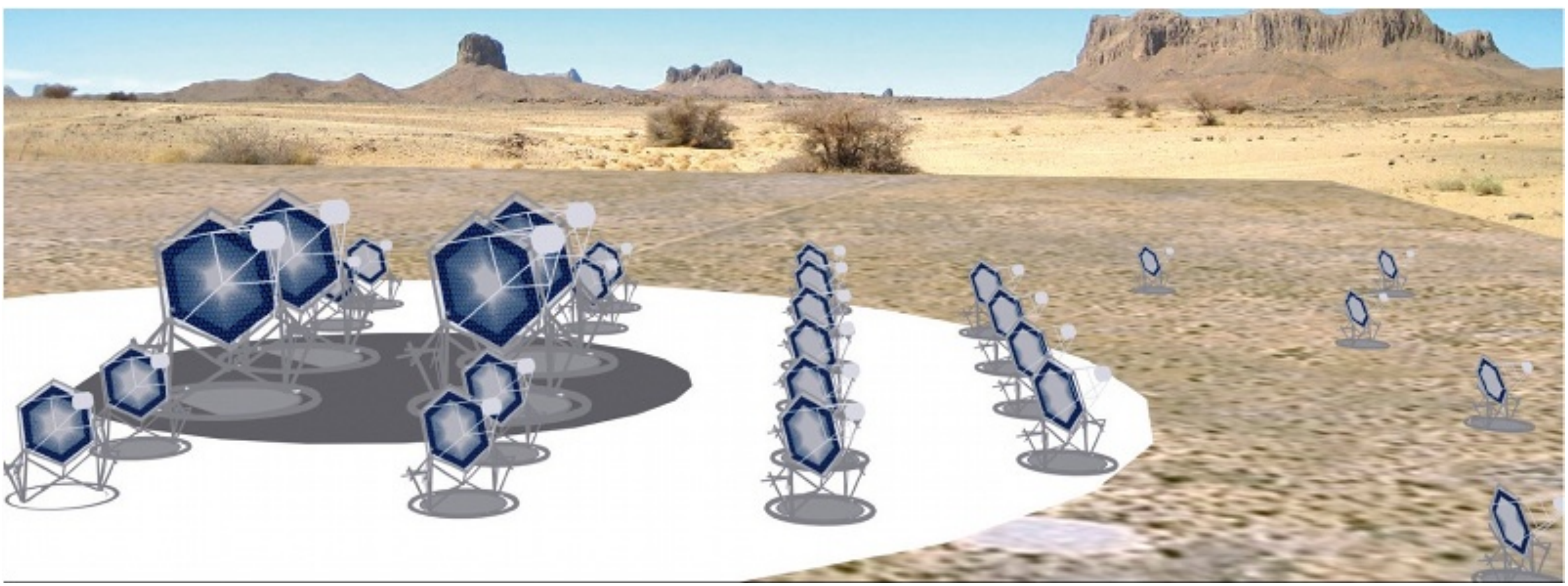
Status and Plans for the Cherenkov Telescope Array

Brian Humensky
University of Chicago / Columbia University
June 11, 2011
on behalf of the CTA Consortium

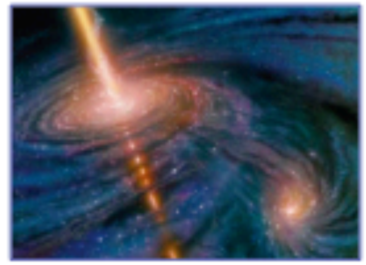


Outline

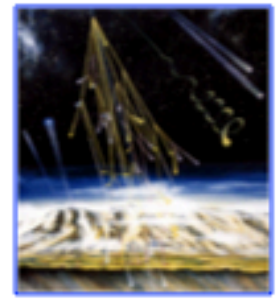
I. Science Drivers

II. Status and Plans for CTA

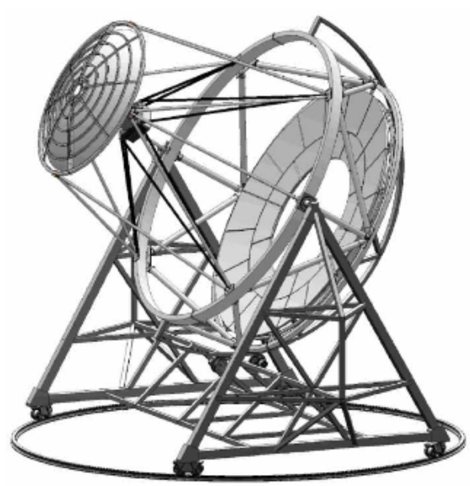
III. CTA-US Activities

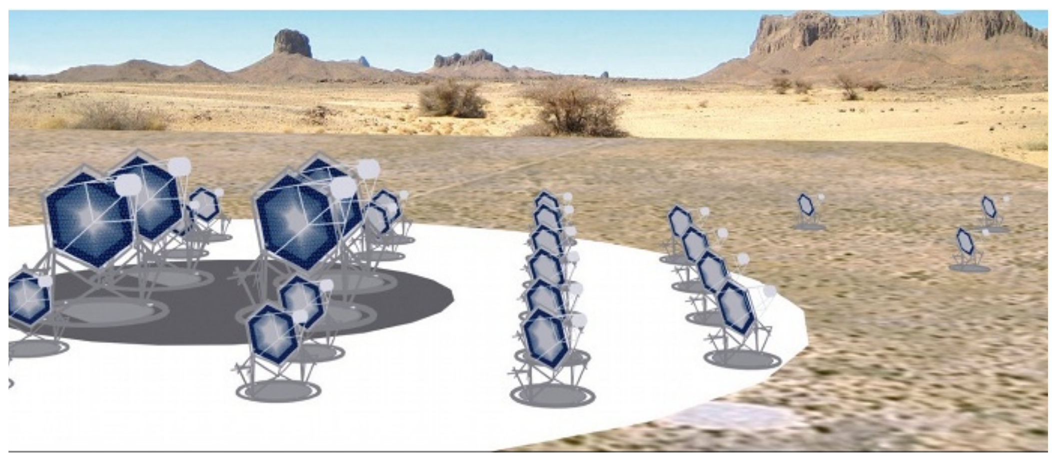


AGNs



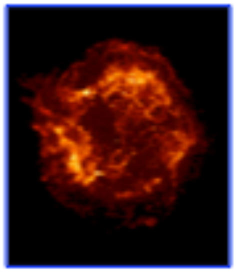
Origin of cosmic rays

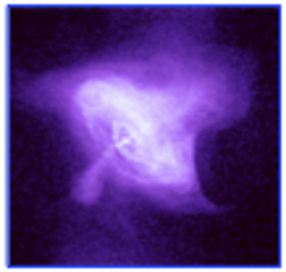




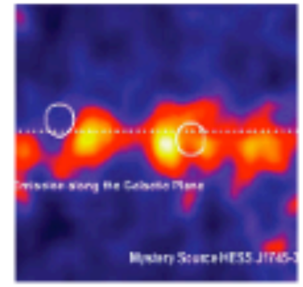
Gamma-ray Science – Broad!

