ハイコントラスト望遠鏡「PLANETS」：開発の現状と今後

Current status and future plan of the development of a high-contrast telescope “PLANETS”

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We are carrying out a 1.8-m aperture off-axis telescope project PLANETS (Polarized Light from Atmospheres of Nearby ExtraTerestrial Systems). The high-contrast performance of PLANETS telescope optics is provided by low-scattering off-axis mirror system, adaptive-optics (AO), and stable atmospheric conditions of an observatory site at a high-altitude. In particular, the off-axis system brings us no cross-shaped diffraction pattern caused by the secondary mirror support in the optical path, and thus the scattering light of PLANETS is estimated to be more than 10 times better than that of a normal large telescope.
A major scientific target is to detect faint emissions of gasses erupted from Jovian satellites Io and Europa. These emissions are so faint (10^-3 to 10^-6 to the brightness of planetary or satellite body) close to the main disk (less than a few arcsec). We will elucidate the spatial and time variations of Io volcanoes and its influence on Jupiter's magnetosphere by monitoring volcanic activities on Io's surface with infrared AO imaging at 1-4 um, and neutral emissions (O 630 nm and Na 589 nm) distributed in the atmosphere surrounding Io, plasma torus emission in the inner magnetosphere (S+ 672 nm, S++ 631nm, O+ 733nm, O++ 501nm), and Jupiter infrared aurora emission (H3+ 3.4um, 3.9um). We also observe visible emission (O 630 nm and 558 nm) caused by the dissociation of water molecules suddenly released by Europa's water ejection activity, and clarify the relationship between tidal action and eruption activity, and between surface topography and eruption location. Another major scientific target is the escaping gases surrounding planets. We are examining the detection possibility of Martian ionospheric gases and ion tail using the PLANETS telescope. The target is solar resonance emissions of N2+ at 391.4 nm/427.8 nm and CO+ at 505 nm.
The telescope optics has a Gregorian focus with a FOV of 6 arcsec(F/13). The main mirror is Clearceram Z-HS with a diameter of 1850 mm and thickness of 100 mm. So far, the glass blank of main mirror was made in 2010, the rough grinding was carried out by Harris/Excelis in 2012. In December 2019, the mirror was shipped from Hawaii to Japan for the final polishing. We glued 36 metal adapters on the backside of mirror to connect the mirror support. We adopted the mirror support with warping harness which is similar to that of TMT and the Seimei telescope. We made the elemental test of the whiffletree system, and confirmed that the performance for stress input is as expected by the structure model with a finite element method (FEM), and the repeatability (hysteresis) for stress change is in the acceptable range. We are now carrying out final polishing using a dragging three probe method with a robot-arm system at LogistLab and will complete it within a year. We expect to obtain the accuracy of main mirror better than 20 RMS nm by the final polishing. In addition, we will fabricate the telescope mount and structures using the proto-type mount Seimei telescope. We will assemble the whole PLANETS telescope system, and achieve the first light and technical demonstration, particularly on the high-contrast and low-scattering capability, in Japan within a few years. Further, we already have the construction permit at the summit of Haleakala (CDUP) from the State of Hawaii, and we plan to install PLANETS there as soon as we get the funding for the observatory construction.

P-40

2/8 PM3 17:40 1min

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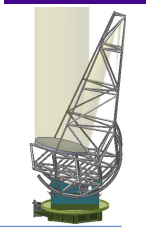
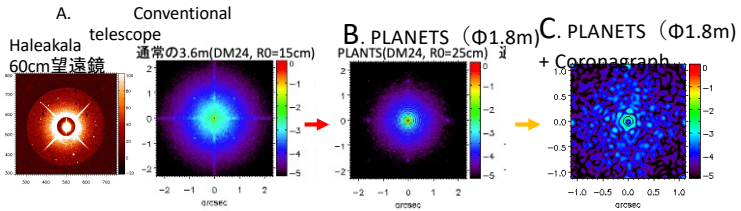
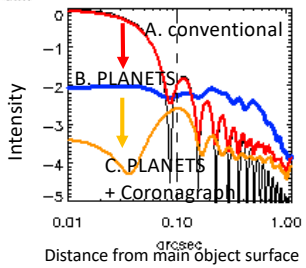


