A Dream of a Mission: The Stellar Imager and Seismic Probe

A voyage of exploration to understand the stars, the formation of planetary systems, and the existence of life

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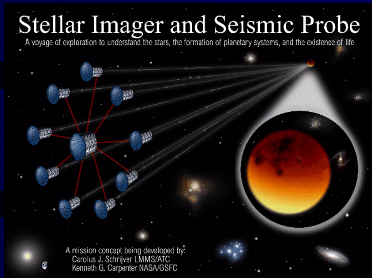


Primary Science Goals

- Study spatial and temporal stellar magnetic activity patterns in a sample of stars covering a broad range of activity level, in order to understand the underlying dynamo process(es) and thereby
  - enable improved forecasting of solar activity on time scales of days to centuries, including Maunder-like minima and “grand maxima” that significantly affect geospace and earth’s weather
  - understand the impact of stellar magnetic activity on astrobiology & life
- Enable asteroseismology (acoustic imaging) to measure internal stellar structure and rotation and their relationship to the dynamo
- Complete the assessment of external solar systems
  - image the central stars of systems for which the Origins IR-interferometry missions find and image planets, and determine the impact of the activity of those stars on the habitability of the surrounding planets

Stellar activity is key to understanding life in the Universe and Earth's habitability

The stellar magnetic field

- slows the rotation of the collapsing cloud, enabling star formation
- couples evolution of star and pre-planetary disk
- results in energetic radiation conducive to the formation (& destruction) of complex molecules
- governs the habitability of the biosphere through space weather and planetary climate through luminosity, wind, magnetic fields, and radiation

- Problem: there is no comprehensive model of solar/stellar magnetic activity

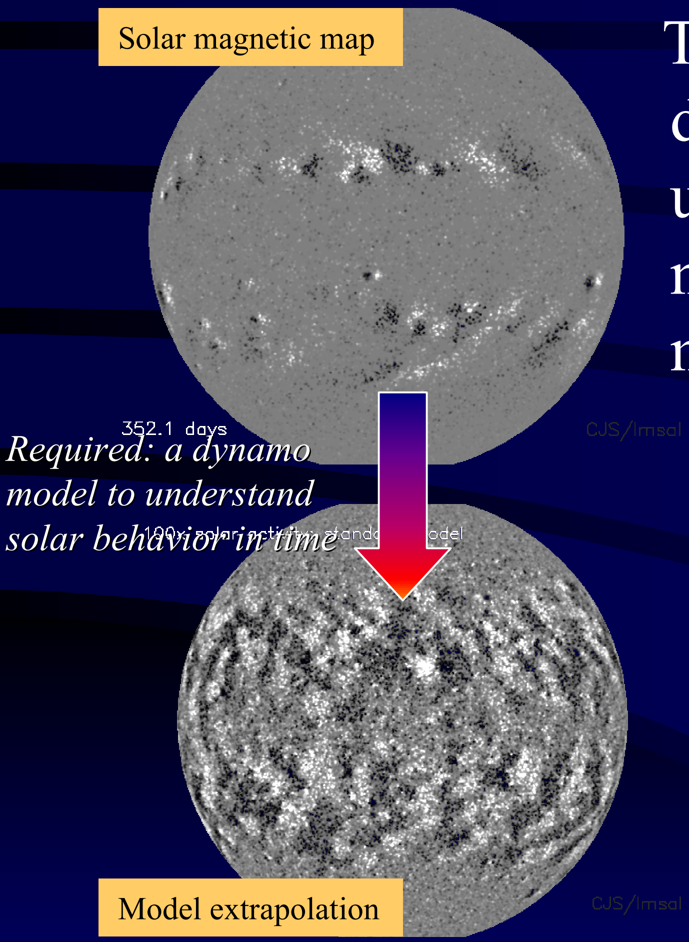
The impact of the Stellar Imager and Seismic Probe

Imaging stars and their environments and measuring their internal structure and dynamics constitute a voyage of discovery and exploration that will

- outdate theories that take stars to be static, layered spheres
- deepen our understanding of a broad range of physical processes
- strengthen the foundation of our view of the universe
- help forecast the activity of the Sun for our society that is living with a star

Living With a Star

Space-weather forecasting



To forecast solar and heliospheric activity days to decades in advance, and to understand solar activity in the past, we need to develop and validate a dynamo model

- Testing grounds:
  - The Sun in detail
  - Population studies:
    - Stars like the Sun
    - Other ``cool'' dwarf & giant stars
    - Very young stars
    - Magnetically interacting binary stars

Population study of cool stars

- To understand the dynamo, we need to know how magnetic fields are generated and how they behave in different circumstances
- The sun is only one example
  - provides insufficient constraints on theories of dynamos, turbulence, structure, and internal mixing
  - must observe other stars to *establish how mass, rotation, brightness and age affect the patterns of activity* & determine:
    - What determines cycle strength and duration?
    - How common is solar-like activity?
    - Can multiple cycles exist at the surface?
    - What are Maunder-minimum states like?
    - How do polar spots form?
    - What are extremely (in)active stars like?