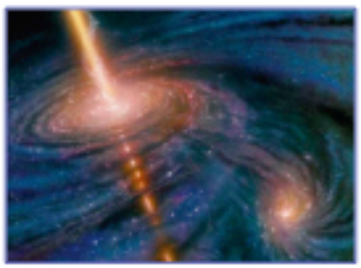
cta
cherenkov telescope array

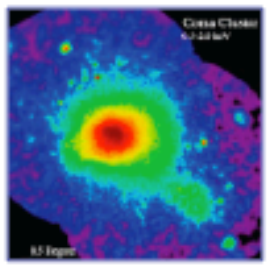

SNRs


Pulsars and PWN


Micro quasars
X-ray binaries

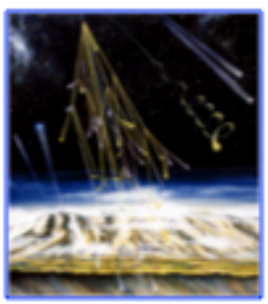

Galactic Center

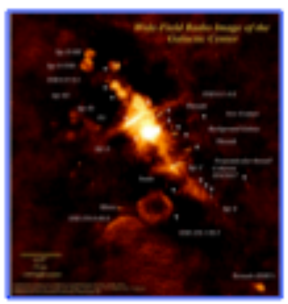

AGNs

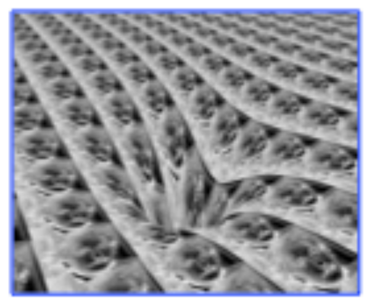

Galaxy Clusters

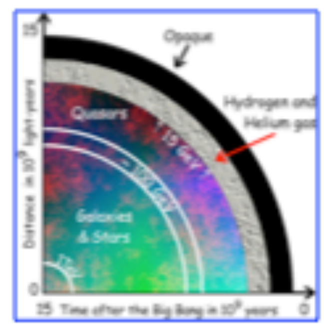

Starburst Galaxies


GRBs

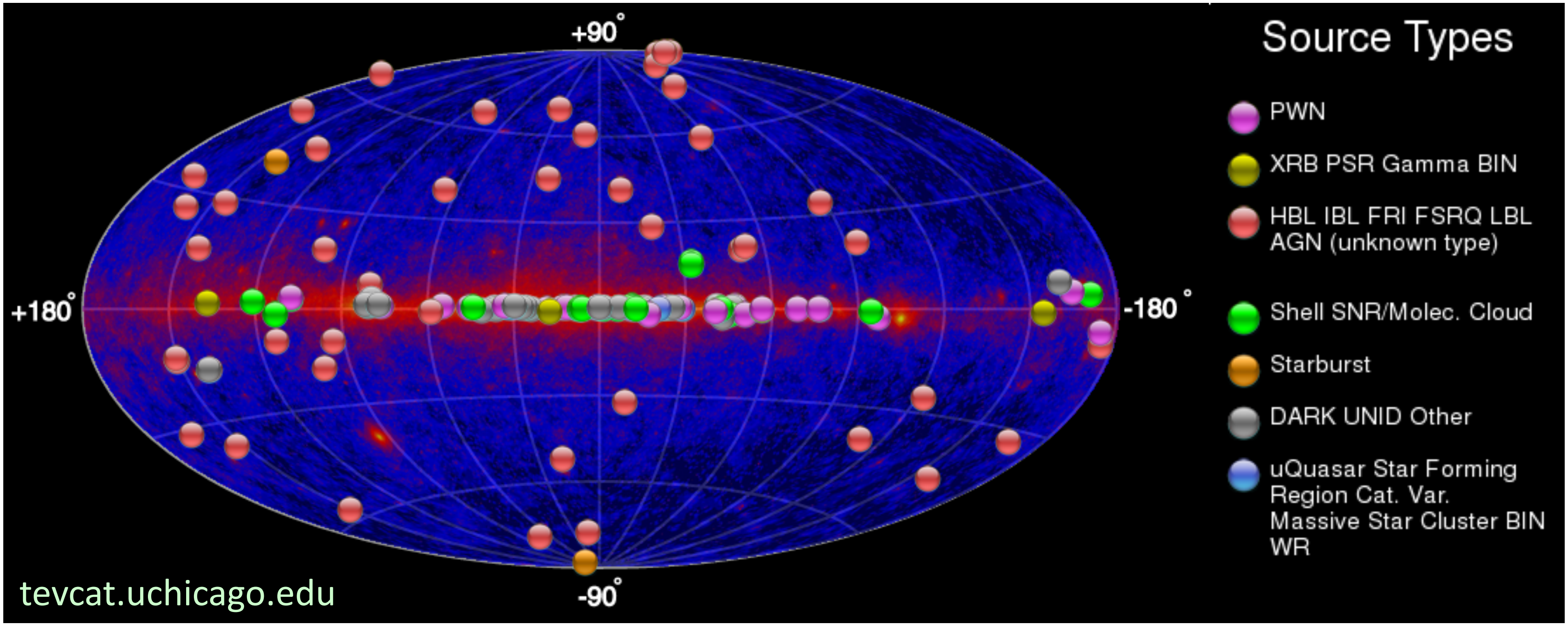

Origin of
cosmic rays


Dark matter


Space-time
& relativity


Cosmology

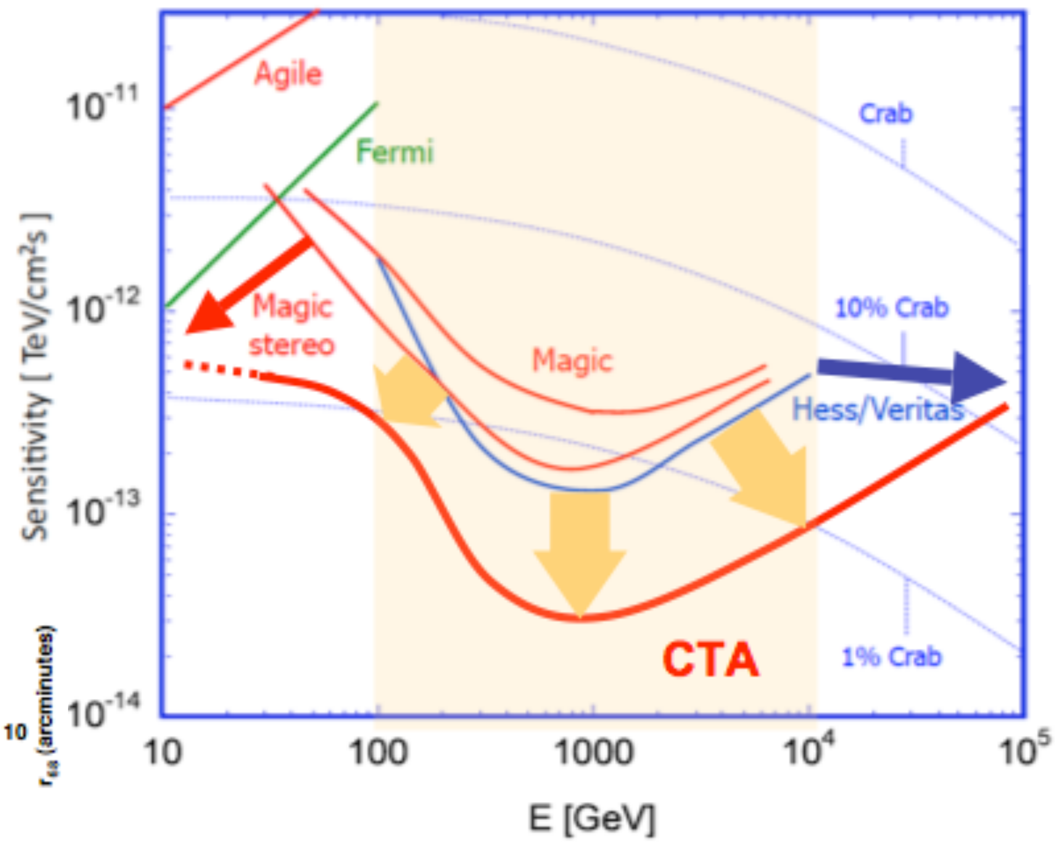
Snapshot: γ-ray Astronomy Today

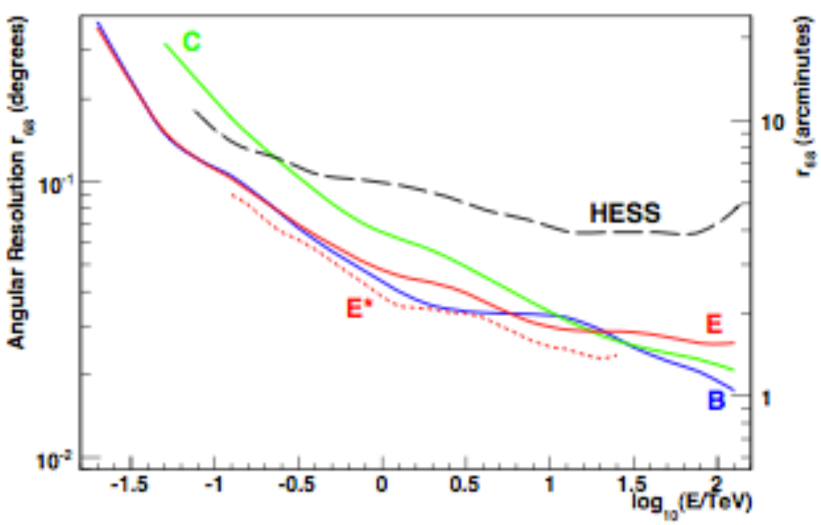


- **Summer 2011: > 120 TeV sources, many classes.**
  - **H.E.S.S., MAGIC, MILAGRO, VERITAS.**
- **Fermi Gamma-ray Space Telescope: 2nd catalog will have > 1800 GeV sources, plus maps of galactic and extragalactic diffuse emission.**

