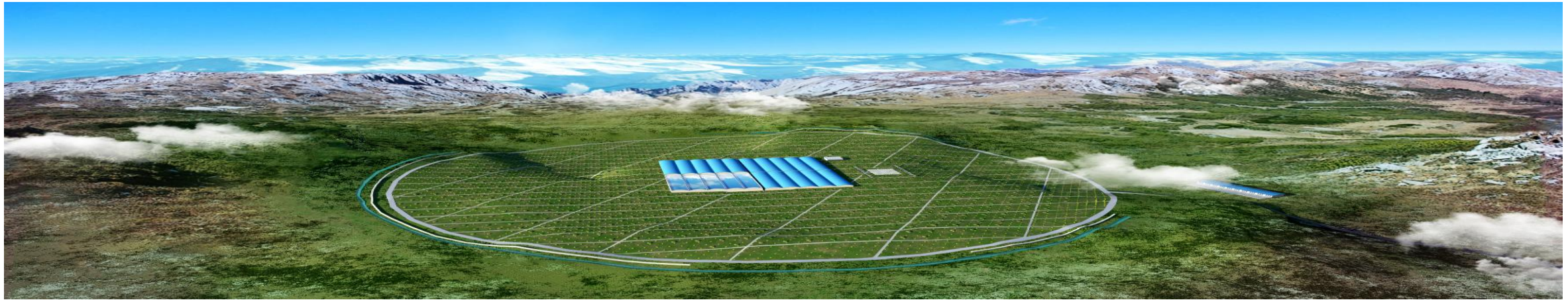
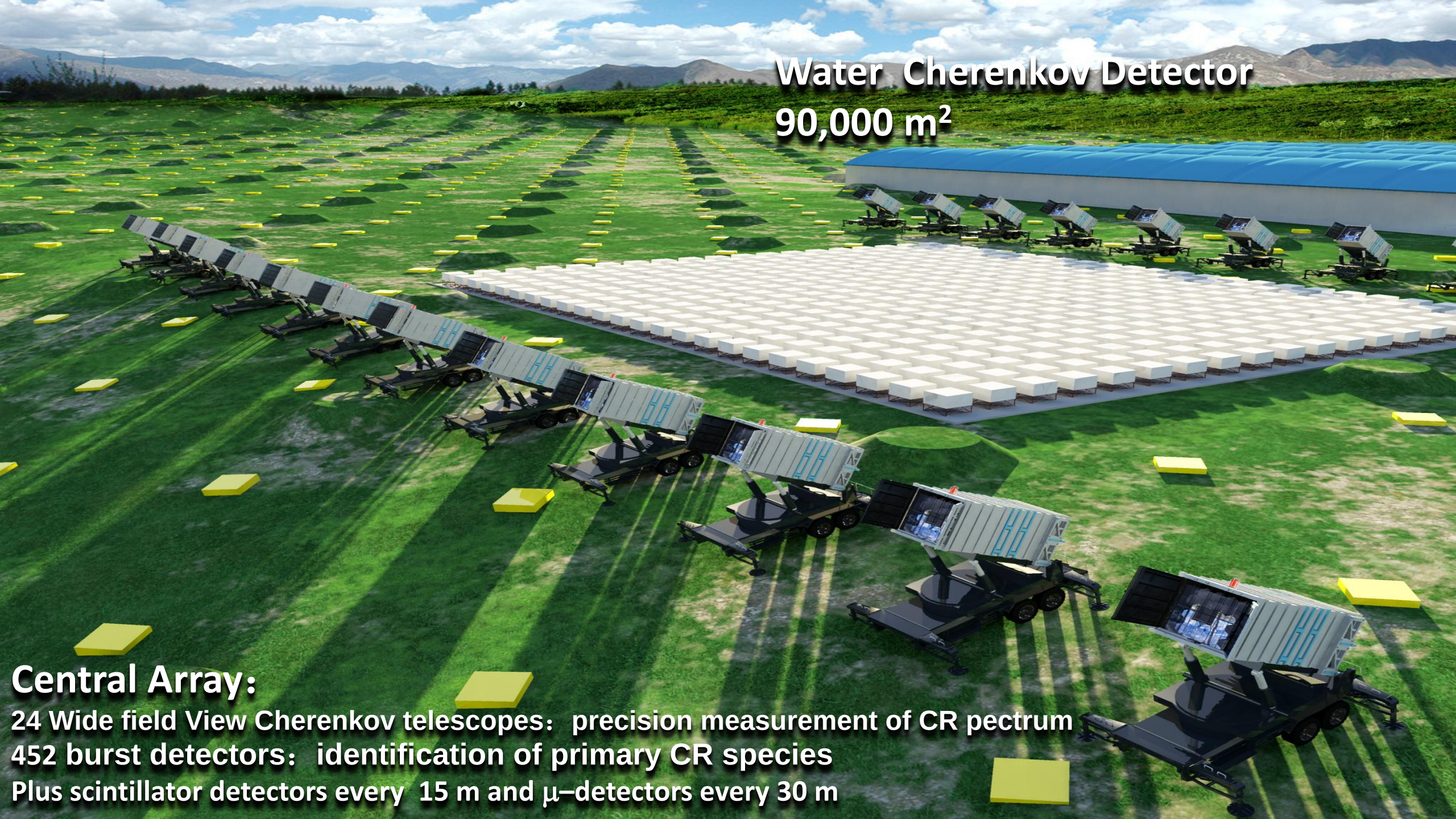
LHAASO Project

Zhen Cao IHEP, China, Beijing

LHAASO site




Water Cherenkov Detector
90,000 m²
Central Array：
24 Wide field View Cherenkov telescopes：precision measurement of CR pectrum
452 burst detectors：identification of primary CR species
Plus scintillator detectors every 15 m and μ–detectors every 30 m

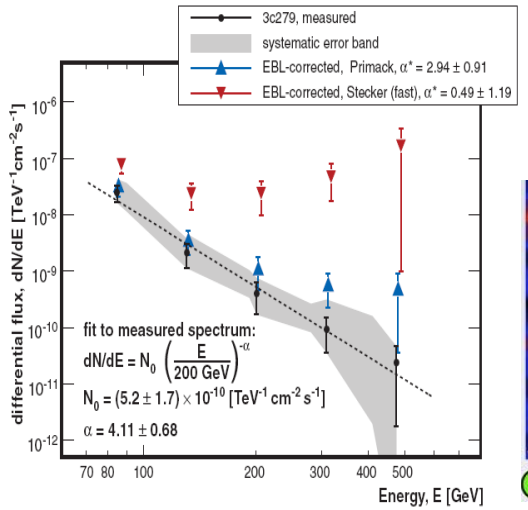
Outline

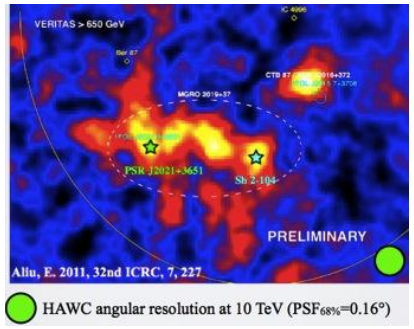
- LHAASO science
- Prototype experiment at ARGO-YBJ site
- LHAASO site and status
- Collaboration

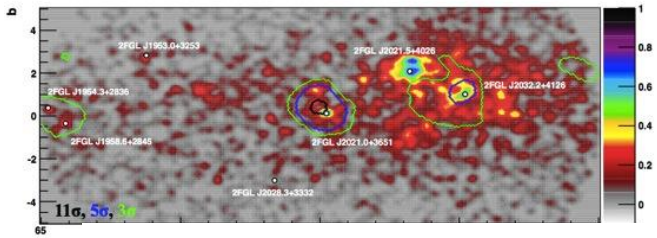
Summary of the status of the VHE γAstronomy

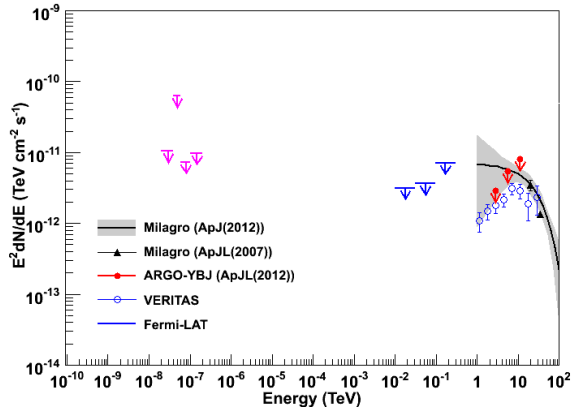
- The most fascinating discoveries in TeV gamma ray astronomy
  - RXJ 1713: a possible hadronic source
  - Fast transient AGNs: PKS 2155-304,Mrk501,…
  - Very remote Quasar: 3C279 (z=0.5362)
  - Very hard spectrum of very extended source in Cygnus region
  - Cygnus Cocoon
  - ……

3C279
***Science* 320, 1752 (2008); MAGIC**

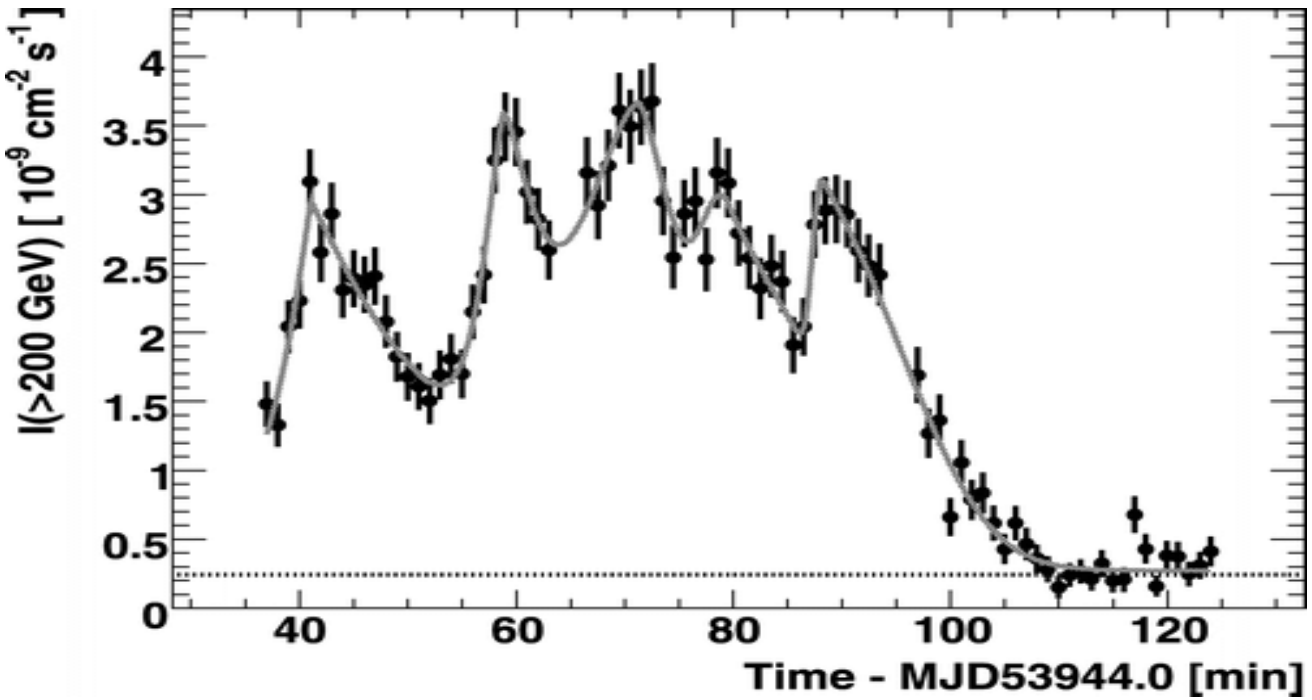






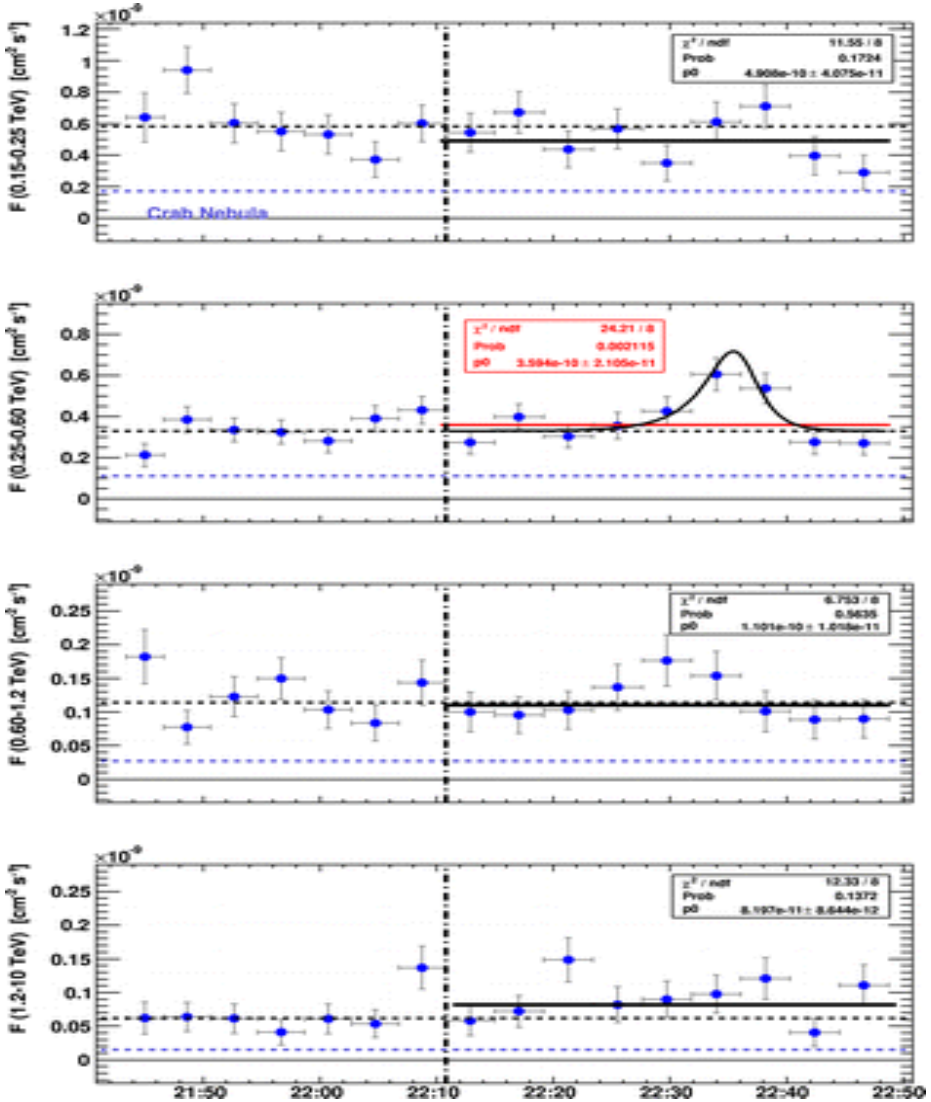


PKS 2155−304



Aharonian et al. 2007 - H.E.S.S.

Mrk 501

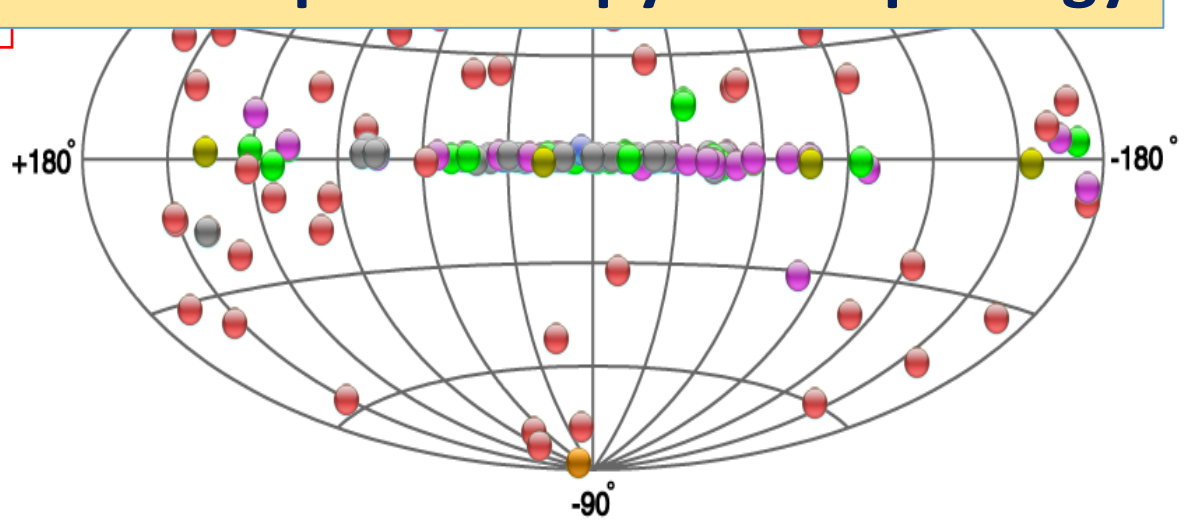


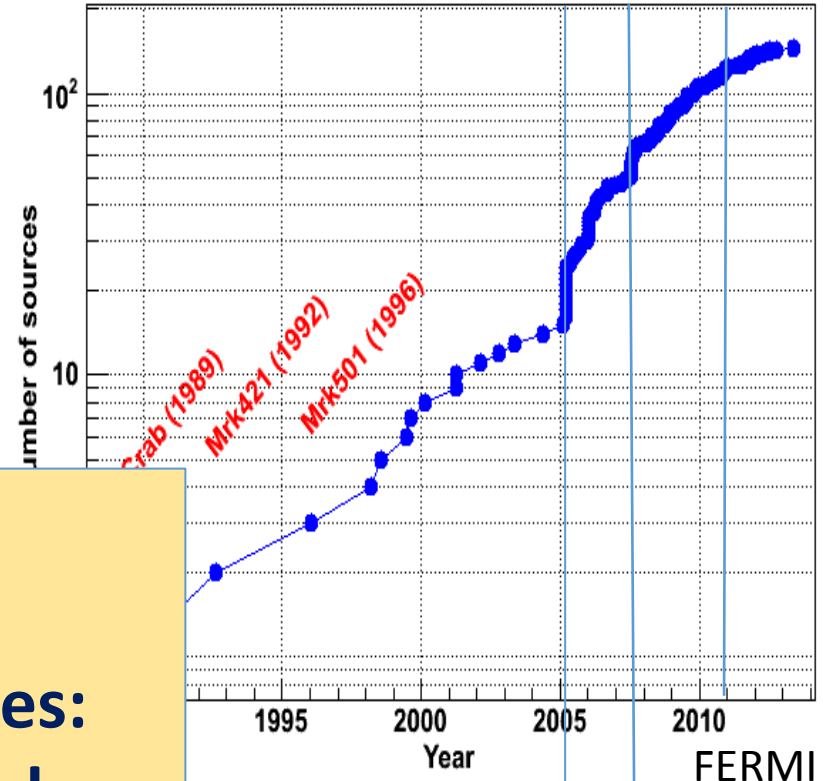
Albert et al. 2007 - MAGIC

Source Types

- PWN
- Binary XRB PSR Gamma BIN
- HBL IBL FRI FSRQ LBL AGN (unknown type)
- Shell SNR/Molec. Clou Composite SNR
- Starburst
- DARK UNID Other
- uQuasar Star Forming Region Globular Cluster Cat. Var. Massive Star Cluster BIN BL Lac (class unclear) WR