Activity and Stellar Interiors - the Need for Asteroseismology

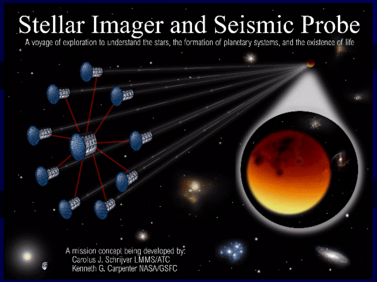
- Although its clearest manifestations are visible on the stellar surface, a full understanding of the dynamo requires a knowledge of the subsurface layers of the star in which it resides
- Asteroseismology (acoustic imaging) of the star enables us to address questions related to the stellar interior
  - Where is the seat of the dynamo?
  - What determines differential rotation and meridional circulation, and what role do they play in the dynamo?
  - What is the impact of magnetic deceleration on internal rotation and stellar evolution?
  - How are stellar interiors modified in extremely active stars?

SISP Primary Performance Goals

- Image different stars of different activity
  - for a substantial sample of nearby dwarf and giant stars, obtain a resolution of order 1000 pixels (~40,000 km on a Sun-like star)
  - study a sample in detail, revisiting over many years
  - measure:
    - sizes, lifetimes, and emergence patterns of stellar active regions
    - surface differential rotation, field dispersal by convective motions, and meridional circulation
    - directly image the entire convection spectrum on giant stars, and the supergranulation on, e.g., the solar counterpart α Cen
- Enable asteroseismology, using low to intermediate degree non-radial modes to measure internal stellar structure and rotation.

SISP Design Requirements

- Imaging of stellar activity
  - High contrast at UV wavelengths
  - Obtain a stellar image as fast as possible to avoid rotational smearing and activity evolution
- Imaging of stellar interiors
  - Short integration times for seismology (minutes for dwarf stars to hours for giant stars)
  - Low-resolution imaging to measure non-radial resonant waves (30-100 resolution elements)
  - Flexible interferometer configuration



