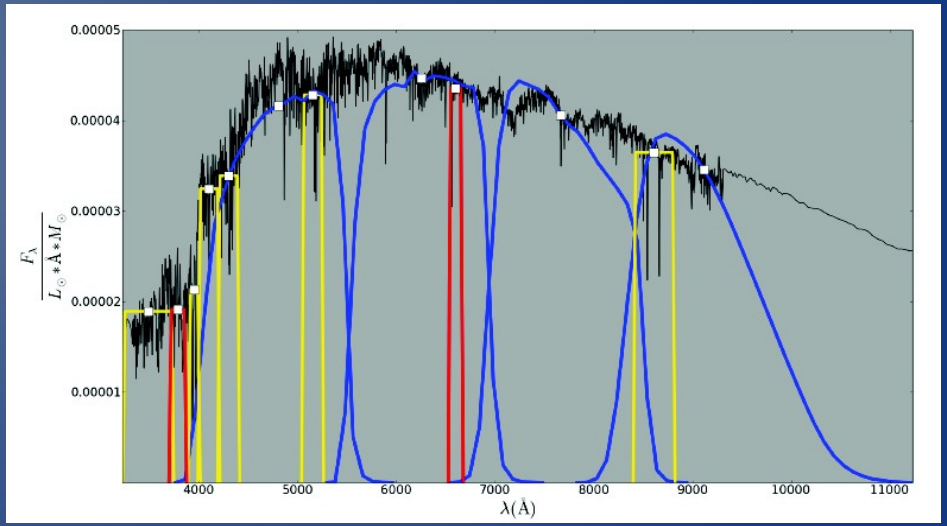

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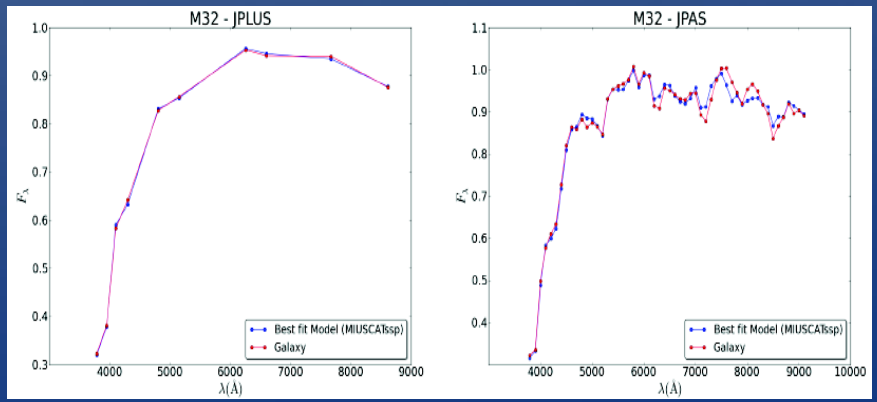


SMAPS
Southern massive astrophysical panchromatic survey

- Extensão do JPAS para o hemisfério sul
- Ideia: clonar telescópios, câmeras, etc do JPAS e instalá-los em Cerro Tololo (Chile)
- Custo < US$30M
- SMAPS+JPAS: primeiro levantamento óptico de todo o céu!
- *SMAPS+JPAS: primeiro levantamento tipo "IFU" de todo o céu!*