Map and number of the γ ray sources





FERMI Catalog releasing

MAGIC Switched on

HESS Switched on

Two directions

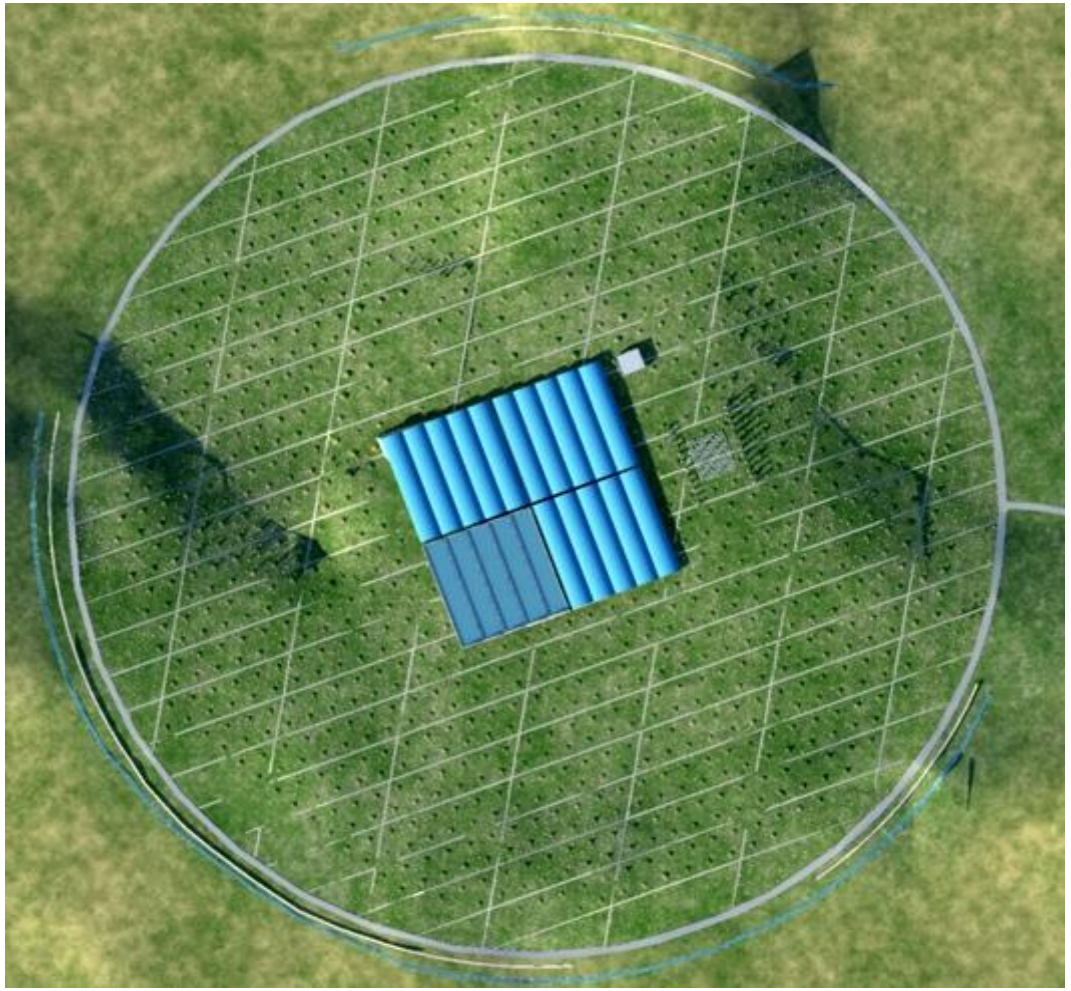
1. Survey for more sources

2. Deep study on interesting sources: spectroscopy & morphology

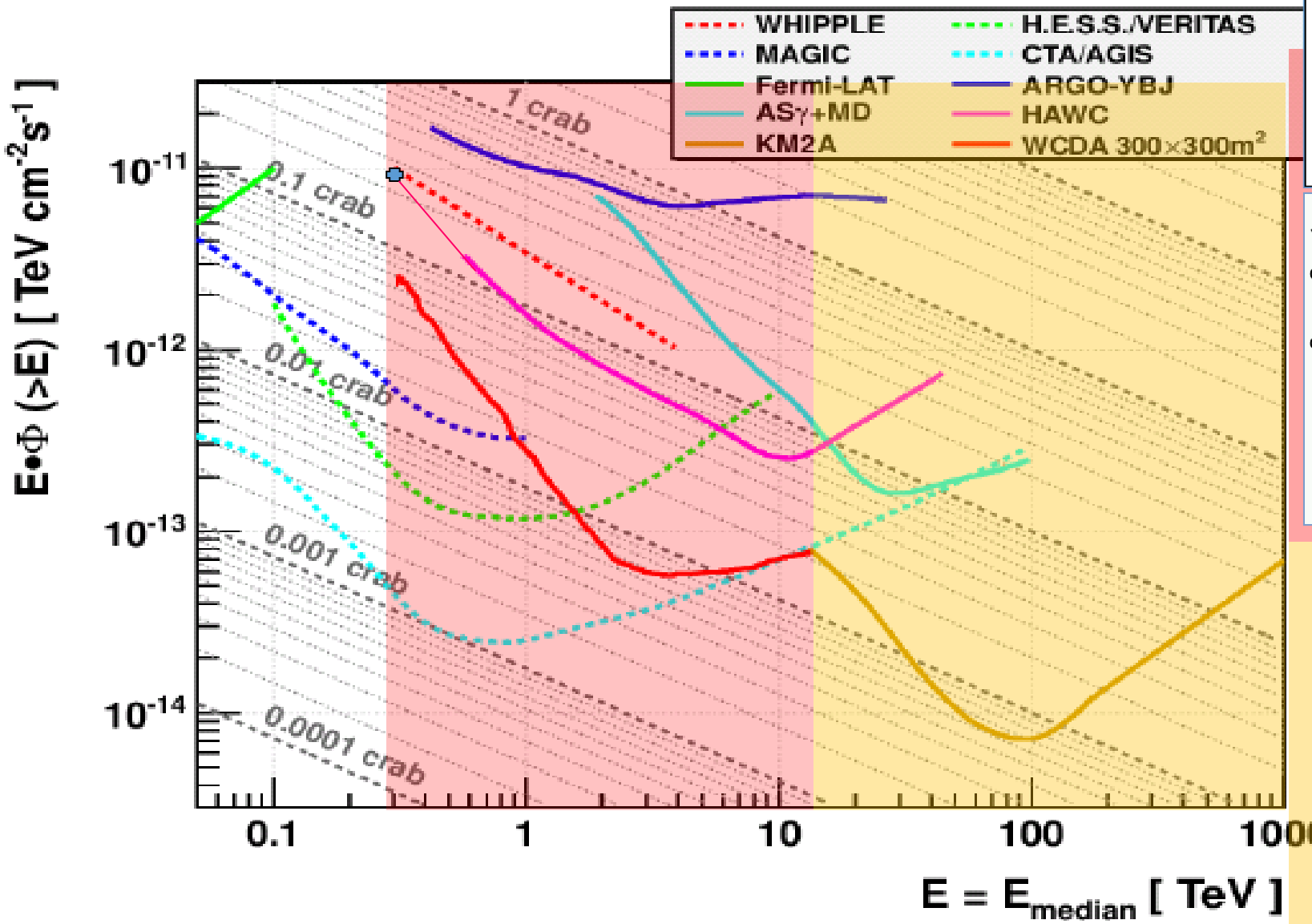
LHAASO

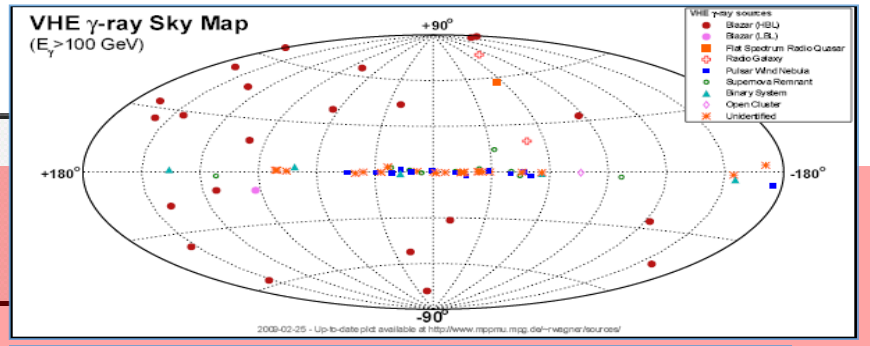
- Two Gamma Ray Astronomic Devices
  - A Wide FOV Survey Facility
  - A Spectrometer for Interesting Sources

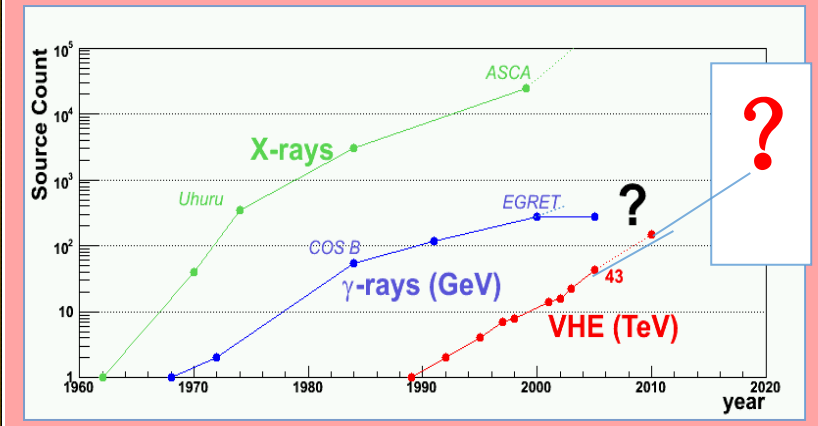
+

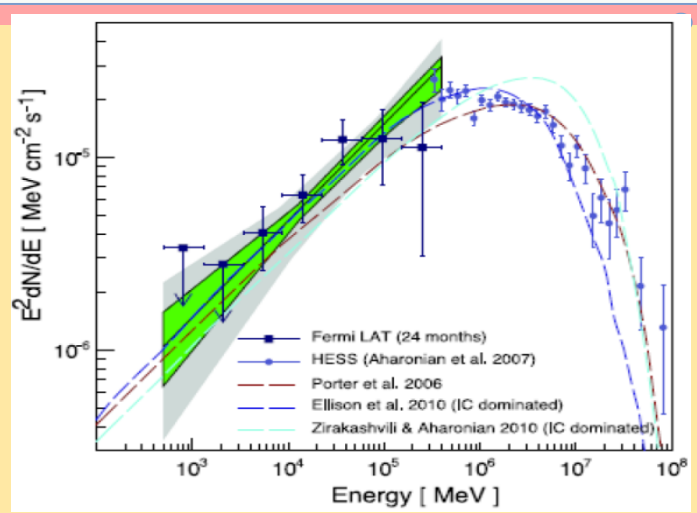


Survey for γ-sources
very detailed spectroscopy investigation



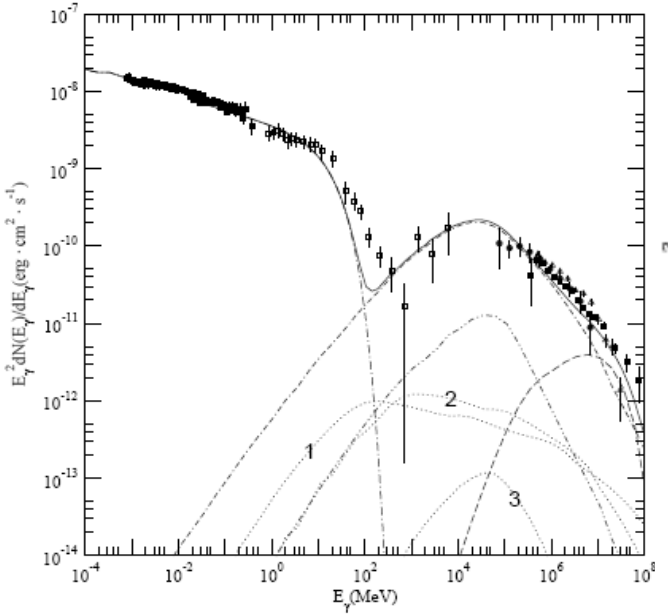


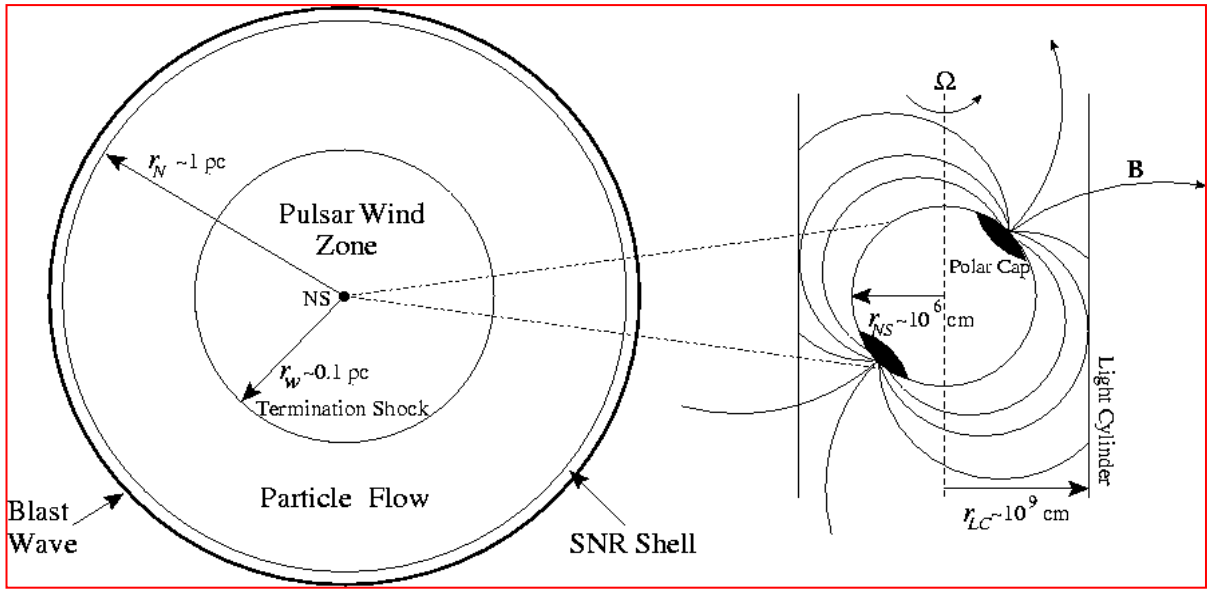




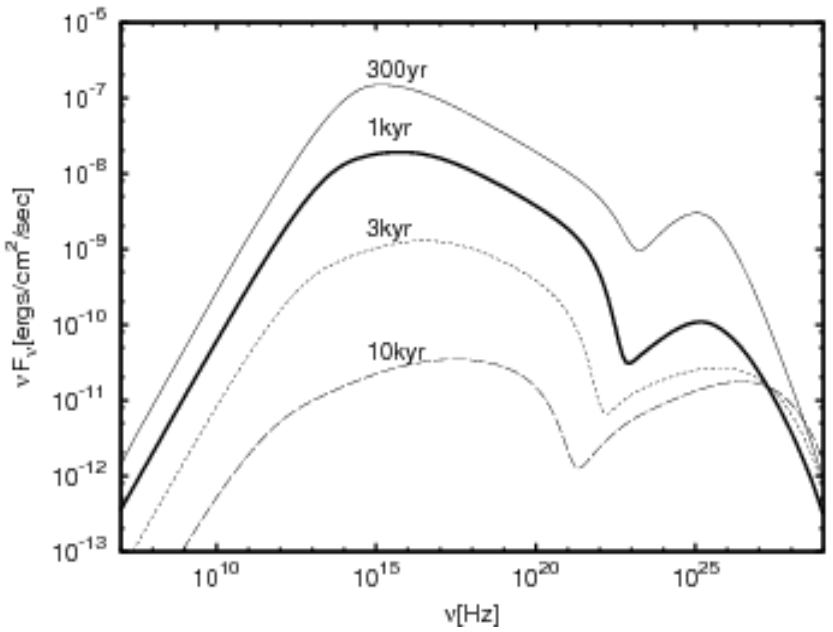
A. 34 Pulsar Wind Nebula

Standard Candle
Crab Nebula

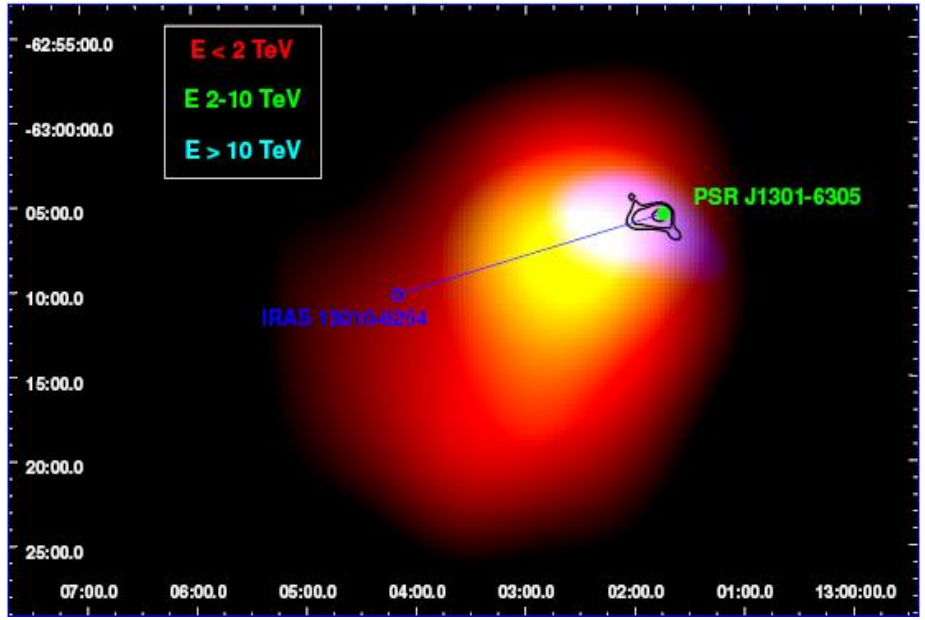




Evolution



Spatial drifting



A&A 548, A46 (2012)

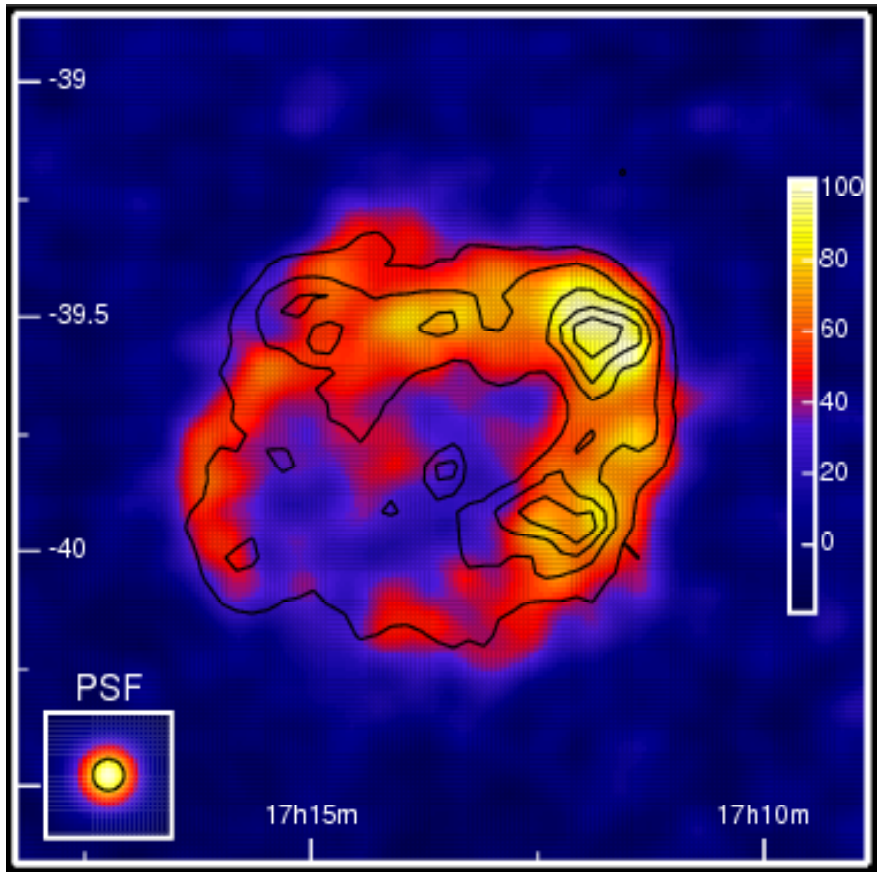
B. 23 SNRs

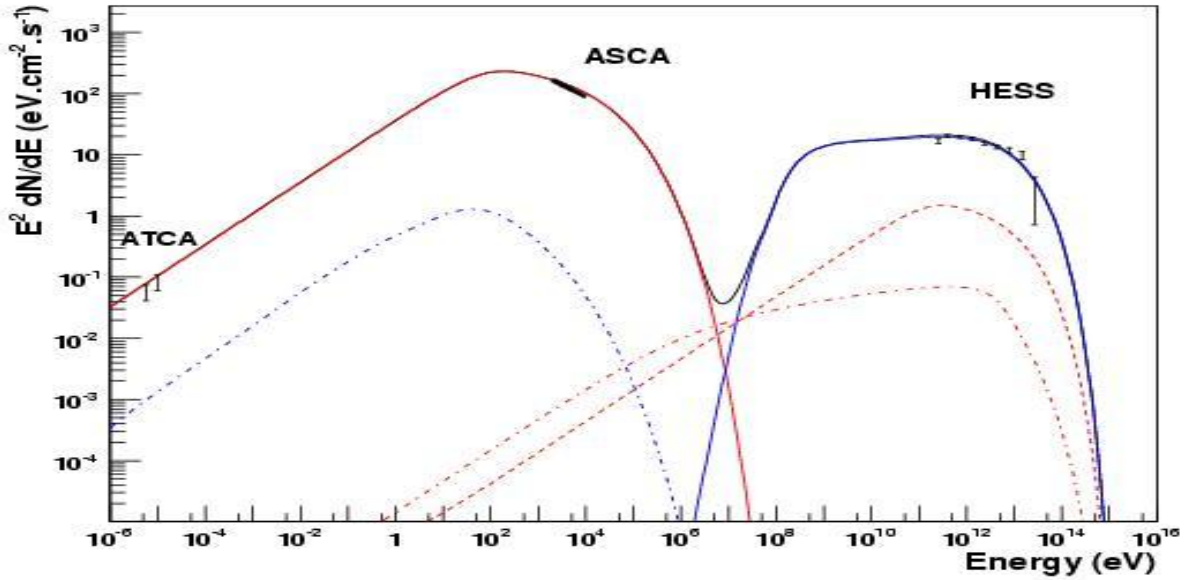
(Shell or Composite w/clouds)

