中国科学技术大学
University of Science and Technology of China

Wide Field Survey Telescope (WFST)

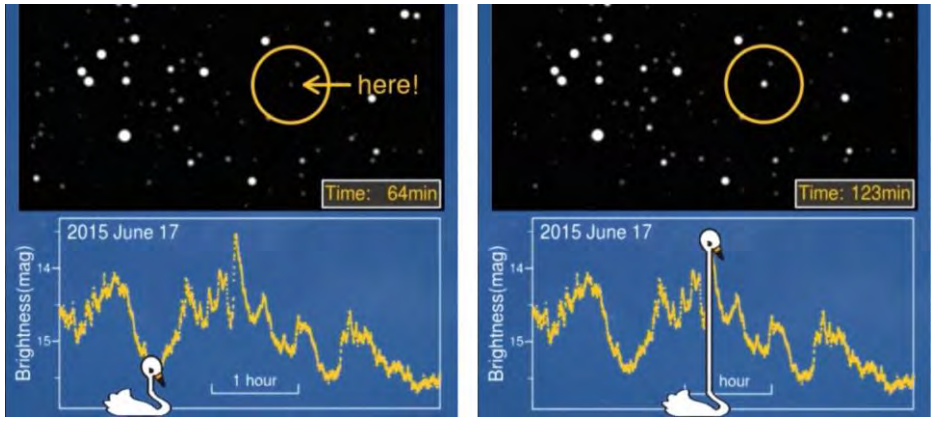
On behalf of the WFST team @ USTC & PMO

Xu Kong
(USTC)

中国科学院紫金山天文台
PURPLE MOUNTAIN OBSERVATORY, CAS

1. Time Domain Astronomy

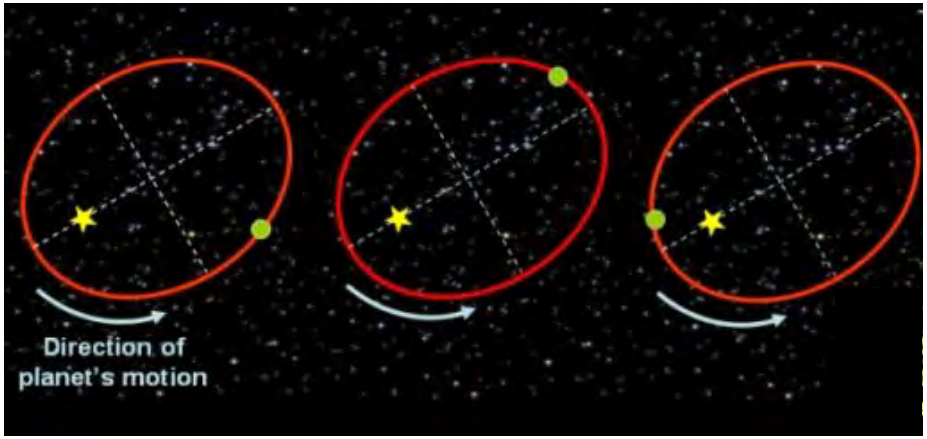
- Many astronomical objects show variabilities.
  - Transients
  - Moving objects
  - Variables

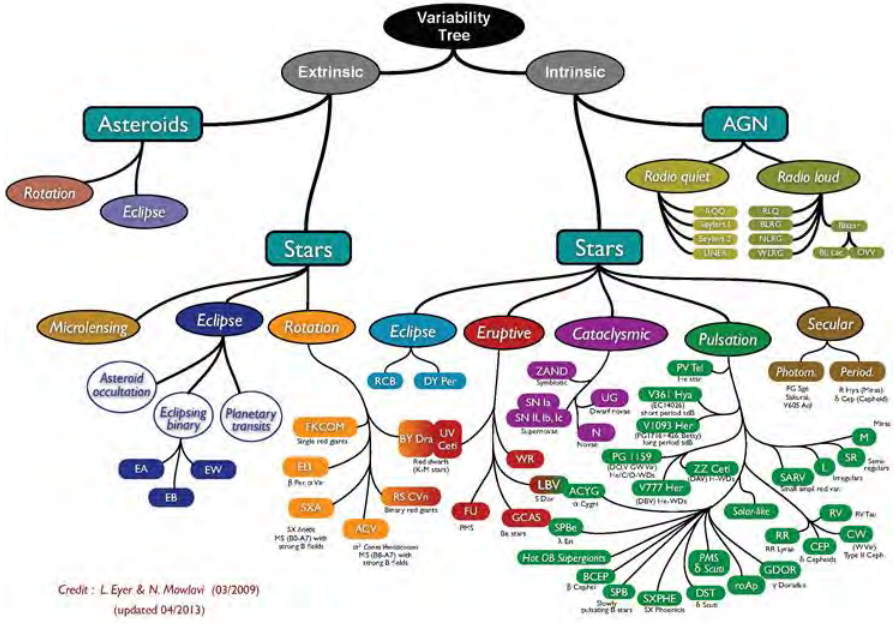


Variable objects

- Time variability encodes key information about the source physics -- Time Domain Astronomy

