Planetary Ring Studies: Tools of the Trade

Mark R. Showalter
SETI Institute

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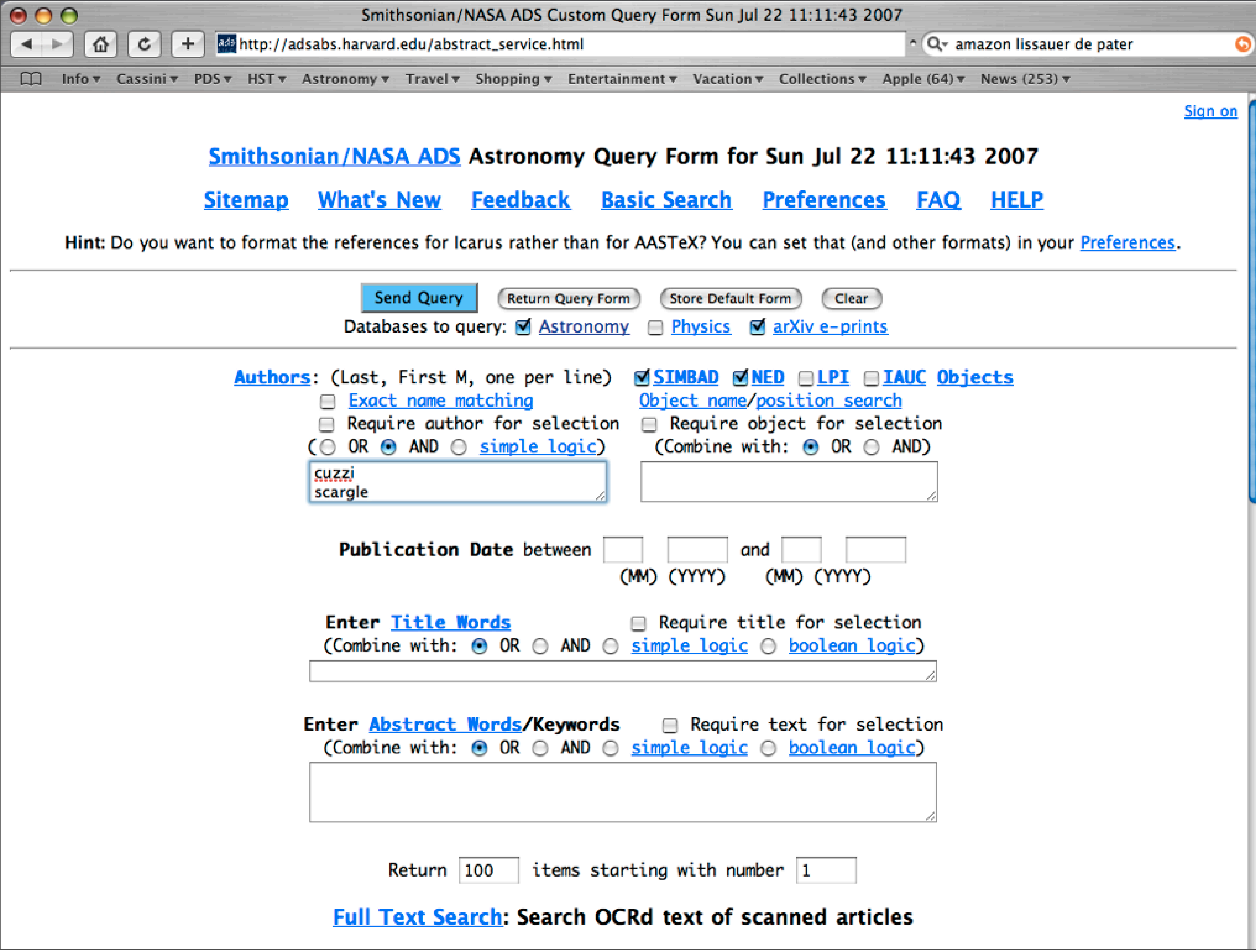
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Publication:	Astrophysical Journal, Part 1 (ISSN 0004-637X), vol. 292, May 1, 1985, p. 276-290. (ApJ Homepage)
Publication Date:	05/1985
Category:	Lunar and Planetary Exploration; Saturn
Origin:	STI; LPI [AN-850775%J]
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Abstract

Voyager images have revealed radial undulations of the inner and outer edges of the 325 km wide Encke gap in Saturn's A ring. These waves are present at some, but not all, longitudes. Their locations and wavelengths provide strong indirect evidence for the presence of at least one dominant moonlet of about 10 km radius orbiting near the center of the gap. Implications for 'shepherding' theory are discussed.

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THE ASTROPHYSICAL JOURNAL, **292**:276–290, 1985 May 1

WAVY EDGES SUGGEST MOONLET IN ENCKE'S GAP

JEFFREY N. CUZZI AND JEFFREY D. SCARGLE
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Received 1984 September 4; accepted 1984 November 14

ABSTRACT

Voyager images have revealed radial undulations of the inner and outer edges of the 325 km wide Encke gap in Saturn's A ring. These waves are present at some, but not all, longitudes. Their locations and wavelengths provide strong indirect evidence for the presence of at least one dominant moonlet of about 10 km radius orbiting near the center of the gap. Implications for "shepherding" theory are discussed.

Subject headings: planets: satellites — planets: Saturn

I. INTRODUCTION

The complex structure discovered in the rings of Saturn by the *Voyager* spacecraft has provided a fertile testing ground for a variety of dynamical theories. Especially within the outer (A) ring, gravitational resonances with known satellites external to the rings are of sufficient strength and abundance to account for most of the observed structure (Lissauer and Cuzzi 1982; Holberg, Forrester, and Lissauer 1982; Esposito *et al.* 1984). However, resonances with external satellites are incapable of accounting either for the "record-groove" appearance of the B ring or for the existence of a handful of essentially empty gaps with widths between 50 and 400 km which occur in the A, C, and Cassini Division regions of the rings (Cuzzi *et al.* 1984).

The existence of a population of embedded "moonlets" has been invoked to explain these latter effects. A moonlet exerts a torque on adjacent ring material which results in transfer of momentum to or from the ring (Lin and Papaloizou 1979,

The physics of this kinking was developed by Julian and Toomre (1966) and described also by Lin and Papaloizou (1979) and Dermott (1981). Encke's gap contains several narrow ringlets qualitatively similar to the F ring; in this paper we report the observation and analysis of edge waves running along the inner and outer edges of the Encke gap. These waves are more easily understood than the kinky ringlets, and strongly support the hypothesis that the Encke gap contains at least one, as yet unseen, embedded moonlet of roughly 10 km radius. In subsequent papers we will present complementary evidence and studies of the kinky ringlets in the Encke gap. We will also systematically explore the edges of other empty gaps. Preliminary, very cursory, investigation has revealed no wavy edges in other gaps such as Huygens or Maxwell.

