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S2-009: 次期太陽観測衛星「Solar-C」ミッション提案

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Solar-C WG (ISAS/JAXA)
Project Office for Solar-C

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Solar-C Working Group

- 2007年 発足 2案検討 A案:黄道面脱出 B案:高分解能分光観測
- 2008年 1st Solar-C Science Definition Meeting
- 2010年 2nd Solar-C Science Definition Meeting
  WG ＞ 5・国際sWG
- 2011年3月:主案決定: ○評価項目 (1)サイエンス(2)衛星と搭載装置の技術的成熟性(3)JAXAに要求する総開発経費の試算(4)外国宇宙機関の幅広い参加が可能か(5)主要観測装置1台相当の国内開発が可能か
  ☆サイエンスの優劣はなし(A=B) ☆技術実証に時間を要する(A>B)
- 2011年度 ミッション・サイエンスの精錬
  ↓ サイエンス要求→ミッション要求→システム要求
  システム/ペイロード(要素技術etc)の開発成立性の検討
- 2013年度 ミッション提案(準備)完

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Mission Goals

Understand solar and heliospheric **magnetic activity**
Develop and observationally test **algorithms for solar activity prediction**
Develop an understanding of the **magnetic coupling** of convection zone – photosphere – chromosphere – transition region and corona

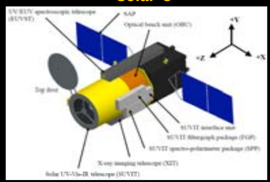
Expected achievements

- **3D magnetic structure in the solar atmosphere**
- **Solar flare prediction** – contribution to **SW and SSA**
- Chromospheric and coronal heating - Origin of **solar wind**
- **Fundamental plasma processes - Magnetic reconnection**

Distinct features

- a **fundamentally new way of viewing** the entire solar atmosphere, essentially with the same high spatial and temporal resolution, in addition to performing simultaneous high resolution spectropolarimetric measurements for the first time.
- a very **challenging mission** to design, develop, scientifically and technically, and to deliver **an order-of-magnitude improvement** over present measurement capabilities.

Solar-C



Model Payloads

SUVIT: UV Optical IR Telescope
Aperture: 1.5 m diameter
Focal Instruments:
wide & narrow band imager
spectropolarimeter (2D)

XIT: X-ray Imaging Telescope
Normal incidence EUV imager
angular res.: 0.2" arcsec
(optional) Grazing incidence soft X-ray imager
CMOS-based Ph-counting with 1" ang. res.

EUVST (UV/) EUV Imaging Spectrometer/LEMUR
Angular resolution: 0.3 arcsec
Wavelength: 17-130 nm
Temperature coverage: 0.01 - 20 MK

International task shares

Spacecraft		JAXA
Launch vehicle		JAXA
SUVIT	Large-aperture telescope	JAXA (with feed optics to focal plane)
	Primary/secondary mirror	ESA (with test flat)
	Focal plane instrument	
	Filtergraph	NASA
	Spectro-polarimeter	JAXA-led international consortium
EUVST		ESA/NASA
XIT	Normal incidence	NASA
	Grazing incidence (optional)	TBD

Project status/plan

- JAXA-based working group with more than 70 members & contributors from JAXA, NAOJ, Kyoto U., Nagoya U., Riken, NIST, LMSAL/US, HAO/US, HSAC/US, MPS/DE, IAC/ES, and MSSL/UK [Working group PI: Tetsuya Watanabe (NAOJ)]
- Selected as one of eight most important future projects by astronomy/astrophysics division of Science Council of Japan
- Recognized as one of key future JAXA missions in solar and heliospheric physics
- Expected to include substantial contributions from the United States and Europe
- To be ready for Mission Proposal in FY2013
- Target launch year ~2020.

US-Japan Collaboration

-**NASA contribution**: It is a high priority of the **SHP Panel** that NASA and its partners form a Science and Technology Definition Team for Solar-C as soon as possible. The panel expects that NASA contributions would involve **the most technically challenging elements, such as the focal-plane packages (cameras, detectors, and so on),** which would afford the U.S. science community an opportunity to make critical advances in remote-sensing capabilities.
-The total cost to NASA through Phase E should be capped at $250 million. Solar-C presents a unique opportunity for solar and space physics to make flagship-level science advances for the cost of an Explorer.