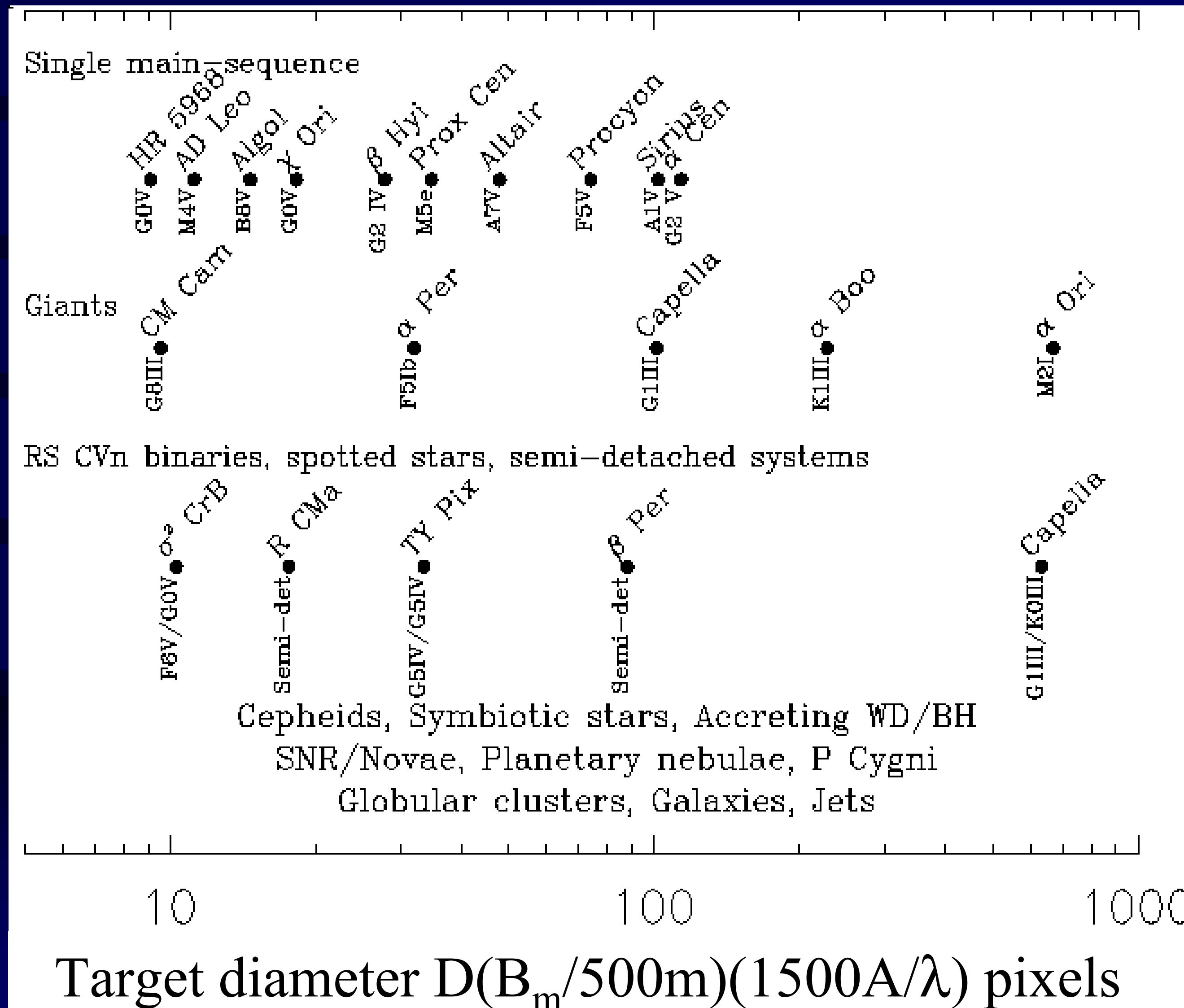
Strawman Design Elements

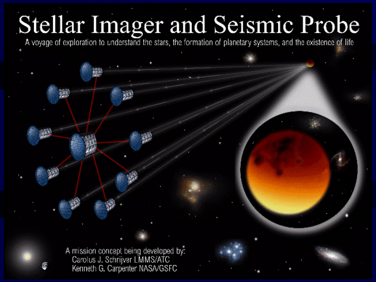
- SISP is a large space-based UV-optical interferometer, that provides a tool to astrophysicists of the same fundamental nature as the microscope to biologists, yielding
  - a spatial resolution of 60 and 120 micro-arcsec at 1500 Å and 2800 Å
  - ~ 1000 pixels of resolution over the surface of nearby dwarf stars
  - 9 or more 1-meter class telescopes, plus central "hub"
  - largest telescope-pair baseline at least 500 meters
  - observes in
    - ~10-Ångstrom UV pass bands (C^{3+} (100,000 K), Mg^{+} h&k (10,000 K))
    - broadband, near-UV or optical continuum (3,000-10,000 K)
  - telescope formation reconfigurable for synthesis imaging
  - 5-10 year mission to study stellar activity/magnetic cycles:
    - individual telescopes/central hub can be refurbished or replaced as needed

SISP Sample Targets

Sample target categories:

χ Ori	"Young Sun"
β Hyi, α Cen	Solar analogs
HR 5968	Maunder-minimum star
α Boo	"Ancient Sun"
Altair, Procyon, α Per	Onset activity
AD Leo, Prox Cen	Flare star; deep convection
CM Cam	Giant polar spot
Capella , σ CrB	Magnetically interact. binary
TY Pyx	Compact binary
R CMa, β Per	Semi-detached binary
α Ori	Supergiant star
Algol	Mass transfer
Sirius	Hot star