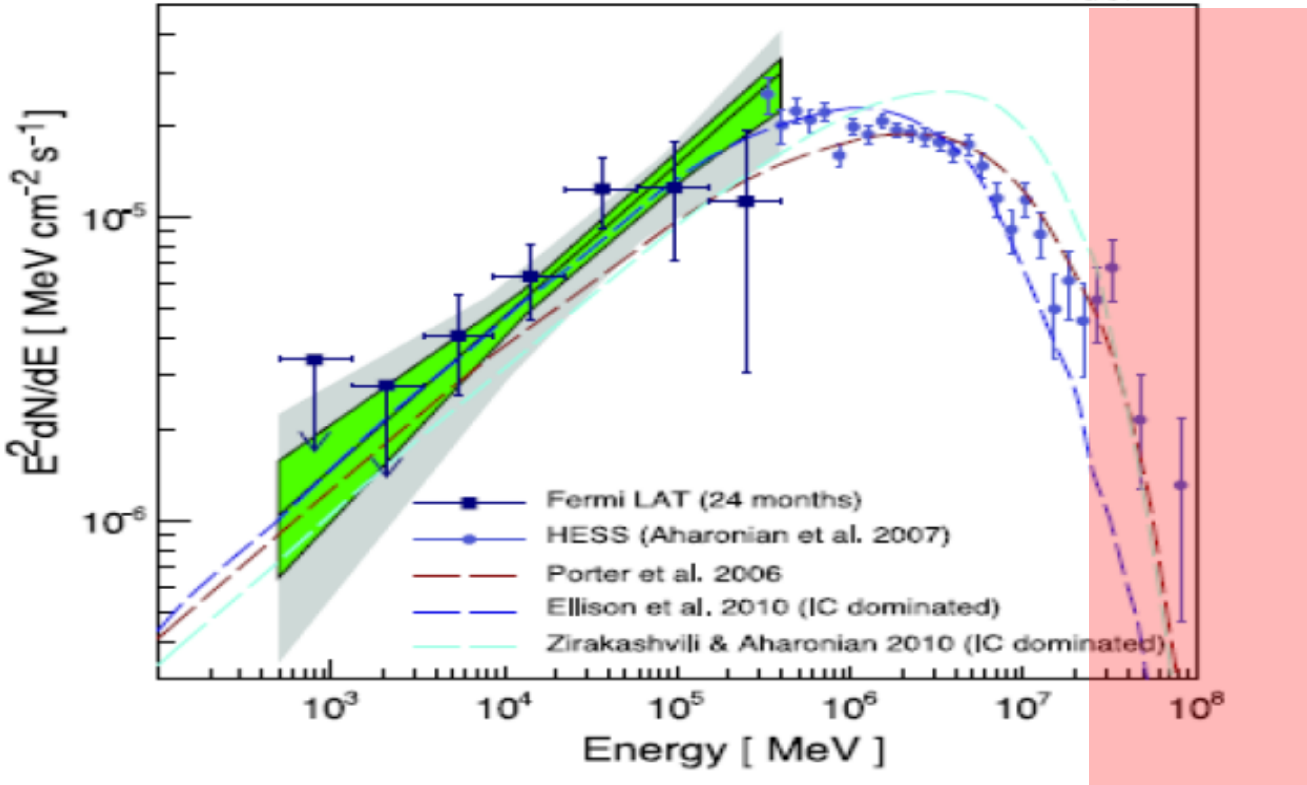
RXJ 1713.7−3946

Morphology is important,

Spectroscopy is even more!

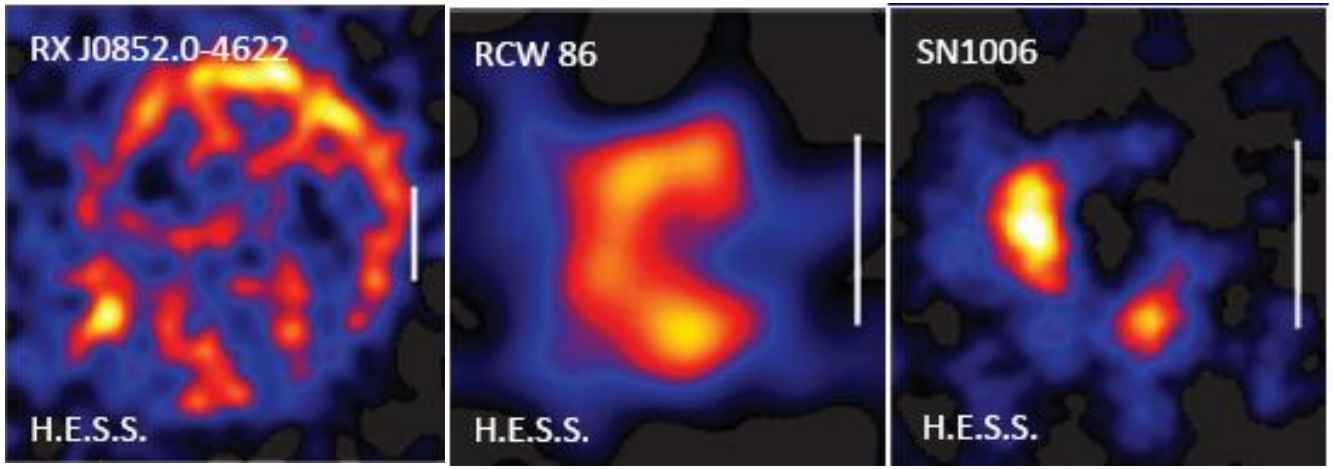


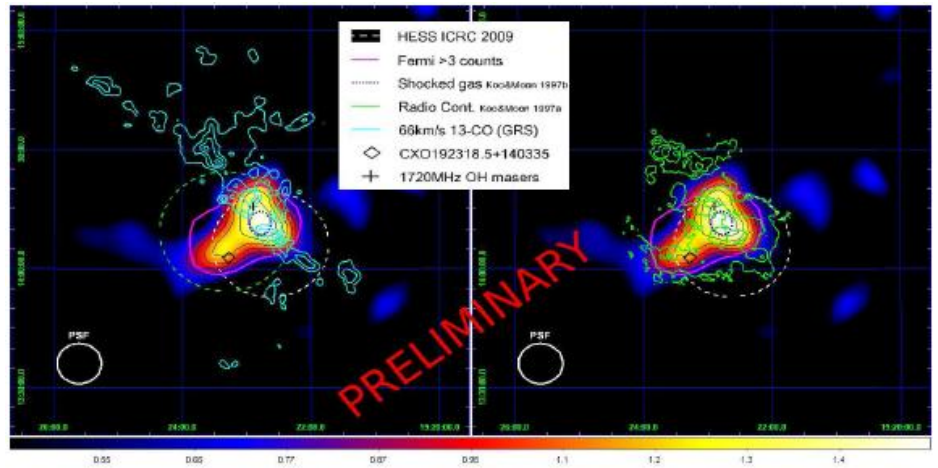




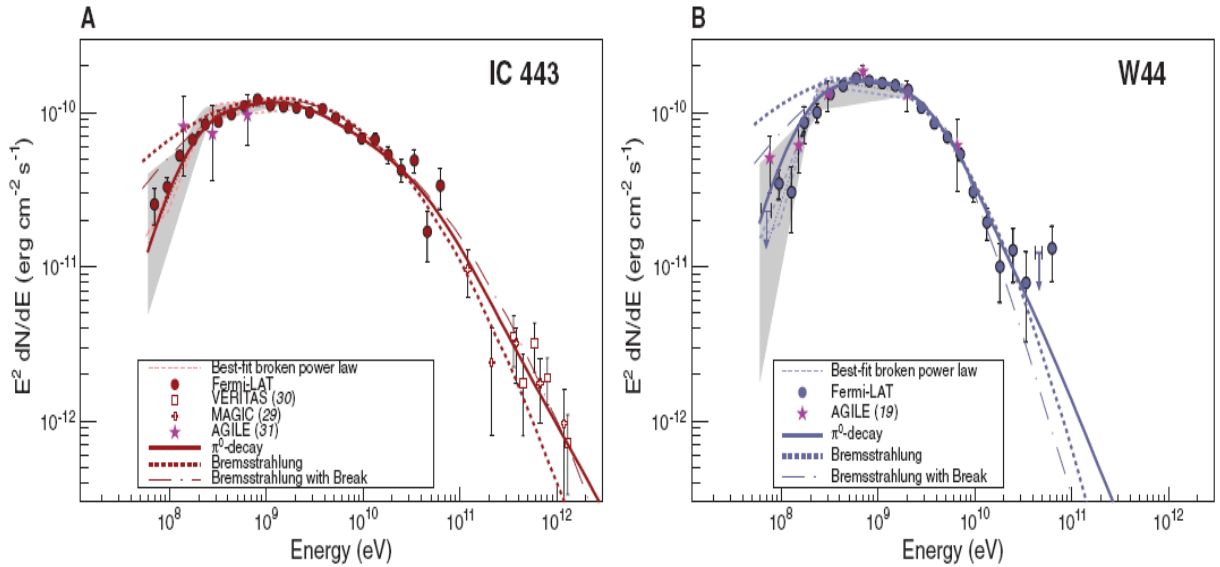
SNRs

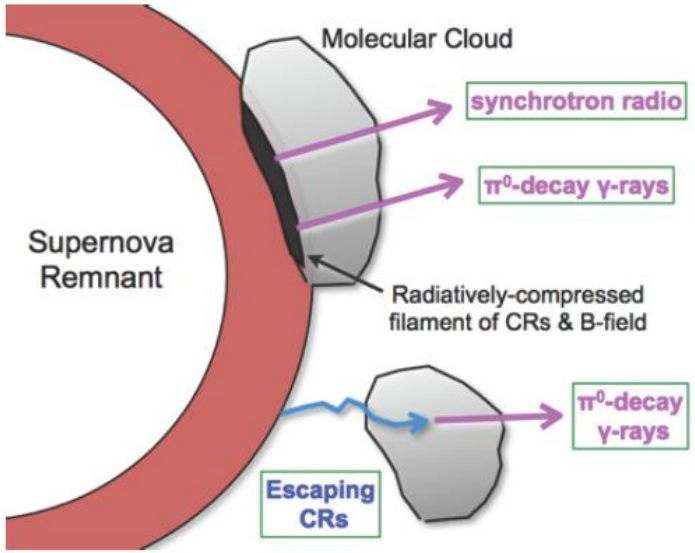
Young SNRs





Old SNRs



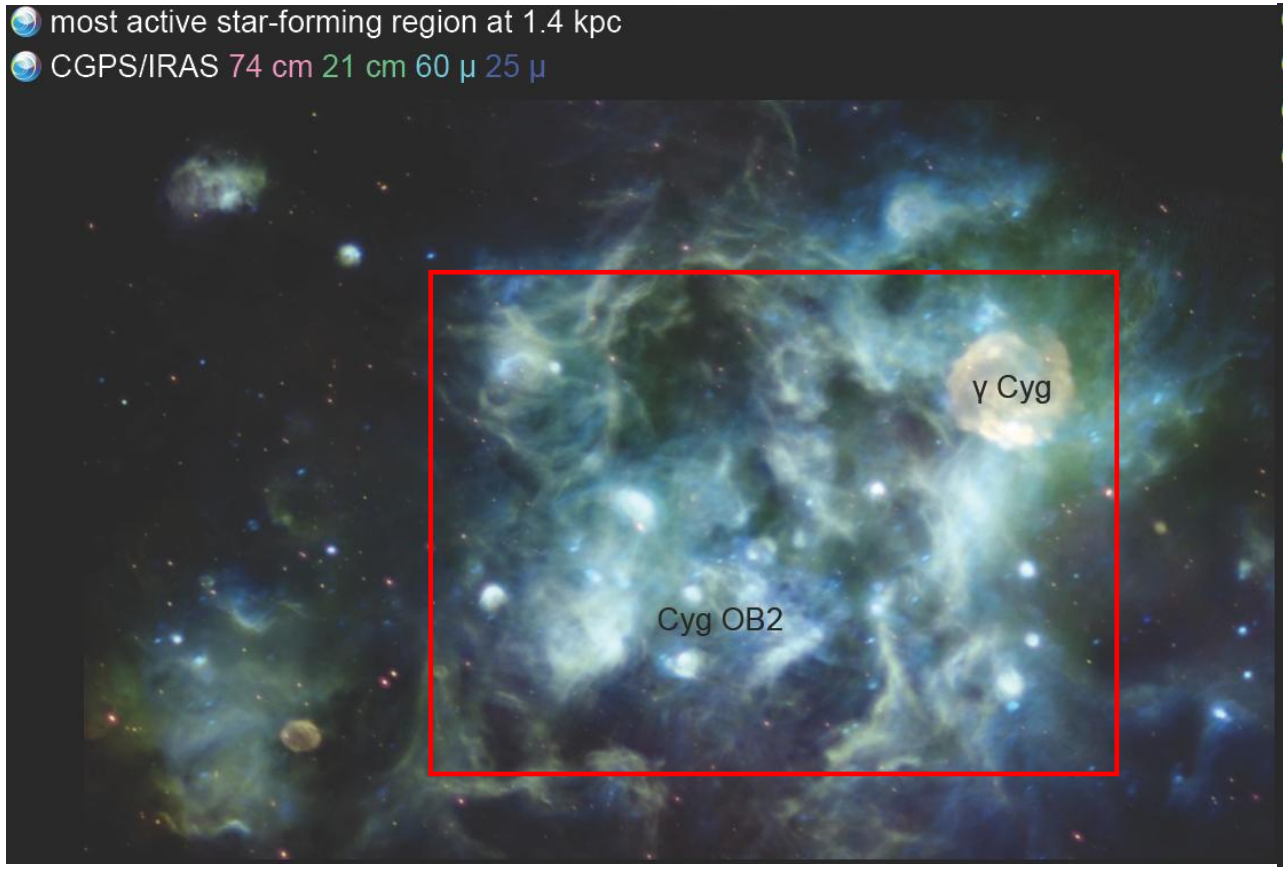


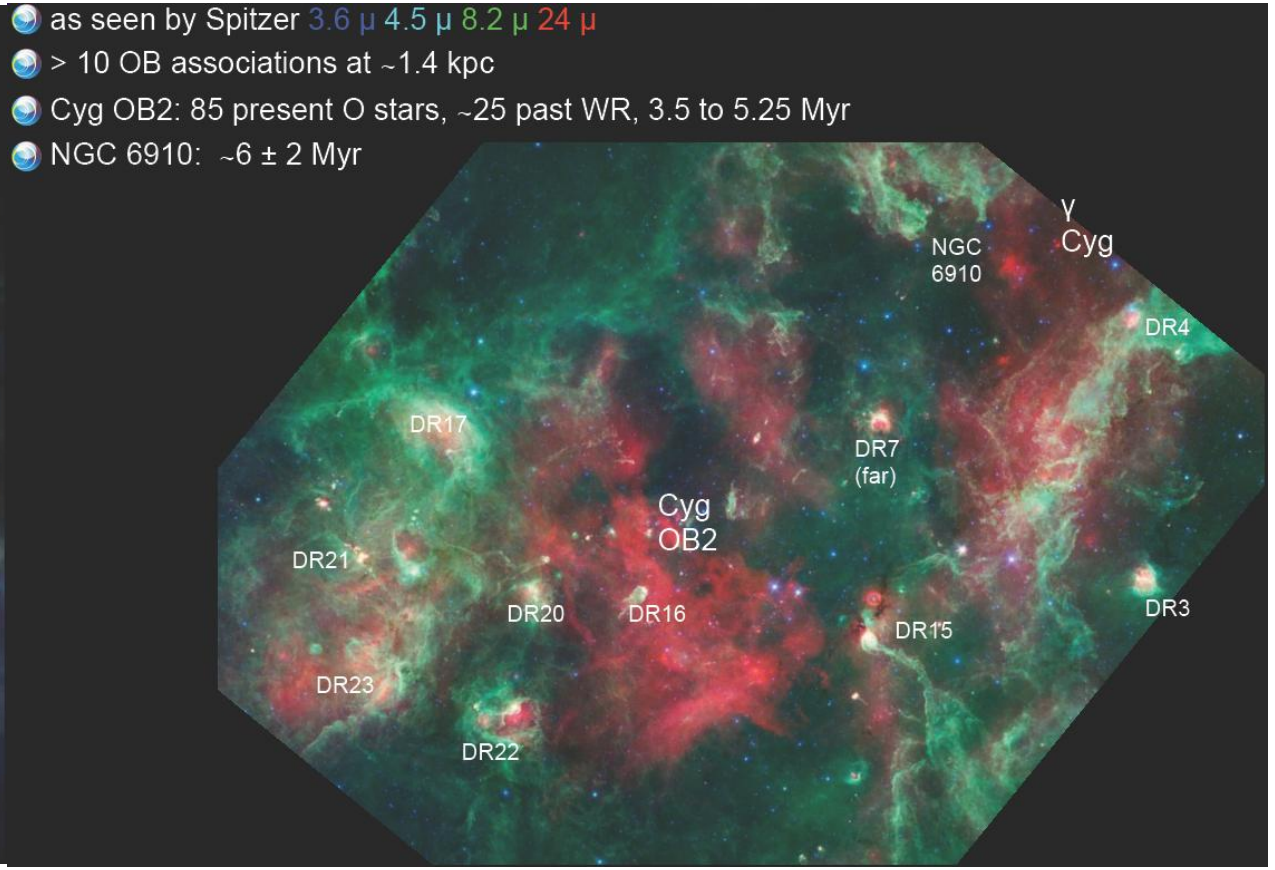
Science 339, 807 (2013)

CR sources?