Schedules (earliest possible)

FY2014: Pre-project (phase-A)
FY2015-16: Basic design (phase-B), PDR
FY2016-17: Detailed design (phase-C), CDR
FY2018-20: Fabrication, testing (phase-D), PQR/PSR
FY2020 - : Launch, Operation (phase-E)

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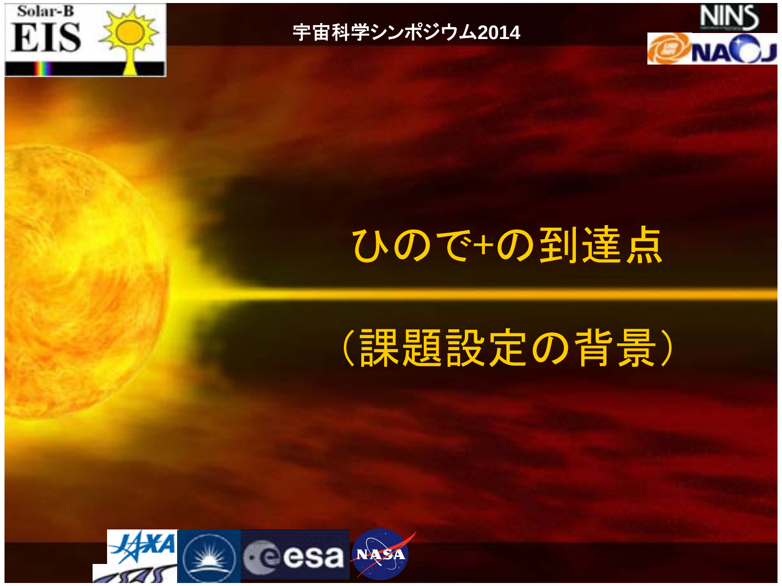
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ひので+の到達点
（課題設定の背景）
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ウム2014
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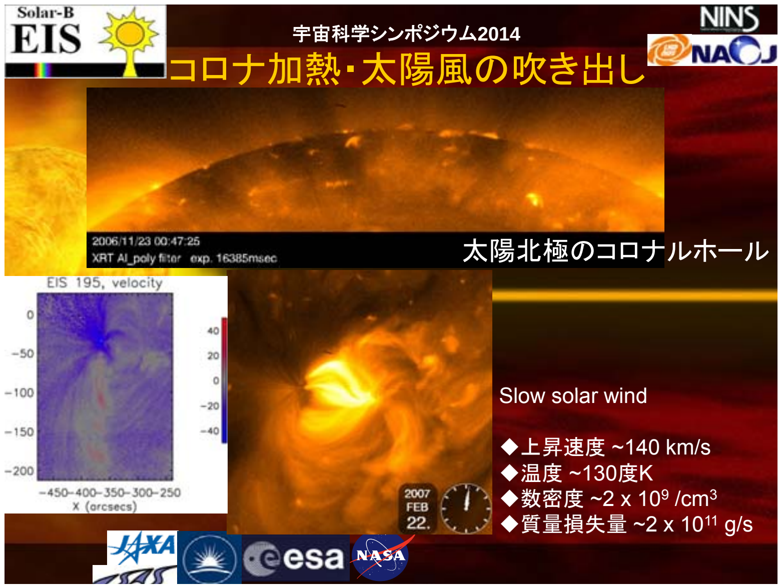
NAOJ
courtesy of yk
彩層のダイナミズム
微細磁気活動
JAXA
esa
NASA
courtesy of tjo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コロナ加熱・太陽風の吹き出し
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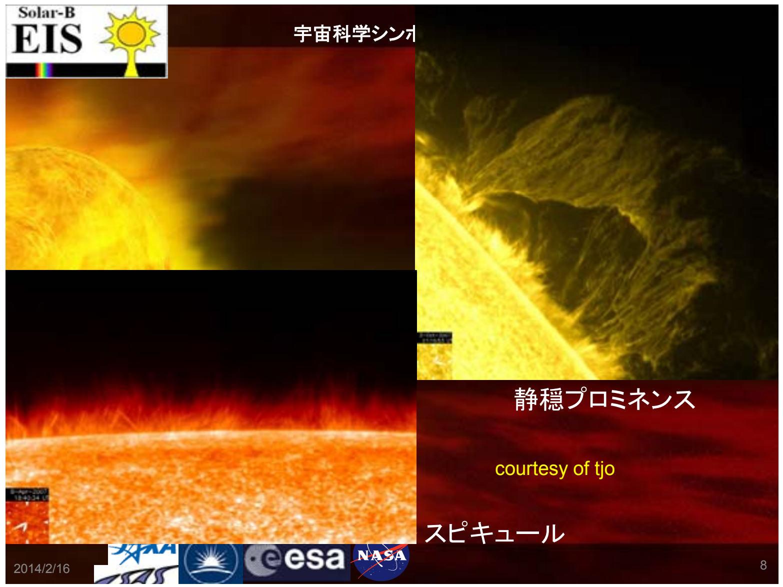
XRT Al_poly filter exp. 16385msec
太陽北極のコロナルホール
EIS 195, velocity
X (arcsecs)
2007
FEB
22.
Slow solar wind
◆上昇速度 ~140 km/s
◆温度 ~130度K
◆数密度 ~2 x 10^{9} /cm^{3}
◆質量損失量 ~2 x 10^{11} g/s
JAXA
esa
NASA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courtesy of tjo
スピキュール
2014/2/16
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課題設定の背景

<これまでの観測から分かっている磁気大気構造>

ひので+偏光分光観測
- ～ 0.3秒角の光球磁場を安定的に観測
- ～ 0.1秒角の光球構造の存在（瞬間的な地上の画像観測より）
- ～ 0.1秒角のダイナミックな磁気構造

ひので+画像観測
- ～ 0.2秒角のダイナミックな彩層構造

ひので+分光観測
- ～ 0.3-0.5秒角のダイナミックなコロナ構造

... the observation of such small scale structures and processes is within our reach! ..