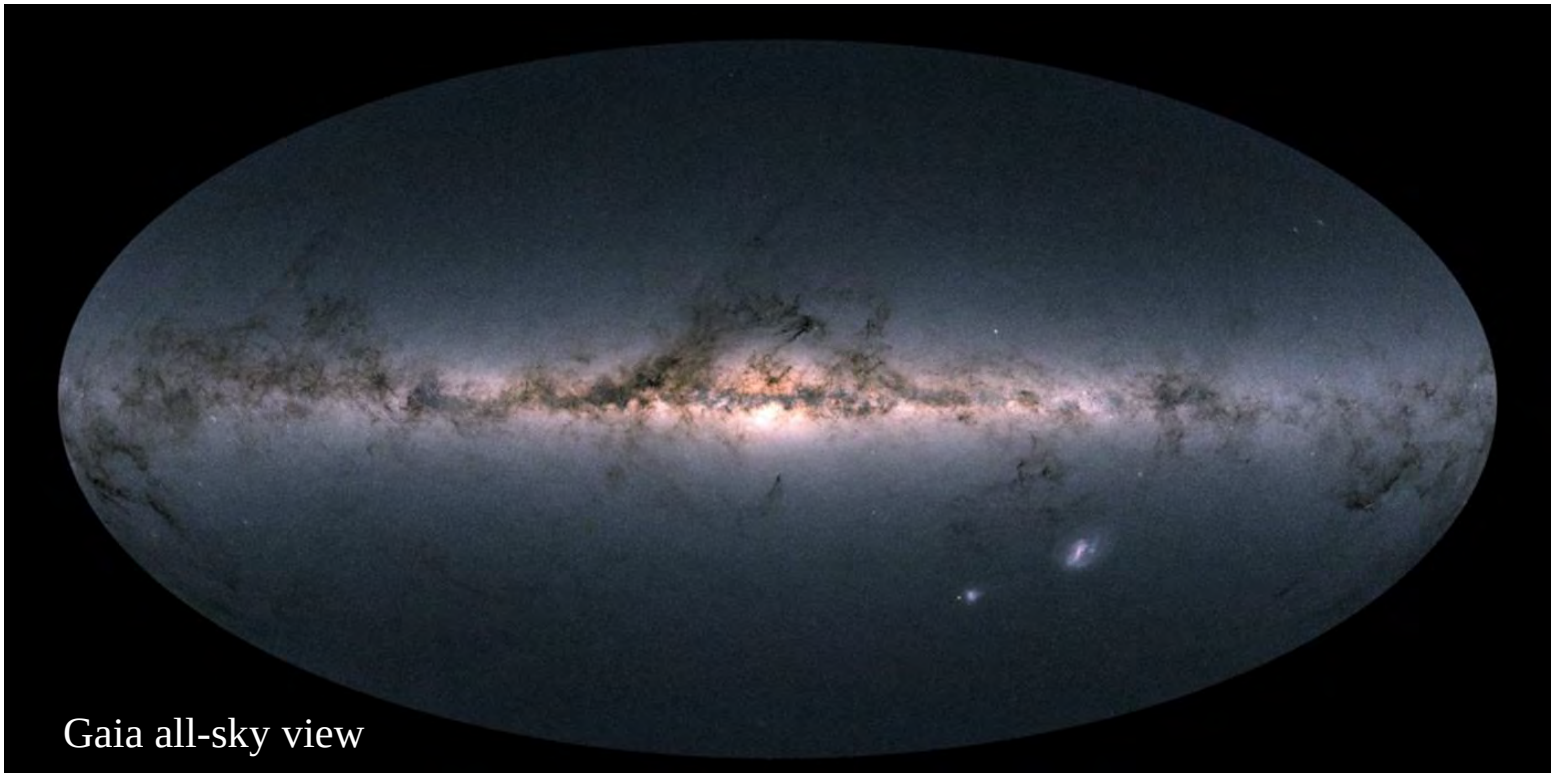
Moving objects





L. Eyer & N. Mowlavi 2008

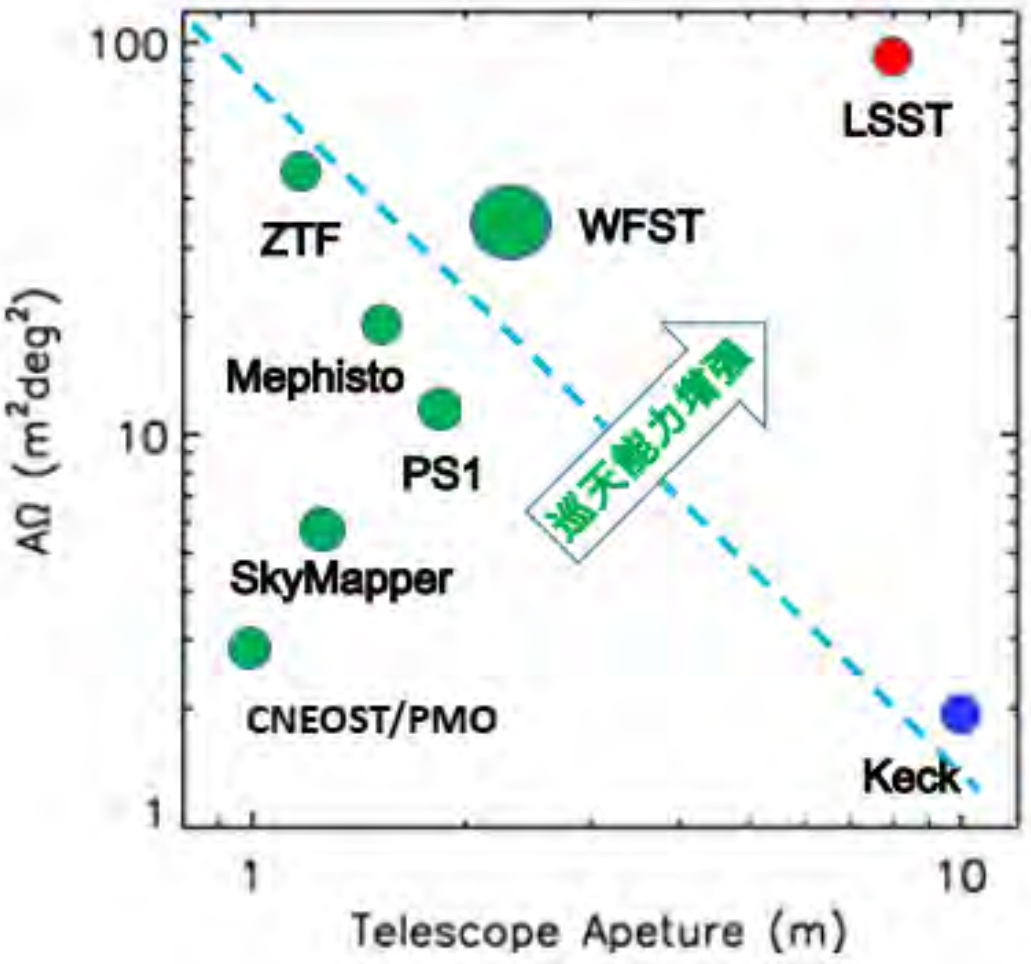
Telescopes for Time Domain Astronomy



Need a powerful data acquisition facility in terms of both observation depth and sky coverage

Telescopes: with large field of view (FoV), high efficiency, wide band coverage and high image quality.

Major Time Domain Optical Survey Facilities



- In the Southern hemisphere, LSST is the upcoming powerful time-domain facilities,
- In the Northern hemisphere, however, ZTF, PS1… are relatively small telescopes for TDA.

We need a powerful data acquisition facility in terms of both observation depth and sky coverage on Northern sky.

2. WFST Overview

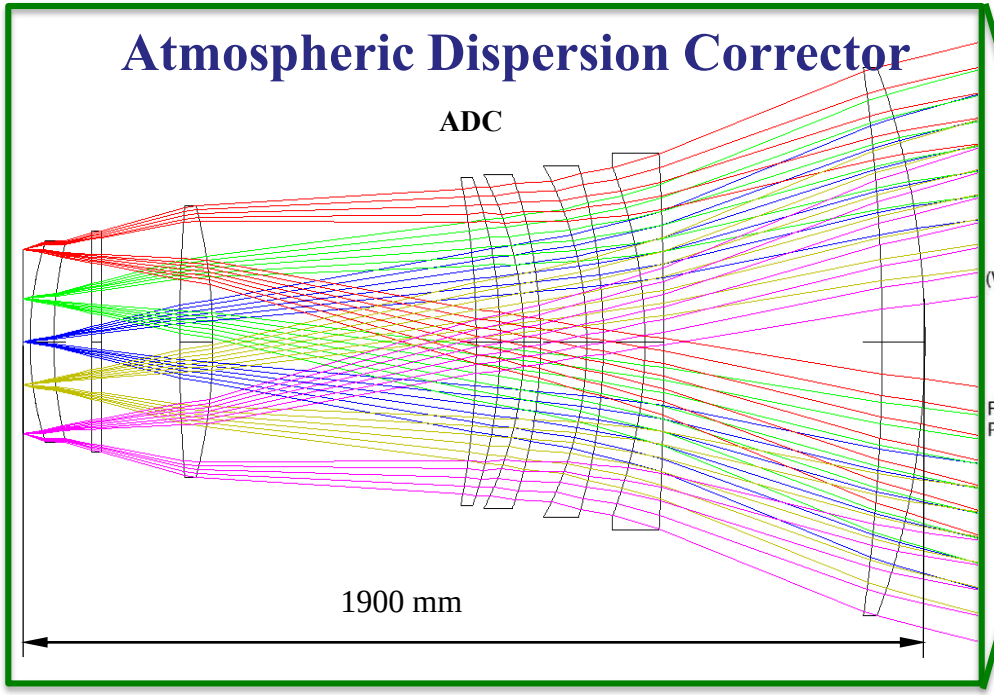
- 2.5-meter primary mirror
- A prime focus camera with a field of view of 7 square degrees
- Filled with 9 × 9K×9K mosaic CCD detector (E2V CCD290-99).
- r ~ 22.8 mag in 30s integration, 6000 square deg/night
- All sky (20000 square deg on the northern sky) + deep field surveys in u,g,r,i,z and w filters

