# Galactic Bulge VHE Tau Neutrino and Gamma-ray Monitor with Ashra-1/NTA


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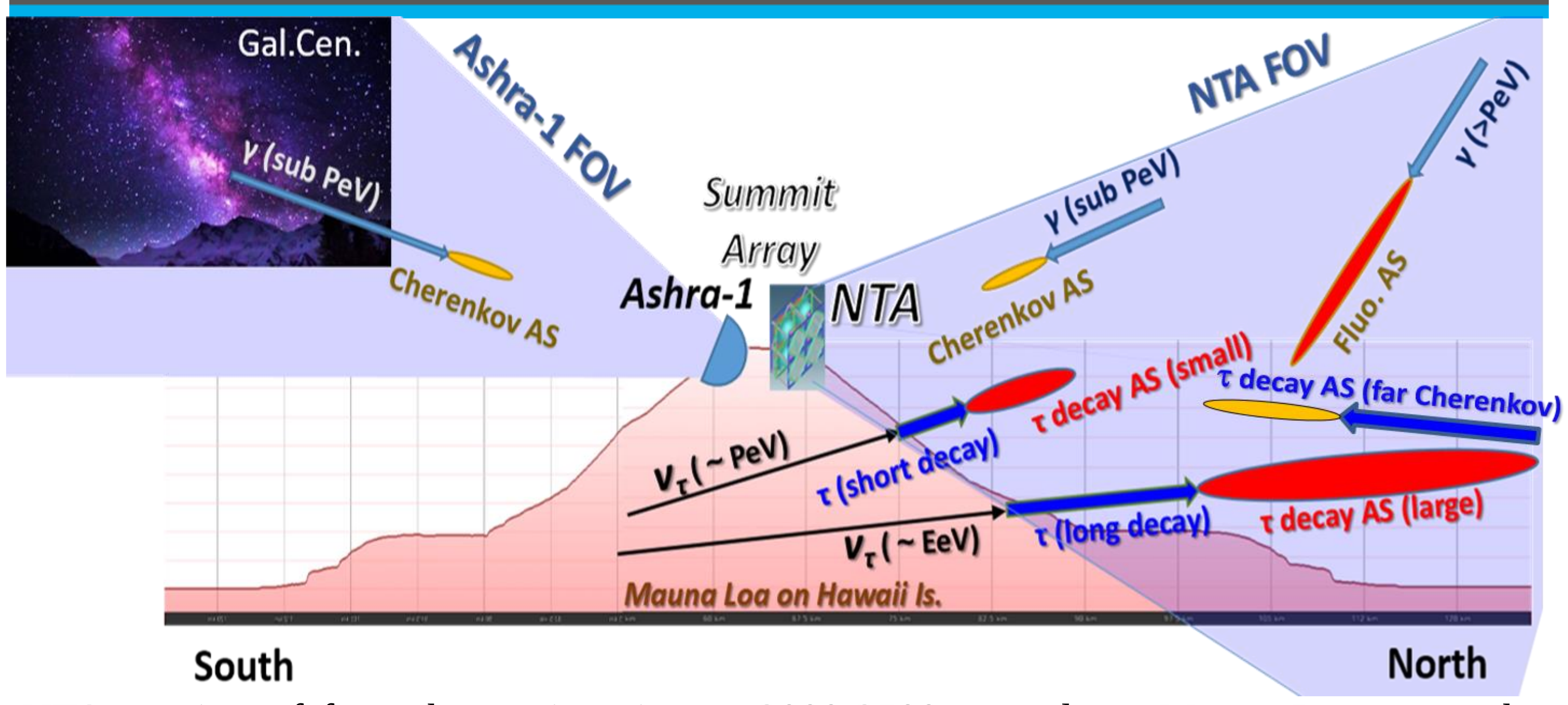
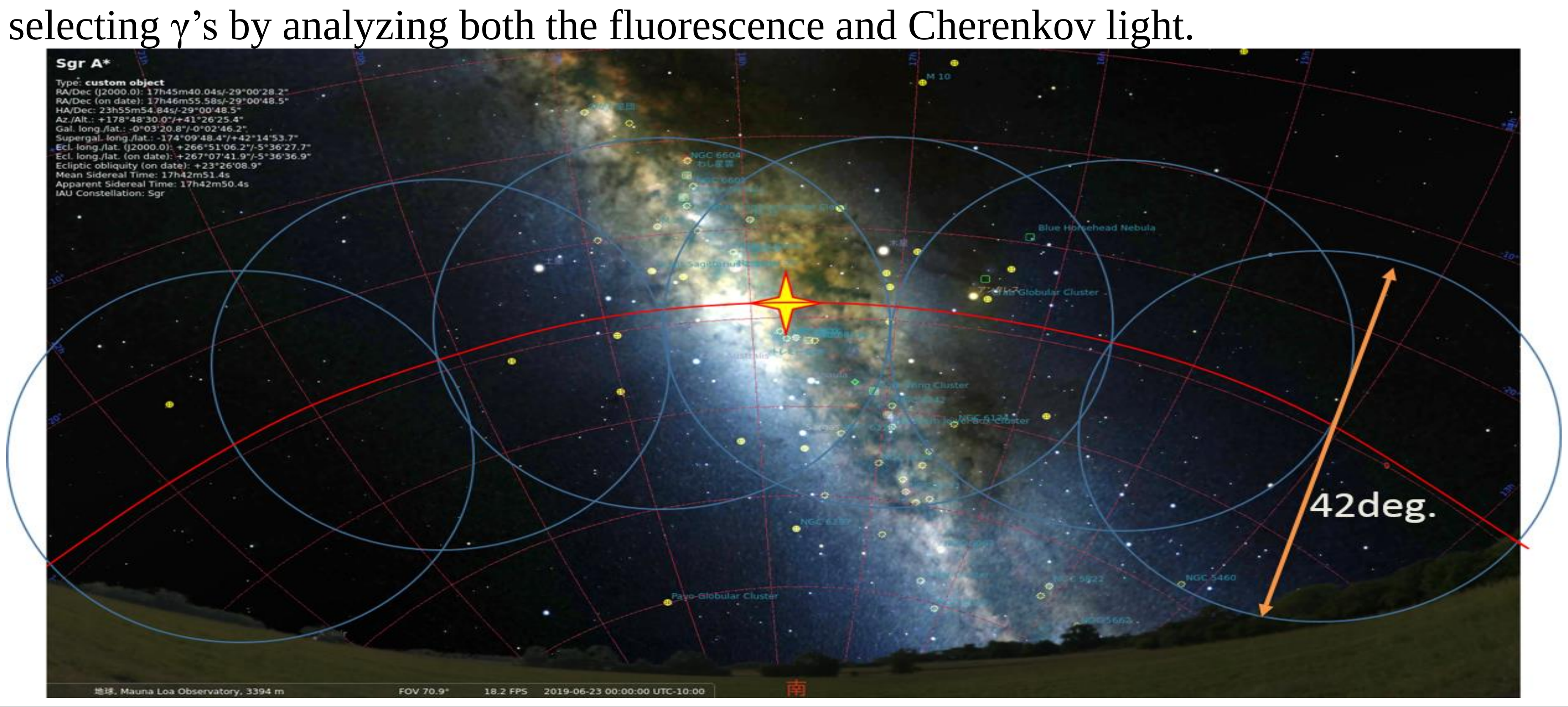
## Pevatron Identification with PeV-EeV ν and TeV-PeV γ