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サイエンス課題

- 彩層・コロナ・太陽風の加熱／加速機構及び各大気層のエネルギ伝播の解明
- フレア・ジェット・CMEなど太陽・太陽圏・地惑圏の短期的な活動を駆動する大規模爆発現象の物理的起源の決定
- 太陽プラズマ実験室で発生する磁気再結合・MHD波動／衝撃波／乱流・プラズマ不安定性など基礎物理過程の観測と理解・宇宙天気
- 太陽周期活動・宇宙気候をつくりだす基本機構の同定

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サイエンス課題攻略へのユニークな手段

- 分光偏光観測による光球・彩層微細構造、3次元磁場構造及びその時間変化の決定と, 詳細な外挿モデルや動力学シミュレーションを駆使した遷移層・コロナなど「low-β」大気下層境界条件の導出
- 最高空間分解能による全温度大気層のつなぎ目のない観測
- 全大気層に普遍的なダイナミクスを理解する高時間分解能観測
- 全大気層の高波長分解能分光観測

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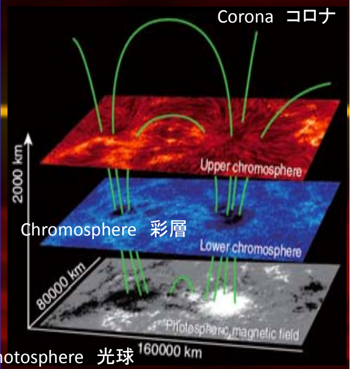
太陽の活動現象の現場

- 活動現象には磁場が中心的な役割を果たしている
  - エネルギー源は磁場を通して渡される光球下の対流運動
- 磁場は光球下より供給
  - 磁場の生成は光球下
- 光球からコロナ間の磁気結合
  - 光球からコロナまで数千km
    - 角距離にして5秒角程度
    - この間に5800Kから10^6Kに温度上昇
  - 磁場が異なる温度の大気間を貫通して大気間は接続されている
  - 彩層・コロナ・フレアの温度上昇は磁気的加熱による
  - 黒点の発生する領域は閉じた磁気構造, 太陽風が吹き出す場所は開いた磁気構造

光球と彩層, 光球からコロナまでを同時に観測することが活動現象を理解する基本



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ひので vs Solar-C

	findings	ひので		Solar-C	
		spectroscopy	magnetic field	spectroscopy	magnetic field
コロナ	ヨ0.3coronal loops	2"		0.3"	
遷移層	ヨ0.2structure	2"		0.3"	
彩 層	ヨ0.2spicule/prominece			0.2"	0.2"
光 球	ヨ0.2magnetic structure	0.2"	0.2"	<0.1"	<0.1"

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Expected achievements

- **3D magnetic structure in the solar atmosphere**
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⇒ Science Cases

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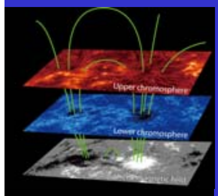
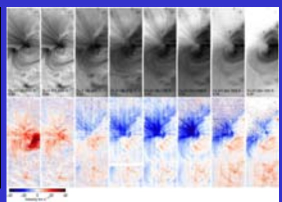
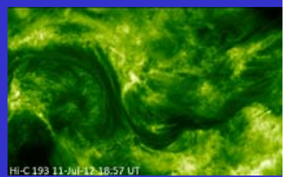
Science Cases

Magnetic conectivity throughout the atmosphere







SUVIT: Photo- & chromo- spheric magnetic Fields
S:~ 0.1 - 0.2"
C:< 10s

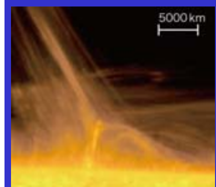
EUVST: chrom. ~ TR ~ corona
T: 0.02–20 MK S: ~ 0.3"
C: ~ 0.2 s

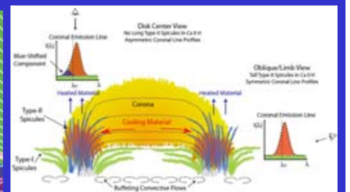
XIT: TR ~ corona
T: 0.08–20 MK
S: ~ 0.2" - 0.3"
C: ~ 0.1 -10 s