C. Big objects (regions) in the sky

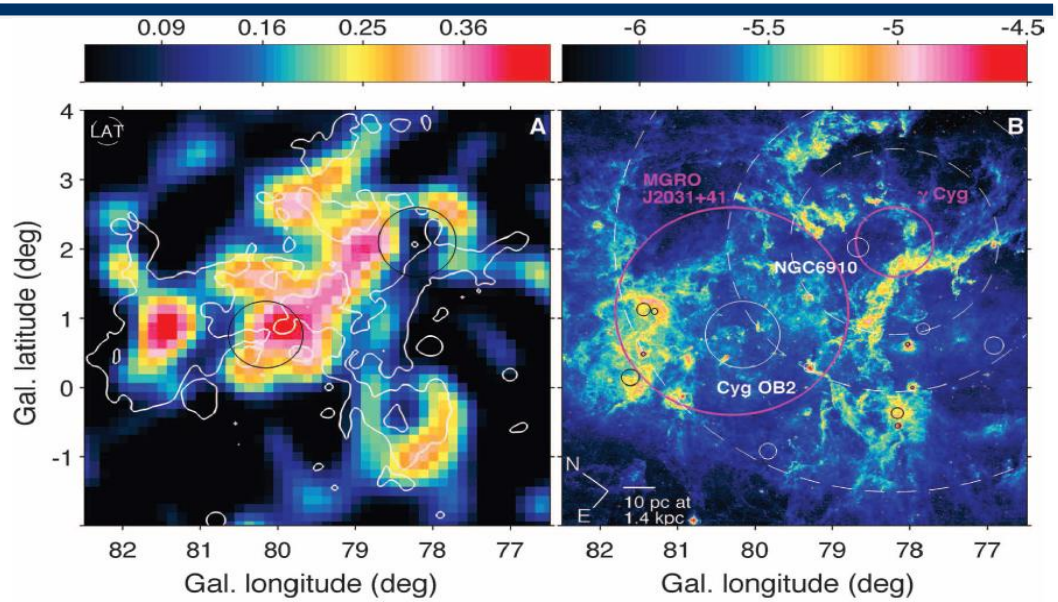
The most active region in the northern sky



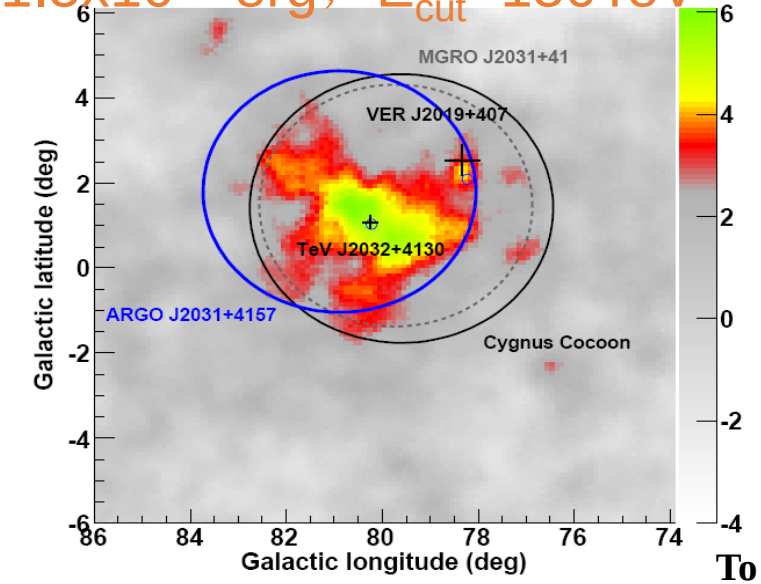


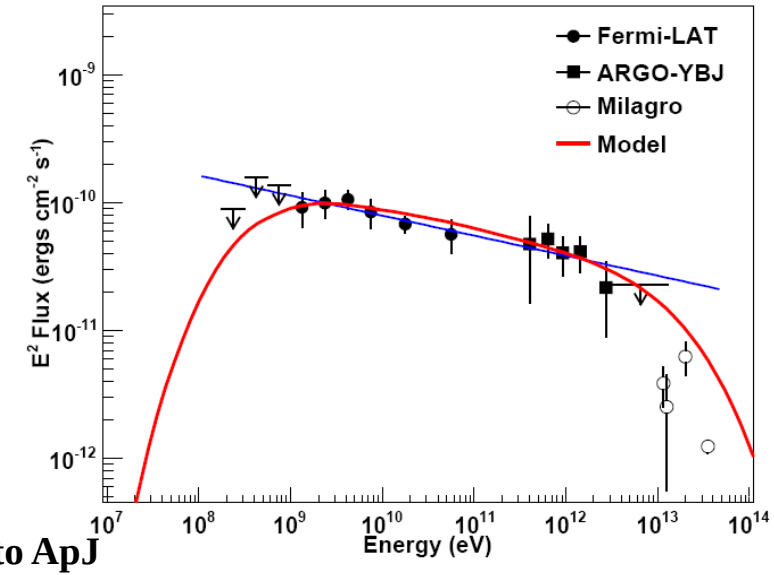
Cygnus Cocoon (FERMI Cocoon)

- FERMI Cocoon
- ARGO J3031+4157
- **The first γ ray Superbubble**
- **it is too big to IACT**
- Could be a possible hadronic source w/ total hadronic energy of 1.5×10^{50} erg，E_{cut}=150TeV



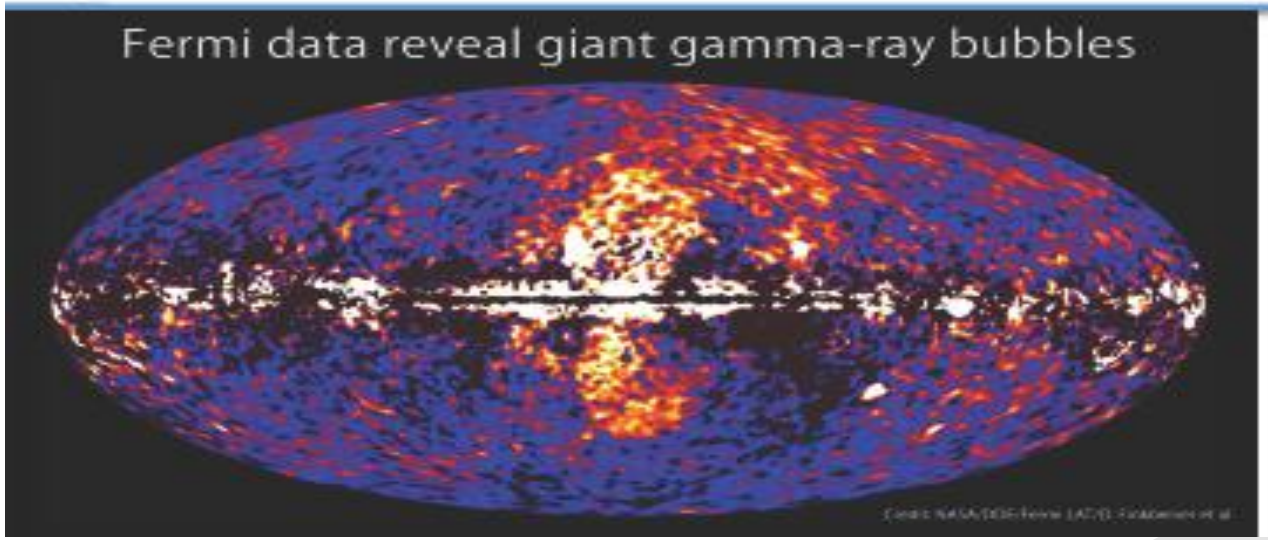
Science 334, 1103 (2011)

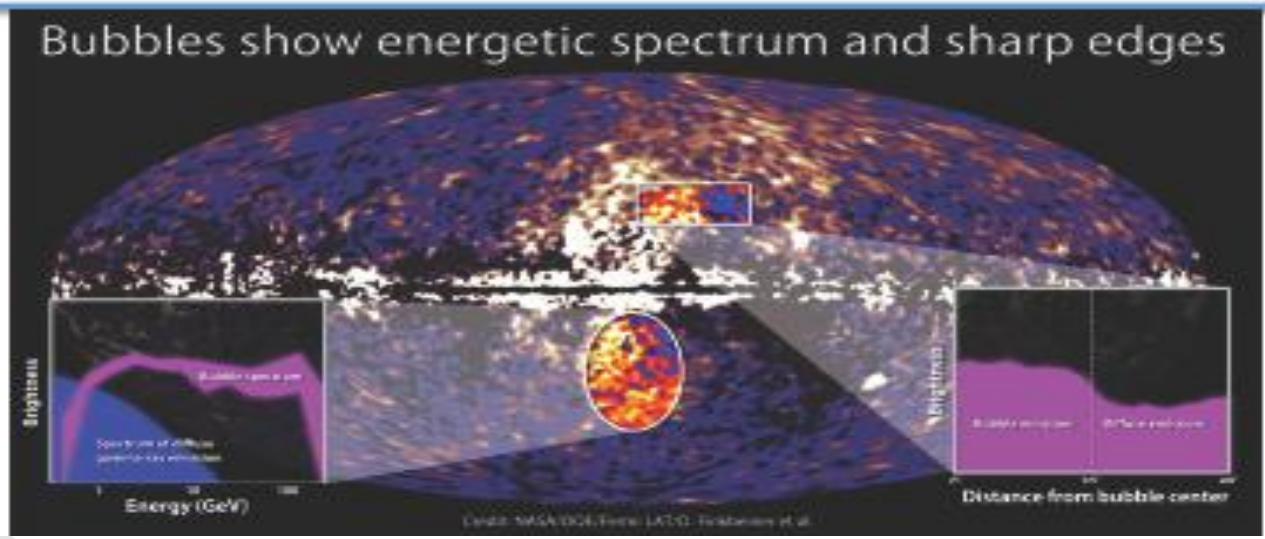


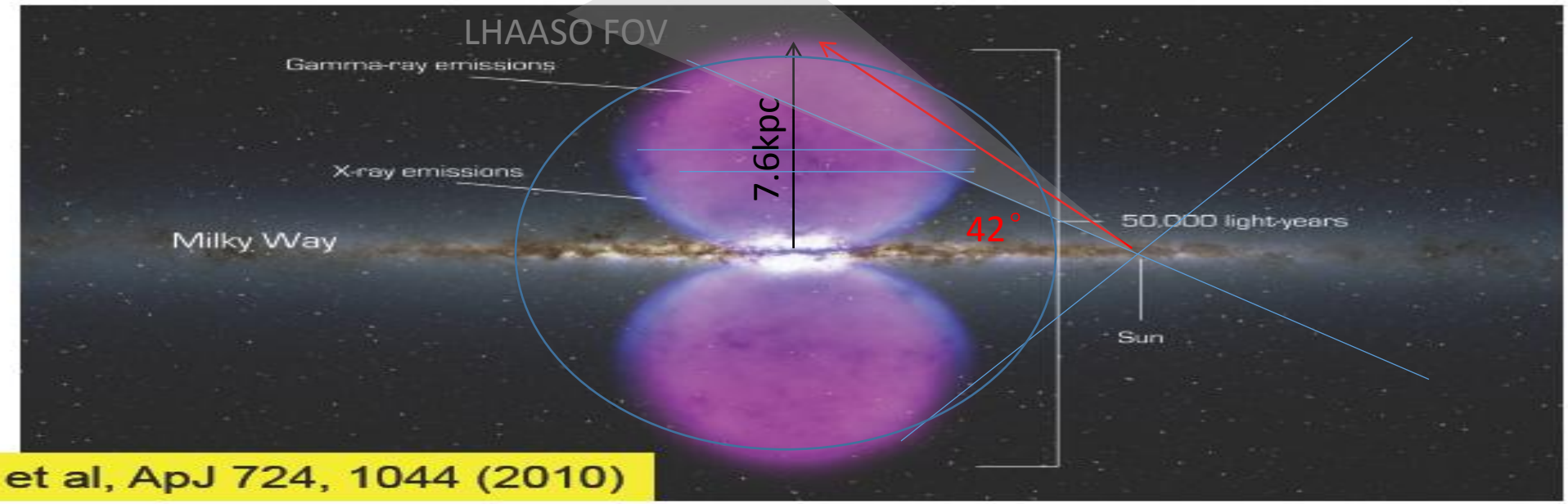


To be submitted to ApJ

Energetic *bubbles* in our galaxy

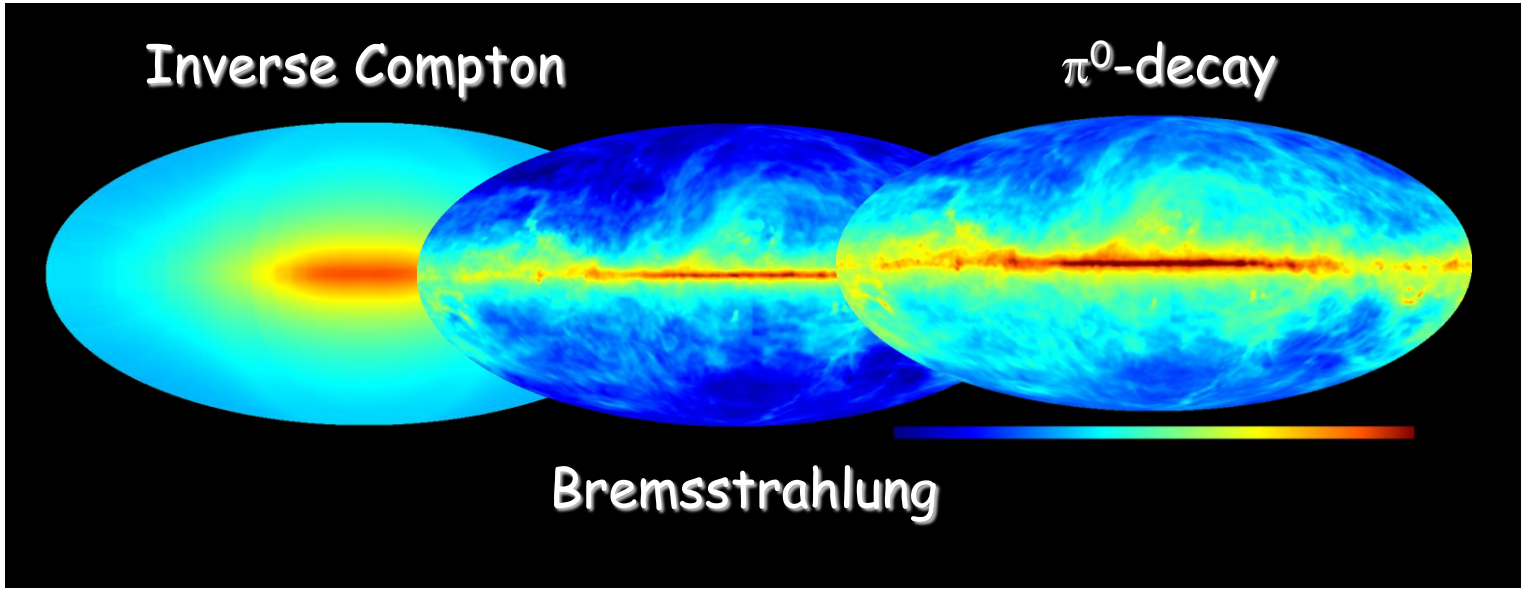






Meng Su et al, ApJ 724, 1044 (2010)

D. Galactic plane diffuse gamma-ray

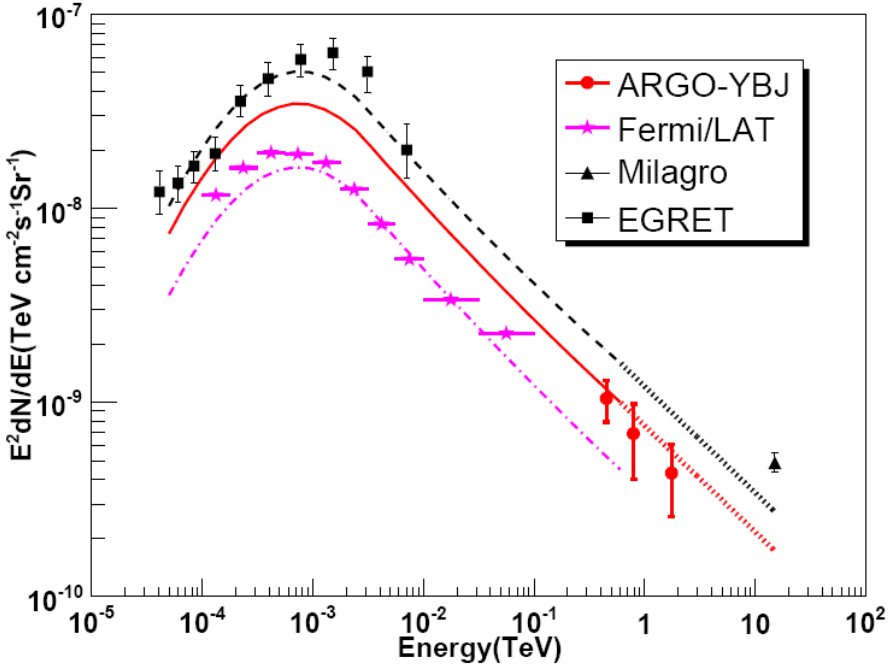


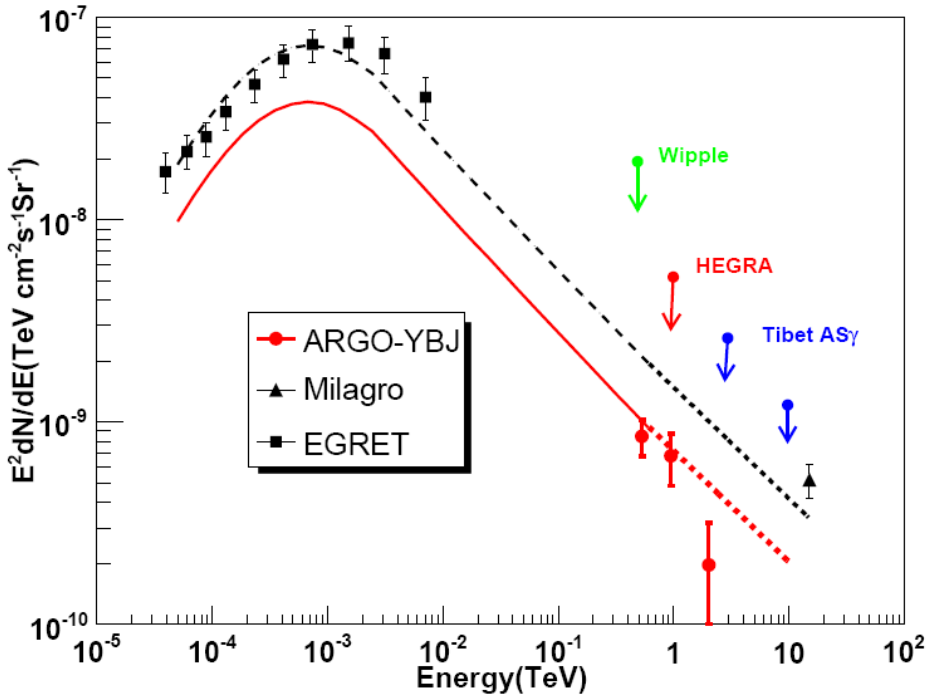
- **Diffuse gamma rays produced by interactions of cosmic rays with the interstellar medium and radiation fields. They can be used to probe the cosmic ray spectrum and density throughout the whole Galaxy.**

Diffuse γ rays: EGRET, FERMI, ARGO-YBJ and MILAGRO

$65° < l < 85°, |b| < 5°$ $25° < l < 65°$ and $85° < l < 100°, |b| < 5°$

Cygnus region

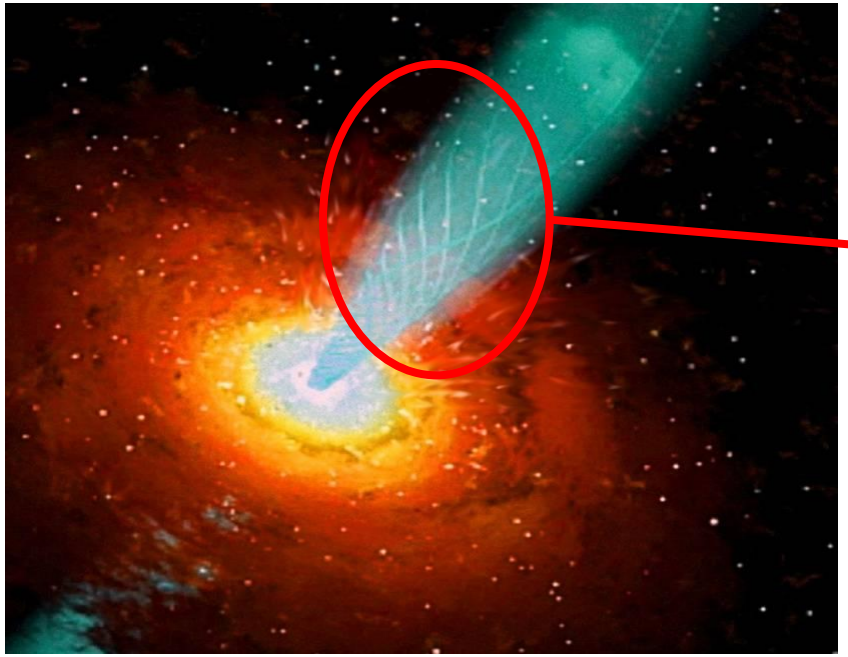


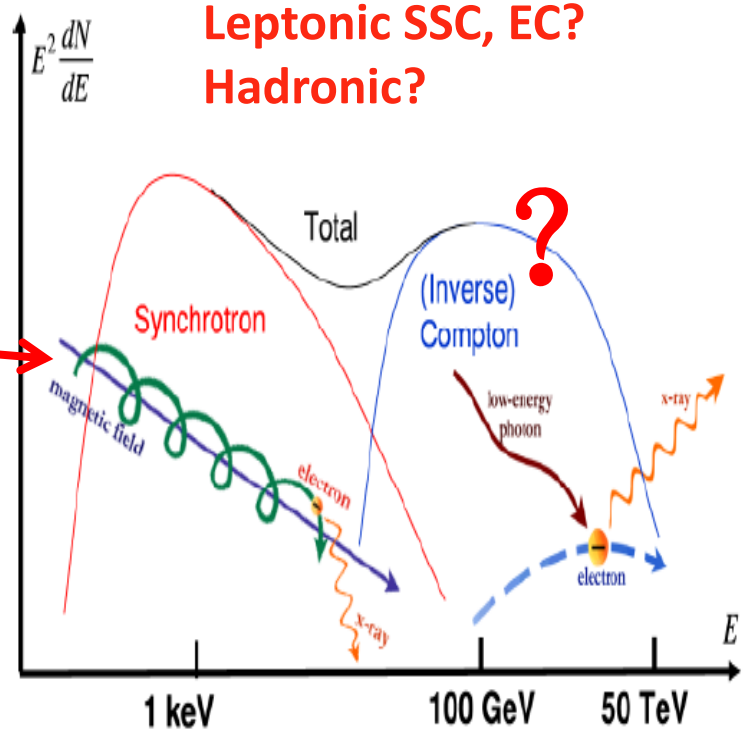


From 30MeV to 20TeV, traces CR propagation well.