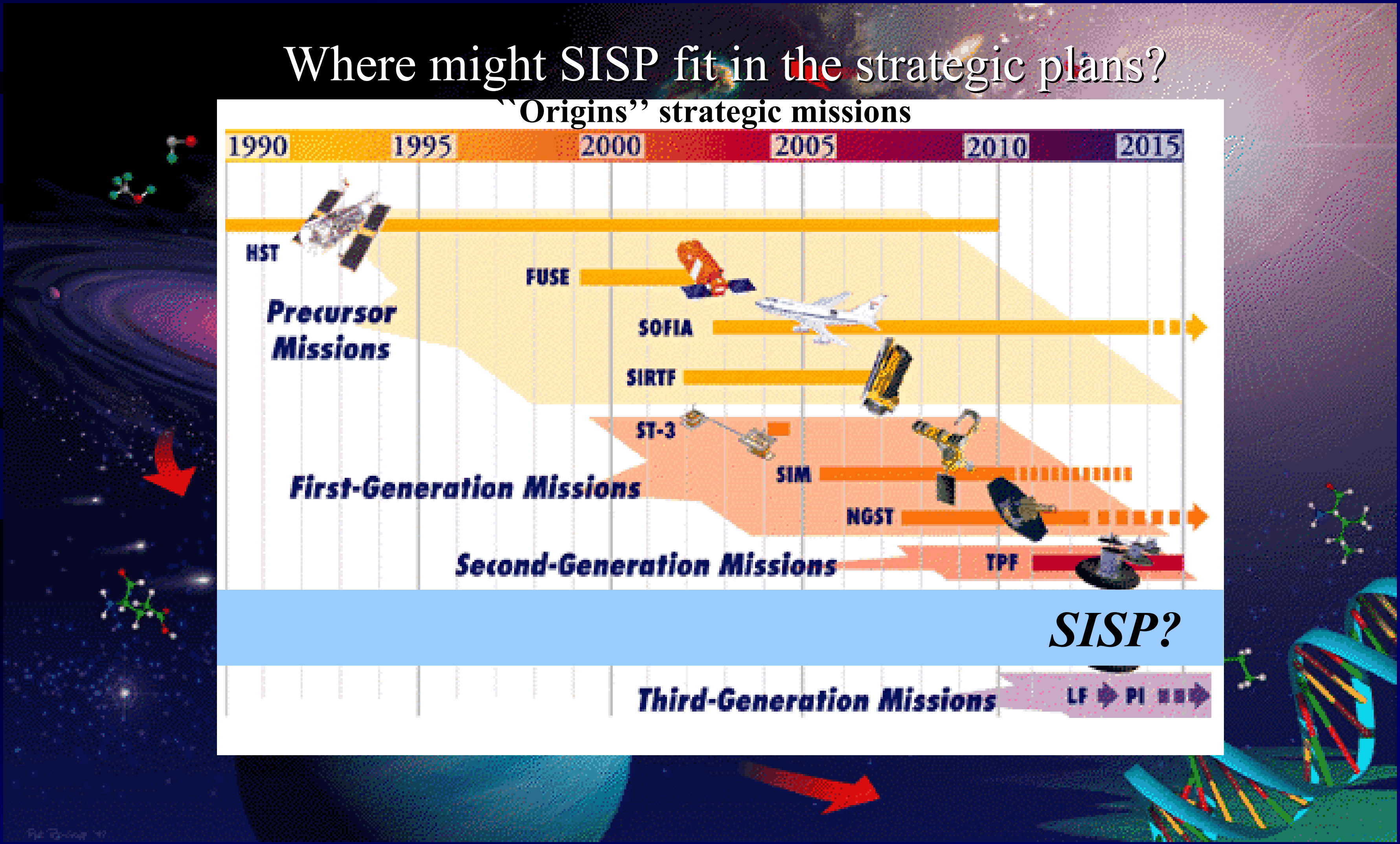


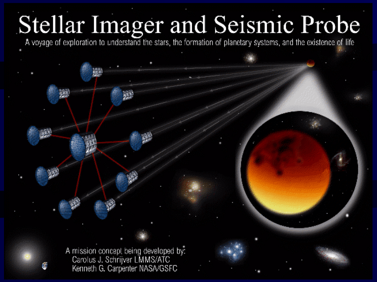


Place in NASA Strategic Roadmaps

- SISP fits on strategic path of Origins interferometry missions
  - it is a stepping stone towards crucial technology…
    - SISP is comparable in complexity to the ***Terrestrial Planet Finder***, and it may serve as a useful technological and operational pathfinder for the ***Planet Imager***: SISP resolution is ~40x less demanding than ultimate NASA goal
  - … while addressing science goals of 3 NASA/OSS research Themes
    - understand why the sun varies (SEC)
    - understand the origin of stars, planetary systems, and life (Origins)
    - understand the structure and evolution of stars (SEU)
  - it is complementary to the planetary imaging interferometers
    - ***Terrestrial Planet Finder*** and ***Planet Imager*** null the stellar light to find and image planets
    - SISP images the central star to study the effects of that star on the habitability of planets and the formation of life on them.
    - TPF, SISP, and PI together provide complete views of other solar systems

SISP: a ``2-nd generation'' mission





Current Status

- Included in far-horizon SEC Roadmap (summer 1999)
- Mission concept further developed by
  - C.J. Schrijver (Stanford-Lockheed Institute for Space Research)
  - K.G. Carpenter (LASP - NASA/GSFC)
  - in consultation with informal Concept Development Group
- Presentations of mission concept
  - October, 1999 Cool Stars, Stellar Systems, & the Sun Conference
  - NASA GSFC and HQ on March 6 and March 14, 2000
  - at meetings such as AAS and SPD
- Web site created: **http://hires.gsfc.nasa.gov/~sisp**
- “white paper” written to describe science goals/technology req’ts
- Included in SEC “State of the Theme” report (May, 2000)
- next steps
  - Architecture/Feasibility Studies
  - ground-based Testbed Development Program