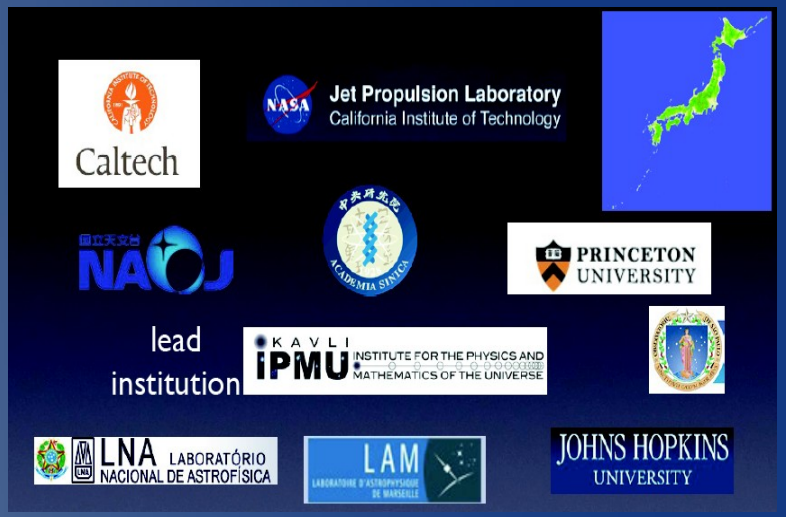
- *www.fma.if.usp.br/smaps*

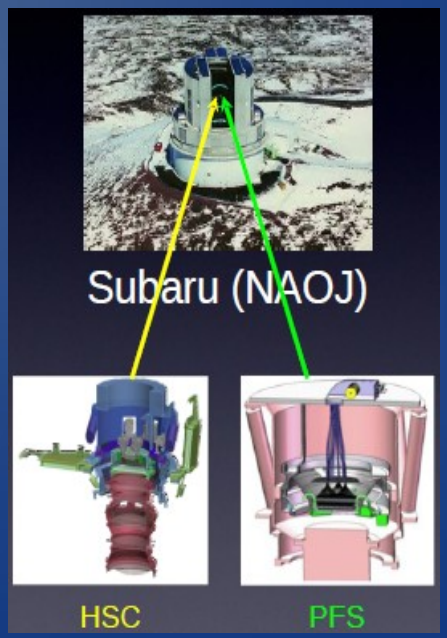
- Agosto 2013: embarque do T80 Sul para Cerro Tololo
- Outubro 2013: final da construção da cúpula
- Dezembro 2013: parte fria da câmera completa

PFS/SuMIRe
Prime Focus Spectrograph for the Subaru Measurement of Images and Redshifts survey

http://sumire.ipmu.jp/pfs/intro.html

- Projeto estratégico para a astronomia japonesa
- Período: 2017-2023
- PFS: será o melhor espectrógrafo dos anos 20!