To be submitted to ApJ

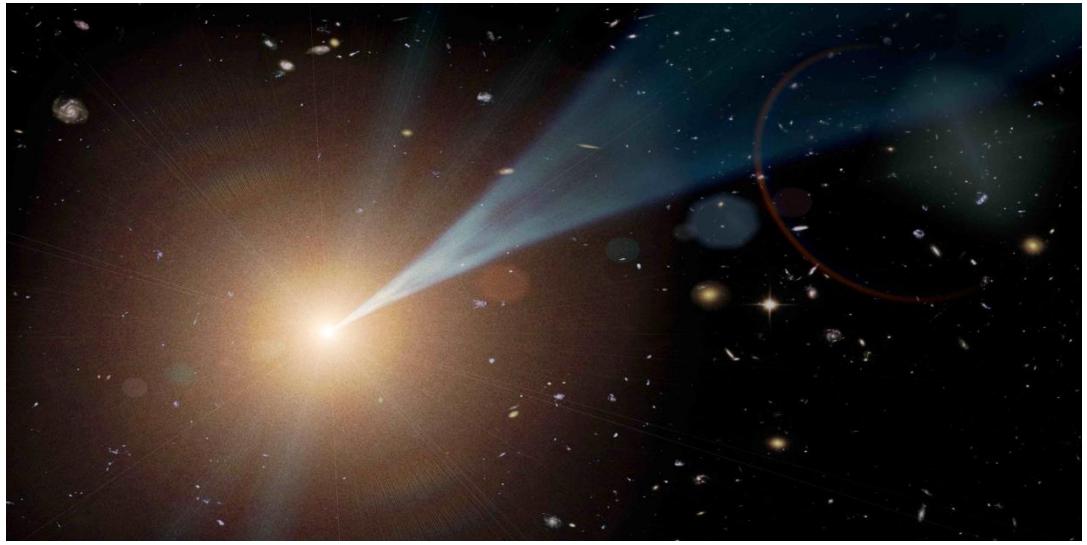
E. AGNs



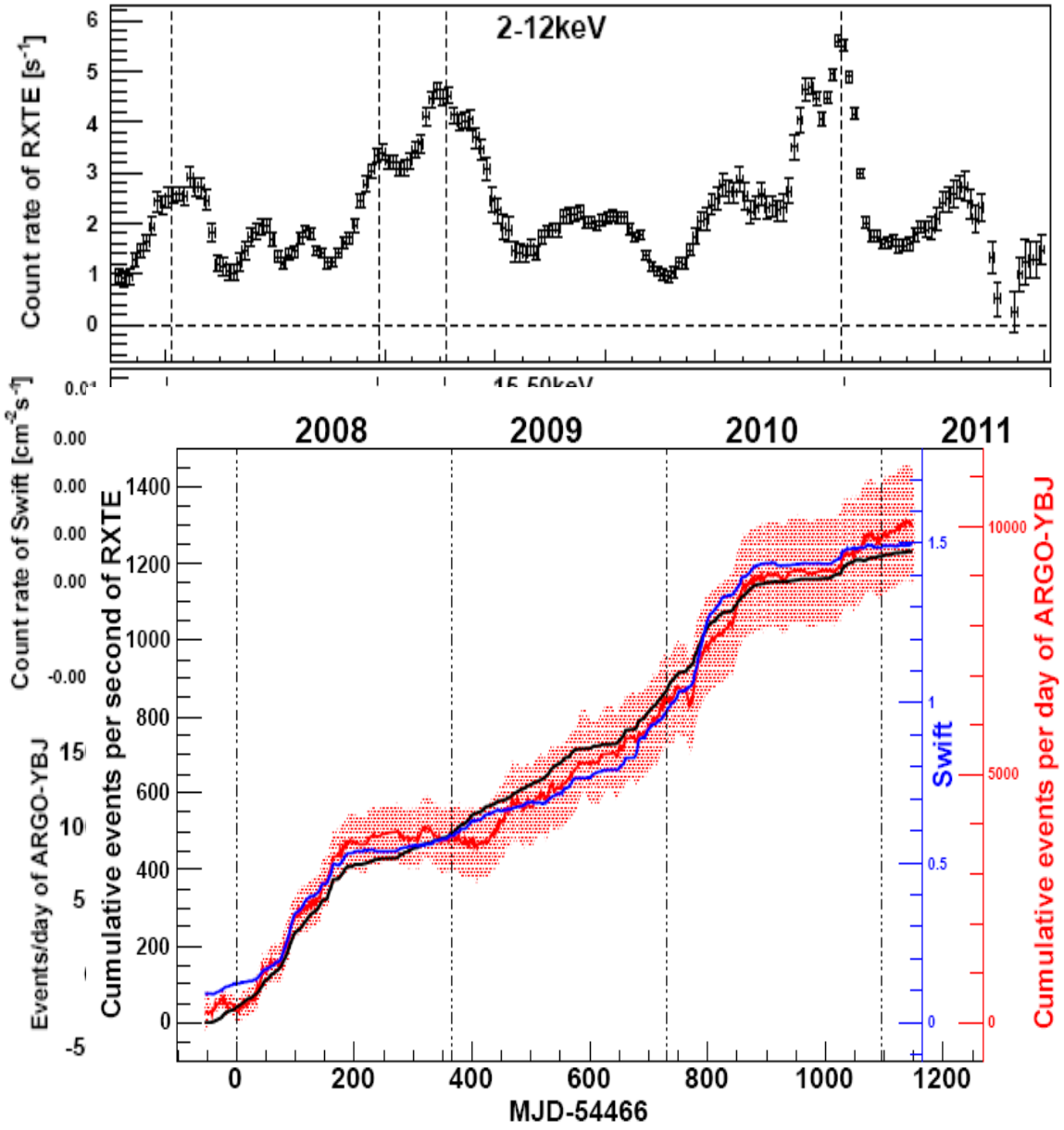


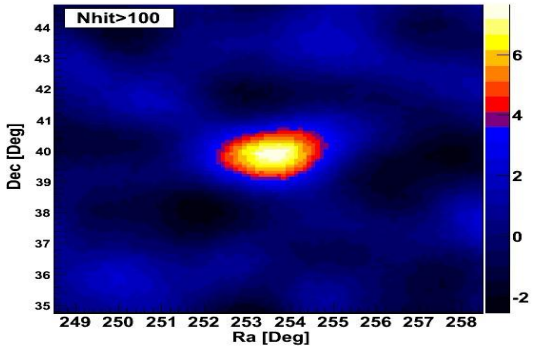
Different models will predict different correlations between low and high energy components. Thus, **long-term continuously multi-wavelength observations, especially at X-ray and TeV band,** are crucial to understand the emission mechanisms and underline processes of the outbursts.

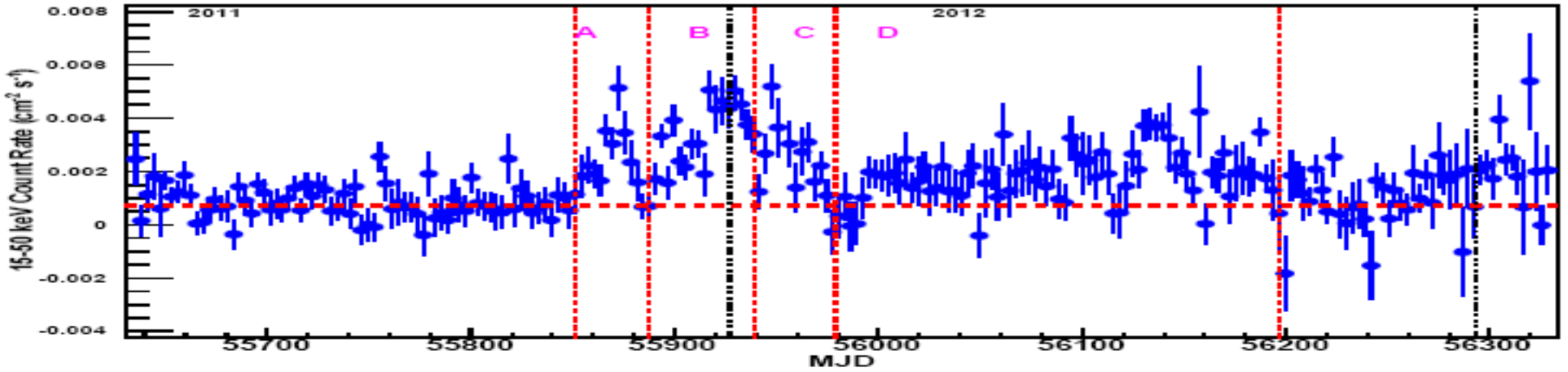
Survey of transient AGNs



Transient AGNs：Mrk421







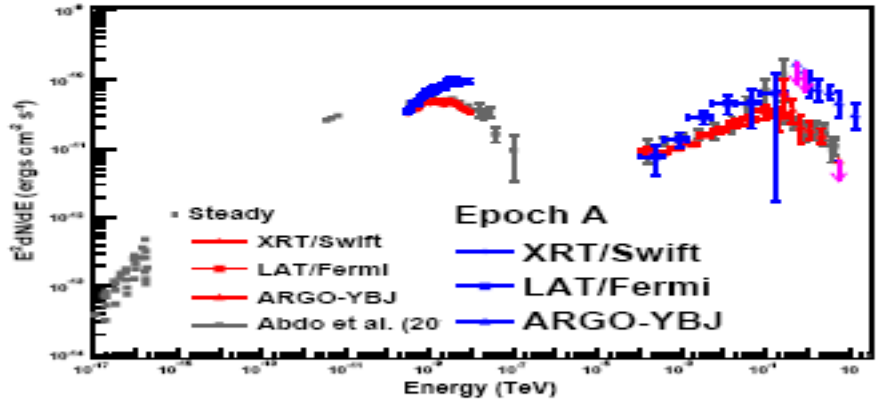
2011flare of Mrk501
S=7.7σ

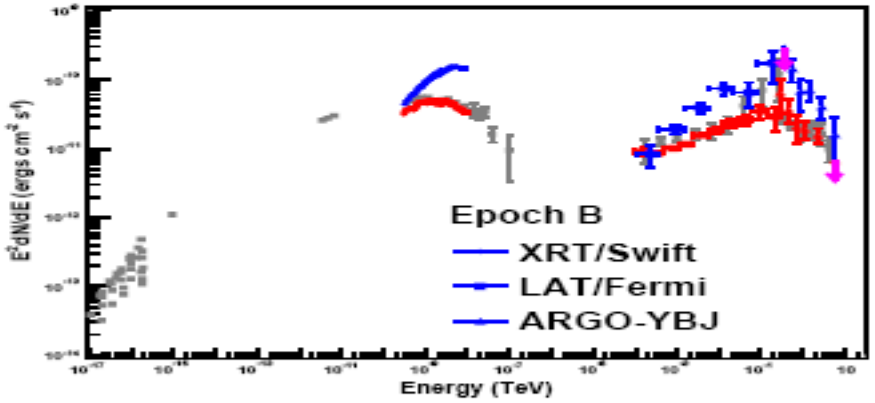
Fig. 3: Three day-averaged light curve of Mrk 501 at 15—50 keV measured by BAT/*Swift*. The vertical dashed lines indicate the four epochs analyzed in this paper. All the errors are statistical at 1 σ.

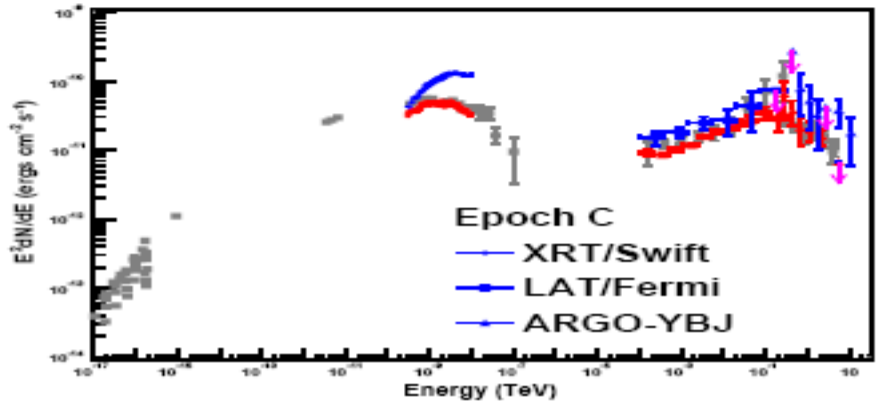
The evolution of the Spectrum during flares