Science Cases

Energy transport and release

(waves, reconnection, shocks, instability…)



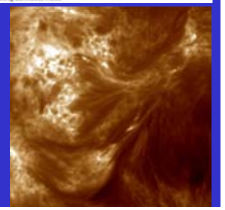


Chromospheric jets & type II spicules

SUVIT: Photo- & chromo- spheric magnetic Fields
S:~ 0.1 - 0.2"
C:< 10s

EUVST: chrom. ~ TR ~ corona
T: 0.02–20 MK S: ~ 0.3"
C: ~ 0.2 s

XIT: TR ~ corona
T: 0.08–20 MK
S: ~ 0.2" - 0.3"
C: ~ 0.1 -10 s



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The chromospheric and coronal heating problem

No.	目的	SUVIT 要求	SUVIT SP-IFU		SUVIT Filtergraph		EUVST 要求 / 仕様			XIT 要求 / 仕様	
4	様々な波動が光球・彩層で発生する現場、層状大気(彩層-遷移層-コロナ)中を伝わる際にどう振る舞うか、特に波動が強く反射されたり、モード変換を起こす現場を特定する。	光球におけるMHD波動の励起、及び、彩層における波動の振る舞いを、速度・磁場の時間変動としてとらえる。	Mode lamda Sampling Cadence FOV	Normal scan CaII854 0.14"x0.18" 12s 9″x9″	BFI NFI Sampling Cadence FOV	CN-band FeI525 IV 2λ CaII854 10λ 0.015" (BFI) 0.0225" (NFI) 15s (CaII, CN) 30s (FeI) 60"x60"	遷移層・コロナを伝搬する様々なMHD波動の振る舞いを分光でとらえる Mode Resolution Exposure Cadence FOV Temperature # lines	SS Ultra-Fast 0.28" 0.1s 0.2s 0.28"x91" 0.02-20MK 4 lines	Dynamics Fas 0.28" 0.5s 10s 5.6"x280" 0.02-2MK 8 lines	高視野画像で大局的な磁場構造を捉え、動画観測から、視線方向にtransverseな波動の振る舞いをとらえる lamda Resolution Cadence FOV	 0.8MK(171Å) 0.05MK(304Å) 0.2″ 10s 400″x400″
5	ナノフレアによる熱化を追うために、500万度以上のプラズマの振る舞いをFeXVIII (logT=6.8)と0.5-2keVのスペクトルを用いて計測して、100万度プラズマや足元の磁場と比較する。	コロナループの足元にある彩層の磁場を計測して、彩層における磁場・速度場や電流シートの有無を調べる。	Mode lamda Sampling Cadence FOV	Mosaic normal scan HeI1083 0.14"x0.18" 600s (12s/pos) 60"x60"	BFI NFI Sampling Cadence FOV	CN-band CaII854 IOUV 5 0.015" (BFI) 0.0225" (NFI) 30s 60"x60"	遷移層、コロナのプラズマ量を各温度ごとに分光観測から計測し、プラズマのDEM分布を明らかにする。特に、ナノフレアの熱化が顕著に現れると期待されるFe XVIII(630万度)の強度および視線方向運 Mode Resolution Exposure Cadence FOV Temperature # lines	AR Full 0.28" 1s 1000s 280"x280" 0.02-20MK 8 lines	AR Context 0.56" 1s 500s 280"x280" 0.02-20MK 16 lines	Fe XVIII(630万度)とFe IX (80万度)の強度の空間分布を計測し、その時間変化および視線方向にtransverseなプラズマ流を動画としてとらえる。 lamda Resolution Cadence FOV	 6.3MK(94Å) 0.8MK(171Å) 0.2″-0.4″ 10-50s 400″x400″

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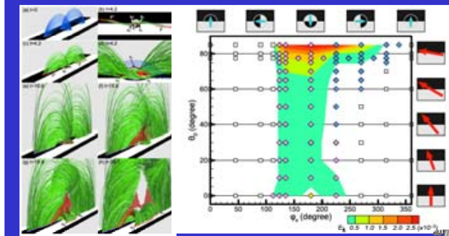
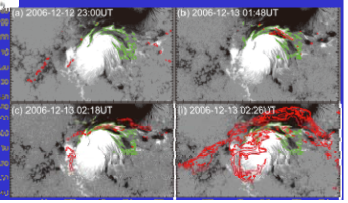
Science Case

Magnetic activity prediction



Numerical simulation of a solar eruption triggered by flux emergence with opposite polarity compared with pre-existing large-scale field (left), and diagram summarizing the numerical (right), which shows that large-scale eruption happens when emerging field has strong shear.



Evolution of photospheric longitudinal fields (gray-scale) and chromospheric Ca II emission (red contours) observed with HINODE SOT through the X-class event on 13 December 2006 (Kusano et al. 2012). Green lines indicate the polarization inversion line.