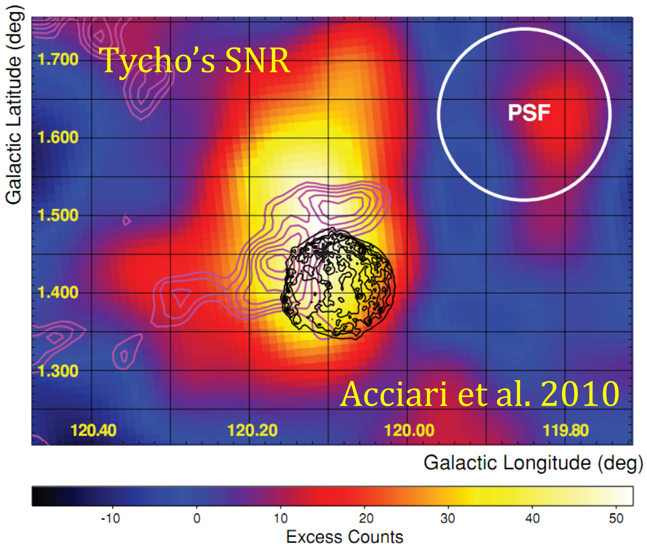
Why CTA?

- **Can do a lot better! Goals:**
  - **10x sensitivity improvement over existing arrays.**
  - **Extension to lower and higher energies.**
  - **Improved angular, energy, time resolution.**



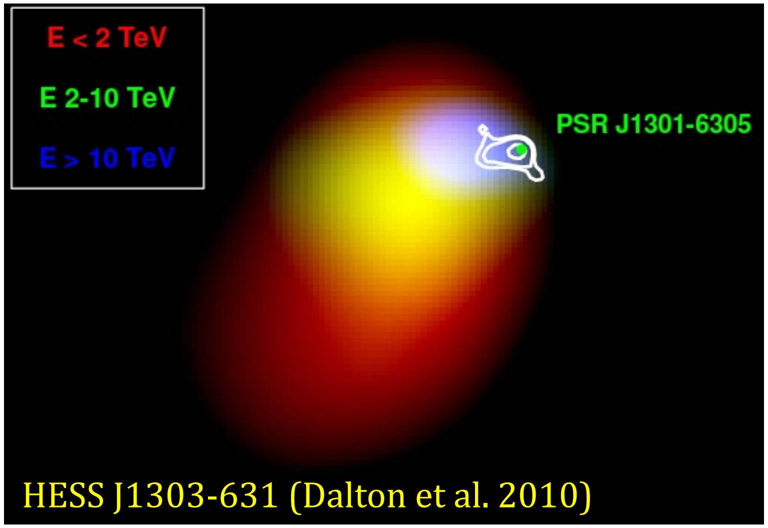


Galactic Science



- Origins of Galactic cosmic rays.
- Particle acceleration in shocks.
- Propagation of cosmic rays in the Galaxy; escape from sources.
- Magnetohydrodynamic flows in PWNe.
- Particle acceleration in microquasars and pulsar binaries – periodic boundary conditions!

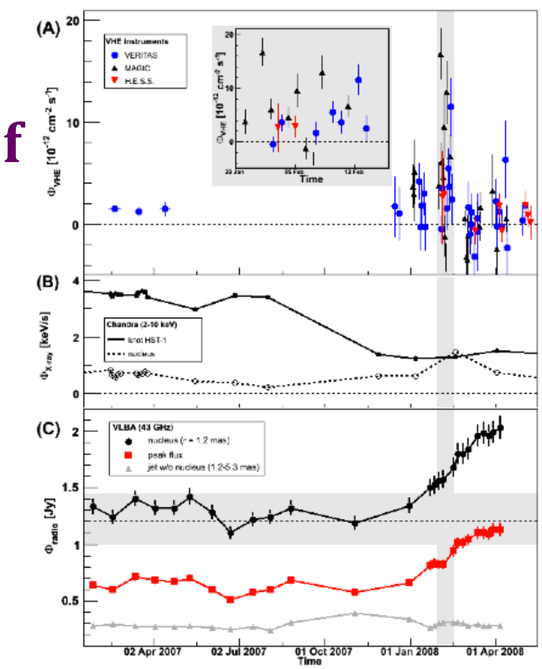
- CTA potential:
  - Census of PWNe and young SNRs across the Galaxy.
  - Detailed, energy-resolved maps of gamma-ray-bright SNRs and PWNe.
  - Sensitive, high-resolution survey of Galactic Plane:
    - MWL associations, diffuse emission.
  - High-energy cutoffs of accelerators -> hadrons or leptons?

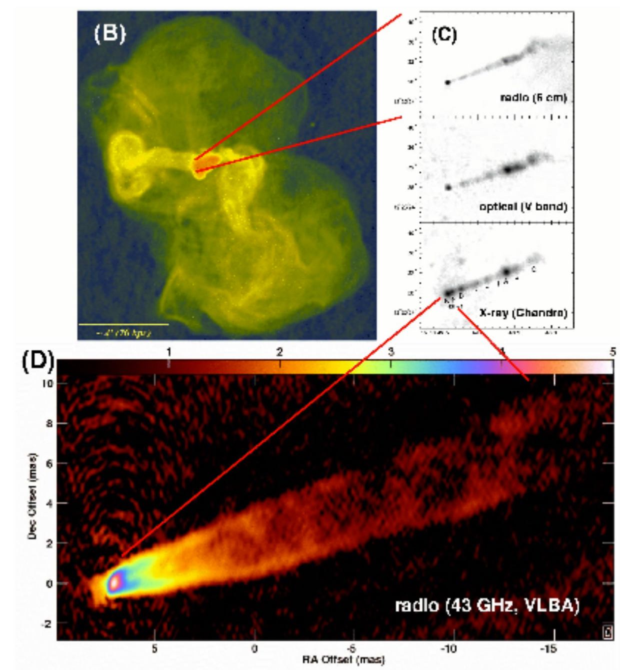


Extragalactic Science

- **AGN jets -> particle acceleration in highly relativistic plasmas.**
- **Radio galaxies -> correlated variability in TeV, X-rays, radio constrain size/location of emission region.**
- **Starburst galaxies -> CR energy density.**
- **Potential new classes: Galaxy clusters, intergalactic shocks, gamma-ray bursts.**