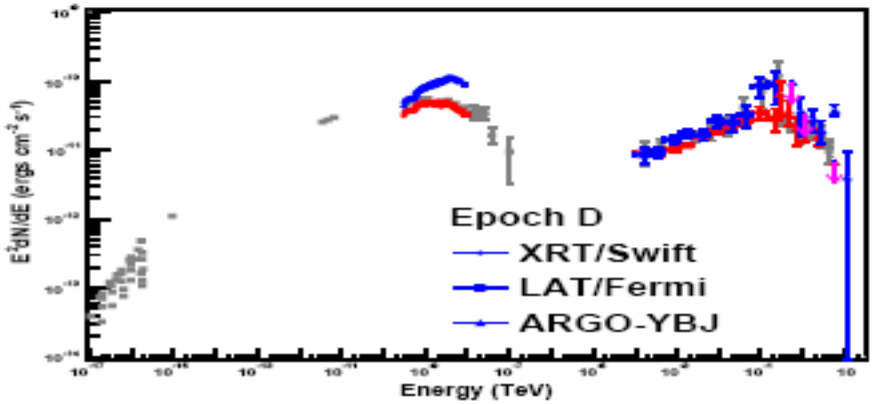
IGMF measurement

Emitting Mechanism

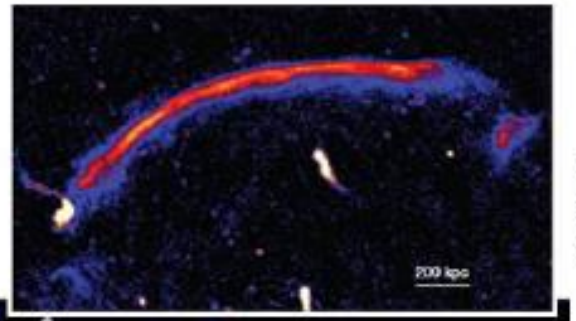


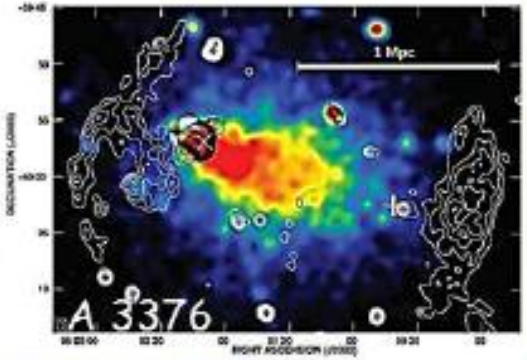


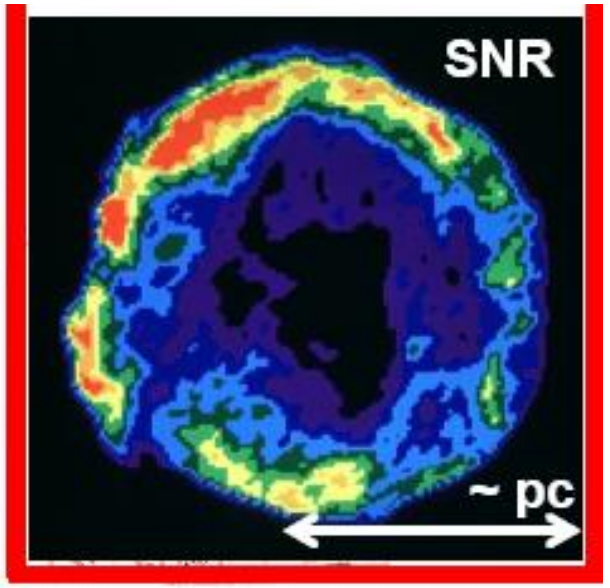


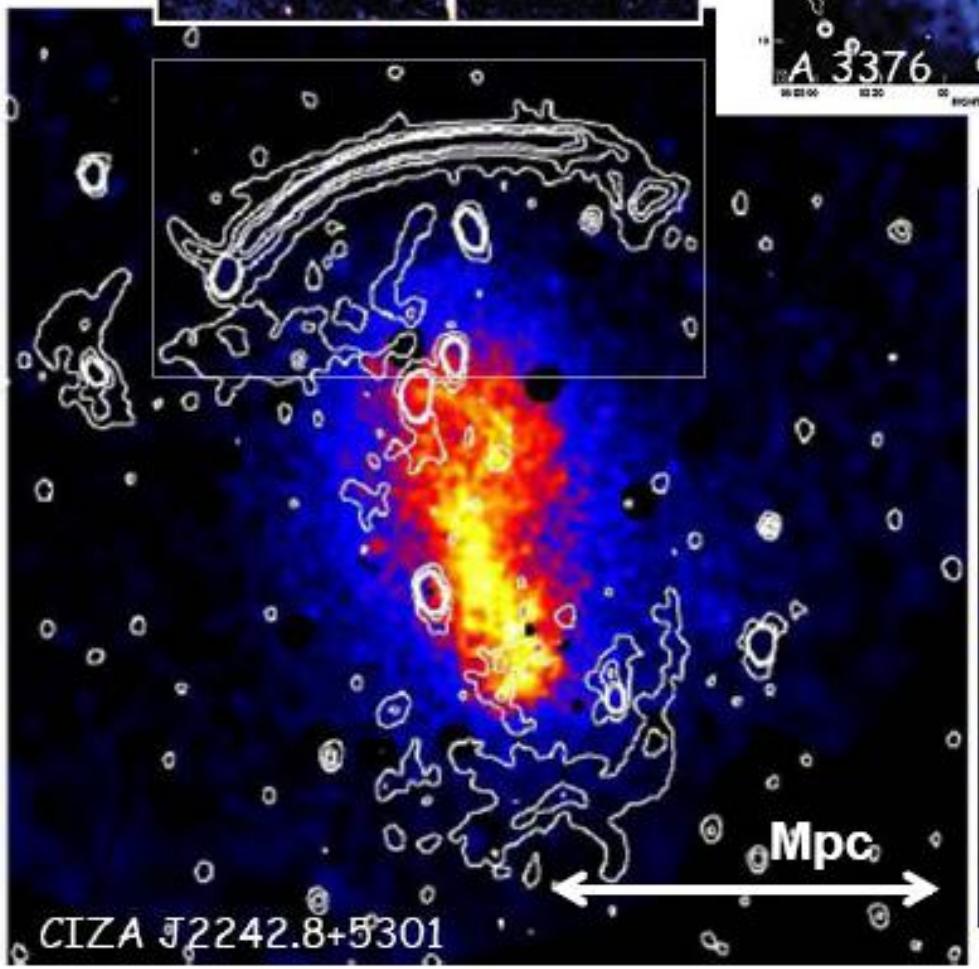


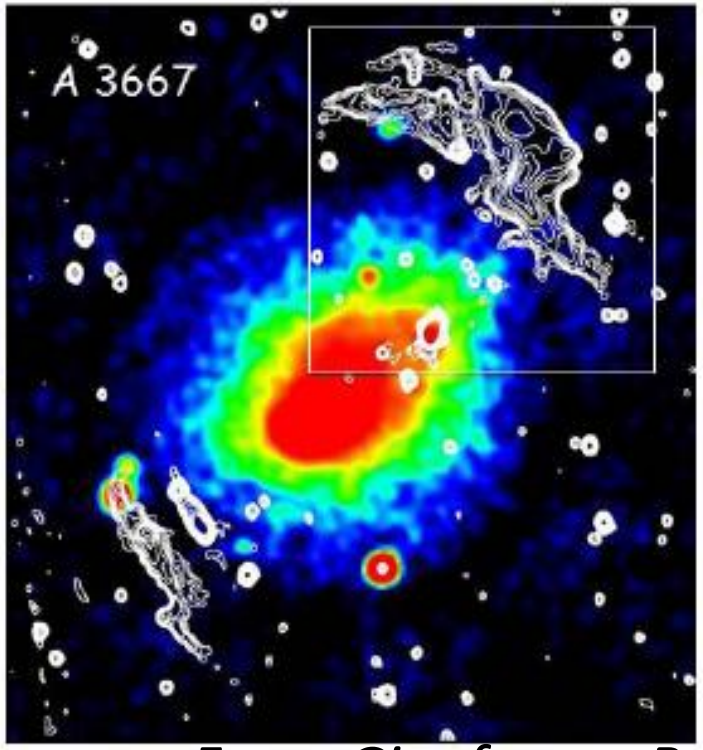
CRe: Giant Radio Relics











Exstra-galactic CR accelerators

- From *Gianfranco Brunetti, IRA , INAF*

From radio to high energies

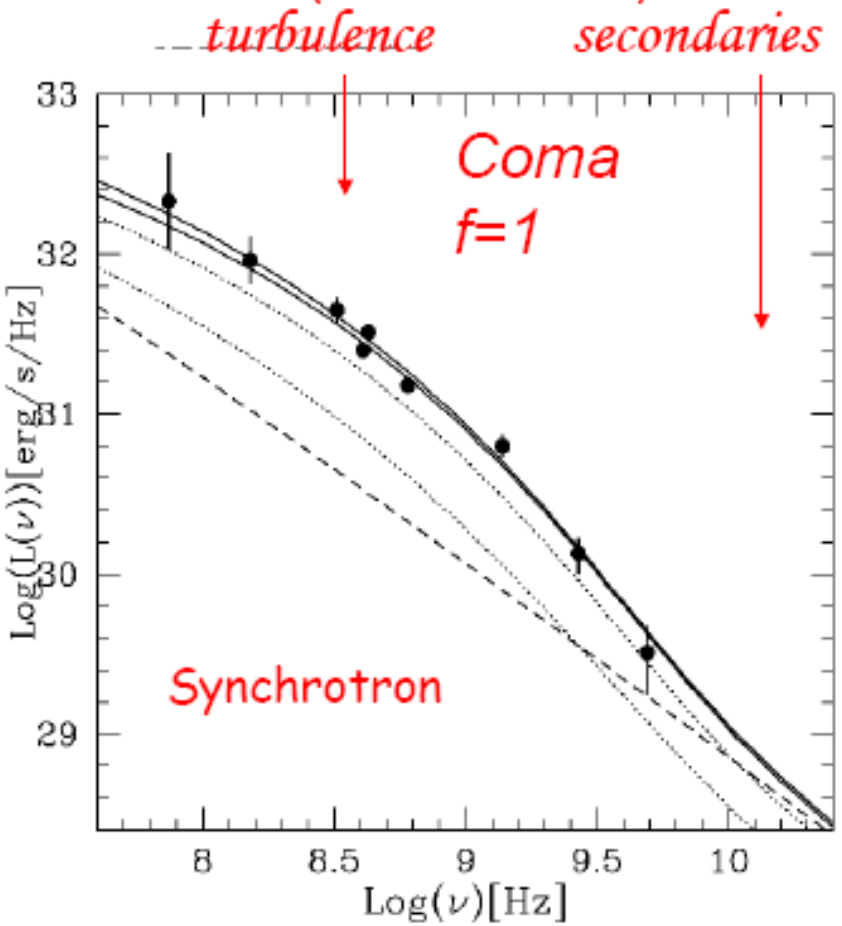
(Brunetti & Lazarian 11)

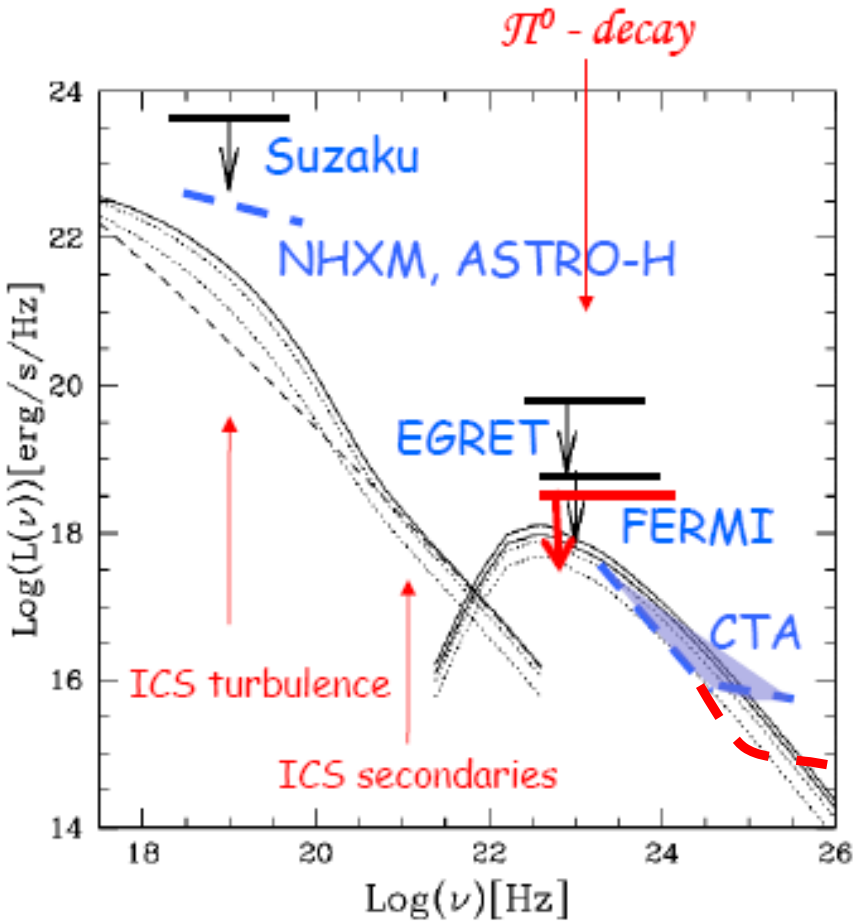
Calculations that consider the general case where both primaries (CRp,CRe) and secondaries (CRe) interact with Turbulence (reaccelerated)

$$f = \frac{PRIMARY\, e^{\pm}}{SECONDARY\, e^{\pm}} + 1$$

$E_{tur} \approx 10\ \%\ E_{th}$ @k^{-1}~100 kpc

$E_{CRp} = \sim\ \%\ E_{th}$

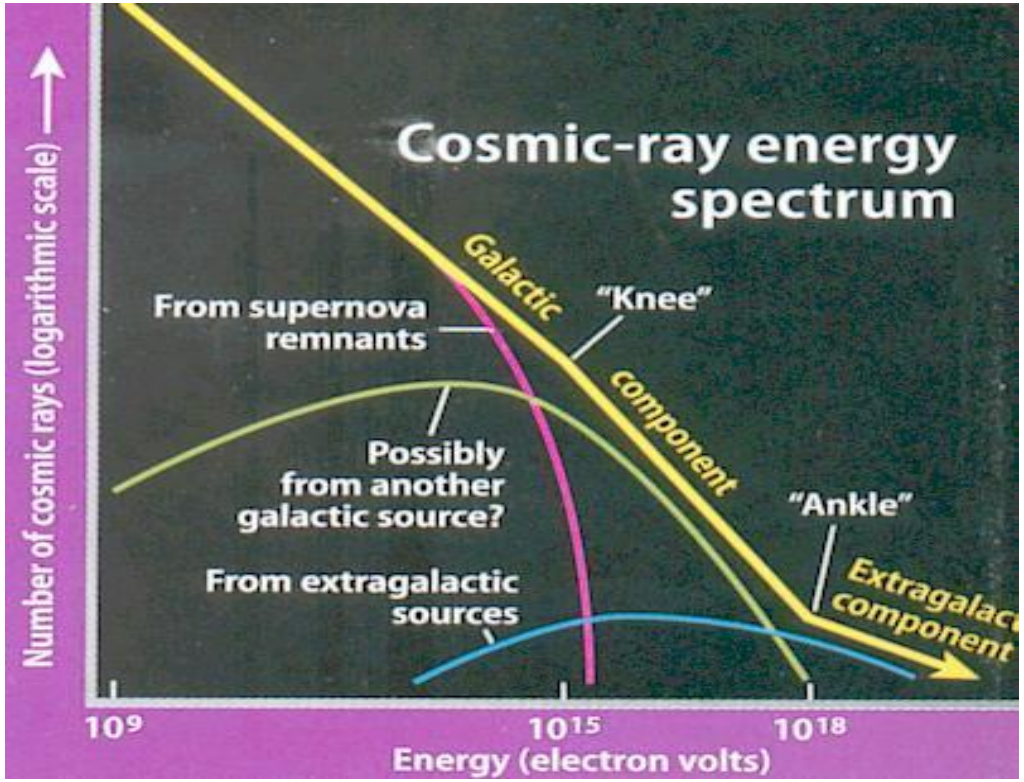


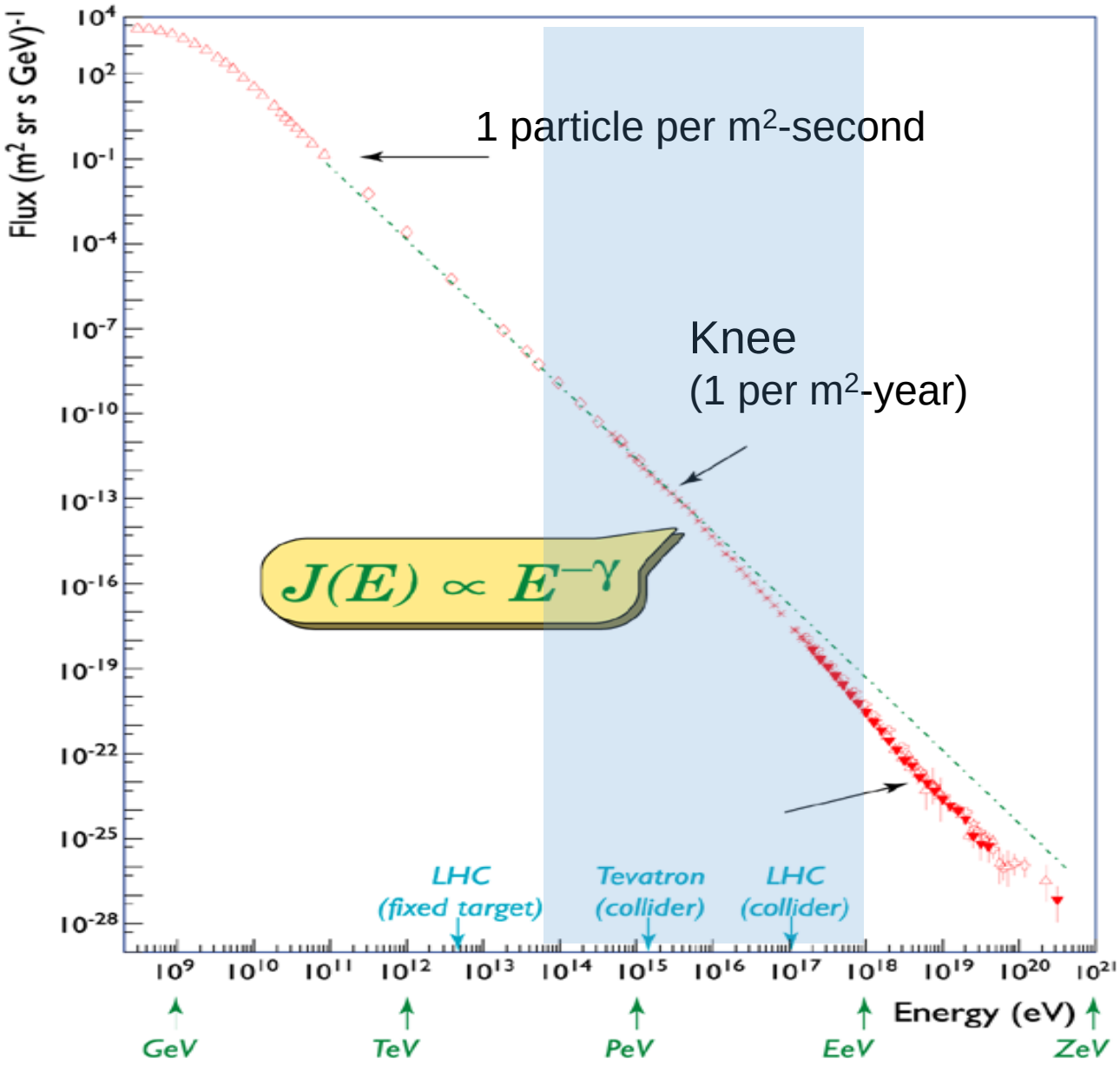


LHAASO

LHAASO science: Charged Cosmic Rays

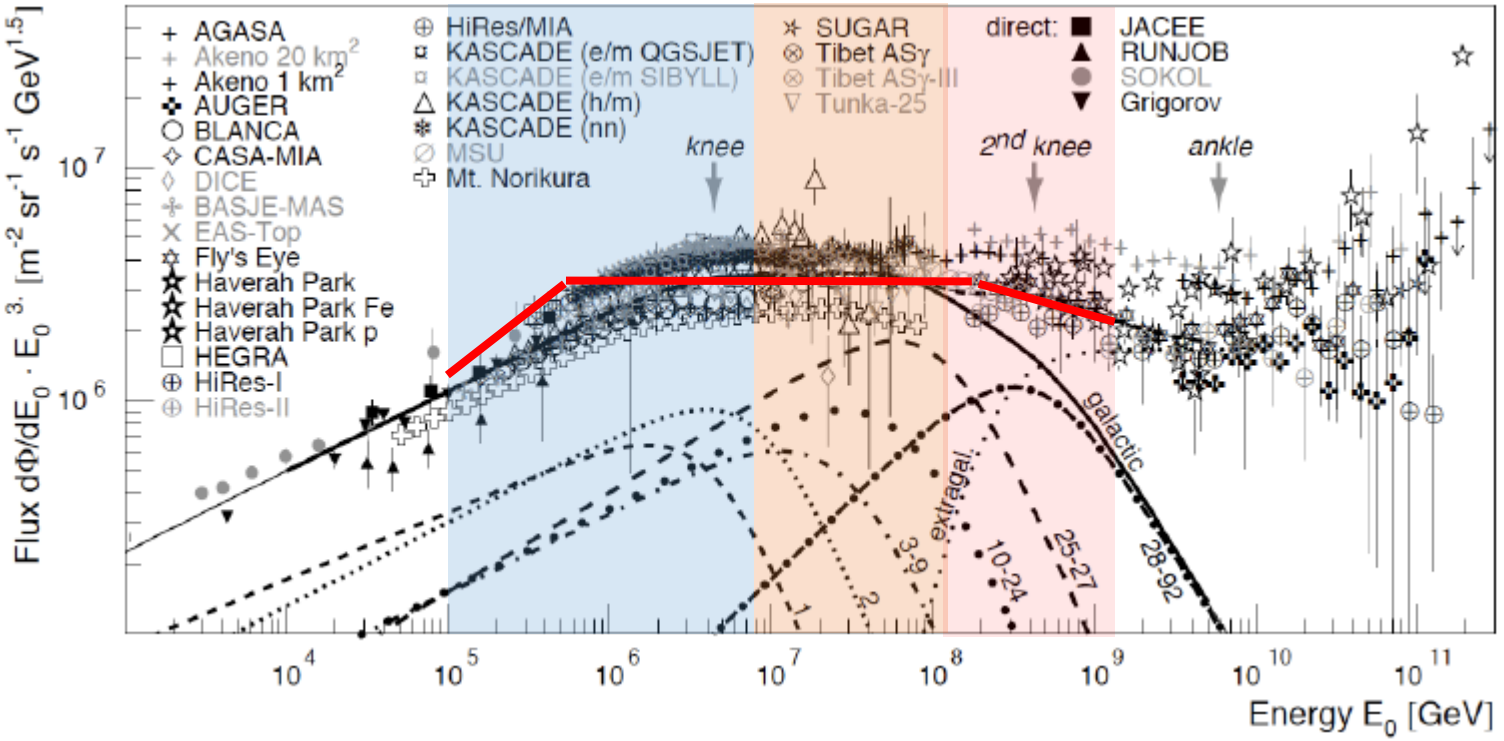
Measurement of cosmic rays above 30 TeV





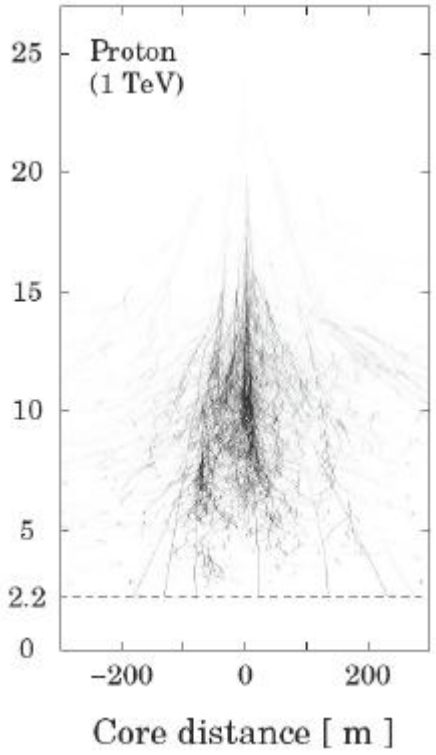
Prospects of CR Physics

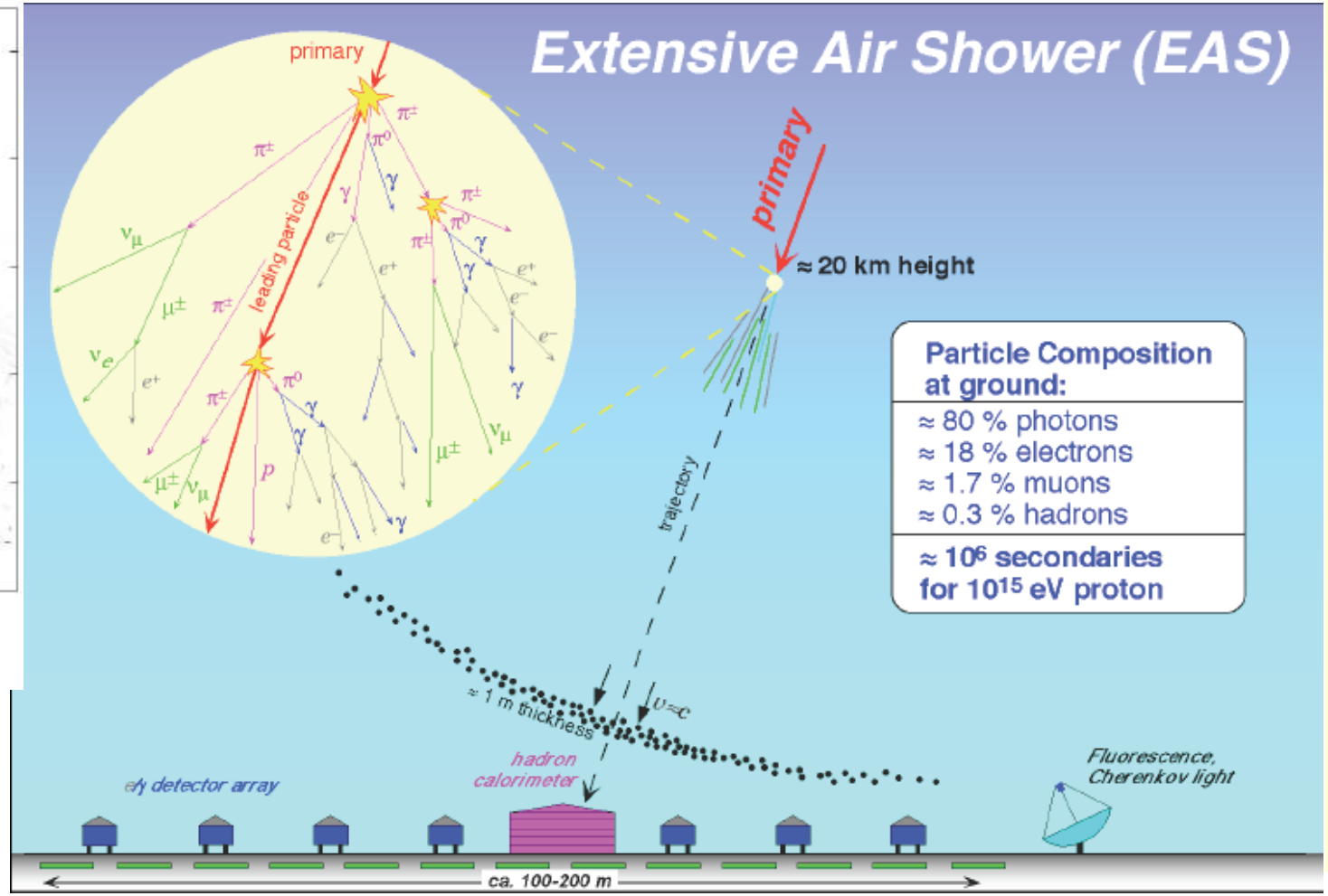
- 30TeV-10PeV
  - Energy scale
  - Knees for *H,He*,…
  - Anisotropy
- 10PeV-100PeV
  - Composition
  - Energy spectrum: knee of *Fe*
- 100PeV-2EeV
  - Spectrum bending and composition changing
  - Transition from galactic to extra-galactic