Section II deals with the observations (*Voyager* images) and techniques for determining wave properties. Section III briefly reviews the relevant physics of local ring-moon interactions. In § IV we compare the observations with theoretical expecta-

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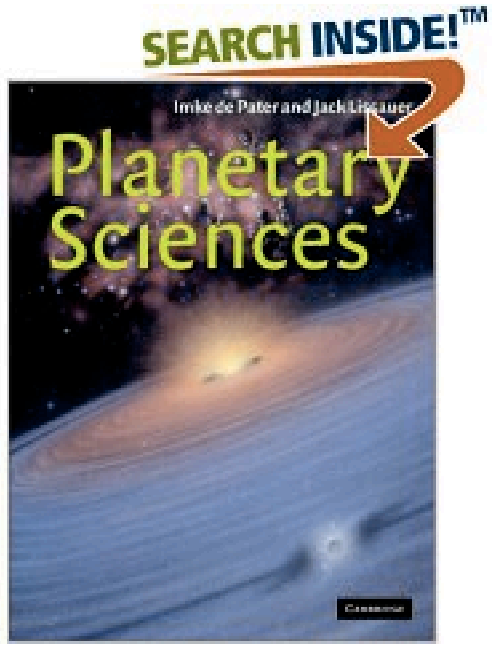

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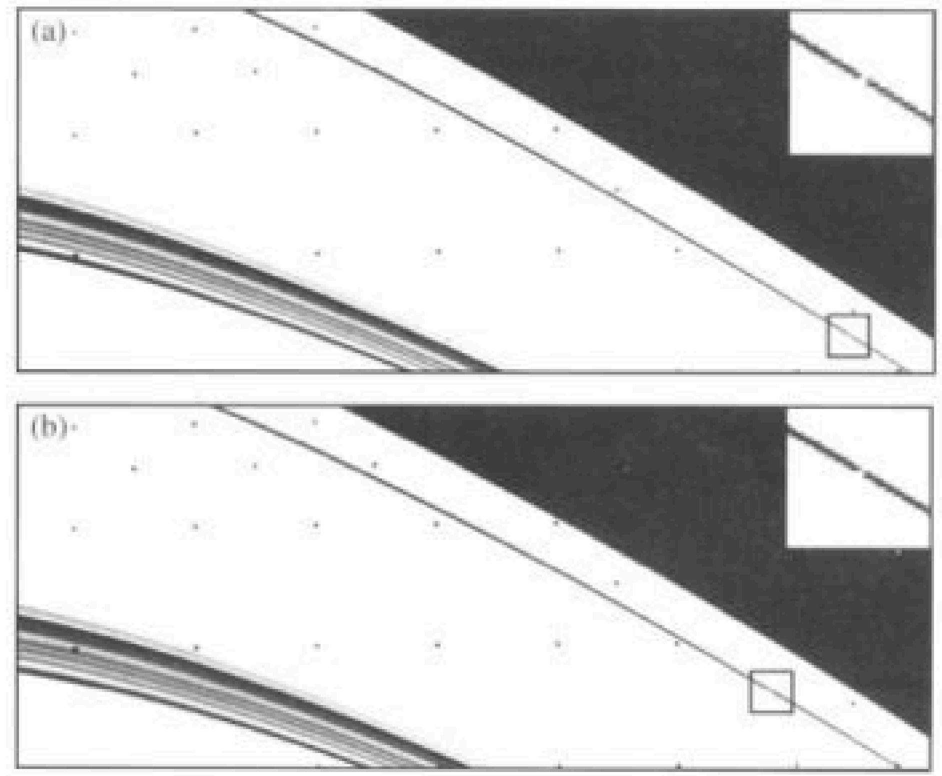

Fig. 10.22. Two *Voyager 2* images that form part of the discovery sequence of the satellite Pan, showing its movement in the Encke gap in Saturn's A ring. The time between each image is 5 minutes. *(Images courtesy of NASA/JPL.)*

The coincidence of this ring with the satellite's orbit (Showalter 1991) suggests that Pan is maintaining ring material in horseshoe and tadpole orbits along the lines proposed by Dermott et al. (1979) for the rings of Uranus. The maximum radial width of the ring (~ 20 km) is compatible with the maximum extent of the horseshoe region (30 km) for this satellite (Dermott & Murray 1981a). If this is the case then the Encke gap system exhibits characteristics of both the shepherding and horseshoe orbit models of ring confinement. This is illustrated schematically in Fig. 10.23. Note that the neptunian satellite Galatea also appears to share its orbit with a faint ring (Showalter & Cuzzi 1992) and similar processes may be operating.

From an analysis of *Voyager* images Cooke (1991) has documented evidence for variable width in the 35 km wide Keeler gap at 136,488 km, close to the outer edge of Saturn's A ring. In many respects the Keeler gap is even more puzzling than the Encke gap. If the gap has been produced by an embedded satellite

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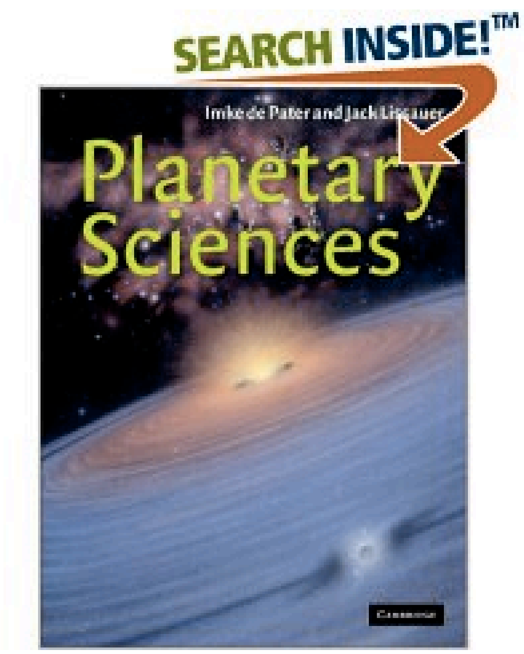

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Ancillary Information System

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SPICE is focused on solar system geometry, time, and related information. The SPICE system includes a large suite of software, mostly in the form of subroutines, that customers use to read SPICE files and to compute derived observation geometry, such as altitude, lattitude/longitude, and lighting angles. SPICE data and software may be used within many popular computing environments. The software is offered in Fortran, C and IDL®, with a Matlab interface in the works.