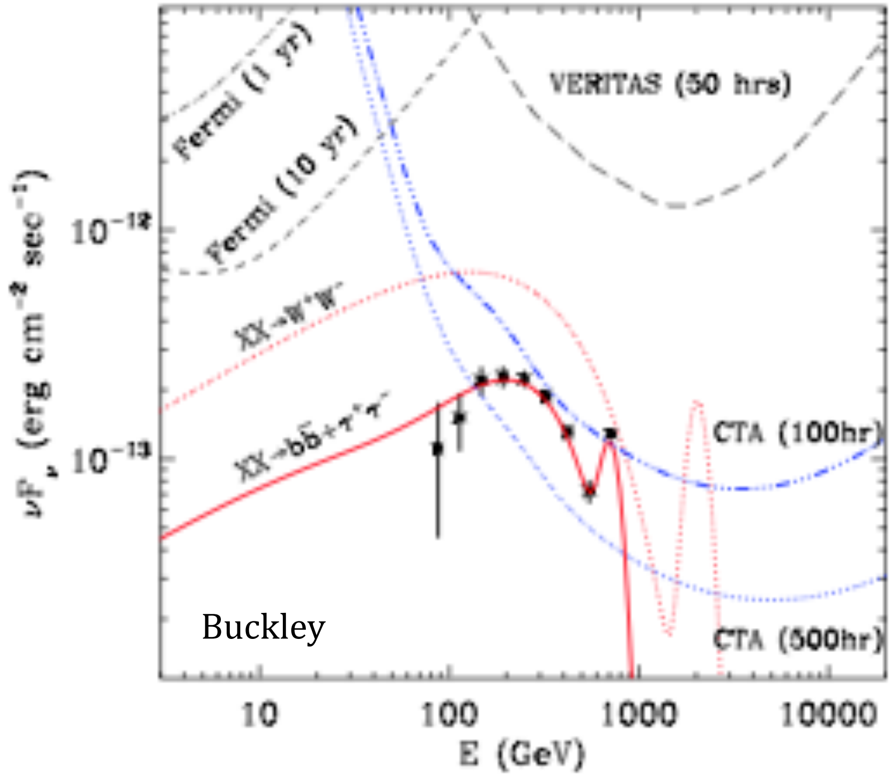
- **CTA potential:**
  – **Population studies of blazars, radio galaxies, starburst galaxies.**
  – **Sub-minute variability of flaring AGN.**
  – **MWL campaigns.**

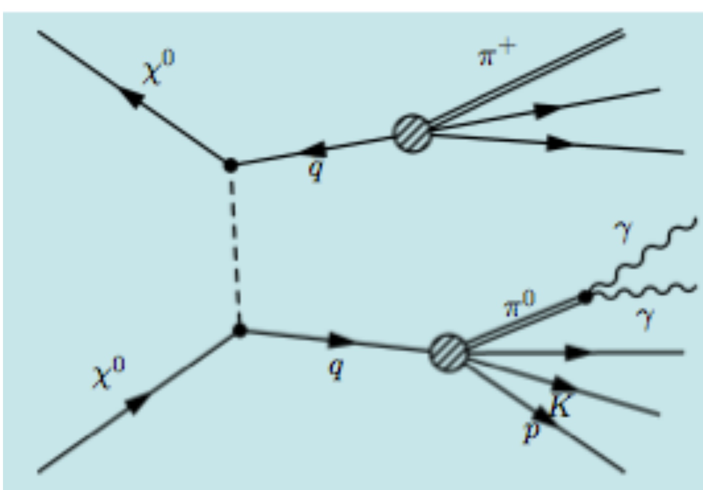




Cosmology & Fundamental Physics

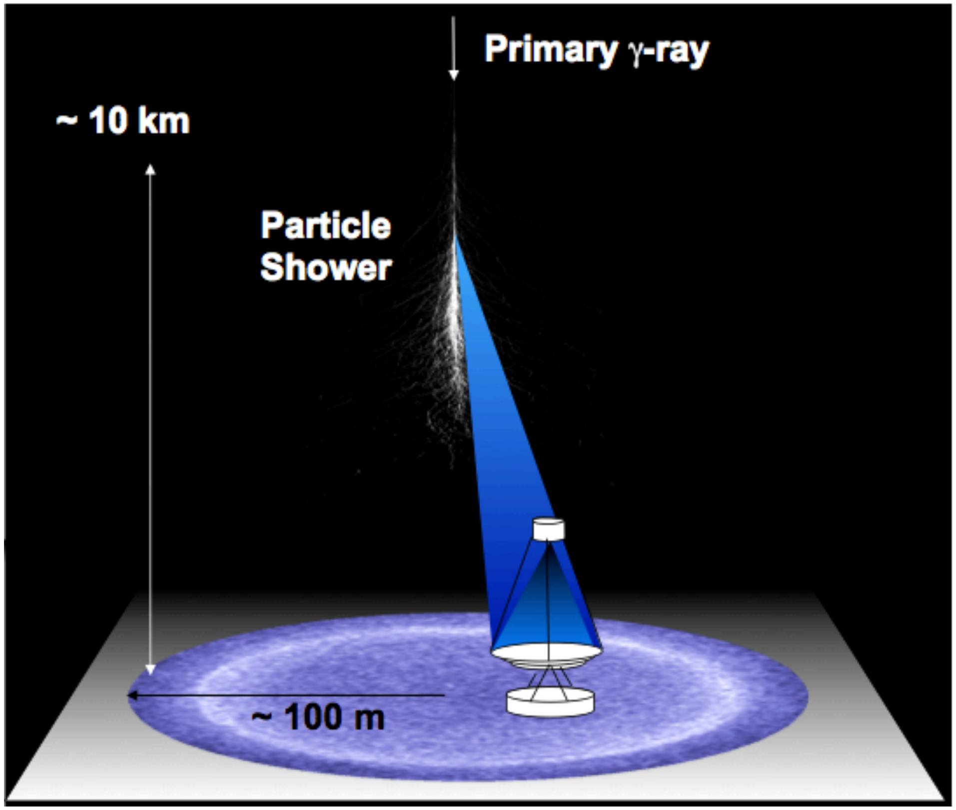
- **Search for dark matter annihilation from**
  - **Galactic Center (astrophysical background!).**
  - **Dwarf galaxies.**
  - **Clusters of galaxies.**



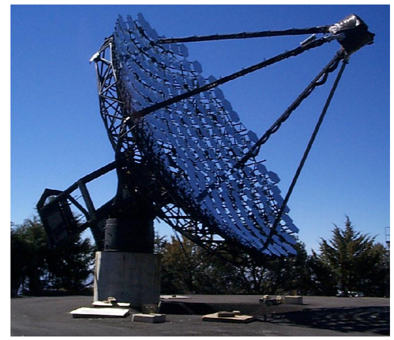


- **Also:**
  - **Extragalactic background light.**
  - **Intergalactic magnetic fields.**
  - **Lorentz invariance violation.**