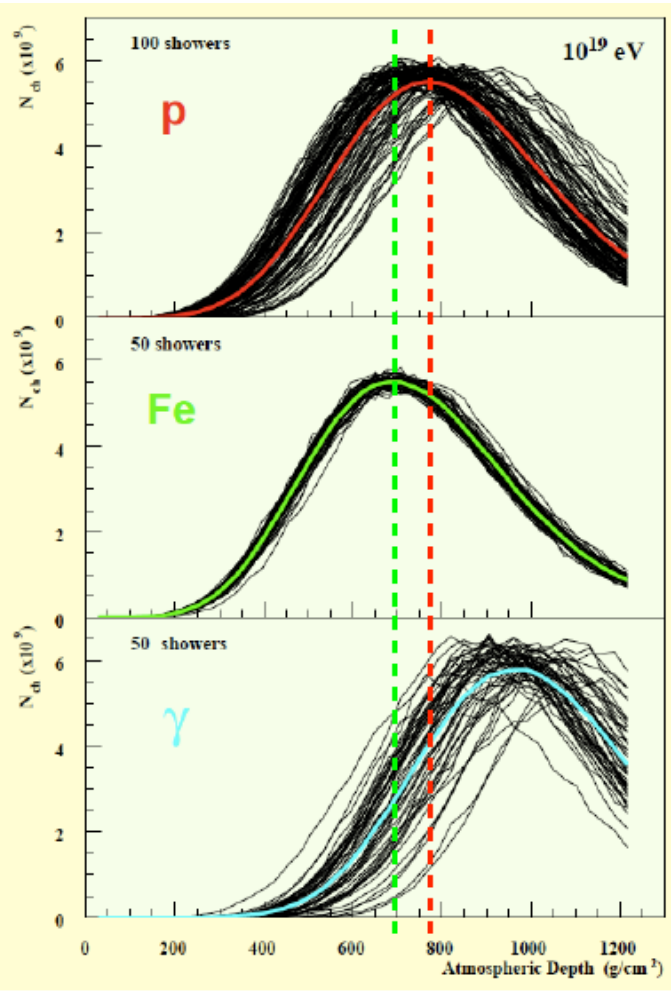


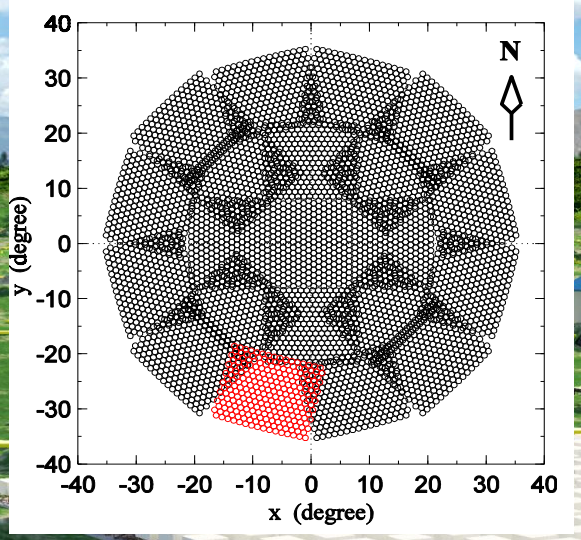
- The difficulty is to select individual species from are showers
- Event by event fluctuations and little recorded info

- **Solution: measuring more info about the showers**









Central Array：

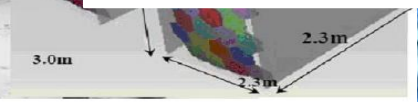
24 Wide field View Cherenkov telescopes：precision measurement of CR pectrum

452 burst detectors： identification of primary CR species

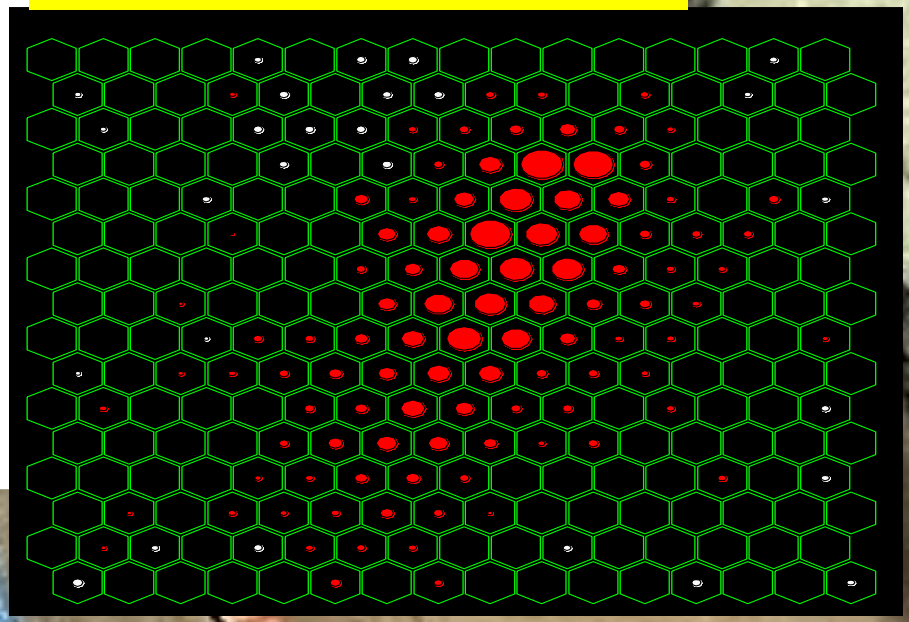
Plus scintillator detectors every 15 m and μ–detectors every 30 m

Wide Field of View Cherenkov Telescope (WFCTA/LHAASO)

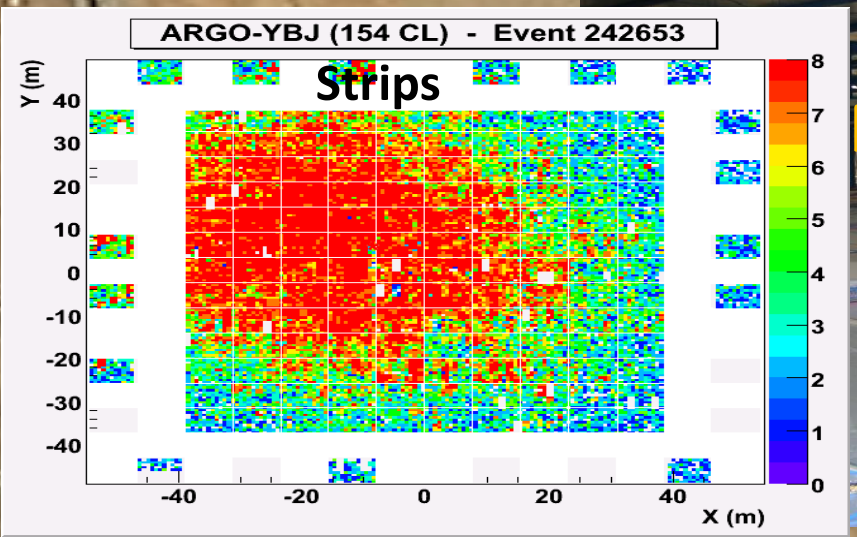
- $5m^2$ spherical mirror;
- 16×16 PMT array
- Pixel size 1°;
- FOV: 14° × 16°;
- Elevation angle: 60°.

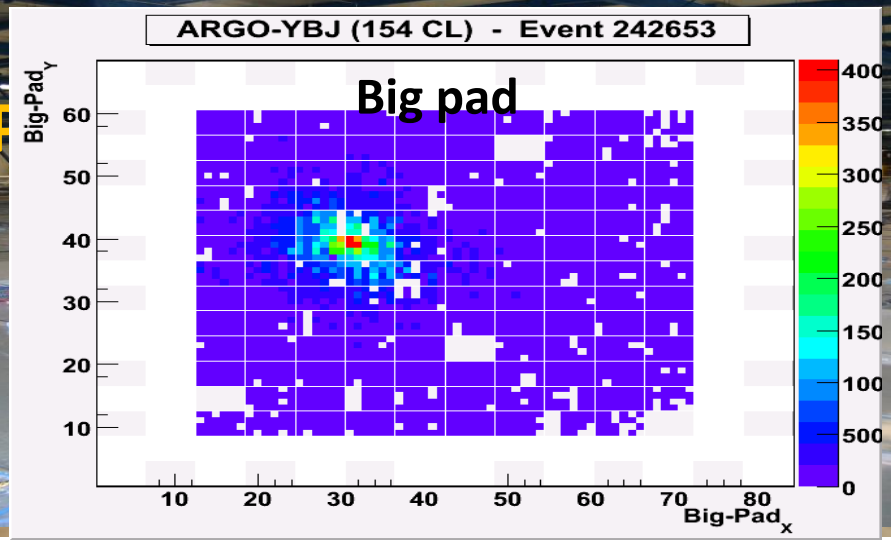


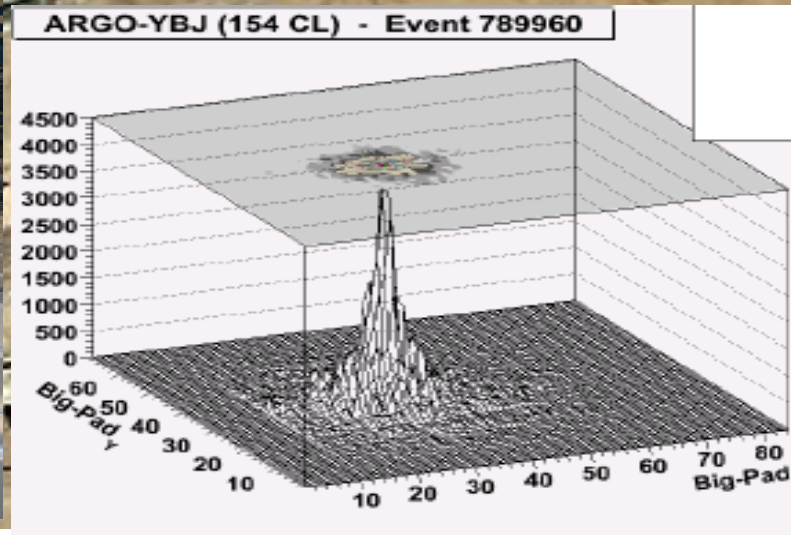
One of Cherenkov event



~ 80 m



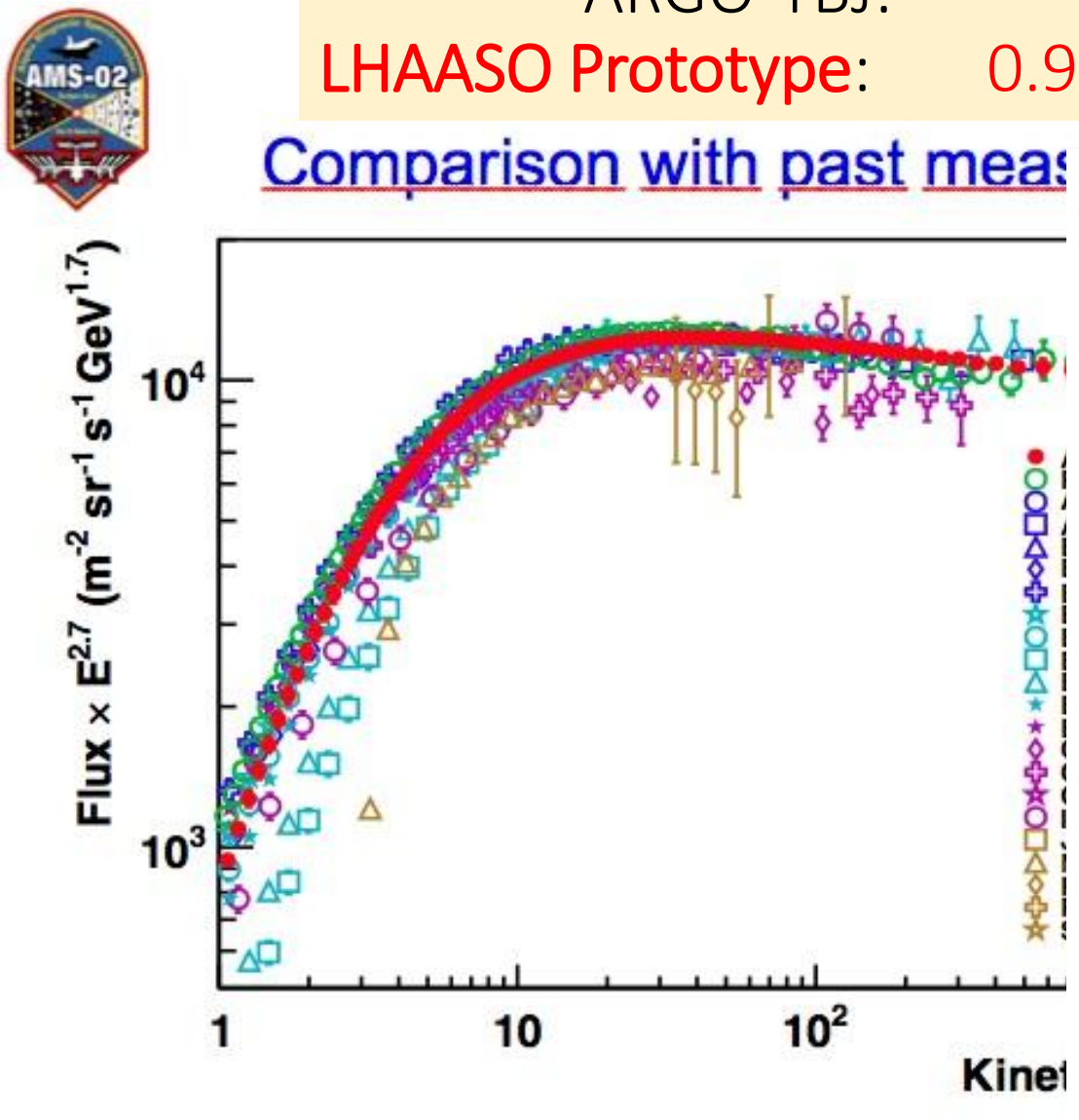


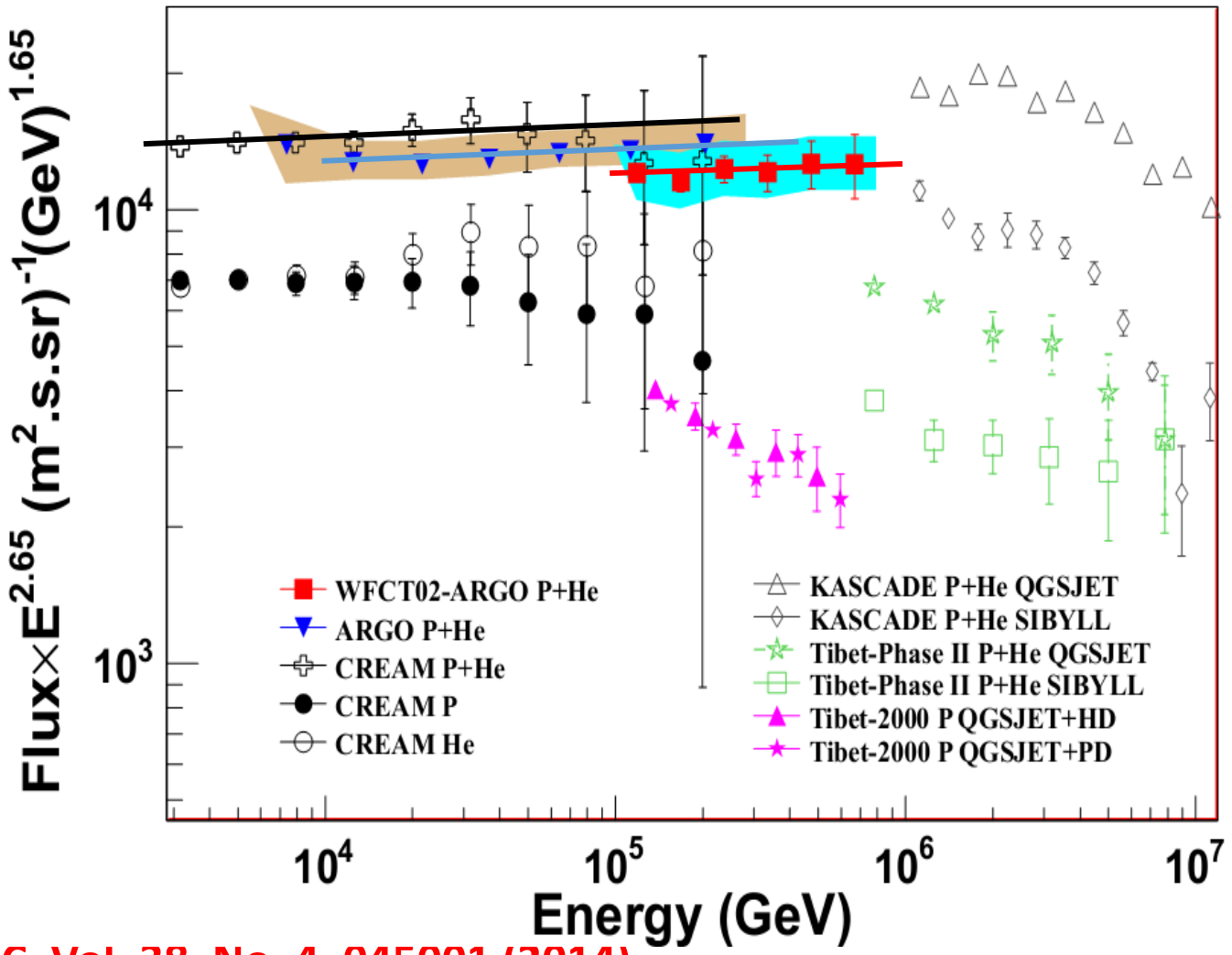


CREAM: $1.09 \times 1.95 \times 10^{-11} (E/400\text{TeV})^{-2.62}$

ARGO-YBJ: $1.95 \times 10^{-11} (E/400\text{TeV})^{-2.61}$

LHAASO Prototype: $0.94 \times 1.95 \times 10^{-11} (E/400\text{TeV})^{-2.62}$





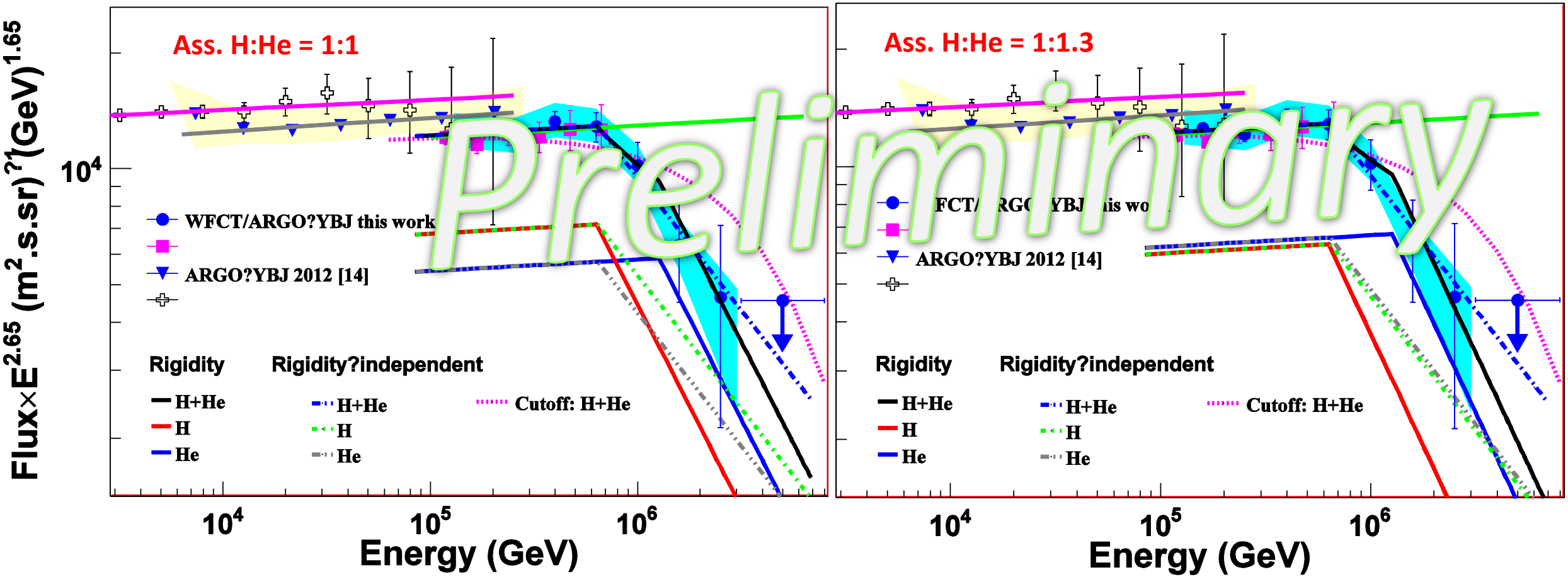
B. Bartoli et al, Chinese Physics C, Vol. 38, No. 4, 045001 (2014)