Wide Field Survey Telescope

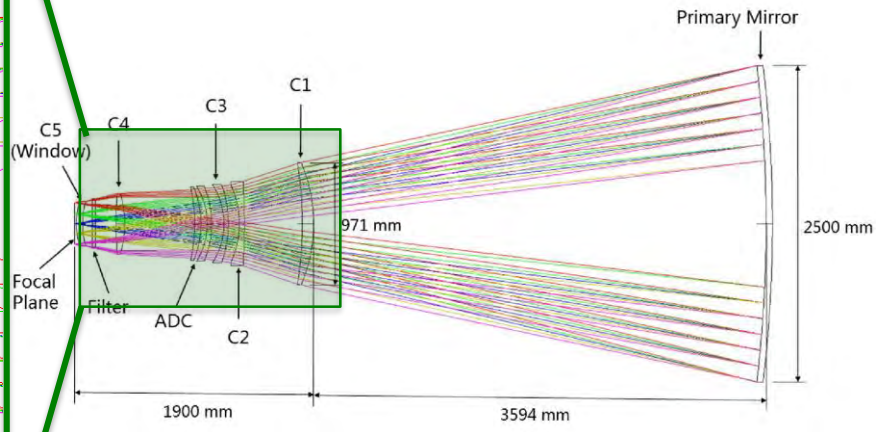
Top-level specifications for WFST

Item	Specifications
Optical Configuration	Prime-focus with corrector lenses
Aperture	2.5 m diameter
Focal Length	6.2 m
Focal Ratio	F/2.48
Field of View	3 deg diameter, 6.55 sq. deg
Etendu	29.3 m^2 deg^2
Wavelength	320 ~ 960 nm (u, g, r, I, z, w)
Image Quality	diameter ≤ 0.4 arcsec (80% ee)
Plate Scale	33 arcsec/mm
Pixel Size	10 um x 10 um
# of pixels	0.9 Giga
Survey Depth	r ~ 23 @ 30s exposure

Prime Focus System with ADC and AO

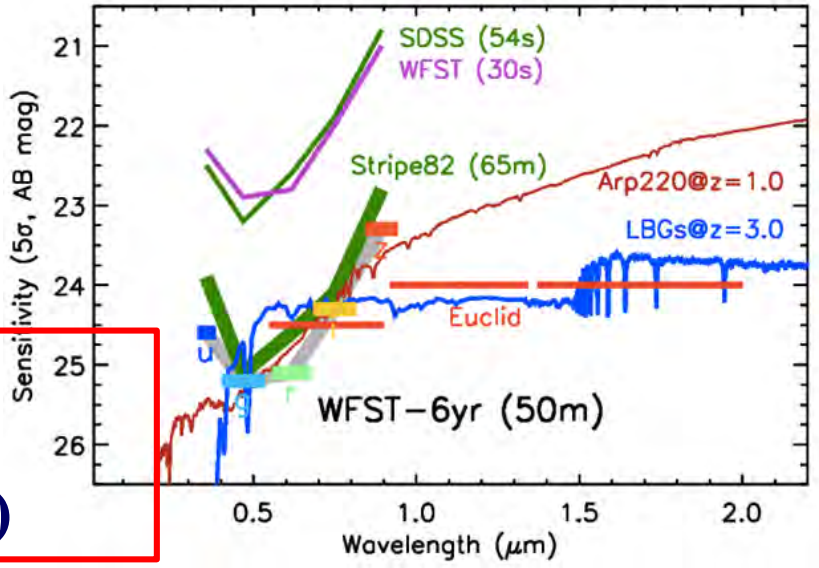


Credit: Ming Liang



active optics system.

Wide FOV (d = 3 deg), high efficiency (> 80%), wide band coverage (ugrizw) and high image quality (0.4 arcsec).

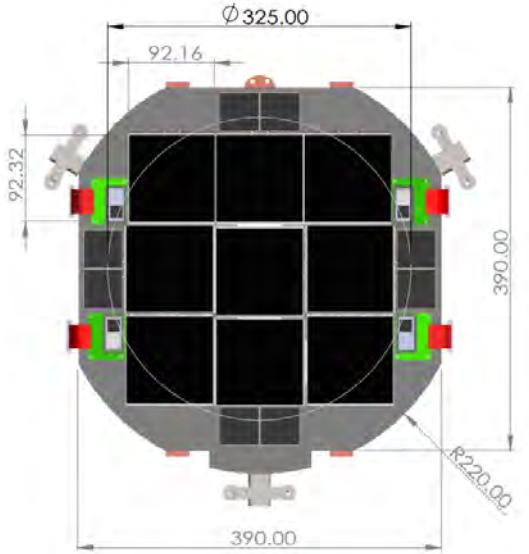


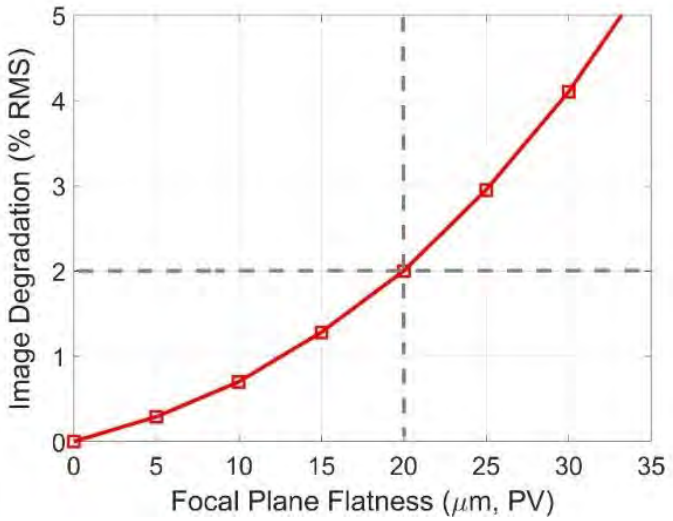
ugriz =

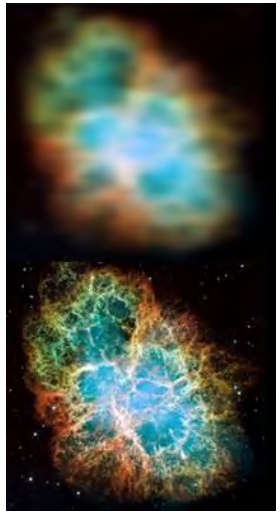
[22.3, 22.9, 22.8, 22.0, 21.0] (30s exp.)

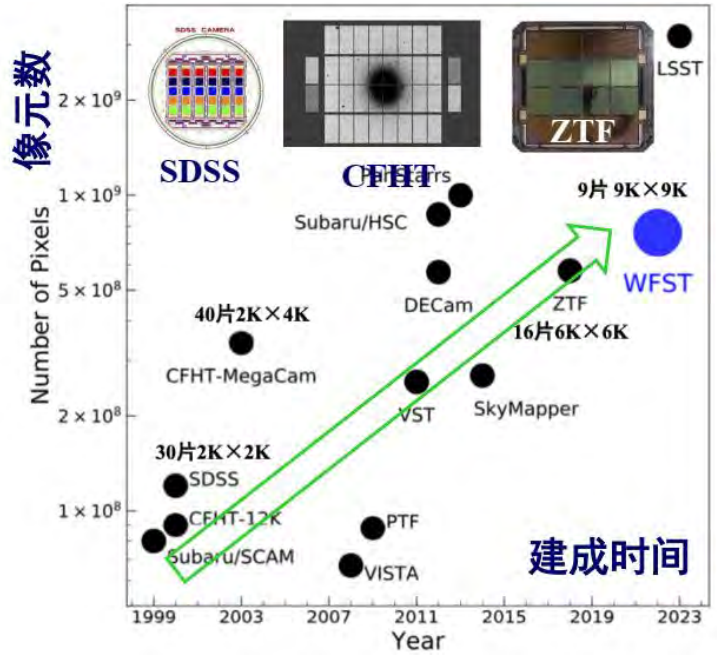
Focal Plane Camera

- 9 pieces of 9K×9K CCD chips with 10 μm×10 μm pixels fills the 300 mm×300 mm focal plane, with flatness less than 20 μm.
- 8 pieces of 4K×4K CCD chips are used for wavefront sensors (AO) and four additional chip is used as guiding sensors.