Imaging Air Cherenkov Technique

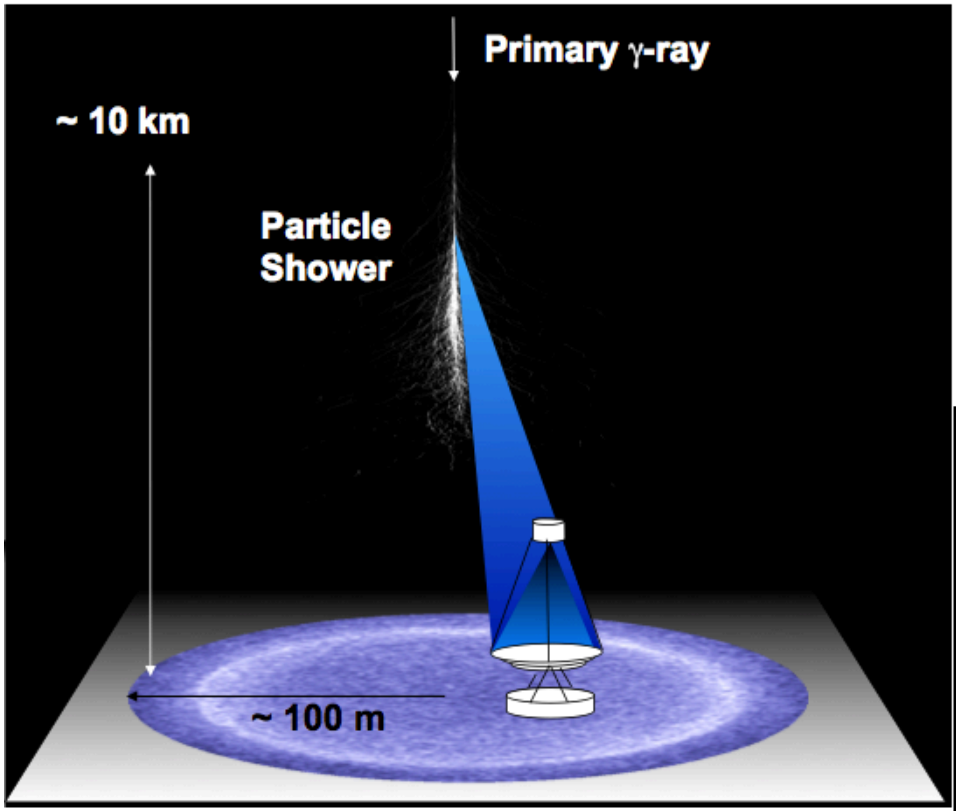


Adapted from J. Hinton, Texas 2010

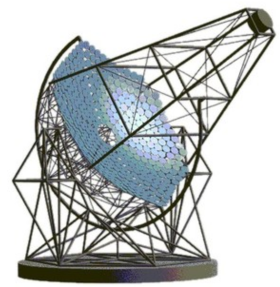


Whipple 10m

Imaging Air Cherenkov Technique

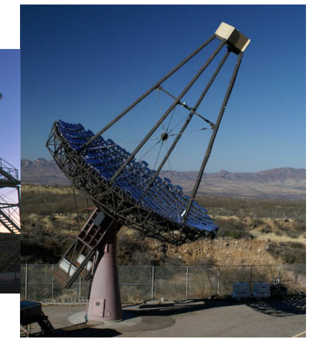


Adapted from J. Hinton, Texas 2010

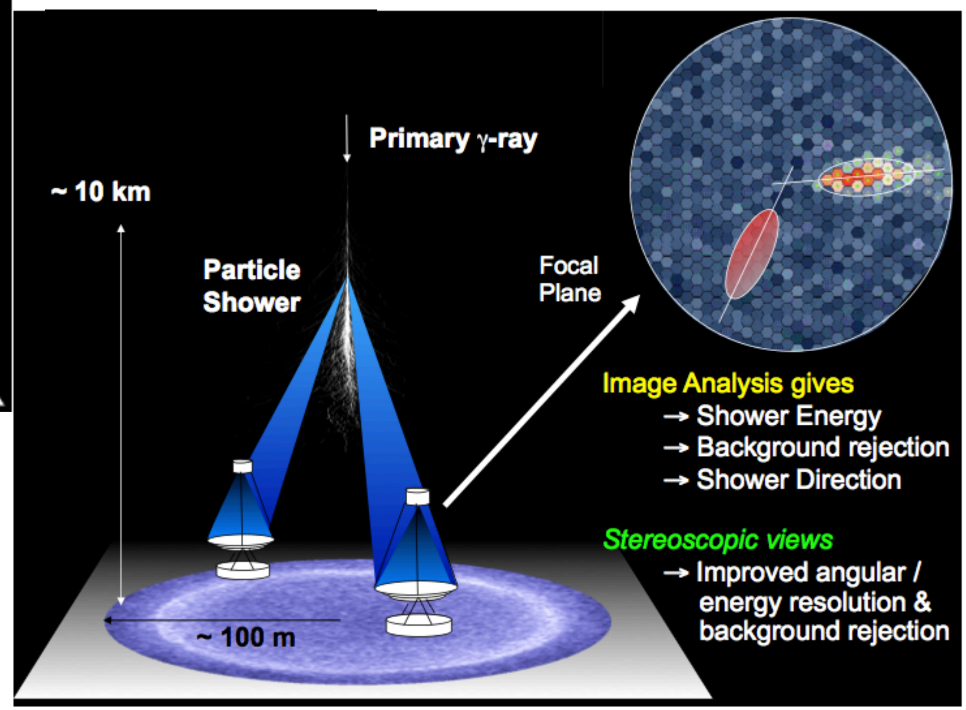


H.E.S.S.

MAGIC



VERITAS



How? Heterogeneous Array

Low-energy section:
few O(20-30) m tel. (LST)
=> push low threshold
- Parabolic reflector
- FOV: O(3-4) degrees
- f/D: O(1.2-1.5)

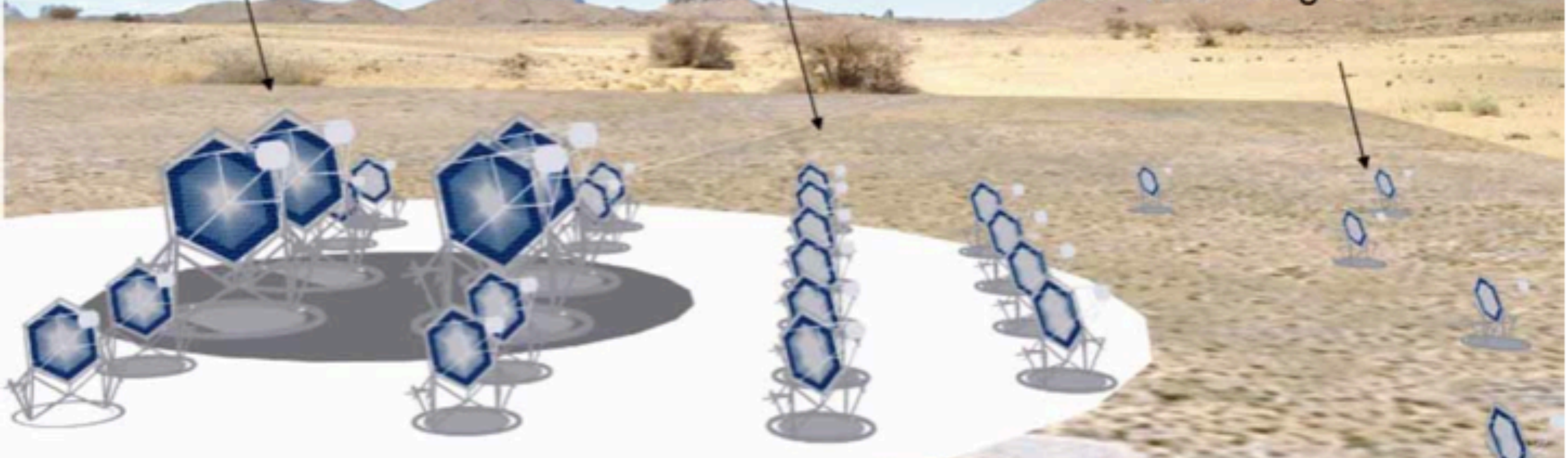
energy threshold
of some 10 GeV

Core-energy array:
many O(10-12) m tel. (MST)
=> workhorse of CTA
-> push cost & reliability
- Davies-Cotton reflector
- FOV: O(6-8) degrees
- f/D: O(1.2-1.5)

mCrab sensitivity
in the 100 GeV–10 TeV
domain

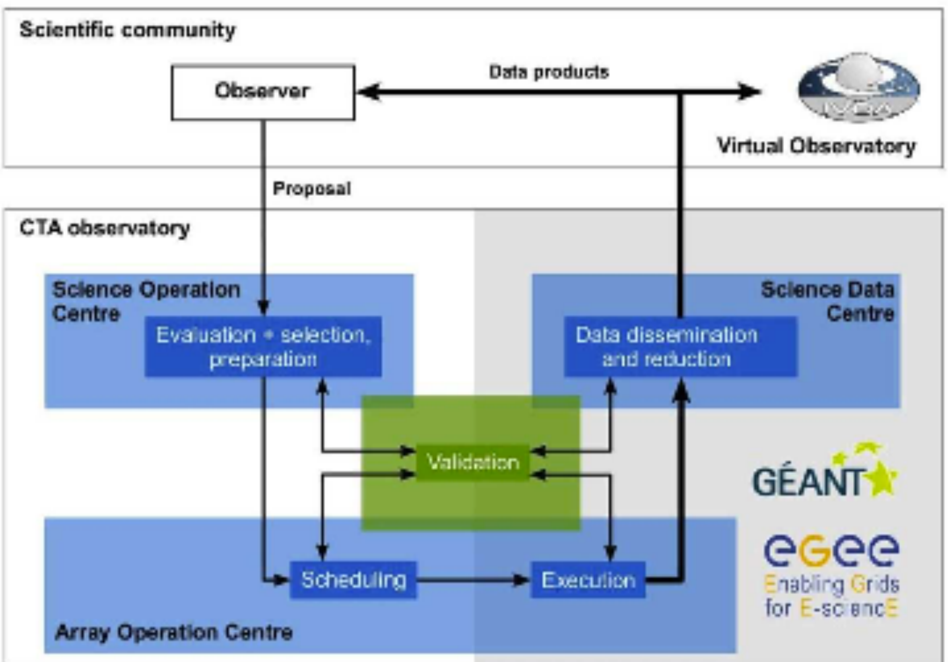
High-energy section:
some O(5-6) m tel. (SST)
=> push low-cost
- Davies-Cotton reflector
(or Schwarzschild-Couder)
- FOV: O(10) degrees
- f/D: O(1.2-1.5)