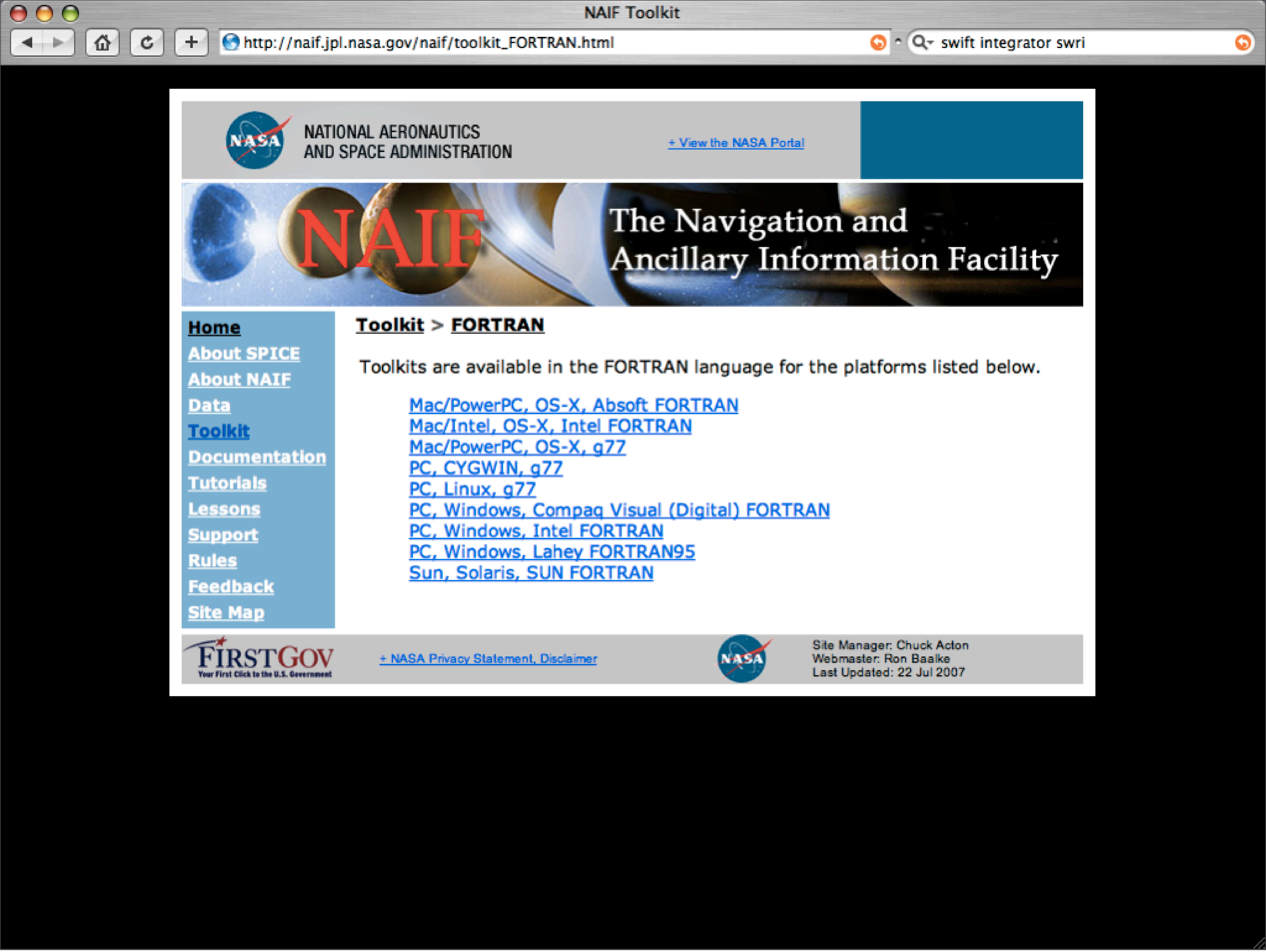
SPICE is used on NASA's solar system exploration missions, and some NASA space physics and astrophysics missions. It is also being used as an adjunct to local national capabilities on some non-U.S. missions such as Mars Express, Rosetta, Venus Express and Hayabusa.

There is no charge to individuals to obtain SPICE data and software.

The export status with regard to SPICE components and services is provided under the RULES link on this website.