高コントラスト望遠鏡PLANETSの特徴



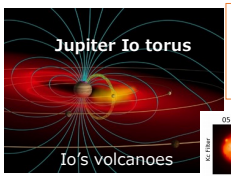
- ✓ 口径2mの軸外し光学系による低散乱特性
  ＋
- ✓ 補償光学系（AO）による大気乱流低減
  ＋
- ✓ コロナグラフ

高コントラスト観測の実現

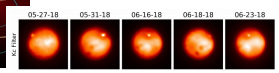


Distance from main object surface

観測ターゲットと科学意義

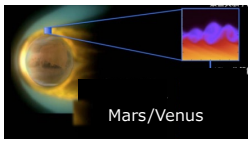


惑星観測において
- ✓ 高コントラスト観測がなぜ必要か？
- ✓ 連続観測がなぜ必要か？
- ✓ 高分散分光観測がなぜ必要か？



我々が継続観測にもちいているT60は、低散乱光学系でなく口径も不足

- 周辺ガス発光は、惑星ディスクの太陽散乱光と比較して10^5〜10^7 倍暗い。
- 通常光学系では、内部散乱光が大きく観測不可能。



望遠鏡仕様と搭載装置

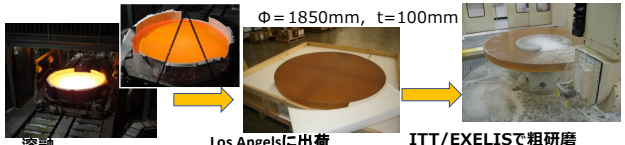
M1: parabola, Φ1.86m, f=4.333m
M2: ellipse, Φ12cm, f = 0.26m
視野 - 6分角（回折限界像は1分角）

装置	仕様
VISP: 可視イメージング分光 ファイバーアレー・AO・コロナグラフ	0.4-0.9μm, R~70,000
MILAHI: 中間赤外レーザーヘテロダイン分光 新開発フォローコーンファイバー	7-11μm, R ~ 10^{6-7}
DiPOL-2: 精密偏光3色イメージャー	B, V, R polarimetry (DoLP ~ $10^{-5\sim-6}$)
EPSRIT: 近赤外エシェル分光撮像 ファイバーアレー・AO	1-4μm, R ~ 20,000
GIGMICS: 中間赤外エシェル分光 新開発フォローコーンファイバー	7-12μm, R ~ 40,000

開発： 1.85-m主鏡製造と研磨

進行中

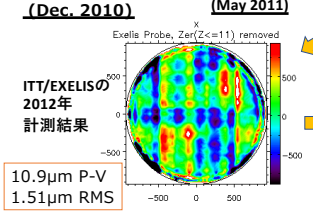
Ohara Clearceram Z-HS



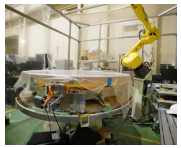
容鋳 (Dec. 2010)

Los Angelsに出荷 (May 2011)

ITT/EXELISで粗研磨 (July 2012)



10.9μm P-V
1.51μm RMS
→ラフネスを~20nmRMSまで改善する必要あり



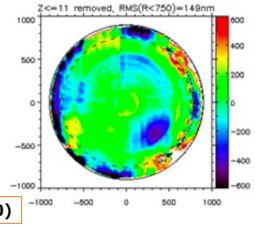
日本で最終研磨(到着 Jan. 2020)