10 km^2 area at
multi-TeV energies



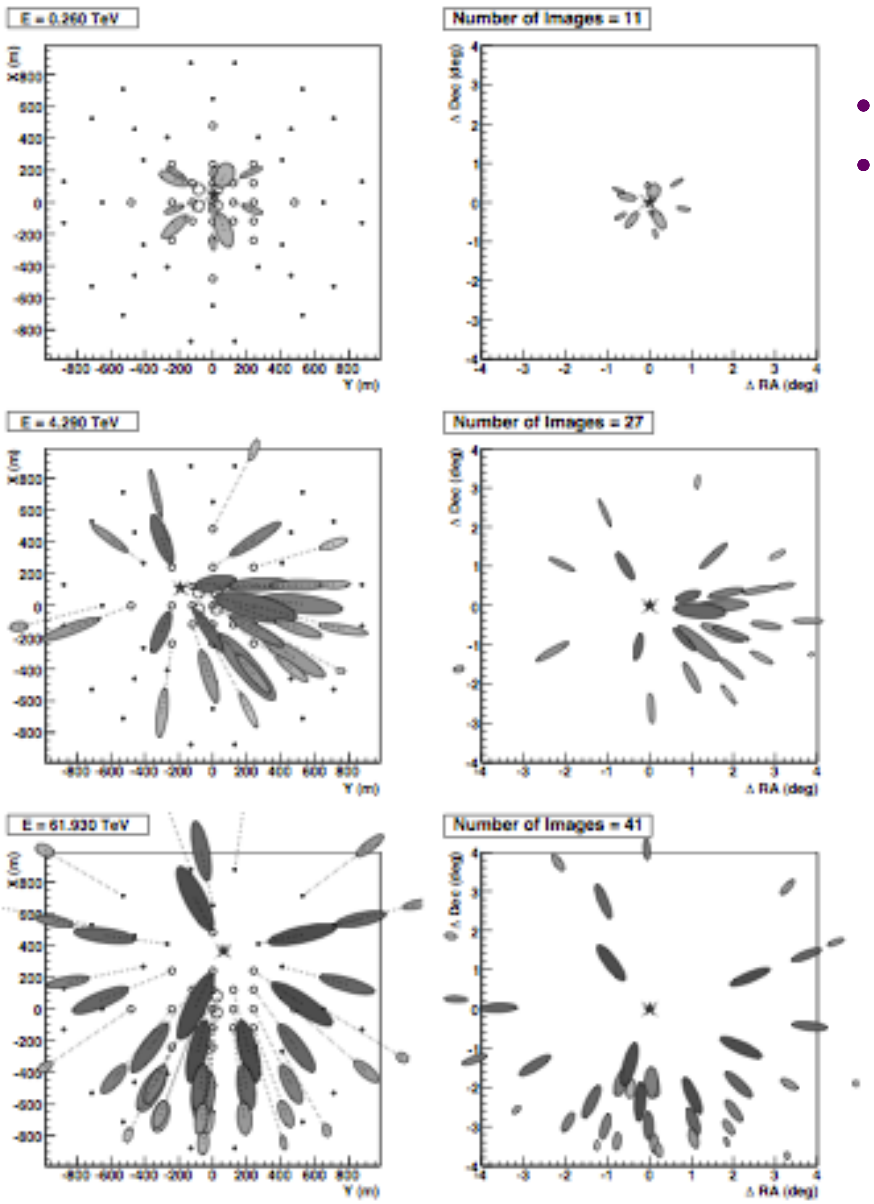
The CTA Consortium & Observatory

- Preparatory phase of project.
  - Design study: arXiv:1008.3703 (2010).
- Over 800 scientists from 25+ Countries, 130+ institutions.
- US community joined in May 2010 (former AGIS Collaboration).
- Endorsed by European Roadmap, U.S. Astro2010 survey and PASAG.

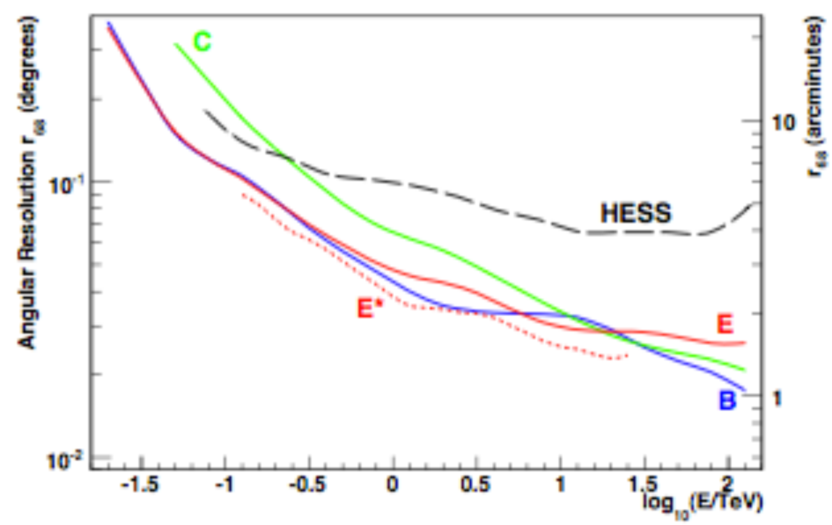


- Operation as open observatory.
  - External proposals.
  - Peer-review selection process.
  - Data and standard analysis tools provided.
  - Northern and Southern sites -> full-sky coverage.