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Solar flares and coronal mass ejections: from understanding to prediction

No.	目的	SUVIT 要求	SUVIT SP		SUVIT Filtergraph		EUVST 要求 / 仕様			XIT 要求 / 仕様	
10	フィラメント噴出に至る過程を理解するために、フィラメントおよびその周辺の磁場構造・動的な構造がどうのように発達していくかを明らかにする。	フィラメントやプロミネンス内部の磁場を直接測定し、その発達の様子をとらえることで、フィラメント噴出やコロナ質量放出の起源となっているコロナ中の磁場構造を明らかにする。	SP-slit Mode lamda Resolution Cadence FOV	 HeI1083, SiI1083 0.2" 2 hr 180"x180"	Mode Lamda Resolution Cadence FOV	λscan (5pos) imaging Mag/Doppler Hα (λscan) CaII854(λscan) CaII854(mag) Continuum 0.1" 1-3 min 180"x180"	爆発全体像をとらえるために、全体をカバーできる最大視野に対して彩層〜遷移層〜コロナの輝線を同時分光観測。 Mode Resolution Exposure Cadence FOV Temperature # lines	AR Context 0.56" 1s 500s 280"x280" 0.02-20MK 16 lines		コロナ中と遷移層での加熱現象(増光)、フィラメント磁場微細構造の撮像観測 lamda Resolution Cadence FOV フィラメント・フィラメントチャンネルの温度分布と時間発展を検出 (XIT- Energy Resolution Cadence FOV	 0.05MK(304Å) 0.8MK(171Å) 6.3MK(94Å) 0.2" 10s 400"x400" 0.5-2 keV 2" 30s (for spectra) 80"x400"
11	フレアの発生トリガーの過程を理解するために、太陽大気中に磁気エネルギーがどのように注入(浮上)され、そしてフレアやCMEを起こすかを追跡する	活動領域光球ベクトル磁場に加え、彩層ベクトル磁場を取得し、磁気浮上やシア運動による、磁気エネルギーの入射・蓄積を定量的に測定するとともに、フレア発生時の磁気シアの時間変化をとらえ、フレアのトリガー過程を調べる。	SP-slit Mode lamda Resolution Cadence FOV	 HeI1083, SiI1083 0.2" 2 hr 180"x180"	Mode Lamda Resolution Cadence FOV	λscan (5pos) imaging Mag/Doppler Hα (λscan) CaII854(λscan) CaII854(mag) Continuum 0.1" 1-3 min 180"x180"	彩層〜遷移層〜コロナの輝線を同時分光観測して、活動領域視野のマップを繰り返し取得 Mode Resolution Exposure Cadence FOV Temperature # lines	AR Context 0.56" 1s 500s 280"x280" 0.02-20MK 16 lines		コロナ中と遷移層での加熱現象(増光)のコンテクスト撮像観測 lamda Resolution Cadence FOV フレア開始前ー初期のARコロナプラズマの温度分布と時間発展、超熱的電子の空間分布(あれば)を検出 Energy Resolution Cadence FOV	 0.05MK(304Å) 0.8MK(171Å) 6.3MK(94Å) 0.2" 10s 400"x400" 0.5-10 keV 1" 30s (for spectra) 80"x400"
12	太陽サイクル活動の強さを決める要因を理解するために、太陽極域に存在する磁場およびその時間変動を長期間モニターする。	太陽極域に存在する磁場およびその時間変動を観測する。	SP-IFU Mode lamda Resolution Cadence FOV	 Mosaic fast scan HeI1083 or FeI525 0.28"x0.36" 1800s 143"x184"	BFI NFI Resolution Cadence FOV	 FeI525 IOUV 5λ 0.2" 180s 184"x184"	極域を彩層〜遷移層〜コロナの強輝線を分光観測し、グローバルな磁場構造を観測。 Mode Resolution Exposure Cadence FOV Temperature # lines	Corona Deep 2.8" 20s 2000s 280"x280" 0.02-2.5MK Full		大局的な磁場構造を把握するために、高解像度かつ高視野の彩層・コロナ画像を観測 [コンテクスト画像情報] lamda Resolution Cadence FOV	 0.8MK(171Å) 0.05MK(304Å) 0.2″ 10s 400″x400″

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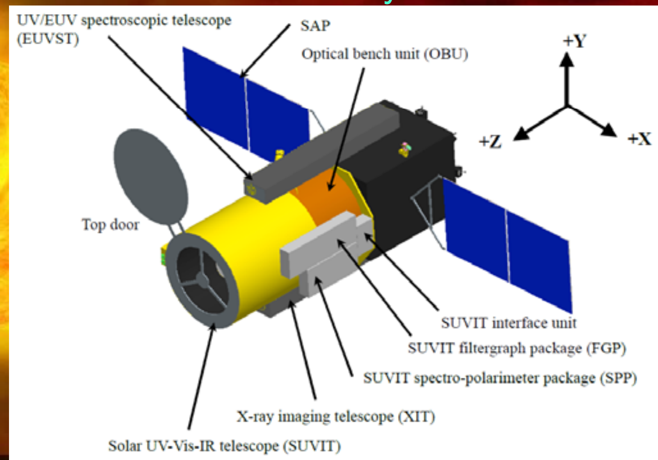
Strawman Payload