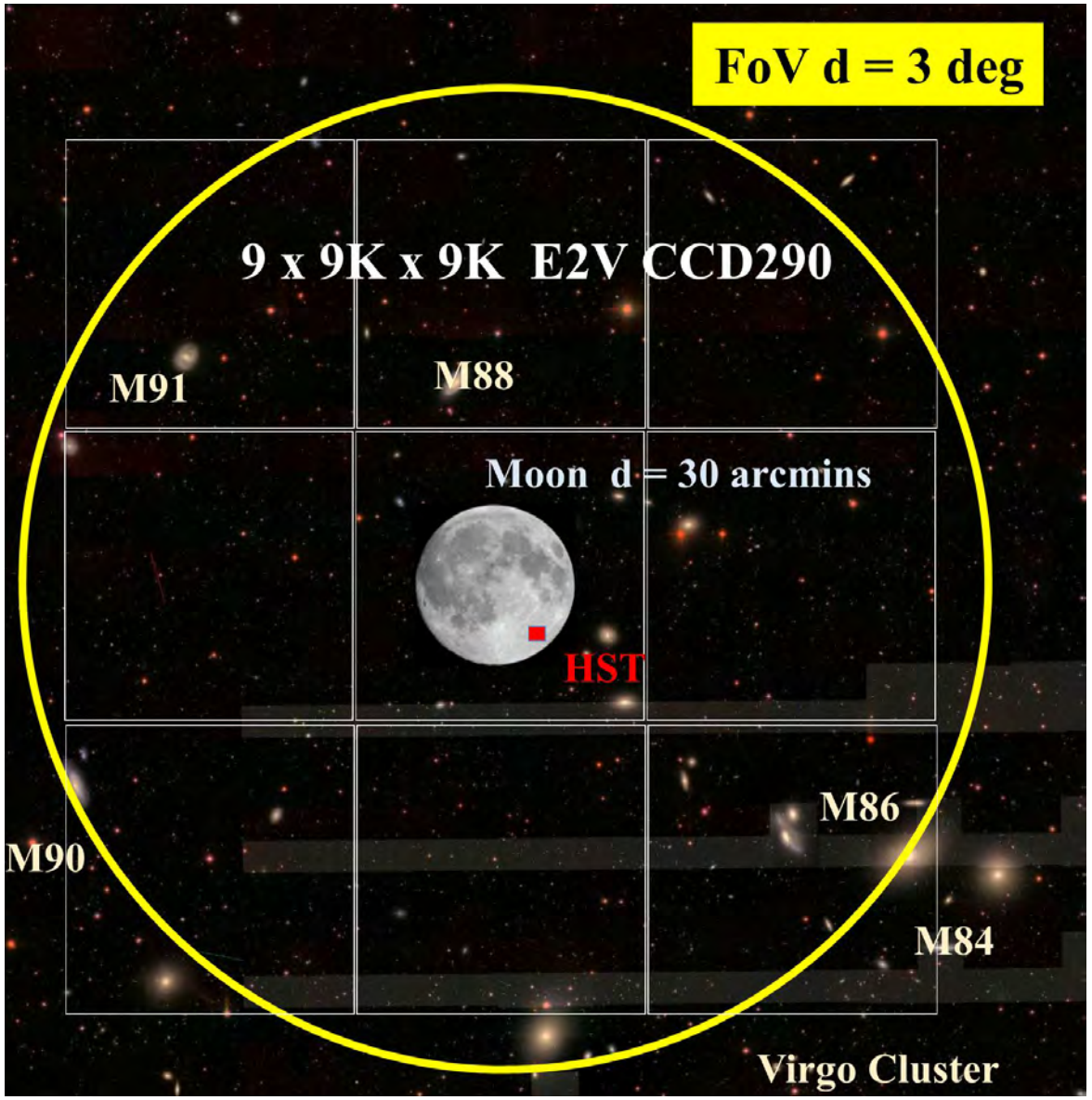






Camera of WFST, at the international advanced level.

A Powerful Survey Machine

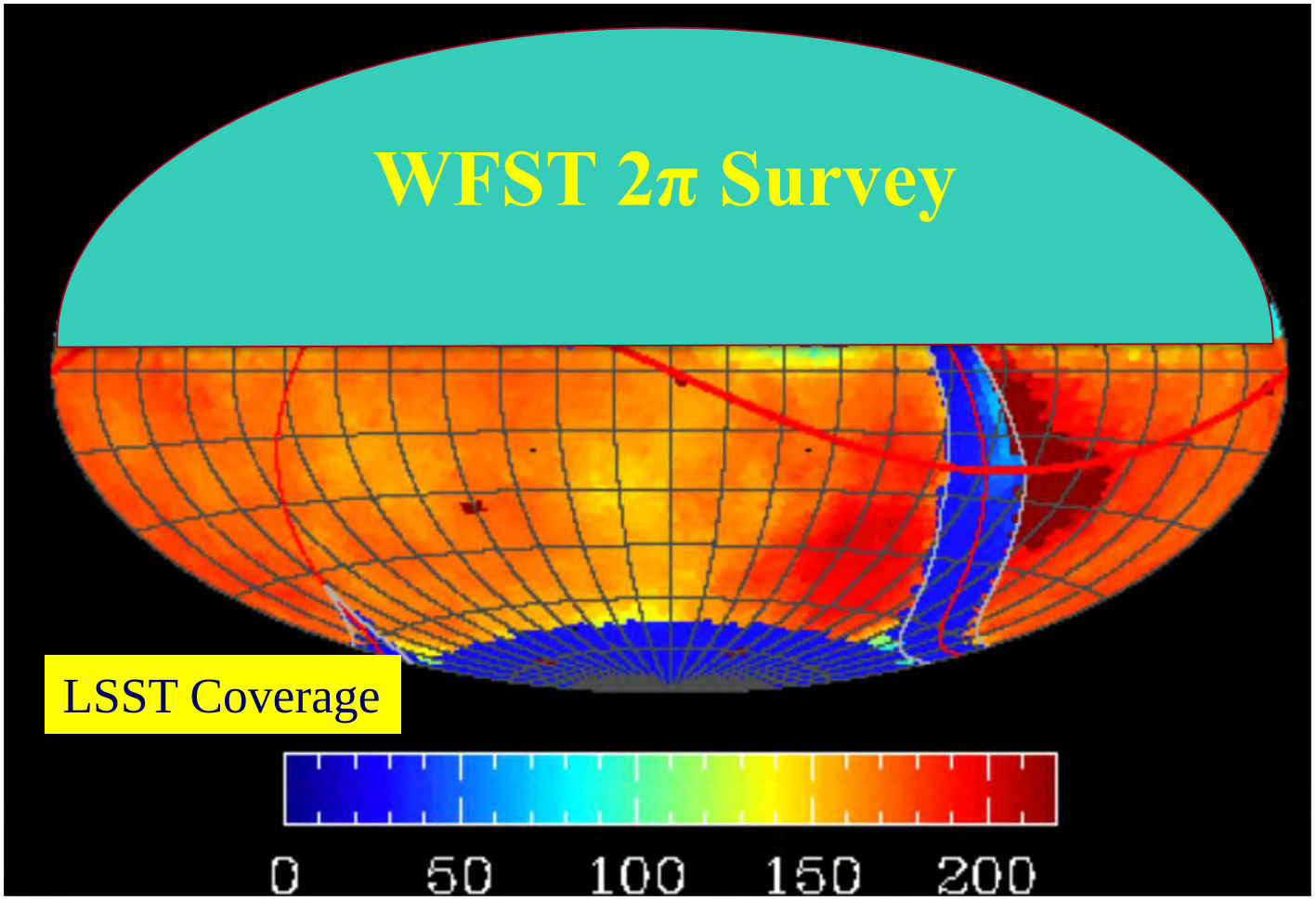


- Flat focal plane
- Distortion-free
- 1pix = 0.33”