Discover the “knee” of the Proton Spectrum below 1 PeV

~6σ deviation from the single-index power law

the knee is at (640 ±87) TeV

spectral index is >3.3 above the knee



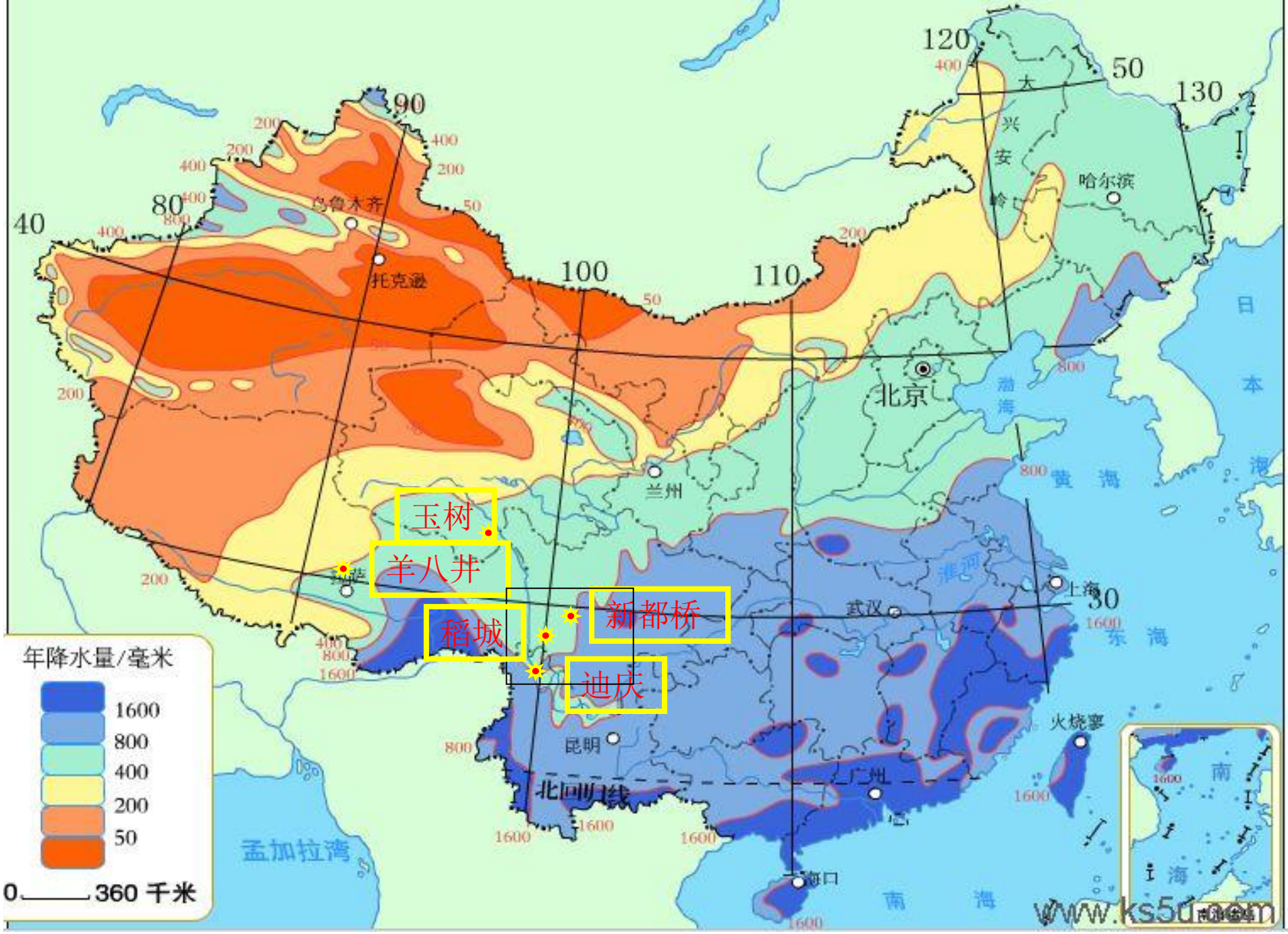
Status of LHAASO

- LHAASO has been included in the roadmap of the infrastructure construction for basic science in a short term (5 years). Total 16 projects are included.
- The local government has approved the LHAASO site last month.
- A ceremony of signing the LHAASO-MOU by the CAS president and Sichuan governor is tentatively scheduled on June 5th.
- Engineering arrays at scales of 1%-10% of the full project.
- Steps ahead: environment impact evaluation, feasibility reviewing, TDR reviewing

The Site

降水：

稻城附近的降水量不如香格里拉，玉树就更少，但都集中在6、7、8三个月（>80%）



地理位置：S217穿过海子山自然保护区中间地带

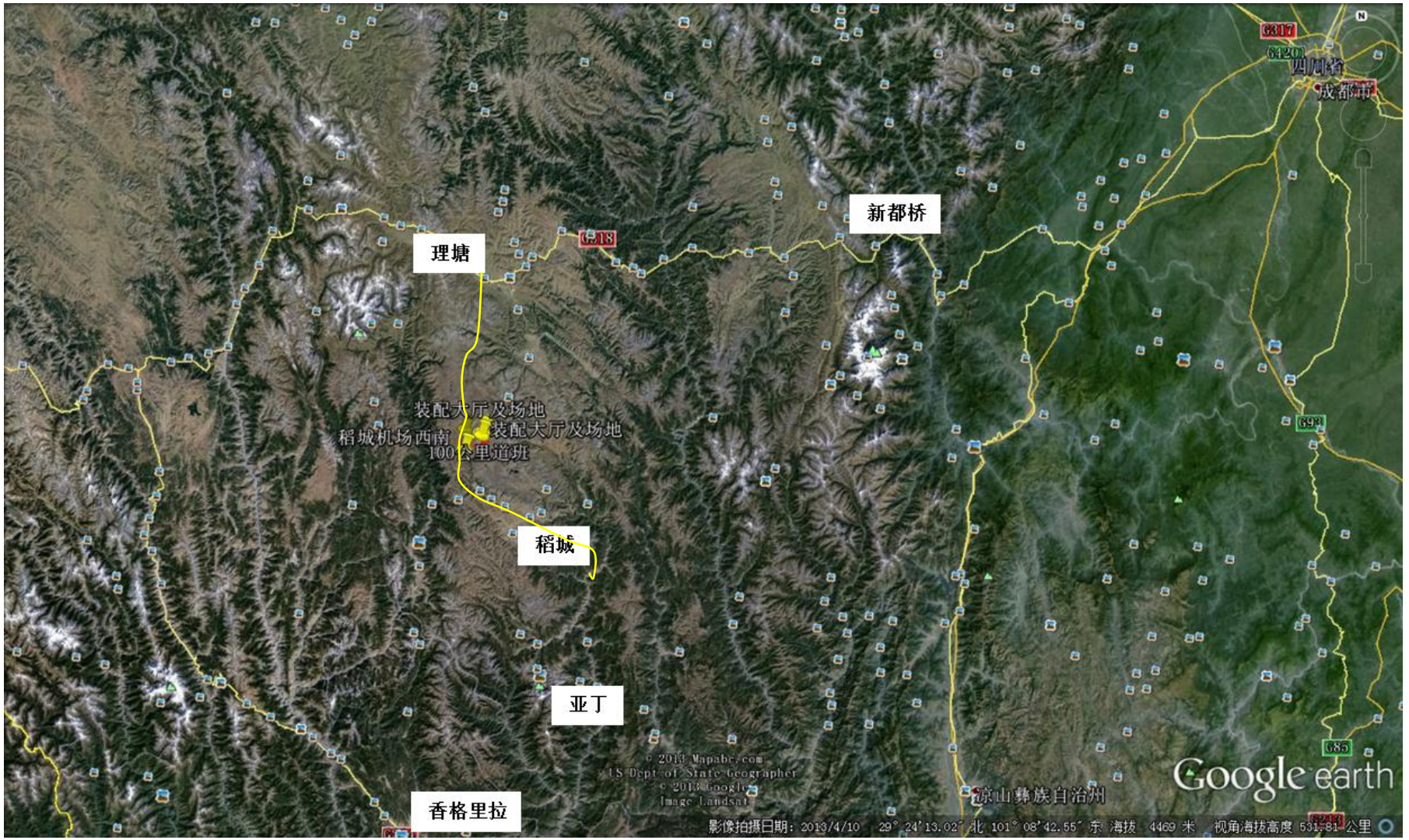
北纬29°21’30.7”，东经100°08’14.65”

海拔4400米

距稻城50公里

距理塘98公里

距成都708公里



理塘（3950m）90公里

兴伊措
4426m

城机场北

装配大厅及场地
装配大厅及场地
装配大厅及场地

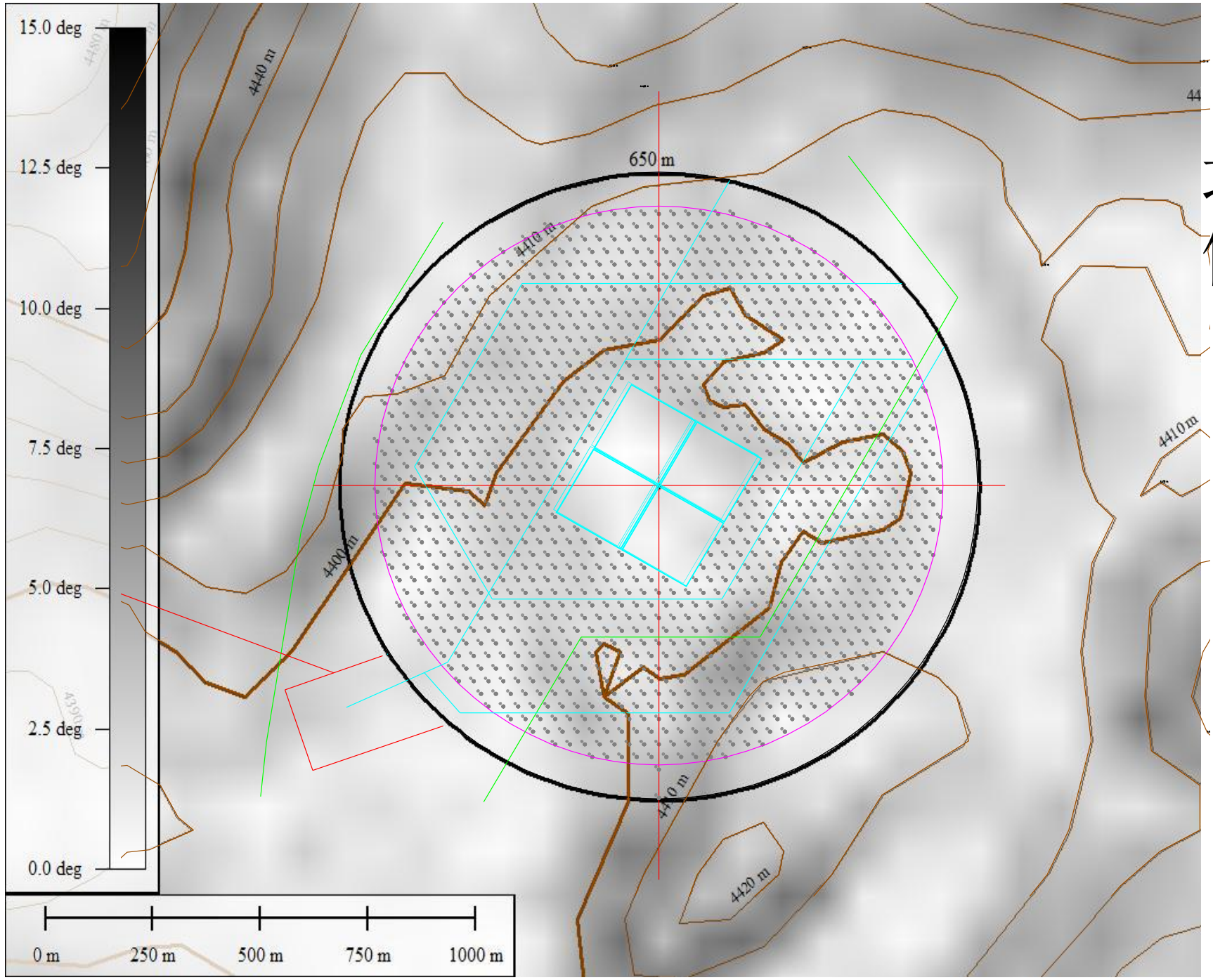
稻城亚丁机场
4410m

~10公里

稻城（3740m）40公里

稻城海子山LHAASO站址

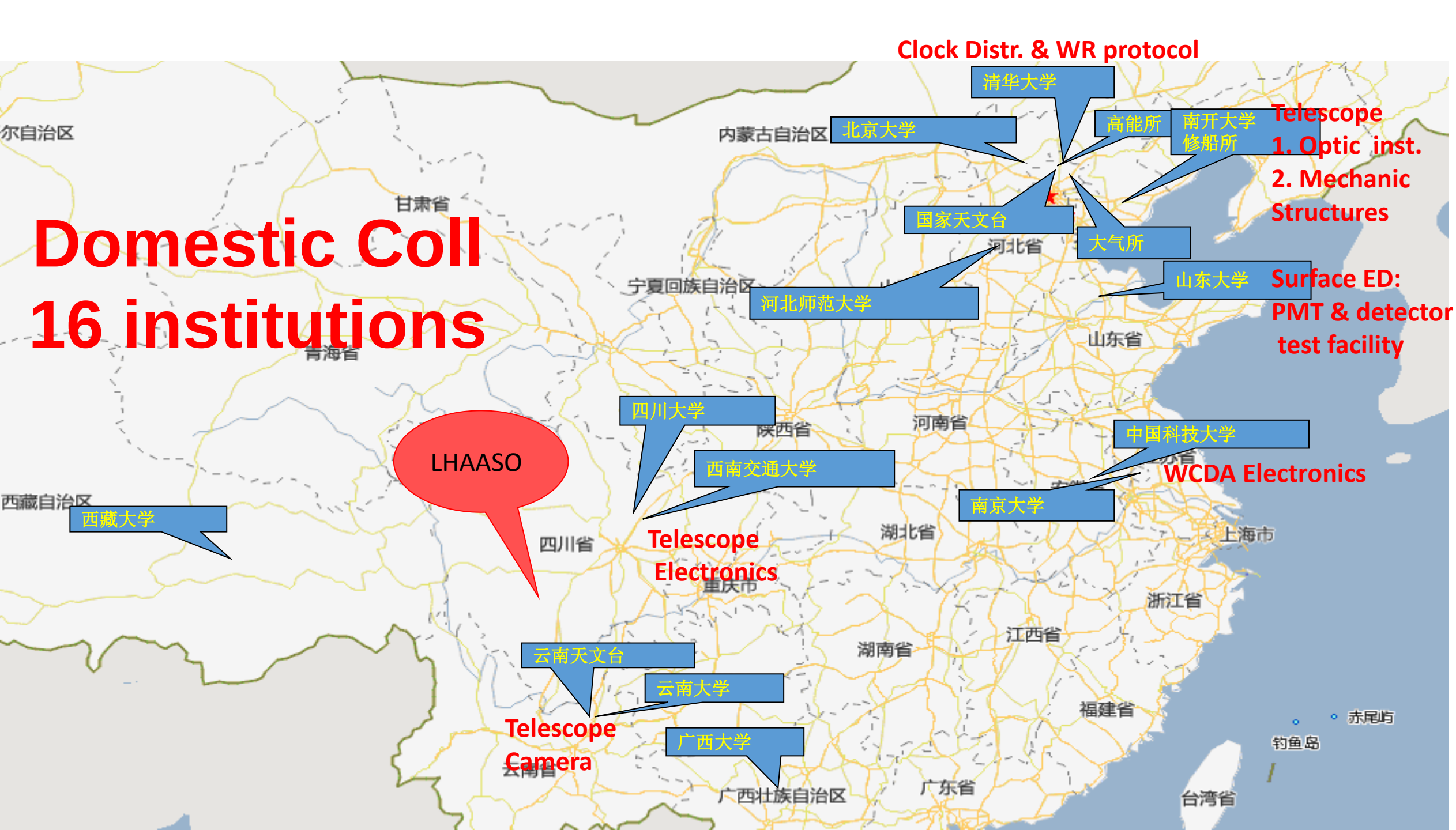
场地中心：
29度21分30.7秒，
100度08分14.65秒
公路入口：
29度21分32.76秒，
100度07分43.03秒
场地西边界：
29度21分30.61秒，
100度07分50.61秒
场地东边界：
29度21分30.68秒，
100度08分38.73秒
场地北边界：
29度21分51.78秒，
100度08分14.50秒
场地南边界：
29度21分9.54秒，
100度08分14.73秒



地形地貌：倾斜度与等高线

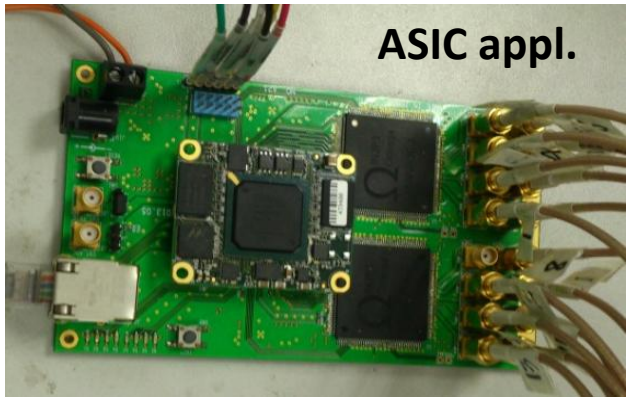
倾斜度大部分小于2度（3.5%）
最大6.38度（11.2%）
最高4423米，
最低4397米，
高差26米（google图）

两条小溪流经，汇入场地南侧的小河
表面为冰川遗迹，存大量飘砾
靠近水边有高山杜鹃灌木
少量草
表面腐殖质~30cm
土石混合层1~数米


Clock Distr. & WR protocol
清华大学
北京大学
高能所
南开大学
修船所
Telescope
1. Optic inst.
2. Mechanic
Structures
国家天文台
大气所
山东大学
Surface ED:
PMT & detector
test facility
河北师范大学
Domestic Coll
16 institutions
四川大学
LHAASO
西南交通大学
中国科技大学
WCDA Electronics
南京大学
西藏大学
Telescope
Electronics
云南天文台
云南大学
Telescope
Camera
广西大学
内蒙古自治区
甘肃省
宁夏回族自治区
河北省
山东省
青海省
陕西省
河南省
西藏自治区
四川省
湖北省
上海市
重庆市
浙江省
江西省
湖南省
福建省
广东省
广西壮族自治区
台湾省
赤尾屿
钓鱼岛

International Collaboration

- **Physicists (IPN-Orsay)**
  - **Yingtao Chen (PhD student funded by CSC)**, Olivier Deligny, Isabelle Lhenry-Yvon, Tiina Suomijärvi, Francesco Salamida (post-doc)
  - New PhD student, Zizhao Zong, currently applying funds from CSC
- **Technical group**
  - Valérie Chambert, Bengyun Ky, Emmanuel Rauly, Thi Nguyen Trung, Eric Wanlin (IPN-Orsay)
  - Gisèle Martin-Chassard, Frederic Dulucq, Christophe de la Taille (OMEGA)
- CAS Project for the China-France collaboration is approved (1.1 M CNY) this year



- Proposing with Italian colleagues: G-astro, GRBs,DM,CRs (submitting to INFN)
- Working group with Russian for neutron detectors
- Thailand solar CR group (working together)

Conclusions

- LHAASO observatory
  - Unique at 10 TeV gamma monitoring
  - Window for evidence for hadronic origin of cosmic rays
  - Provides also crucial CR data in the region of knees
- LHAASO has been selected for funding in China.
- Agreement with Sichuan province for site is scheduled to be signed on June 5th
- Domestic collaboration: for 25 sub-systems
- International Coll. is growing

at Tibet site

et of ~1M

euro sinc