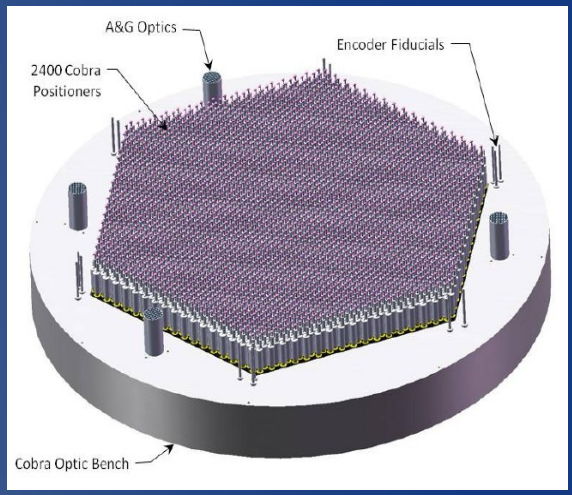


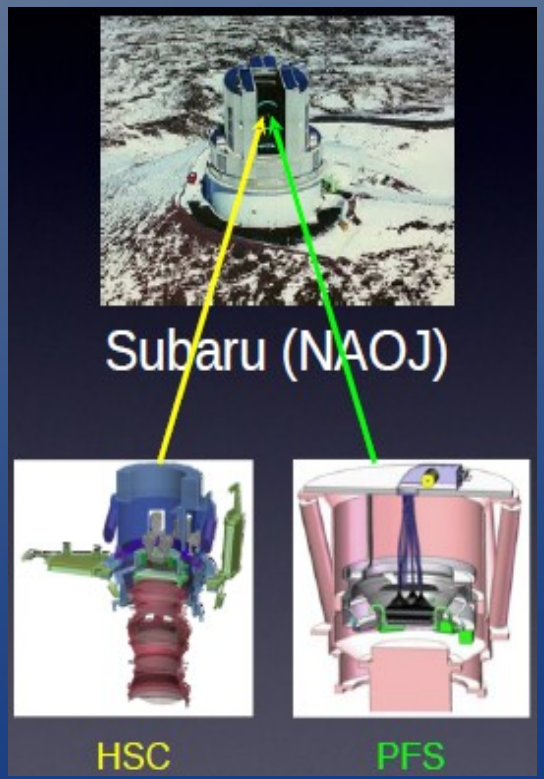
- Brasil- a destacar:
- Tecnologia: subsistema de fibras ópticas (patentes!)
- Ciência: potencial desta colaboração científica