Announcements

- The IERS has announced there will *NOT* be a new leap second (positive or negative) declared for the December 2007 opportunity. Thus the current SPICE generic leapseconds kernel, named naif0008.tls, and any unmodified copy thereof, will remain valid through June 2008.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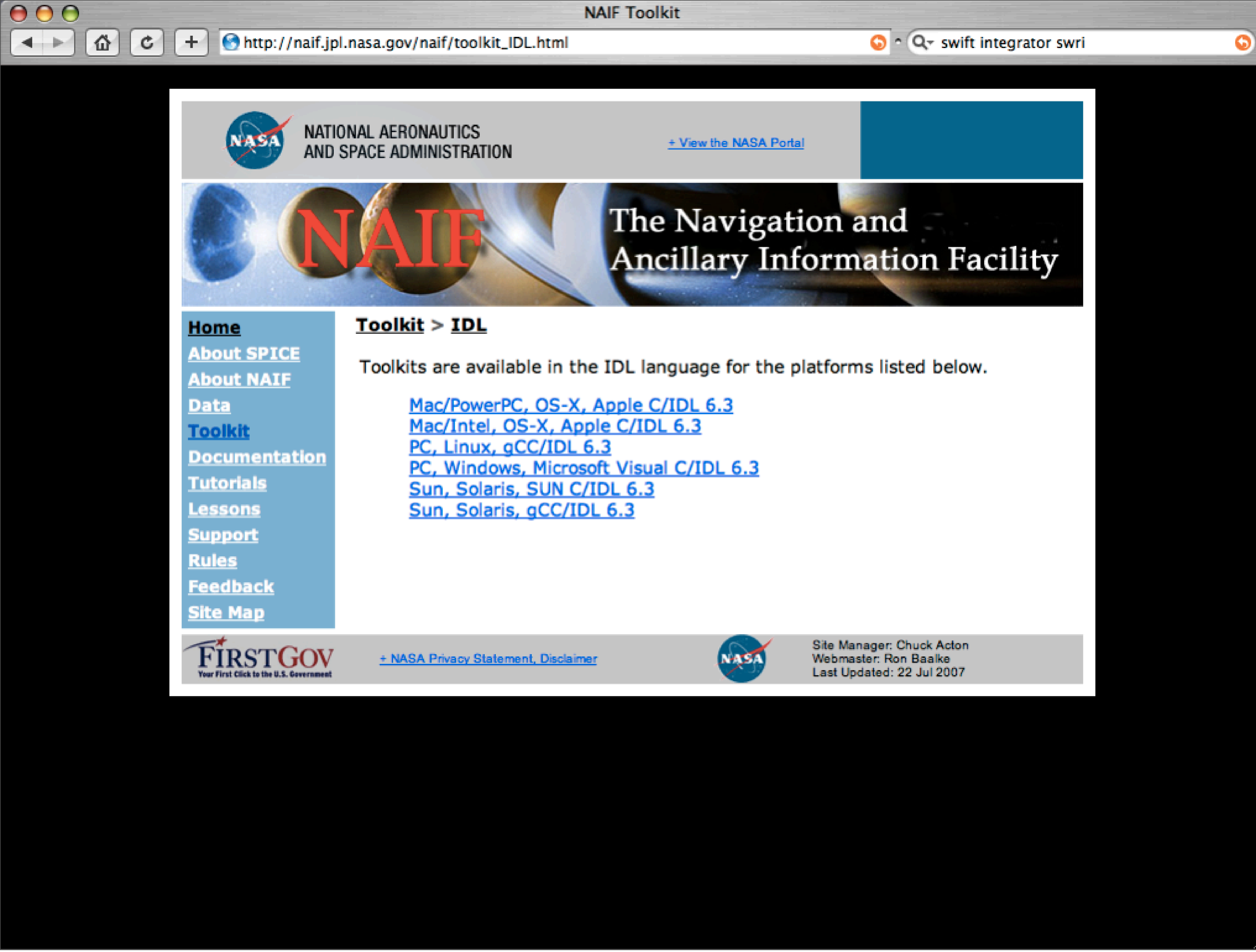
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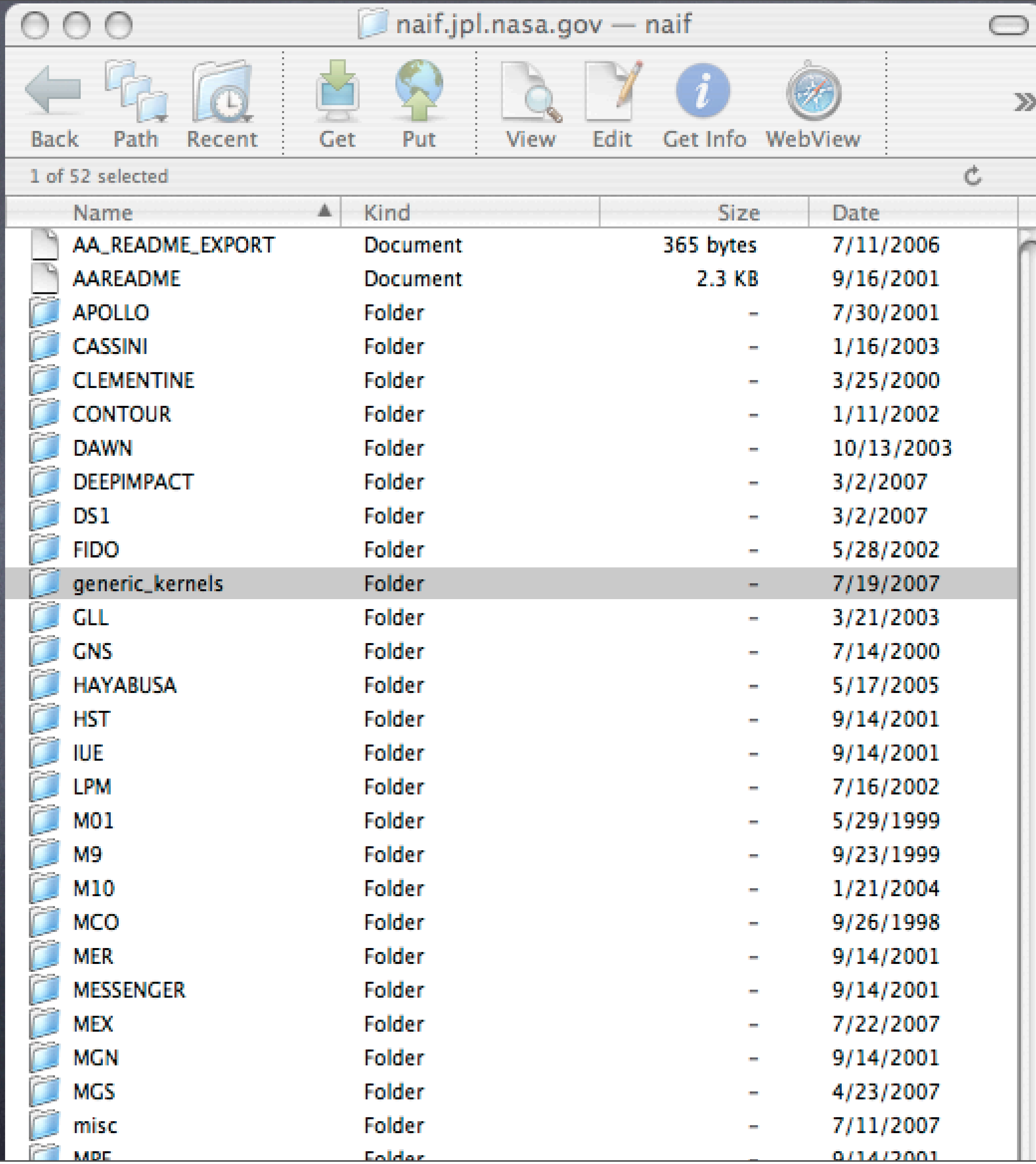
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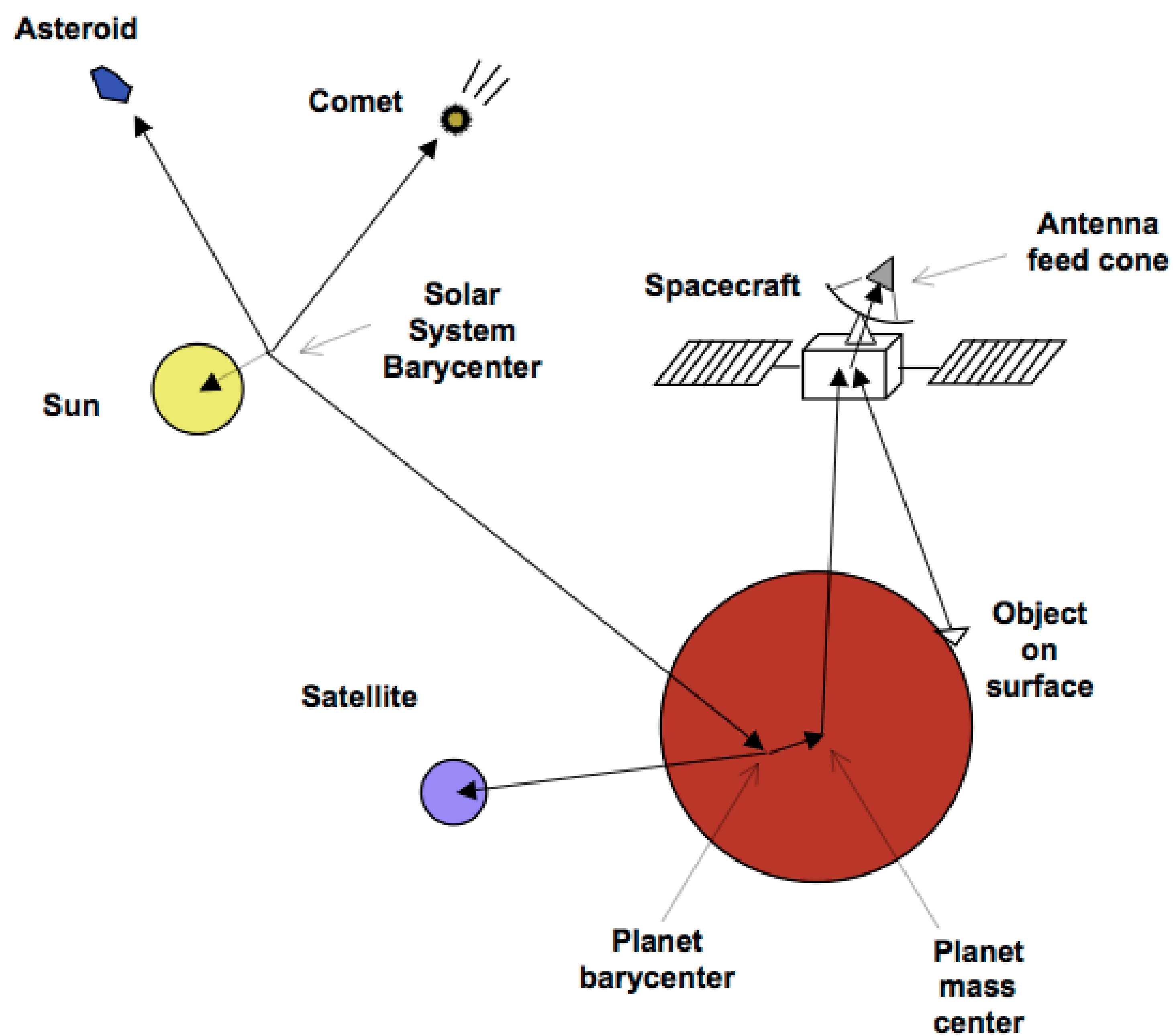