- Exp 30 + 6s, 9hrs/night, 925 pointings cover 6000 square degrees

- Each frame 27K x 27K (16bits) = 1.758 GB
- 1.6 TB per night
- 45 TB per month
- 450 TB per year
- 2.6 PB raw data 6 yrs

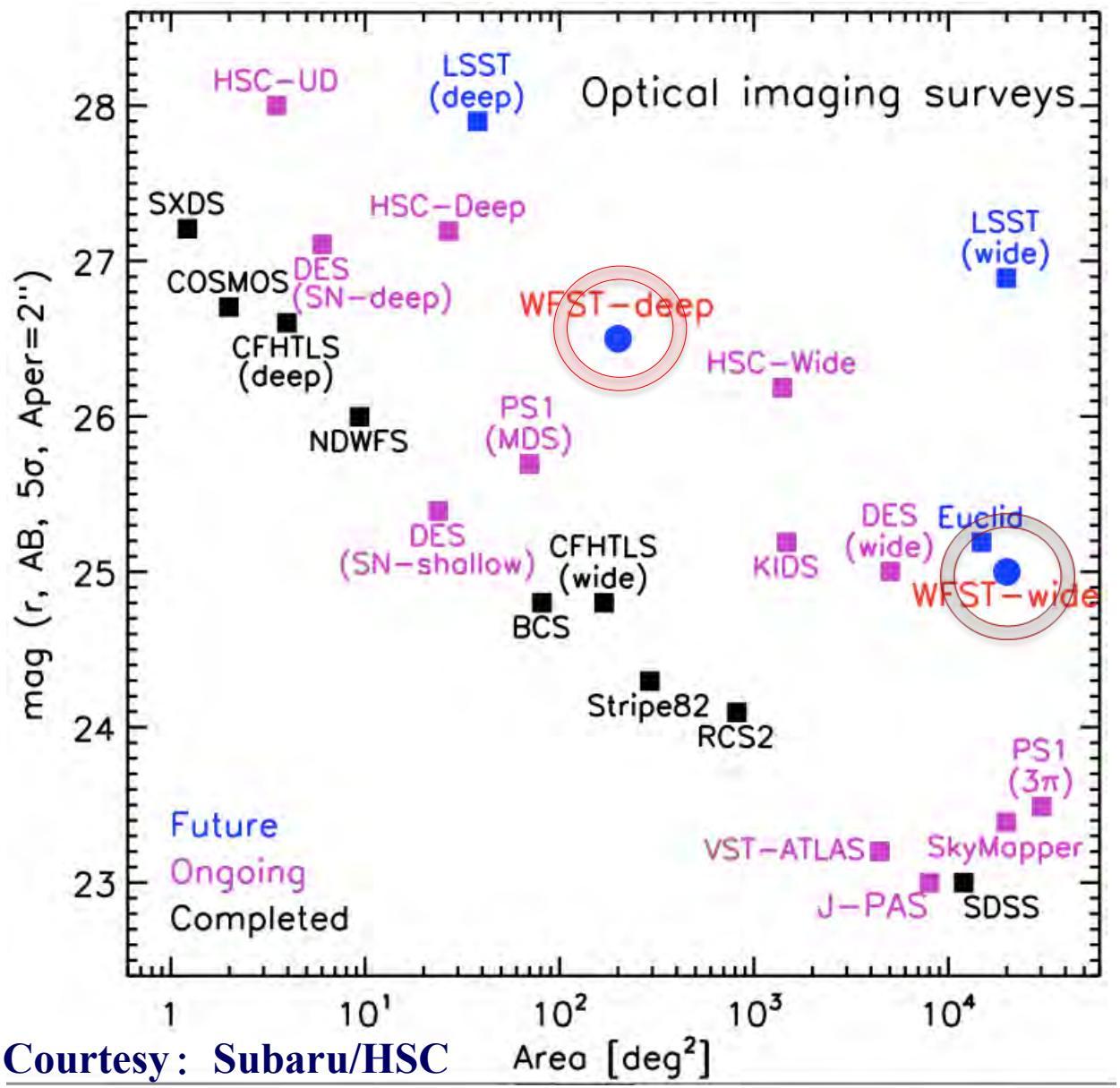
2π Optical Imaging Survey



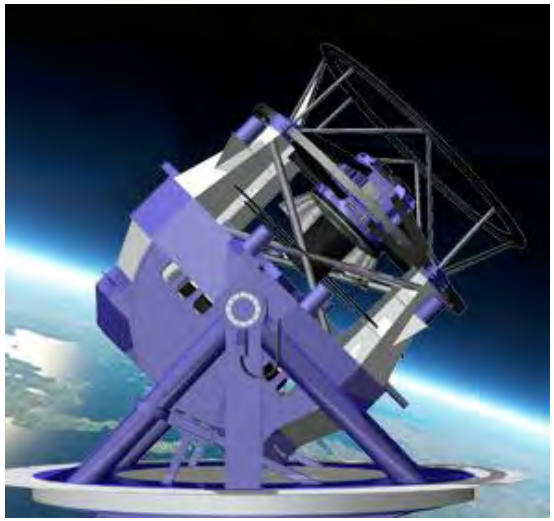
- WFST will map the 2π northern sky every 3 nights
- detect moving objects and variables and transients
- The survey over 6 years reaches r=25.1 (5σ), being the deepest 2π Survey in the Northern sky

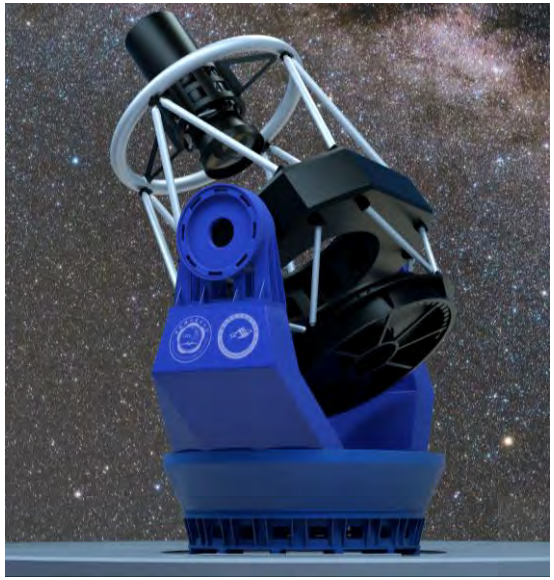
- Synergy with LSST in panoramic view of the solar system, the Milky Way, and the local group; moving and variables objects

Comparison of Optical Imaging Surveys



Courtesy : Subaru/HSC





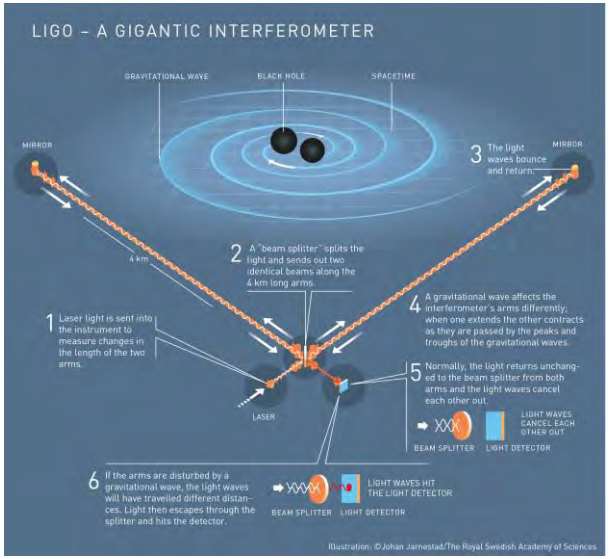
WFST (AΩ = 29.3) costs only 1/50 of LSST.