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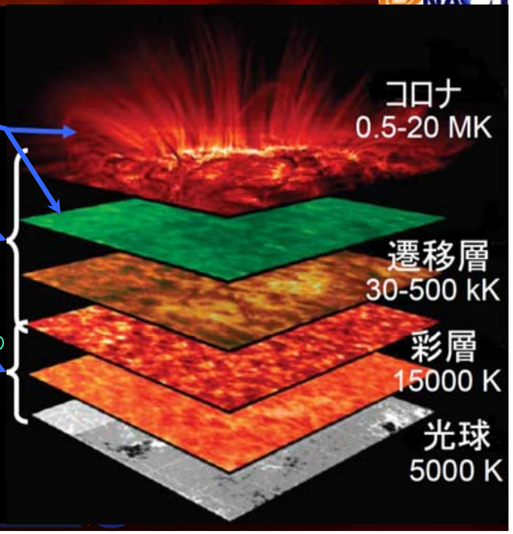
X-ray Img Telescope（XIT）
●コロナ・フレア撮像観測
●空間分解能　0.2"（0.1"pix）

EUV/UV Img Spectrometer（EUVST）
●遷移層・コロナ・フレア観測
●輝線分光診断（温度・密度・速度）観測
●空間分解能　0.28" × 0.28"

Solar UV Vis & IR Telescope（SUVIT）
●光球・彩層
●撮像
●2D　分光
●3D　磁場観測
●空間分解能： 0.1"



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SUVIT

Item	Description
Telescope	Aplanatic Gregorian telescope: diameter of primary: ~1.5m
Focal Plane Instruments	Broadband Filtergraph（BF）, Narrowband Filtergraph（NF）, Spectro-polarimeter（SP）
Wavelength coverage	280 nm（TBD）– 1100 nm
Spectral lines（spectro-polarimetry）	Chromosphere: He I 1083 nm, Ca II 854 nm　Dynamics: Mg II 280nm（not baseline） Photosphere: Si I 1082.7 nm, Fe I 525 nm
Spectral lines（imaging）	Chromosphere: Mg II 280nm（TBD）, Ca II 854nm, H I 656nm, Na I 589nm, Mg I 517nm Photosphere: Fe I 525 nm, continuum（wavelength TBD）
Sampling scale	Imaging: 0.015"（narrow field）, 0.045"（wide field） Spectro-polarimetry: 0.07"
Spatial resolution（or imaging performance）	Imaging: 0.05" at 280nm（TBD）, 0.09" at 525nm, 0.14" at 854nm Spectro-polarimetry: Slit scan: 0.14", IFU: 0.14"（along slit）×0.18"（across slit）
Slit width	Slit: 0.07", IFU: effectively 0.18"
Spectral resolution	Narrowband filtergram: ~50, 000 Spectro-polarimetry: 100, 000 –210, 000（slit）, ~96, 000（IFU）
Exposure time	Intensity observations: 0.05 – 1 sec,　Polarimetric observations: 1 – 20 sec
Polarimetric accuracy of chromospheric lines	1×10^{-4}（6×10^{-3}）for 0.2"（0.1"）sampling and 20（1）sec integration Sensitivity of B_{long}: 1–2（10-20）G, of B_{trans}: ~100（~300G）[Zeeman], 0.1–100 [Hanle] G
Filed of view	Imaging: 61×61 arcsecs（narrow field）, 184×184 arcsecs（wide field） Slit scanning polarimetry: 184×143 arcsecs 2D spectro-polarimetry（IFU）: 10×10 arcsecs

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EUVST

Item	Description
Telescope	Off-axis single mirror telescope: diameter of primary: 30 cm
Focal Plane Instruments	Spectrographs, Slit imaging camera for co-alignment
Wavelength coverage	Spectrographs: First order: 16.9–21.4 nm, 69.0 – 85.0 nm, 92.5 – 108.5 nm, 111.5–127.5 nm Second order: 46.3–54.2 nm, 55.7–63.7 nm Slit imaging camera: A chromospheric line/band（e.g., continuum around 160 nm）
Temperature coverage	0.01 – 20 MK
Imaging performance	0.28″ in 80% encircled energy over nominal field of view（FOV） （0.14″ reachable in the 17-21 range on a reduced FOV）
Spatial sampling	0.14" at detector
Slit	0.14″, 0.28″, 0.56″, 1″, 5″
Spectral resolution（λ/Δλ）	17, 000–30, 000
Exposure time	0.1 – 20 sec
Field of view	280 arcsec（along slit）× 300 arcsec（scanning direction）