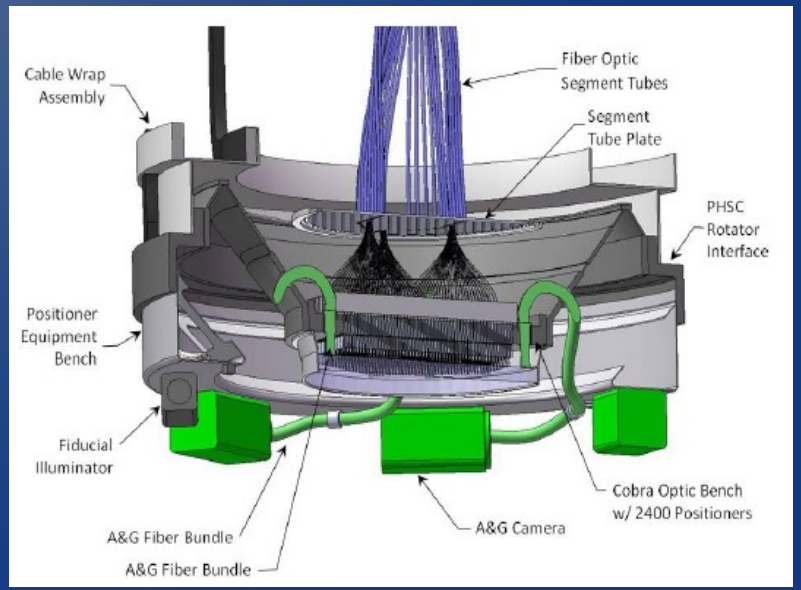
arXiv:1206.0737

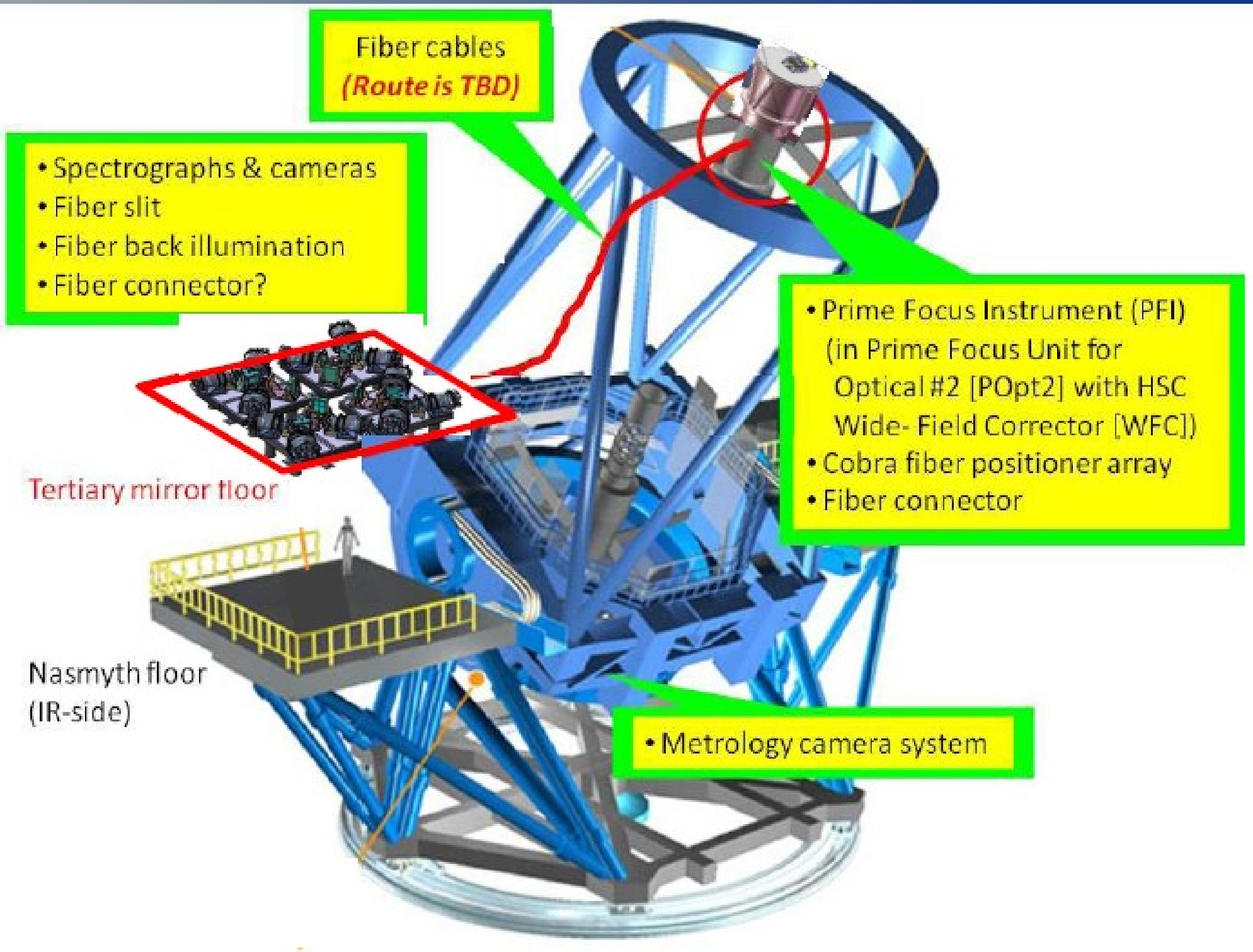
PFS/SuMIRe
Prime Focus Spectrograph for the Subaru Measurement of Images and Redshifts survey

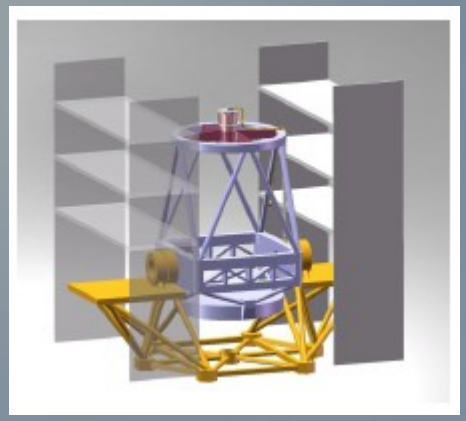
- 2400 fibras, num telescópio com campo de 1.3 graus de diâmetro
- Resposta: 0.38 – 1.3 microns, R ~ 3000
- ~500 mil galáxias com 1<z<2, 30 mil com 3<z<7