3. Key Science Goals

- **New Frontier**:
  - Time-domain Astronomy: discover unknown events
  - Extreme physics: GW EM counterparts, Gama-ray Bursts, Tidal Disruptions, etc

- **Solar System Objects**:
  - Panoramic view: main-belt asteroids, comets, Trojans (Planet X), …
  - Search and monitor Near-Earth Objects

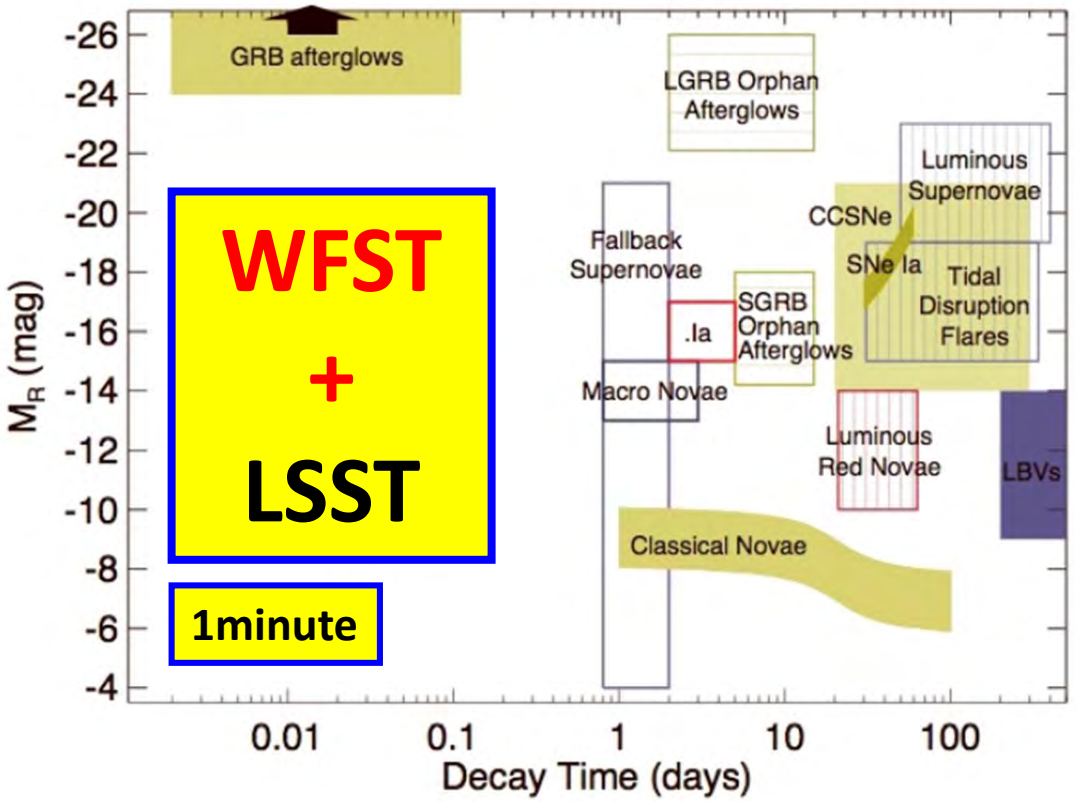
- **MW & Local Group**:
  - Structure: Complete Survey of nearby low-mass stars within 100pc
  - Formation History: Stellar composition and structure to R = 30kpc
  - Archaeology in LG: ultra-faint dwarfs and clusters



New Frontier: Time-Domain Astronomy

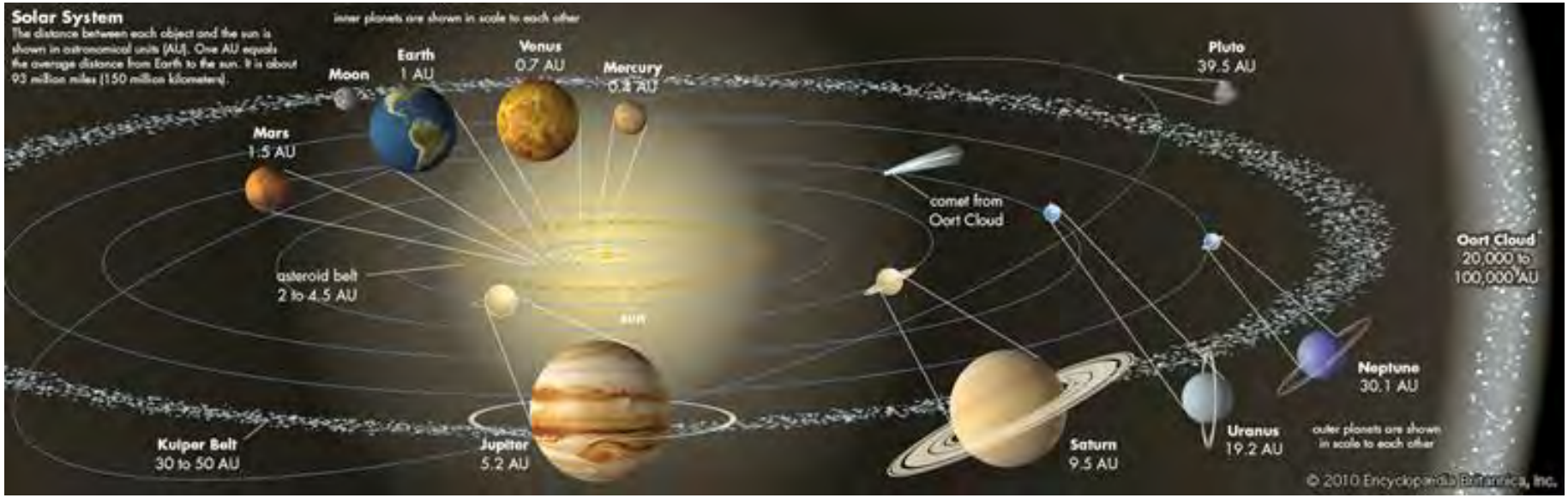
- Gravitational Events
- Tidal Disruption Events
- Supernova
  - SN Physics
  - Extreme Physics
  - SN Cosmology
- Gama-ray Bursts
- Binary of Compact objects
- Variables and Binaries
- AGNs
- **Unknown Events**

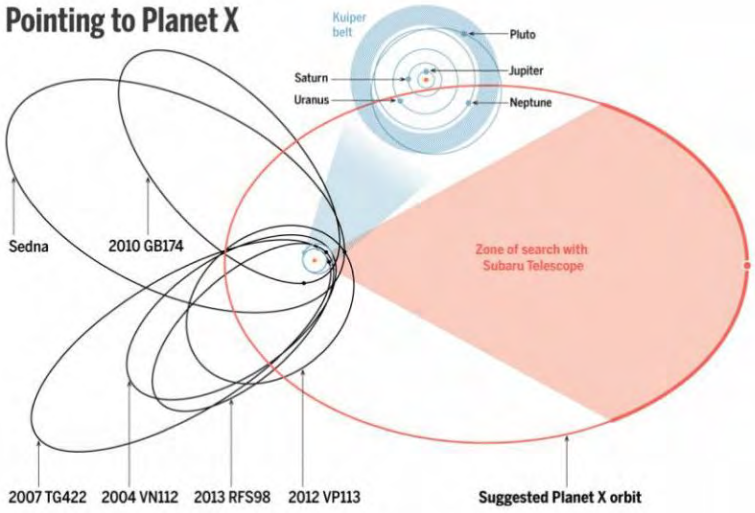
Small telescopes: monitoring of Bright objects! → Larger: Deeper