岐阜・ロジストラボ社において、最終研磨のために、主鏡形状測定を2021年9月から開始。

ロボットアームと3点引きずり法による計測、ならびにデータスティッチング解析アルゴリズムにより、干渉系と比べて格安の検査方法を確立。

2021年10月末から研磨を開始。

c) フェーズ1, 6回目研磨後

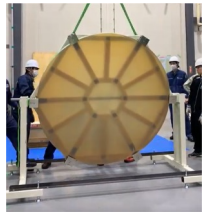


主鏡保持機構

ほぼ完了

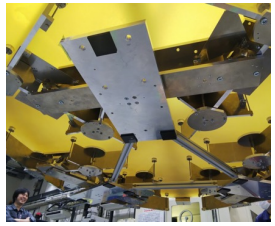
- ✓ 2020年2月より開発開始
- ✓ TMT望遠鏡や京大せいめい望遠鏡で採用されているウィッフルツリー機構を採用
- ✓ 最終研磨に必要な水平（天頂）設置の架台は完了
- ✓ 実際の観測に必要な、天頂角稼働架台は今後

A

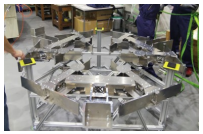


Whiffle-tree mirror support

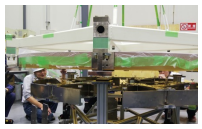
E



C

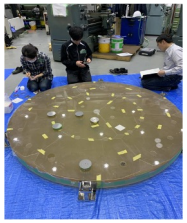


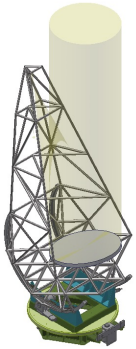
D



Gluing metal adopters

B

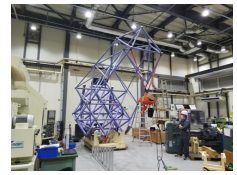




望遠鏡架台

完了

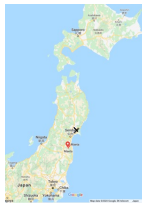
- ✓京大せいめい望遠鏡のプロトタイプ架台を再利用
- ✓軽量・ロバストなトラス構造
- ✓Rガイド・エンコーダ・上部構造は新規開発
- ✓東北大内で開発し、完了ずみ



今後の展望（１）国内試験観測

2022

- ✓東北大学・福島県飯舘観測所のスライディングルーフ施設を利用
- ✓来年2022年に、星を用いて望遠鏡全系の動作確認と、光学系の性能実証を実施する計画
- ✓日本では上空のジェット気流のため、科学目的は達成できない → 国外の高地における気流安定条件が不可欠

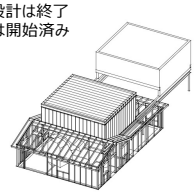


（２）ハワイ観測

2024 -

- ハレアカラは高地にあり、晴天率・気流安定度が世界トップレベル
- ハワイ大との共同研究で、ハワイ大の既存建屋を使用
- ハワイ州からの山頂建築許可（CDUP）をすでに取得済み
- 基本的な設計は終了
- 初期工事は開始済み

3040m, GLAT=20º 42.5' N, GLON=203º 44.5' W



まとめ

【高コントラスト光学】1.8m軸外し主鏡による明るい天体近傍の希薄発光観測に特化。
【世界最高条件の晴天率・気流安定度】ハワイ・ハレアカラ山頂（標高3040m）に設置。
【フレキシブル運用】専有望遠鏡をいかした、モニタリング、ToO、探査機連携観測。
【高分散分光装置】可視〜中間赤外までほぼ全てをカバーする高分散分光装置を搭載する。
【建築のチャンス】ハワイ州からの山頂建築許可（CDUP）を取得済み。
【他分野との共同】多方面の分野の科学研究・実利用産業での活用も期待。

惑星・小天体・突発天体・系外惑星ならびに光赤外装置開発の広い分野から、PLANETS望遠鏡を利用した共同研究をぜひお願いします！