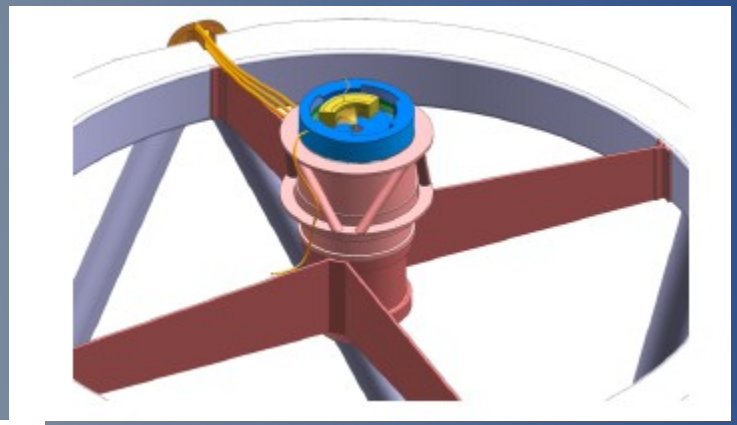


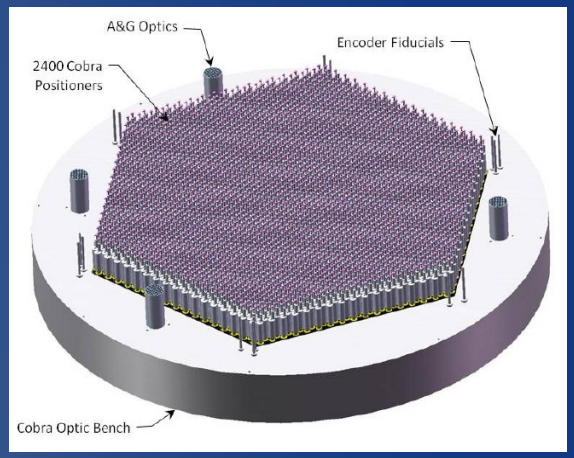


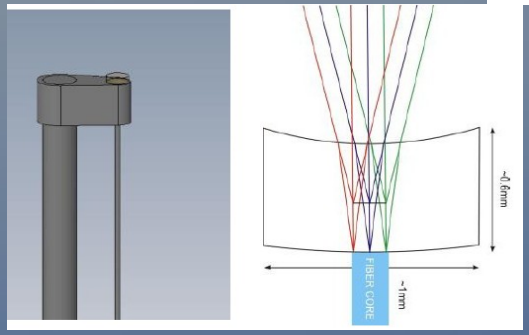


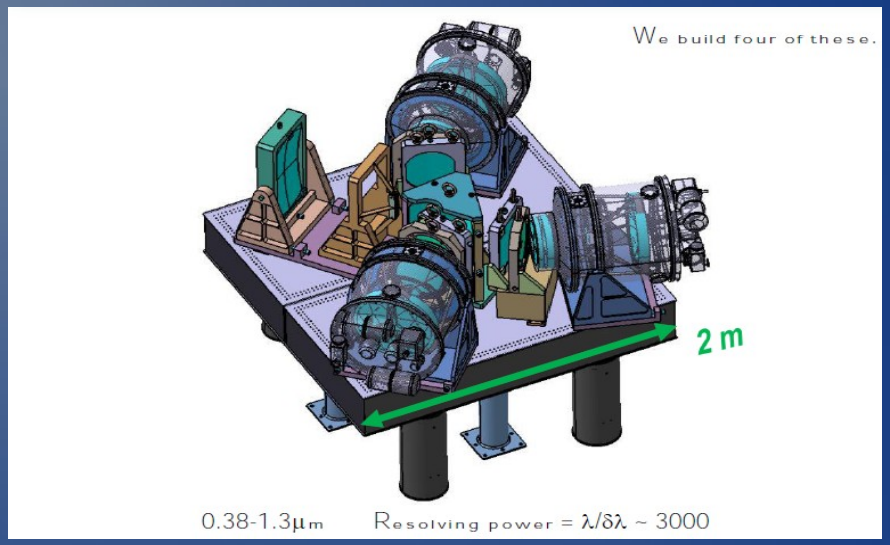

Fiber cables
(Route is TBD)
• Spectrographs & cameras
• Fiber slit
• Fiber back illumination
• Fiber connector?
• Prime Focus Instrument (PFI)
(in Prime Focus Unit for
Optical #2 [POpt2] with HSC
Wide- Field Corrector [WFC])
• Cobra fiber positioner array
• Fiber connector
Tertiary mirror floor
Nasmyth floor
(IR-side)
• Metrology camera system