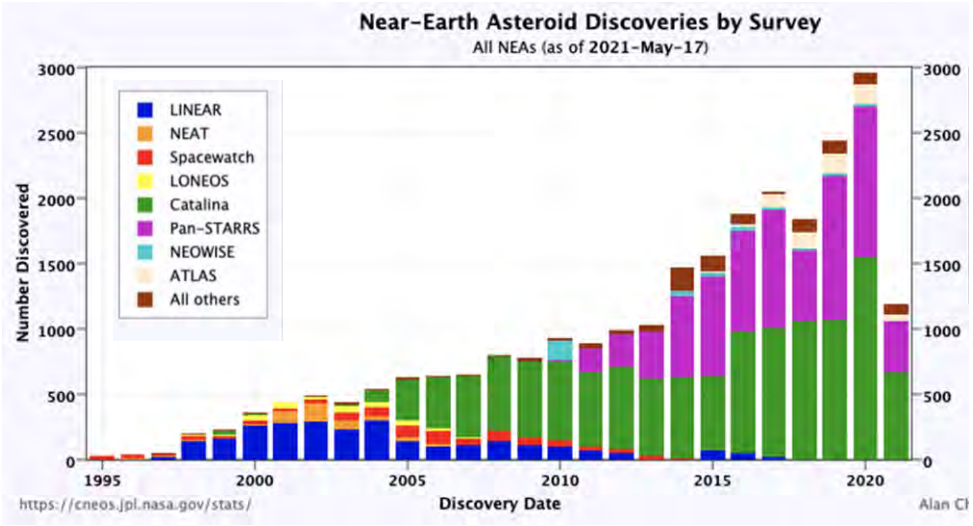


Telescope	AΩ	CCD (Gpix)
SDSS	5.9	0.12
Pan-STARRS1	13.5	1.02
LSST	308	3.2
WFST	**29.3**	**0.7**

Panoramic view of Our Solar System



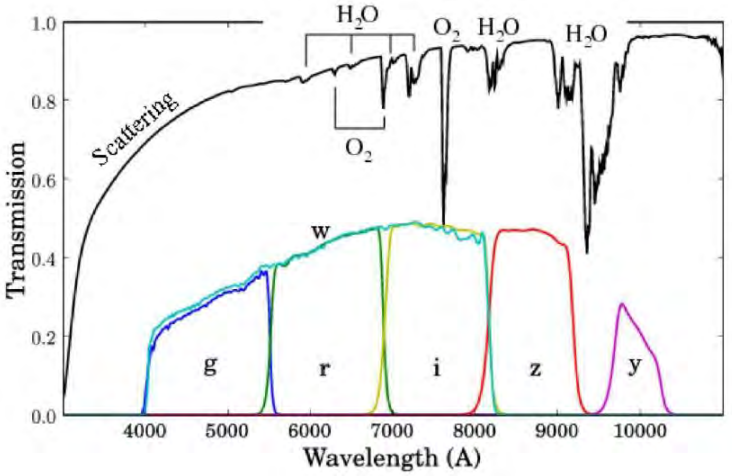




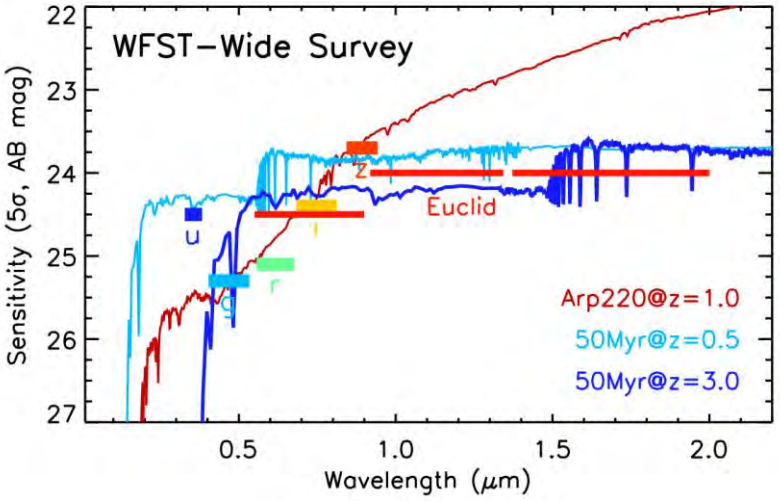
WFST Legacy Data

- **The Deepest Northern Sky 2π Survey with high-quality ugriz deep imaging (r<25.1) and photometric catalogs**
- **Reference catalogs of astrometry, parallax and proper motion for r < 23 stars**
- **Light curves with time scale from hours to 2-3 years for r < 23 variables, AGNs and transients**