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XIT/GI

XIT

Item	Description
Telescope	Wolter-I telescope: diameter of aperture: ~25 cm
Focal plane detector	Back-illuminated CMOS-APS
Energy range	0.5 – ~10 keV
Energy resolution	~150 eV at 5.9 keV
Plate scale	0.5 arcsec sampling
Spatial resolution	1.0 arcsec within 200" off-axis distance
Exposure cadence	Photon integration mode: < 1 sec Photon counting mode: 10（20）sec for 2"（1"）area
Filed of view	Photon integration mode: 400 arcsec × 400 arcsec Photon counting mode: ~80 arcsec × 400 arcsec（baseline） ~200 arcsec × 400 arcsec（goal; cover NS×EW extent of ARs）

XIT/NI

Item	Description
Telescope	Ritchey-Chretien telescope: diameter of aperture: ~30 cm
Focal plane detector	Back-illuminated CCD
Wavelength range	9 – 34 nm（some from 9.4nm, 17.1nm, 19.5nm, 21.1nm, 30.4 nm, 33.5nm）
Plate scale	0.1 arcsec/pixel sampling
Spatial resolution	0.2 – 0.3 arcsec within 200 arcsec off-axis distance
Exposure cadence	< 10 sec
Filed of view	400 arcsec × 400 arcsec

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Solar-C Related Papers

- P2-85 次期太陽観測衛星Solar-C搭載光学望遠鏡(SUVIT)の検討進捗: 末松芳法, 勝川行雄, 原弘久, 鹿野良平(国立天文台), 清水敏文(ISAS/JAXA), 一本潔(京都大学), SOLAR-C WG
- P2-86 SOLAR-C光学望遠鏡(SUVIT): 偏光分光観測装置の光学系検討: 勝川行雄, 原弘久, 末松芳法, 鹿野良平 (国立天文台), 一本潔 (京都大), 清水敏文 (ISAS/JAXA), SOLAR-C WG
- P2-87 SOLAR-C光学磁場診断望遠鏡:像安定化装置(コリレーショントラッカー)に向けた高速CMOSカメラ検討開発: 清水敏文, 岡本丈典, 飯田佑輔, 渡邉恭子(宇宙科学研究所), 小出来一秀(三菱電機先端総合研究所)
- P2-88 Solar-C光学磁場診断望遠鏡:焦点調節機構試作品の真空環境下寿命試験準備: 西塚直人(国立天文台), 清水敏文, 渡邉恭子, 大場崇義(宇宙航空研究開発機構), 田島崇男, 中山聡(三菱プレシジョン)
- P2-89 次期太陽観測衛星Solar-C搭載用機器のコンタミネーション管理と回転駆動機構長期寿命試験の最新状況: 渡邉恭子, 清水敏文, 飯田佑輔, 大場崇義, Kyoung-Sun Lee(JAXA 宇宙科学研究所), 今田晋亮(名古屋大学), 原弘久, 坂東貴政(国立天文台)
- P2-90 SOLAR-C X線/EUV望遠鏡の検討状況: 坂尾太郎, 渡邉恭子(ISAS/JAXA), 成影典之, 末松芳法, 下条圭美, 石川真之介(国立天文台), 今田晋亮(名大STE研), E. E. DeLuca(Harvard-CfA), J. W. Cirtain(NASA/MSFC)ほか SOLAR-C X線望遠鏡検討グループ
- P2-91 SOLAR-Cにする搭載狭帯域チューナブル・フィルターの開発: 萩野正興, 一本潔, 木村剛一, 仲谷善一, 川手朋子, 篠田一也, 末松芳法, 原弘久, 清水敏文
- P2-92 SOLAR-C太陽観測におけるコンタミネーション防護の検討: 原 弘久, 坂東貴政, (国立天文台), 宮崎英治, 木本雄吾(JAXA), 浦山文隆(宇宙技術開発)
- P2-93 宇宙天気研究における次世代太陽観測衛星Solar-Cの科学戦略: 草野完也, 渡邉鉄哉, Solar-Cワーキンググループ, Solar-C準備室

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Solar and Space Physics: A Science for a Technological Society

Solar and Space Physics:
A Science for a Technological Society

Heliophysics
Decadal Survey

Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics)
Space Studies Board
Aeronautics and Space Engineering Board
Division on Engineering and Physical Sciences
NATIONAL RESEARCH COUNCIL

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10.5.2.3 Solar-C

Solar-C is a Japan-led mission expected to include substantial contributions from the United States and Europe.[38] It builds on the highly successful Yohkoh and Hinode collaborations with our most reliable partner. As with Yohkoh and Hinode, Japan will provide the satellite and launch. Almost all NASA funding would go to the U.S. science community for state-of-the-art instrumentation and data analysis. Hence, Solar-C presents an important opportunity to leverage NASA science funding.