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NAIF

Reading an SPK File

Navigation and Ancillary Information Facility

Initialization…typically done once per program execution

Tell your program which SPICE files to use ("loading" files)

CALL FURNSH ('spk_file_name')

CALL FURNSH ('leapseconds_file_name')

Better yet, replace these two calls with a single call to a "furnsh kernel" containing the names of all kernel files to load.

Loop... do as many times as you need

Convert UTC time to ephemeris time (TDB), if needed

CALL STR2ET ('utc_string', tdb)

Retrieve state vector from the SPK file at your requested time

CALL SPKEZR (target, tdb, 'frame', 'correction', observer, *state, lightime*)

inputs

outputs

Use the returned state vector in computing geometry of interest.

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A Simple Example of Reading an SPK File

Navigation and Ancillary Information Facility

Initialization - typically do this just once per program execution

```
CALL FURNSH ( 'NAIF0008.TLS' )
CALL FURNSH ( 'HUYGENS_3_MERGE.BSP' )
```

Better to use a "furnsh kernel" instead of these individual FURNSH statements

Repeat in a loop as needed to solve your particular problem

```
CALL STR2ET ('2004 NOV 21 02:40:21.3', TDB )
CALL SPKEZR ('TITAN', TDB, 'J2000', 'LT+S', 'HUYGENS PROBE',
              STATE,  LT )
```

(Insert additional code here to make derived computations such as spacecraft sub-latitude and longitude, lighting angles, etc. Use more SPICE subroutines to help.)

In this example we get the state (STATE) of Titan as seen from the Huygens probe at the UTC epoch 2004 NOV 21 02:40:21.3. The state vector is returned in the J2000 inertial reference frame and has been corrected for both light time and stellar aberration (LT+S). The one-way light time (LT) is also returned.

A SPICE leapseconds file (NAIF0008.TLS) is used, as is a SPICE ephemeris file (HUYGENS_3_MERGE.BSP) containing ephemeris data for the Huygens probe (-150), Saturn barycenter (6), Saturn mass center (699), Saturn's satellites (6xx) and the sun (10), relative to the solar system barycenter.