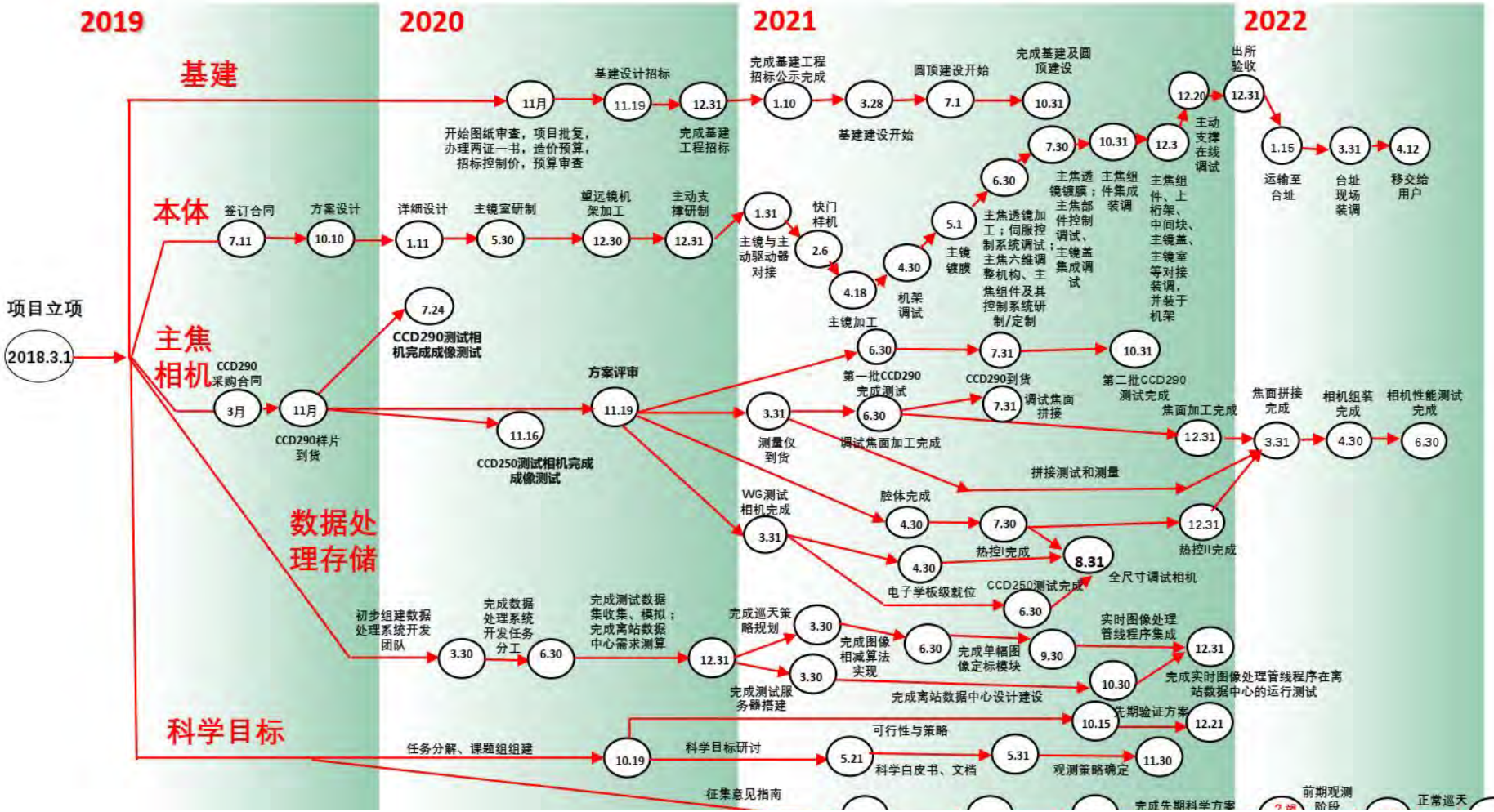
No u in Pan-STARRS and HSC



The Legacy Deep u-band Survey



4. WFST Schedule

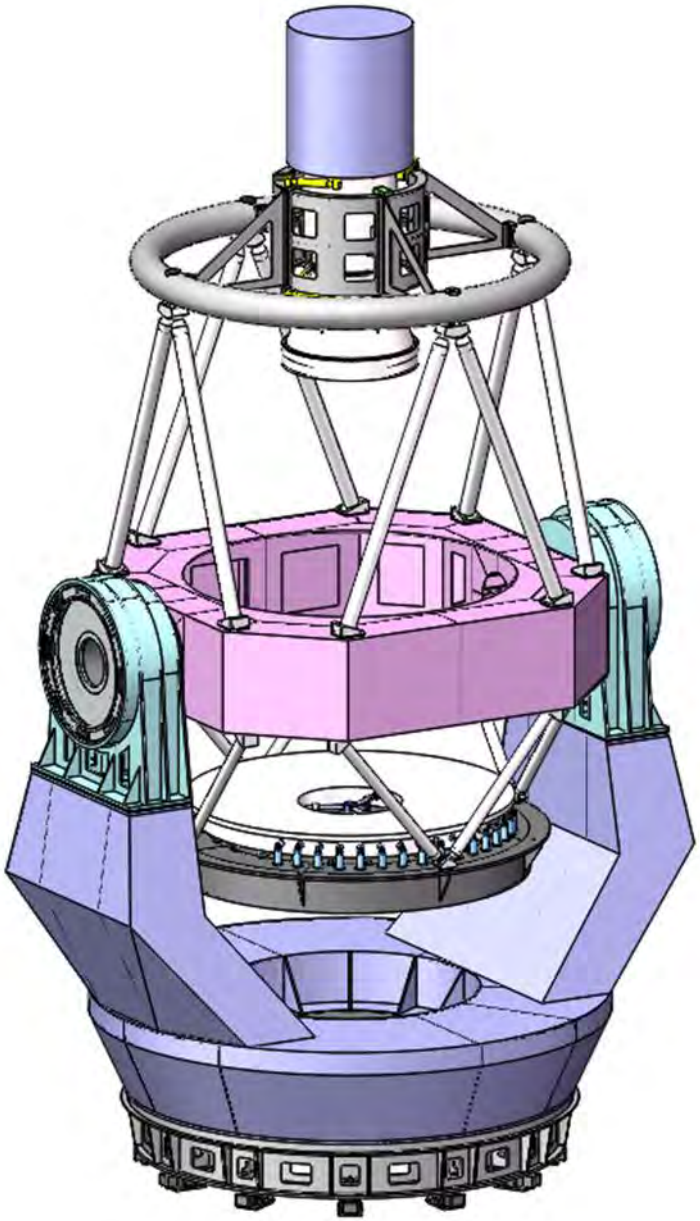


- **Funded March.1, 2018 (¥ 200 million)**
- **Development, Integration and Commissioning: 2018.3 – 2022.x**

4.1 Who will make the telescope?

- Institute of Optics and Electronics (IOE), Chinese Academy of Sciences
- USTC & IOE signed the contract on July 11, 2019, development time in 30 months.

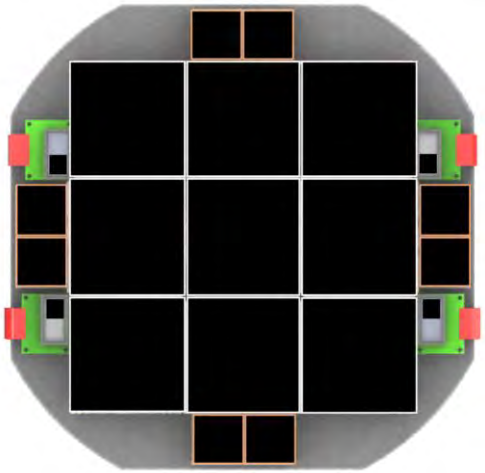
中国科学院光电技术研究所
Institute of Optics and Electronics, Chinese Academy of Sciences



4.2 Who will make the camera?

- Development by the State Key Laboratory of Particle Detection and Electronics, USTC
- CCD From Teledyne E2V
  - 9216 x 9232 10μm x 10μm
  - Image area: 92.2mm x 92.4mm
  - Package size: 98.5mm x 93.7mm
- USTC Signed the contract with E2V on March 12, 2019

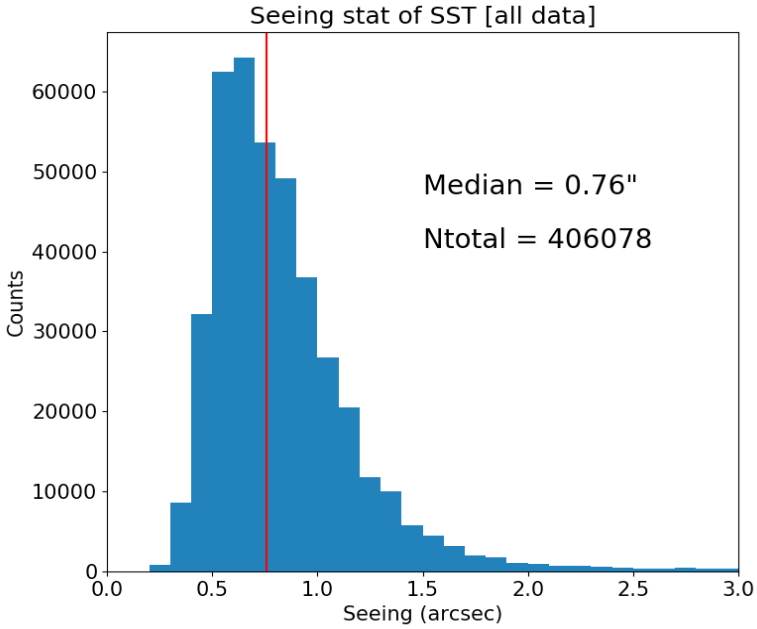
核探测与核电子学国家重点实验室
State Key Laboratory of Particle Detection and Electronics
中国科学技术大学部

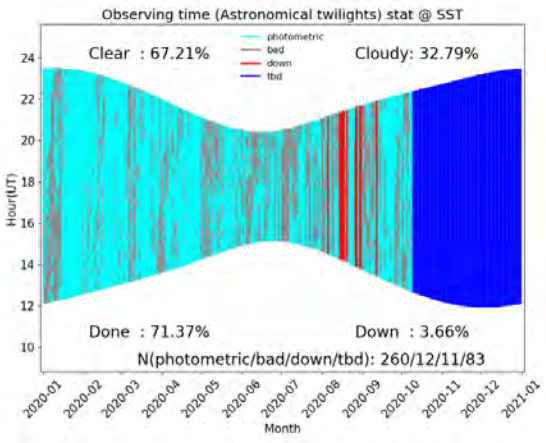


4.3 Where is the site of WFST?

On the top of Saishiteng mountain near the town of Lenghu, Qinghai province.

The site is located at N38.74 deg and E93.34 deg with an altitude of 4200m.





Data Since 2018:

- **the median seeing is 0.76 arcsec,**
- **the observable nights are 83%,**
- **the median night sky background value is 22.3 magV**

5. Summary

- **High sensitivity**
  - **Large collection area (D=2.5m, no secondary mirror)**
  - **Less scattering background light**
  - **High UV throughput + high-altitude site: @ 4000m**

- **High quality imaging (seeing-limited)**
  - **With atmospheric dispersion corrector (ADC)**
  - **With distortion corrector (distortion < 0.1% at edges)**
  - **Homogeneity of image quality (80% < 0.4")**

- **High Survey Power**
  - **AΩ=29.3 (Pan-STARRS1: 13.5, SDSS: 5.9/25.3, LSST: 308)**
  - **Survey speed 6000□° /night @ 30s exposure.**

A Powerful Survey Machine in the Northern Hemisphere.

Thank You For Your Attention!