IceCube reported the detection of PeV scale astrophysical neutrinos (ν's). The origin has not been revealed yet [1]. ν production is closely related to that of gamma-rays (γ's). Cosmic ray protons produce pions in the reactions: $p + \gamma \rightarrow \Delta^+ \rightarrow \pi^0 + p$, $\pi^+ + n$; $p$ + nucleus $\rightarrow \pi^{\pm,0} + X$ then, through the decay process of pion, resulting in ν emission as well as γ's. HESS has reported γ's of energy up to 100 TeV from the region surrounding the supermassive black hole Sgr A* at the Galactic Center [2]. They argue that the γ source is a promising candidate of Pevatron, since the observed hard power-low spectrum of γ's seems to extend likely to PeV energy. The γ source is a promising candidate of Pevatron, since the observed hard power-low spectrum of γ's seems to extend likely to PeV energy. Combined detection of PeV-EeV ν's and TeV-PeV γ's is necessary for knowing the location accurately and clarifying the emission mechanism, providing us with an opportunity of identifying Pevatron leading to a clear proof for the existing. "Multi-astroparticle" paradigm [3] can be performed by the combined Ashra-1/NTA as the first step particularly for the Galactic bulge monitor.

## Imaging $\nu_\tau$ / γ / CR Air-Showers




NTA consists of four observation sites at 3000-3500 m a.s.l. on Mauna Loa to watch efficiently the air volume surrounding Mauna Loa above ground or sea. The technique of observing earth-skimming tau ν (ES-$\nu_\tau$) [4] can enjoy a large target mass by detecting air-showers produced by τ decays in the air (right). In particular, the τ particles are produced by $\nu_\tau$'s that interact with the Earth matter. They traverse, and emerge out of a mountain or the ground, then decay and generate air-showers. This ES-$\nu_\tau$ method has a good detection sensitivity for ν 's originating from hadron acceleration in astronomical objects in the PeV-EeV region. Additional advantages are perfect shielding of cosmic ray secondary particles, precise arrival direction determination, and negligible background from atmospheric ν's [5]. The Ashra detector can efficiently image air-shower Cherenkov and fluorescence light generated from ES-$\nu_\tau$ and γ air-showers in the effective volume of atmosphere in the field of view (FOV). The unique is the point-back resolution better than 0.2°, which will yield a high ability of rejecting hadron initiated air-showers and of selecting γ's by analyzing both the fluorescence and Cherenkov light.



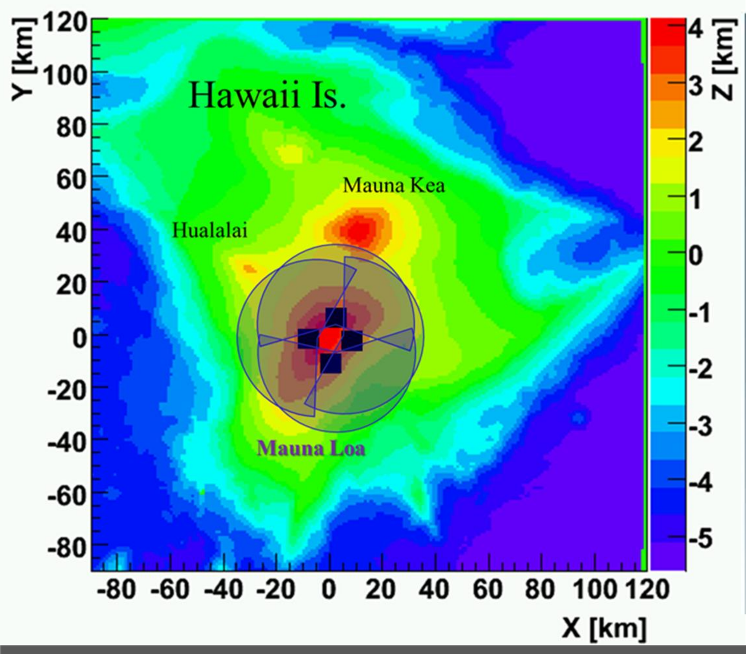

## From Ashra-1 to NTA

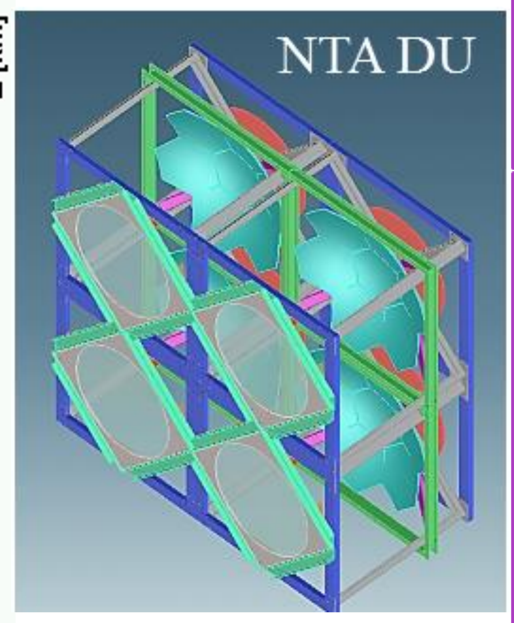
The Ashra Phase I (Ashra-1) [3] light collector as the detector unit achieves a total resolution of ~ 3 arcminutes covering 42 ◦ FOV. The key feature is the use of electrostatic rather than optical lenses to generate convergent beams with a 20 inch Photoelectric Lens Imaging tube (PLI) [6]. The following trigger readout Photoelectric ImagePipeline (PIP) [8] can image and read out three independent phenomena on different time scales, i.e. air-shower Cherenkov emission (ns), air-shower fluorescence (μs), and starlight (s), without sacrificing the S/N ratios. The above figure shows simulated southern sky at the Mauna Loa site at 0:00 on June 23, 2019, where the cross star indicates the location of the galactic center(GC). The track of GC (arc) and the FOV of the rearranged Ashra-1 light collectors (circles) are also shown.