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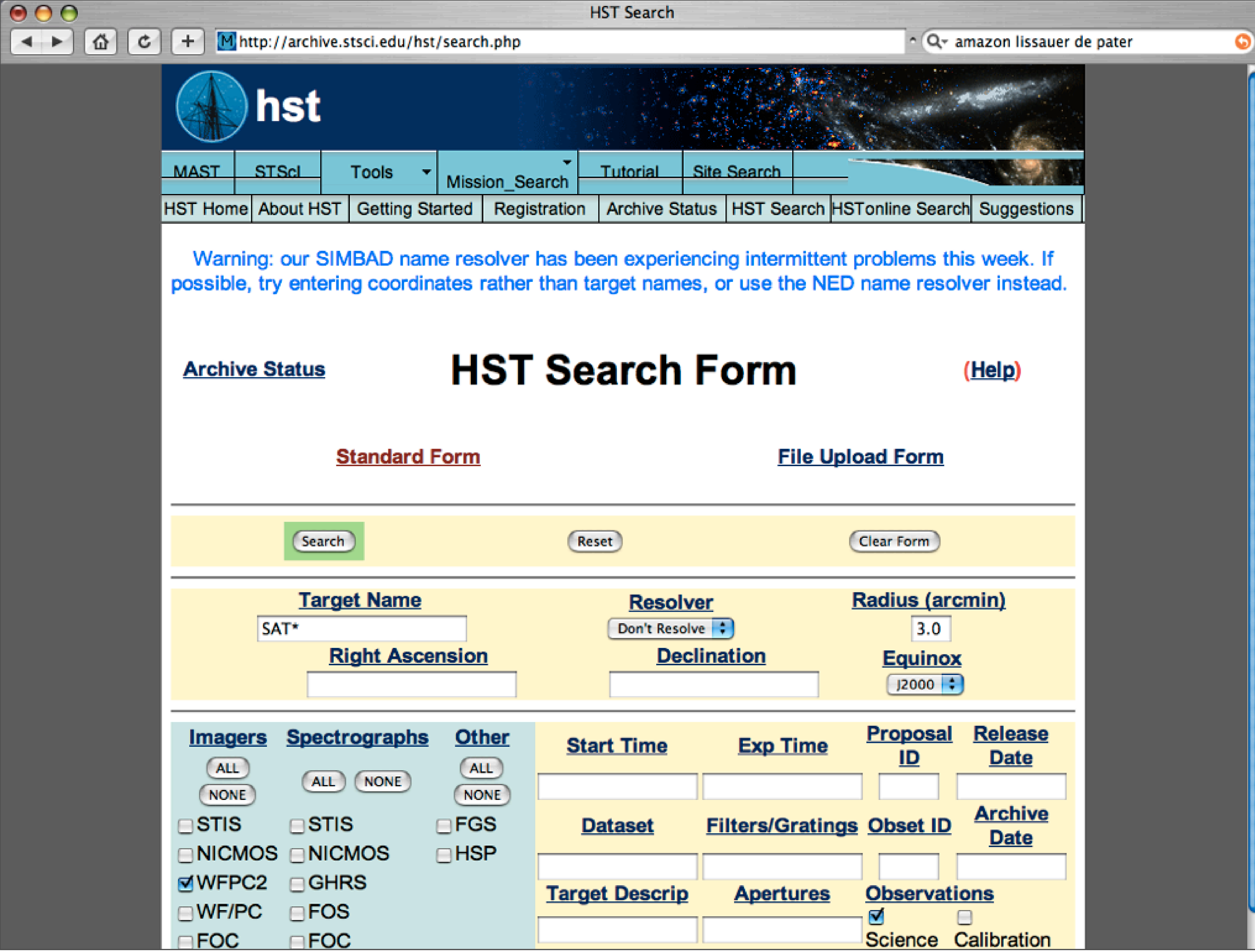
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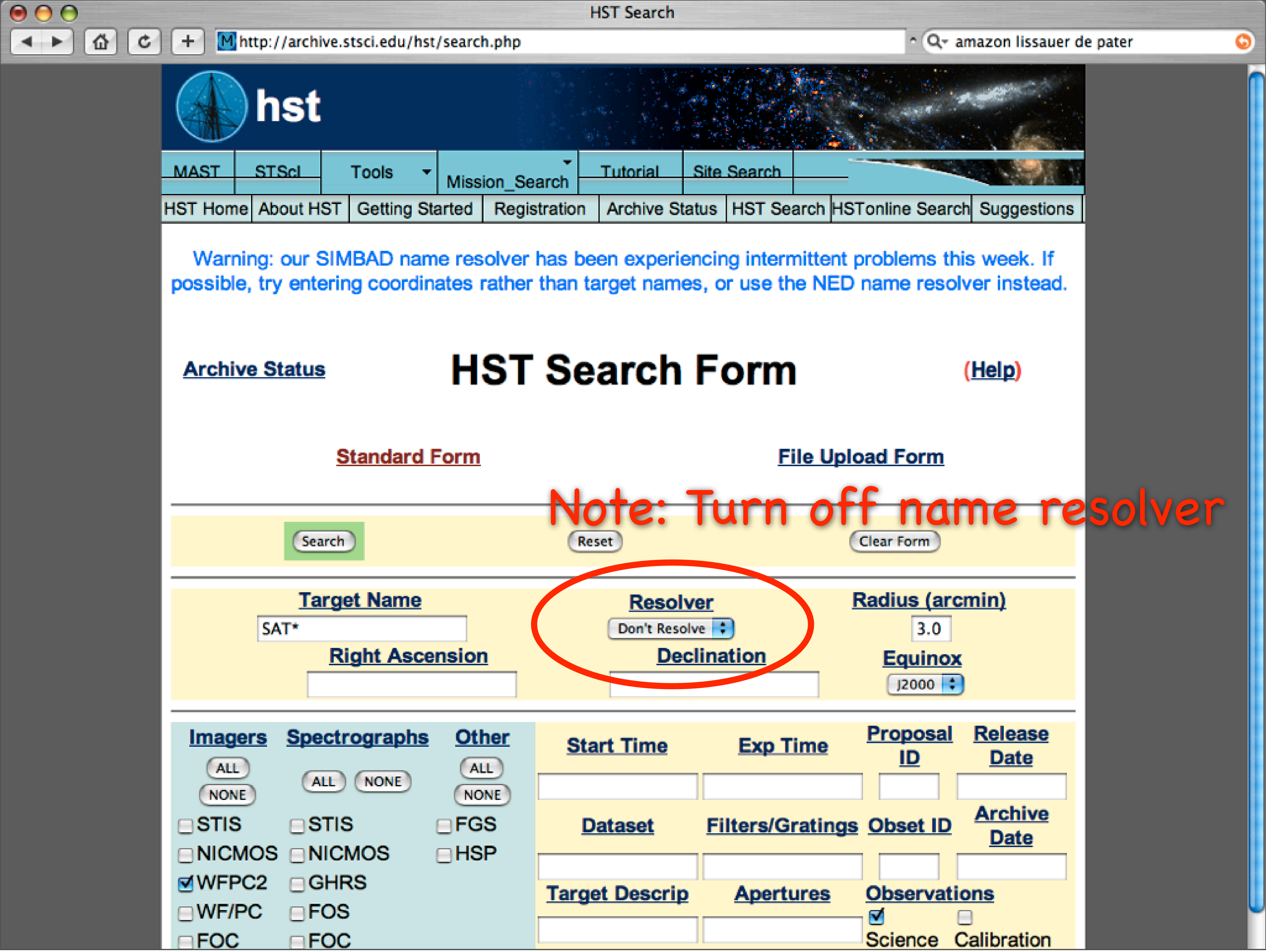
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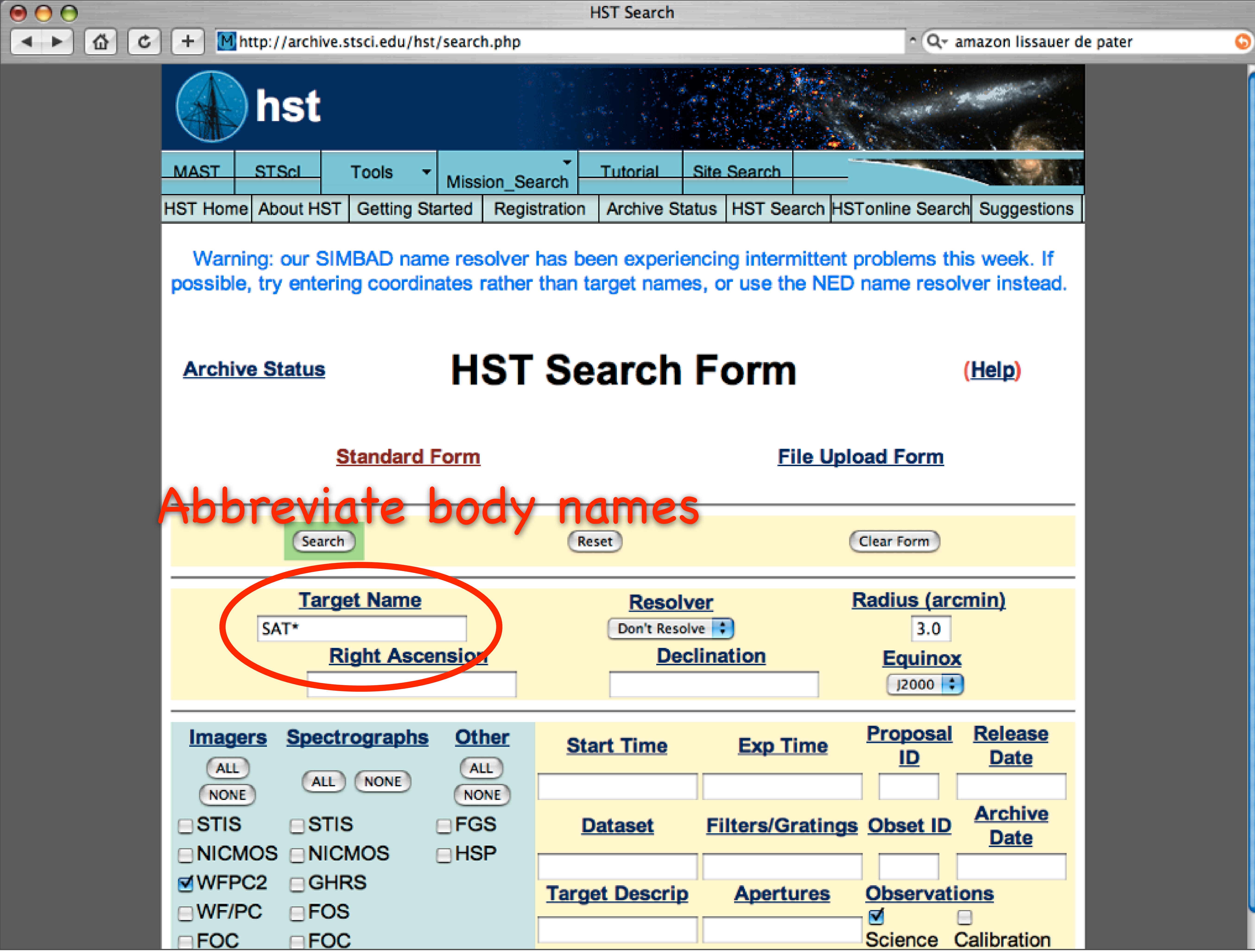
STIS
NICMOS
WFPC2
WF/PC
FOC
STIS
NICMOS
GHRS
FOS
FOC
FGS
HSP
Start Time
Exp Time
Proposal ID
Release Date
Dataset
Filters/Gratings
Obset ID
Archive Date
Target Descrip
Apertures
Observations
Science
Calibration