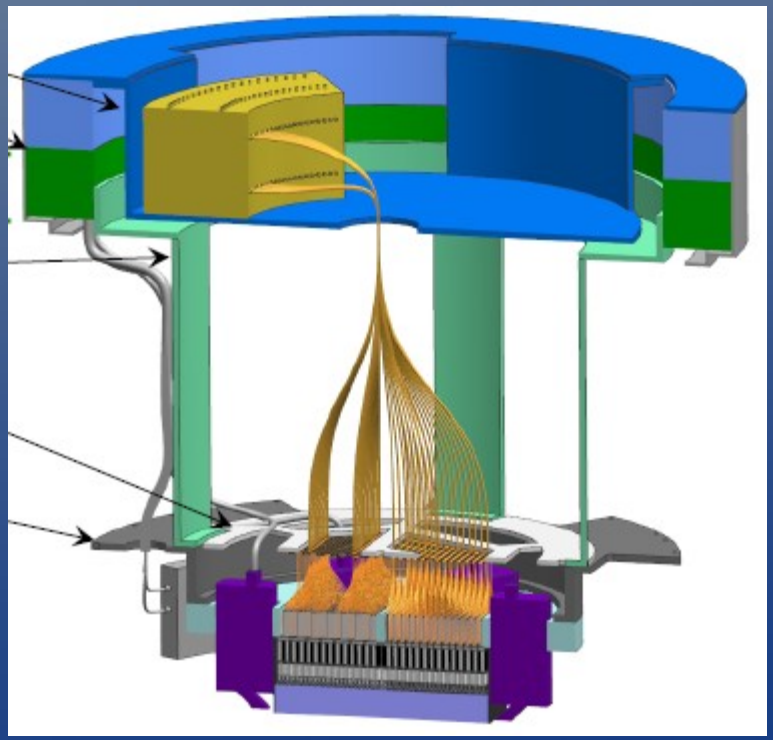


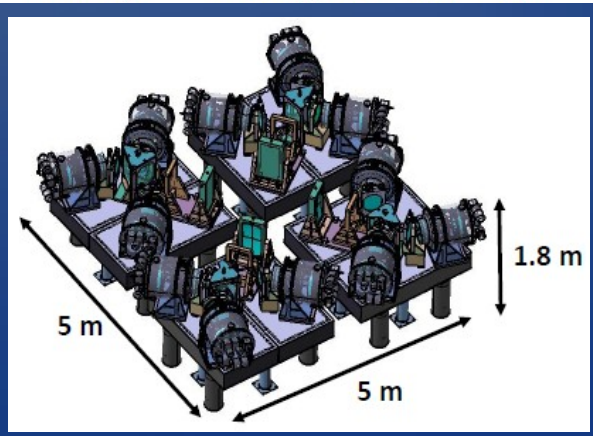



A&G Optics
Encoder Fiducials
2400 Cobra
Positioners
Cobra Optic Bench


~0.6mm
FIBER CORE
~1mm


We build four of these.
2 m
0.38-1.3µm
Resolving power = λ/δλ ~ 3000




1.8 m
5 m
5 m

Resumo:

- Grandes levantamentos são uma ferramenta essencial da astrofísica contemporânea
- Apresentam um grande escopo de aplicações astrofísicas: objetos do sistema solar, formação da Via Láctea, evolução de galáxias, cosmologia,…
- Novos levantamentos:
  JPAS (+ JPLUS & SMAPS),
  PFS/SuMIRe
- Potencial para novas descobertas!