The demon-stration phase has been operated since 2008 at the Mauna Loa Observation Site at 3300 m asl. on Hawaii Island. Following the alert for GRB081203A given by the SWIFT satellite, Ashra-1 succeeded in the first search for PeV-EeV ν τ 's originating from a GRB with the ES- ν τ technique setting stringent fluence limits [9].

## NTA Detector Unit

NTA will use the similar detector unit with Ashra-1 enhancing light gathering efficiency by 10 times with multiple telescope system composed of scaled up light collectors and keeping good point-back resolution less than 0.2°.



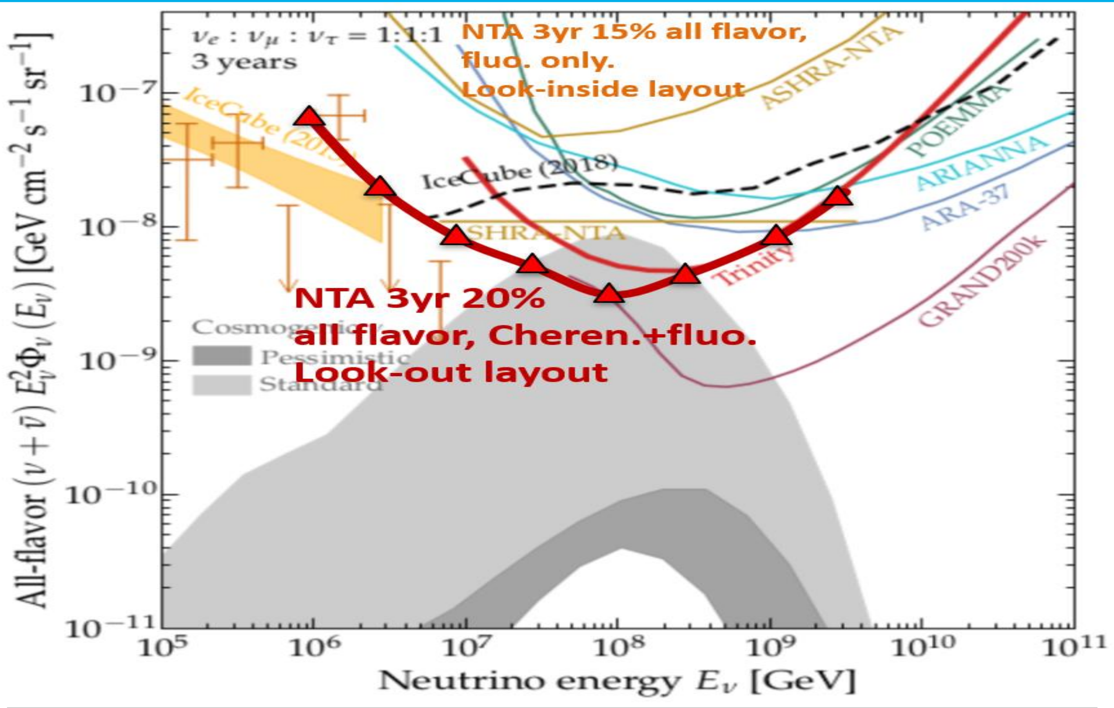



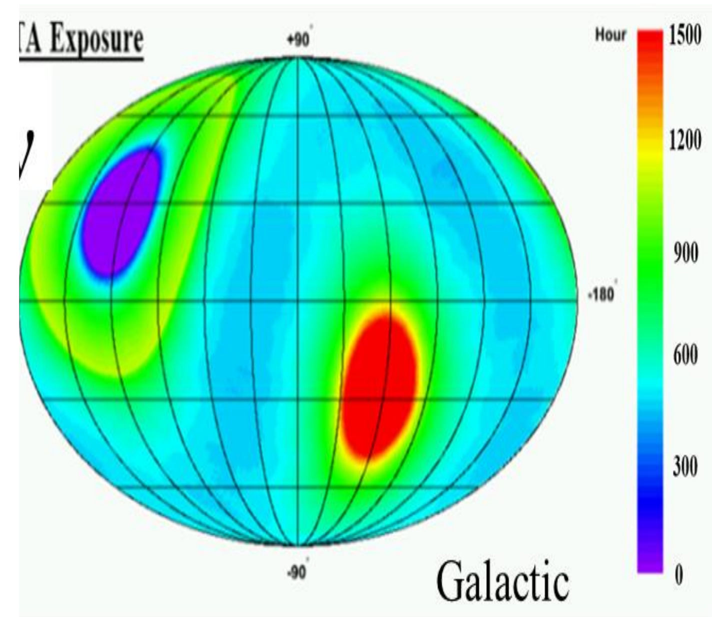

**NTA Detector Unit = Multi-Tel. with 4 LCs**
Ashra-1 x 1.5 scaled-up
+ same trigger & readout

**Light Collector (LC)**
Optics with ϕ1.5m pupil
FOV 30° = focal sphere ϕ50cm

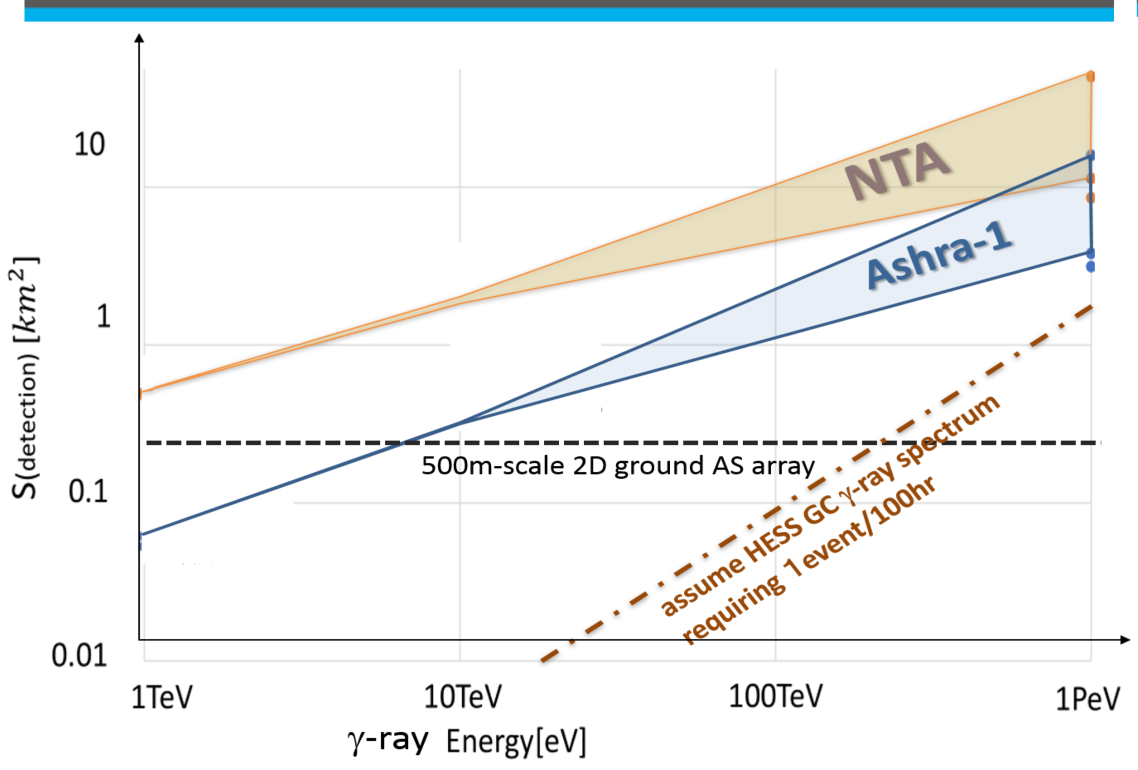
**Detector Unit (DU)**
4 LCs watch same FOV
Coadded 4 images
⇒ Effective pupil = ϕ3m
⇒ Easy to reject CR-μ

## NTA ν Diffuse Sensitivity and Annual Exposure Time




## GC γ Effective Area




## Reference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## New Chapter with Ashra-1/ NTA GC Monitor

The combination between six Ashra-1 light collectors and new NTA detector units can realize the comprehensive observation both with TeV-PeV γ -rays and PeV ν 's. The arranged detector FOVs overlapped by half of adjacent ones. As a result the total rate of the stereoscopic observation is >70% of the GC trajectory. The annual observable time can be 1150 hours × ε during nights without moon in the south, where the weather efficiency ε ~ 90% from the Ashra-1 experience. It is more than 50 times better efficiency than HESS achieved i.e. 227 hours for SgrA ∗ in 10 years [2]. The system can monitor AS CE light of γ -rays from the Galactic bulge efficiently with the large zenith-angle method. Once the northward NTA units detect ν 's from the same direction as γ -rays, we can discuss the physics of the occurrence of γ –rays and ν 's more concretely than ever.