HST Search
http://archive.stsci.edu/hst/search.php
amazon lissauer de pater
hst
MAST
STScI
Tools
Mission_Search
Tutorial
Site Search
HST Home
About HST
Getting Started
Registration
Archive Status
HST Search
HSTonline Search
Suggestions
Warning: our SIMBAD name resolver has been experiencing intermittent problems this week. If possible, try entering coordinates rather than target names, or use the NED name resolver instead.
Archive Status
HST Search Form
(Help)
Standard Form
File Upload Form
Abbreviate body names
Search
Reset
Clear Form
Target Name
SAT*
Resolver
Don't Resolve
Radius (arcmin)
3.0
Right Ascension
Declination
Equinox
J2000
Imagers
Spectrographs
Other
ALL
NONE
STIS
NICMOS
WFPC2
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FOC
GHRS
FOS
FGS
HSP
Start Time
Exp Time
Proposal ID
Release Date
Dataset
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HST Search

http://archive.stsci.edu/hst/search.php   amazon lissauer de pater

Mission Search / Missions / Contacts / STScI / MAST   Search Help / Archive Status

HST Search Results

Edit Query

Display numeric columns graphically using VOPlot

100 rows displayed, but 429 are available.

Click on Dataset or Target Name entries to preview information on data set.
Click on Ref entries to display list of published papers.
Click on Proposal ID entries to display information on observing program.
Records with a @ character next to the mark button are proprietary, and may only be retrieved by authorized users.

Plot marked spectra | Submit marked data for retrieval from STDADS

Mark all | Unmark all | Mark public | Unmark public | Mark proprietary | Unmark proprietary

Mark	Dataset	Target Name	RA (J2000)	Dec (J2000)	Ref	Start Time	Stop Time	Exp Time	Ir
	U5GQ3201R	SATURN-EAST	02 49 6.86	+13 30 52.1	14	1999-11-03 19:47:00	1999-11-03 19:47:00	30.000	W
	U5GQ3202M	SATURN-EAST	02 49 6.82	+13 30 51.9	14	1999-11-03 19:50:00	1999-11-03 19:50:00	5.000	W
	U5GQ3203R	SATURN-EAST	02 49 6.78	+13 30 51.7	14	1999-11-03 19:53:00	1999-11-03 19:53:00	0.500	W
	U5GQ3204R	SATURN-EAST	02 49 6.74	+13 30 51.6	14	1999-11-03 19:56:00	1999-11-03 19:56:00	0.400	W
	U5GQ3205R	SATURN-EAST	02 49 6.70	+13 30 51.4	14	1999-11-03 19:59:00	1999-11-03 19:59:00	0.400	W
	U5GQ3206R	SATURN-EAST	02 49 6.66	+13 30 51.2	14	1999-11-03 20:02:00	1999-11-03 20:02:00	40.000	W
	U6EM2201M	SATURN-EAST	04 54 11.93	+20 46 58.9	13	2001-09-08 04:49:00	2001-09-08 04:49:00	30.000	W
	U6EM2202M	SATURN-EAST	04 54 11.95	+20 46 58.9	13	2001-09-08 04:52:00	2001-09-08 04:52:00	4.000	W
	U6EM2203M	SATURN-EAST	04 54 11.97	+20 46 58.9	13	2001-09-08 04:55:00	2001-09-08 04:55:00	0.400	W
	U6EM2204M	SATURN-EAST	04 54 11.99	+20 46 59.0	13	2001-09-08 04:58:00	2001-09-08 04:58:00	0.350	W