The science objectives of Solar-C are to determine

- *How the energy that sustains the Sun's atmosphere is created on small scales and transported into the large-scale corona and solar wind.*
- *How magnetic energy is dissipated in astrophysical plasmas.*
- *How small-scale physical processes initiate large-scale dynamic phenomena, such as CMEs and flares, which drive space weather.*

Achieving those objectives is a prerequisite for meeting SH science goals 2 and 3. Solar-C is central to our science strategy for the next decade; therefore, the panel strongly endorses U.S. participation in the mission. As with Hinode, the data should be open to the full U.S. science community. Furthermore, a competitive Solar-C guest-investigator program, overseen by NASA, that follows the guidelines of the general guest-investigator program initiative would achieve maximum science benefit (§10.5.3.4).

To meet its three objectives, Solar-C will obtain highly precise spectroscopic and polarimetric measurements designed to determine the full-vector magnetic field accurately, especially in the chromosphere, and high-throughput measurements designed to resolve the plasma dynamics. Furthermore, spectroscopic measurements that cover each temperature domain of the solar atmosphere—the photosphere, lower chromosphere, upper chromosphere, transition region, inner corona, and high-temperature flare—seamlessly will be obtained to improve our understanding of the entire chain of energy transport and dissipation. Finally, high-spatial-resolution measurements will be obtained for resolving elementary physical processes.

Solar-C can meet its measurement strategy with three strawman instruments designed to deliver an order-of-magnitude improvement over present measurement capabilities:

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- A Solar UV-Visible-IR telescope (SUVIT) that will resolve and measure magnetic fields and gas dynamics in the lower atmosphere—from the photosphere through the upper chromosphere—with a diffraction-limited telescope that has an apertures 1.5-m in diameter.
- A EUV/FUV high-throughput spectrometer (EUVST) that will measure spectral lines in the FUV-EUV region from plasma in the upper chromosphere, transition region, lower corona, and flares simultaneously to trace energy flow throughout the solar atmosphere and follow the energy released by such processes as magnetic reconnection and instabilities.
- An x-ray imaging (spectroscopic) telescope (XIT) that will resolve and measure the plasma in the hot corona to improve our understanding of its elemental structure, origins, and dynamics.

NASA contribution to Solar-C. The strawman instruments above are only for the purposes of planning and costing the mission. Concrete plans for the instruments and for the roles of the international partners are urgently needed; consequently, it is a *high* priority of the SHP *P*anel that, as with Hinode, NASA and its partners form a Science and Technology Definition Team for Solar-C as soon as possible. Although the NASA contribution has yet to be decided, the panel expects that NASA contributions would involve the most technically challenging elements, such as the focal-plane packages (cameras, detectors, and so on), which would afford the U.S. science community an opportunity to make critical advances in remote-sensing capabilities. The total cost to NASA through Phase E should be capped at $250 million.

Solar-C presents a unique opportunity for solar and space physics to make flagship-level science advances for the cost of an Explorer.

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Distinct Features

- **a fundamentally new way of viewing the entire solar atmosphere**, essentially with the same high spatial and temporal resolution, in addition to performing simultaneous high resolution *spectropolarimetric* measurements for the first time.
- a very **challenging mission** to design, develop, scientifically and technically, and to deliver **an order-of-magnitude improvement** over present measurement capabilities.

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Project status/plan

-JAXA-based working group with more than 70 members & contributors from JAXA, NAOJ, Kyoto U., Nagoya U., Riken, NIST, LMSAL/US, HAO/US, HSAC/US, MPS/DE, IAC/ES, and MSSL/UK [Working group PI: Tetsuya Watanabe (NAOJ)]

-Selected as one of eight most important future projects by astronomy/astrophysics division of Science Council of Japan

-Recognized as one of key future JAXA missions in solar and heliospheric physics

- Expected to include substantial contributions from the United States and Europe

-To be ready for Mission Proposal in FY2013

- Target launch year ~2020.

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International task shares

Spacecraft		JAXA
Launch vehicle		JAXA
SUVIT	Large-aperture telescope	JAXA (with feed optics to focal plane)
	Primary/secondary mirror	ESA (with test flat)
	Focal plane instrument	
	Filtergraph	NASA
	Spectropolarimeter	JAXA-led international consortium
EUVST		ESA/NASA
XIT	Normal incidence	NASA
	Grazing incidence (optional)	TBD

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Schedules (earliest possible)

FY2014: Pre-project (phase-A)
FY2015-16: Basic design (phase-B), PDR
FY2016-17: Detailed design (phase-C), CDR
FY2018-20: Fabrication, testing (phase-D), PQR/PSR
FY2020 - : Launch, Operation (phase-E)

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