New Regime: Event Confinement

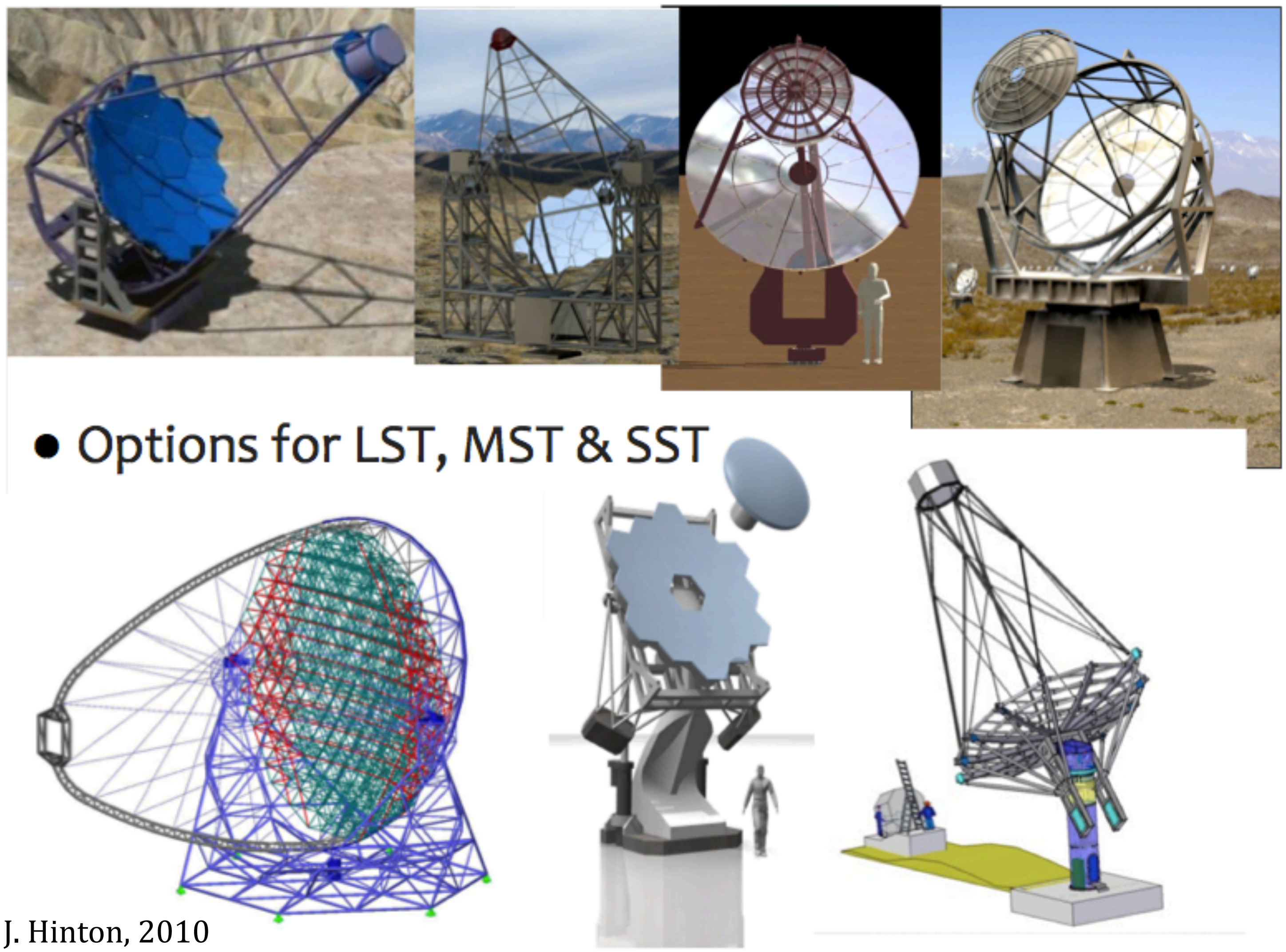


- **Differs from few-telescope arrays.**
- **Majority of effective area is inside array now:**
  - **Better and more uniform sampling of Cherenkov pool.**
  - **Improved angular & core position resolution, background rejection!**
  - **Faster than $\sqrt{N_{tel}}$ sensitivity improvement.**



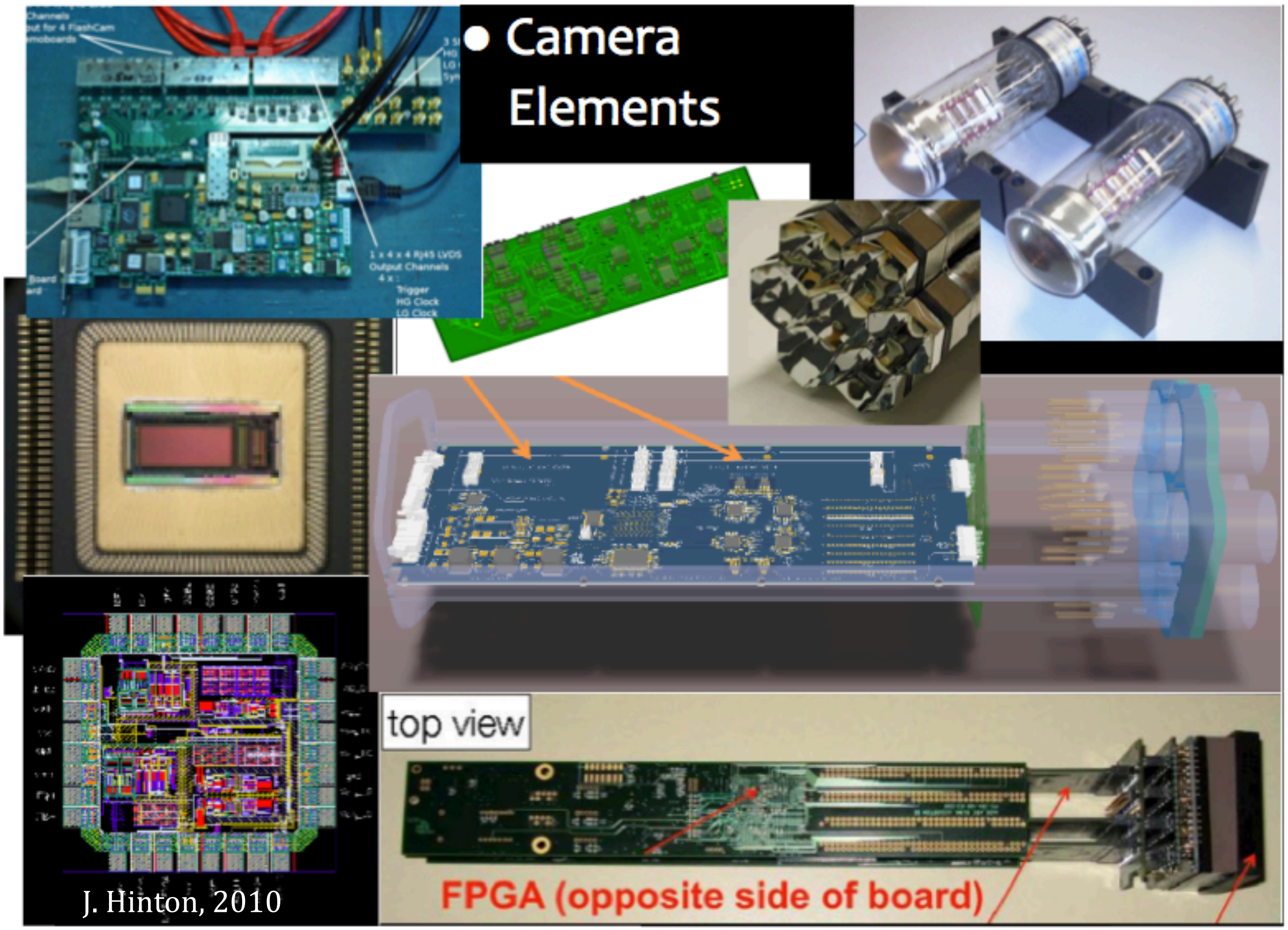
CTA: Telescope Design Options

- **Optimizing cost vs. performance for each size of telescope:**
  - **Slew speed, rigidity, weight, camera plate scale, optical PSF, …**



Camera and Readout Electronics

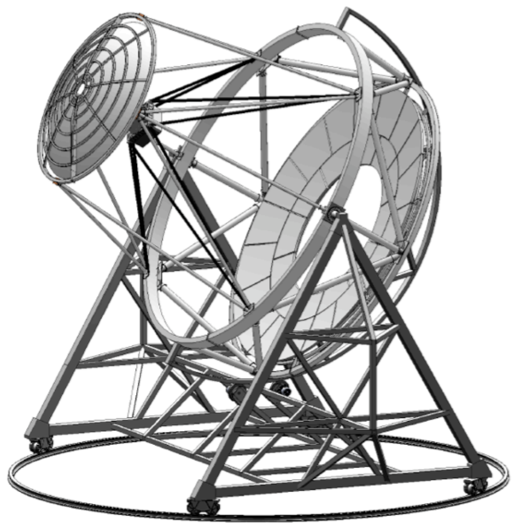
- **Baseline photodetectors: PMTs (evaluating SiPMs, HPDs).**
- **Reliability, ease of maintenance -> key for camera design.**



CTA-US focus: Schwarzschild-Couder Optics

R&D for array of Schwarzchild-Couder MSTs under way (2011-2015).

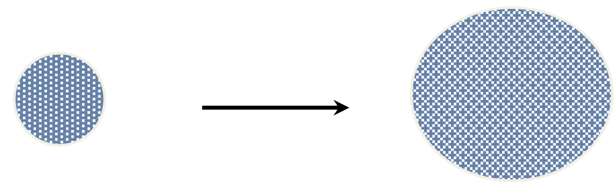
-> Augment DC-MSTs to enhance 0.1-10 TeV sensitivity.



Provides short f/D & compact high-resolution camera.

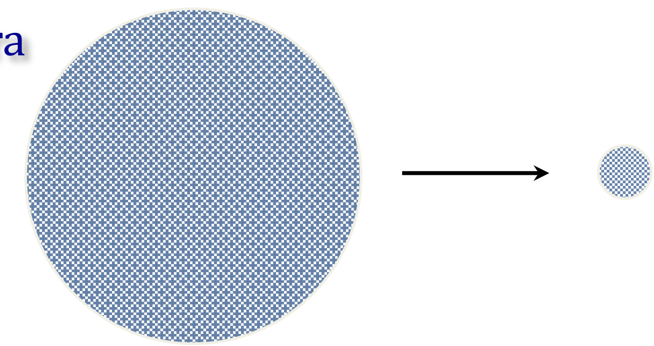
36-telescope array with 100-200 m spacing will provide a ~1 km^2 effective area @ 1 TeV with 0.02-0.05° angular resolution.

FoV

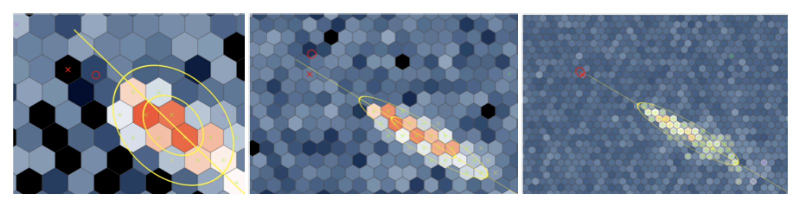


3.5 deg. 8 deg.

Camera Size:



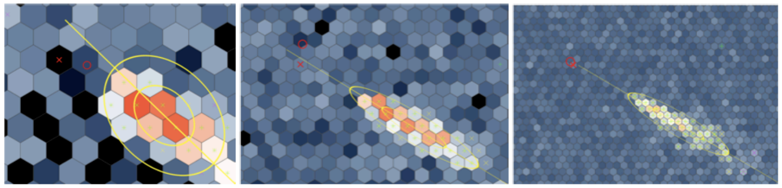
Pixelation



0.28° 0.20° 0.07°

SC Optics: Potential Advantages

- Advantages of Schwarzschild-Couder optical design:
  - Demagnifying secondary mirror yields small plate scale:
    - Cheaper options for camera: multi-anode PMTs now, possibly SiPMs in the future.
  - Spherical and comatic aberrations corrected, astigmatism minimized -> preserve optical PSF off-axis.
    - Allows simultaneously wide FoV (8-10 deg) and fine pixelization (0.07-0.1 deg/pixel).
      - Better-resolved images -> improved angular resolution.



0.28° 0.20° 0.07°

SC-MST: Key Technologies & Challenges

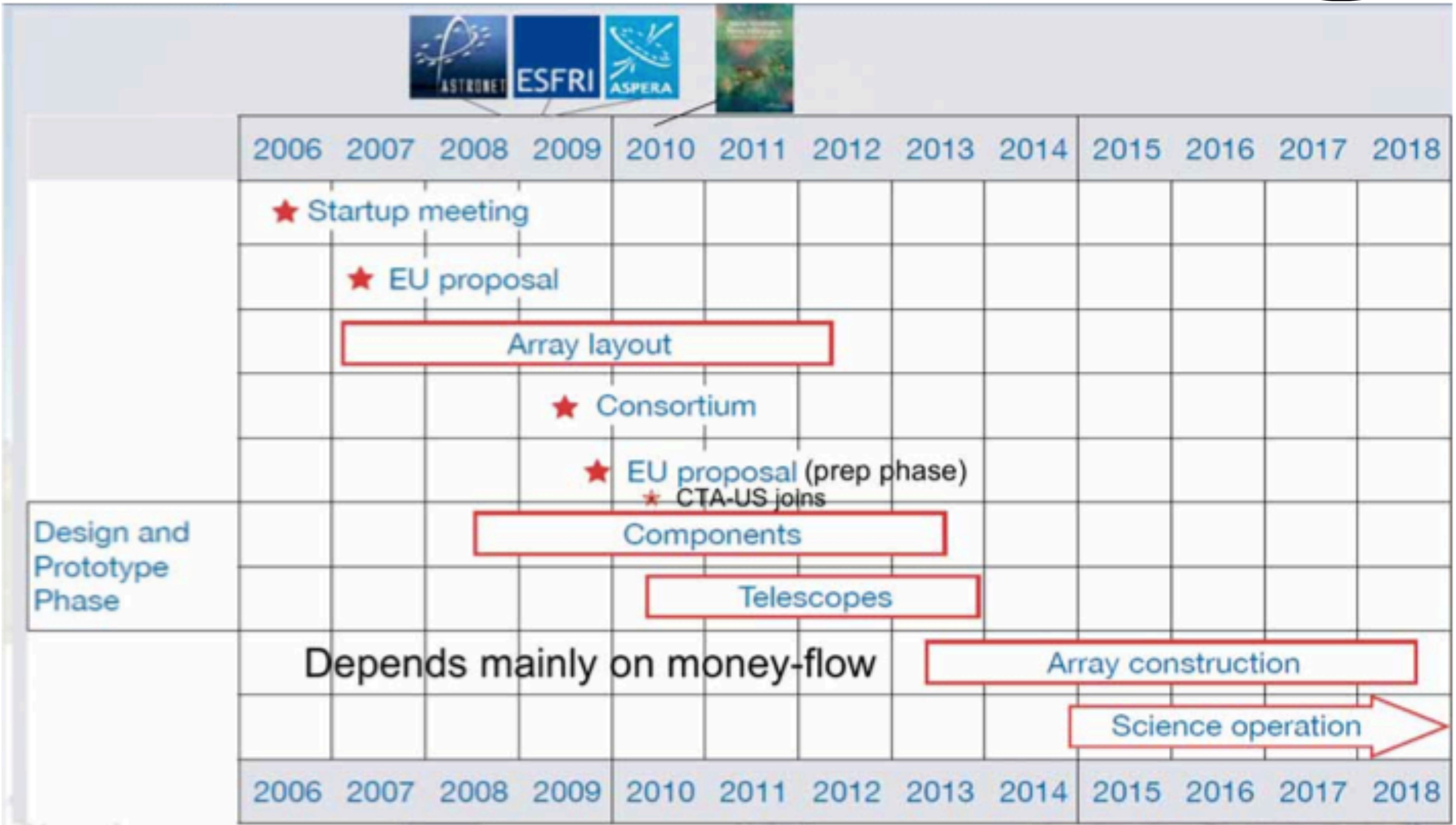
- **Mirror manufacturing – surface roughness RMS of 2-5 nm required to minimize diffusive scattering.**
  - **Comparable to large optical telescopes, but cost an issue!**
    - **Options: cold/hot glass slumping, electroforming, composite mirror technology.**
    - **Ability to coat/recoat & environmental testing.**
- **Telescope structure & mirror alignment.**
  - **Maintain optical PSF ~ pixel size of 0.07 deg.**

Hamamatsu H8500D

- **Large number of pixels! >11k (0.5-2k in existing cameras).**
  - **Multi-anode PMTs – baseline design.**
  - **Custom ASICs for readout.**
  - **Highly integrated modular camera design.**
    - **Reliability, ease of maintenance.**

MAPMT with Front-End Electronics

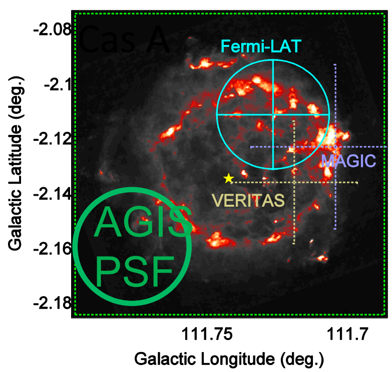
Timeline and Plans



CTA-US R&D phase

CTA-US SC-MST Construction

Summary



Abdo et al. 2010

- Joint successor project CTA: arrays of 40-80 telescopes -> event containment.
  - Increased sensitivity:
    - Population studies of AGN, starbursts, SNRs, PWNe, …
    - Probe Dark Matter parameter space.
  - Spectra over broad energy range 10's GeV – 100 TeV:
    - Search for features & cut-offs → maximum particle energy.
  - Excellent angular resolution:
    - Detailed morphology of SNRs, PWNe (CR acceleration sites?).
    - Improved localizations → MWL associations.
  - Wide Field of View:
    - Efficient, sensitive sky survey.
  - Complementarity, overlap with Fermi, HAWC.
- World-wide consortium, strong support from European Roadmap and Astro2010, PASAG in U.S.
- U.S. focus: Schwarzchild-Couder MSTs for superior angular resolution, extend sensitivity in core energy range.

CDR: arXiv:1008.3703

Backup Slides

Observing Modes