MAST: HST Preview

http://archive.stsci.edu/cgi-bin/mastpreview?mission=hst&dataid=U5GQ3201R

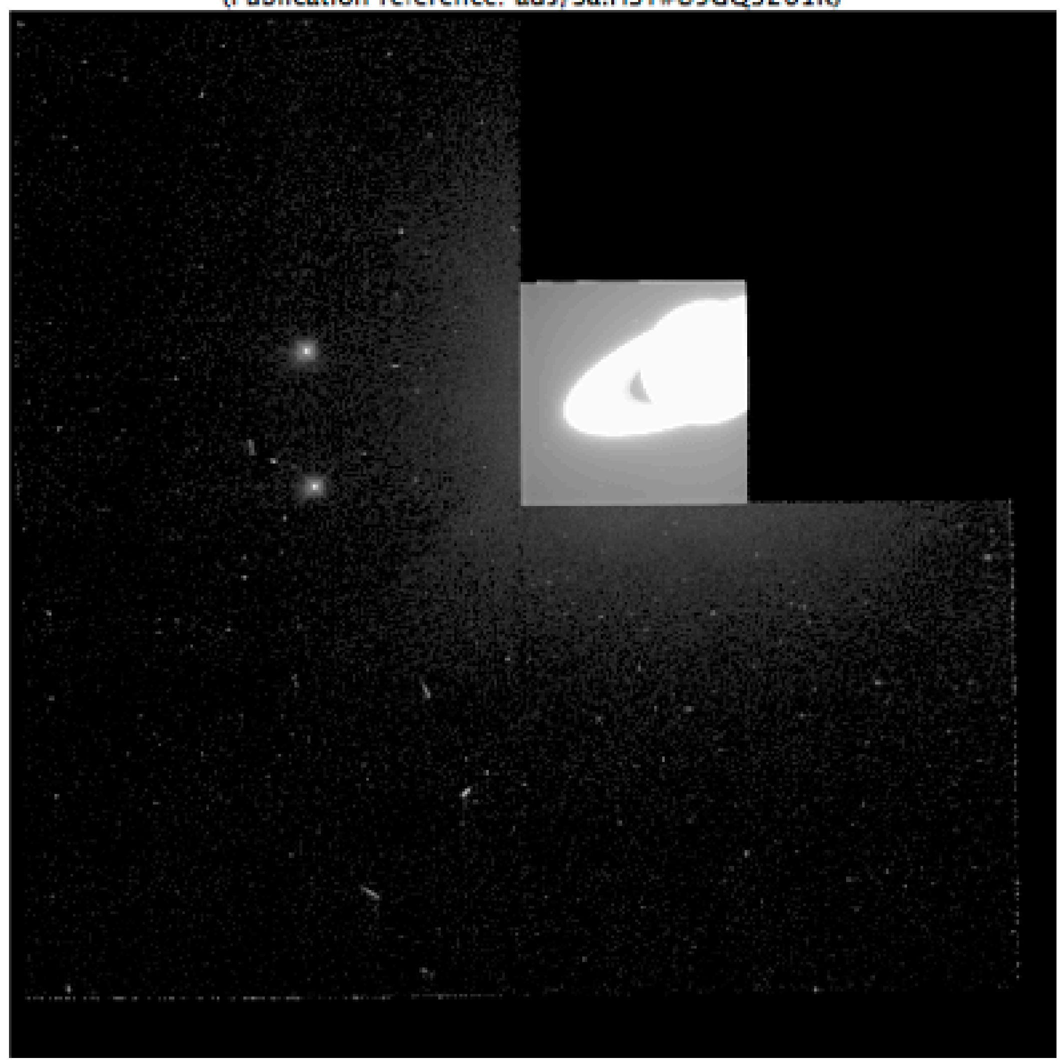
HST Preview

MAST | STScI | Tools | Mission_Search | Tutorial | Site Search

About MAST | Getting Started | Suggestions

Preview for U5GQ3201R

(Publication reference: ads/Sa.HST#U5GQ3201R)



Preview calibrations are uncertain so preview data should be used for diagnostic/quick-look purposes only.

FITS format   More preview format options

Exposure Information

Target Name: SATURN-EAST
RA: 02 49 06.86

Observation Date: Nov 3 1999 7:47PM
Exp Time: 30

Instrument: WFPC2
Filter/Grating: F336W

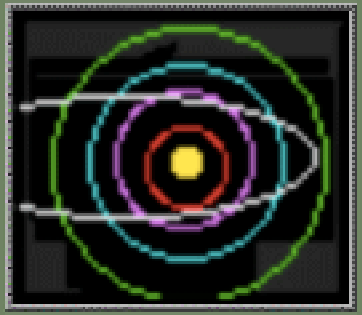
SWIFT

- Free, supported integration tool for N-body simulations.
  - Non-colliding bodies only.
  - FORTRAN-77.
- www.boulder.swri.edu/~hal/swift.html

SWIFT

http://www.boulder.swri.edu/~hal/swift.html

SWIFT



A solar system integration software package

The SWIFT subroutine package written by Hal Levison and Martin Duncan is designed to integrate a set of mutually gravitationally interacting bodies together with a group of test particles which feel the gravitational influence of the massive bodies but do not affect each other or the massive bodies. Four integration techniques are included:

- Wisdom-Holman Mapping[1] (WHM). This algorithm was created by Jack Wisdom & Matt Holman (Click here for a reference).
- Regularized Mixed Variable Symplectic (RMVS) method. This handles close approachs between test particles and planets. This algorithm was created by Hal Levison & Martin Duncan (Click here for a reference) and based on WHM.
- A fourth order T+U Symplectic (TU4) method. This algorithm was created by Jeff Candy and W. Rozmus. Also see Martin Duncan, Brett Gladman, and Jeff Candy (Click here for a reference).
- A Bulirsch-Stoer method.

The package is designed so that the calls to each of these look identical so that it is trivial to replace one with another.

We know that SWIFT will run on HP9000s, SUNs, MIPS, IBM RS6000, DEC alphas (UNIX and Linux), PC's (Linux) and DECstations. We do not support VMS, but Sandy Keiser of DTM have written a version for VMS, which we are distributing. Click here for more information of the VMS version. If you are going to run SWIFT on a machine not listed, please let us know how it works.

You can get a compressed tar file of swift by clicking here. Put swift.tar.Z into a directory that you will use as the main SWIFT directory. Now you uncompress and un-tar the file by entering:

```
uncompress swift.tar.Z
tar xovf swift.tar
```

Light Scattering Codes

- Mie Scattering (spheres):
  - web.mit.edu/cegeon/Public/Classes/Mie/
- T-matrix models (irregular particles):
  - www.giss.nasa.gov/~crmim/t_matrix.html
- Discrete dipole approximation (arbitrary particle shapes of limited size):
  - www.astro.princeton.edu/~draine/DDSCAT.6.0.html

Index of /cegeon/Public/Classes/12815/Mie

http://web.mit.edu/cegeon/Public/Classes/12815/Mie/

miev mie scattering

Index of /cegeon/Public/Classes/12815/Mie

Name	Last modified	Size	Description
Parent Directory	16-Oct-2003 16:19	-	
Compile_Run	09-Aug-1999 15:30	1k	
ErrPack.f	09-Aug-1999 15:30	3k	
ErrPack.o	14-Oct-2003 12:23	6k	
MIEV.doc	09-Aug-1999 15:30	21k	
MIEV0	15-Oct-2003 00:18	897k	
MIEV0.f	09-Aug-1999 15:30	63k	
MIEV0.o	14-Oct-2003 12:23	97k	
Makefile	09-Aug-1999 15:30	1k	
ex3-x100n001.txt	14-Oct-2003 17:45	9k	
ex3-x100n1.txt	14-Oct-2003 17:34	9k	
ex3-x1n001.txt	14-Oct-2003 17:47	9k	
g.f	15-Oct-2003 00:17	2k	
g.txt	15-Oct-2003 00:12	14k	
g100.txt	15-Oct-2003 00:18	14k	
ouput001.txt	14-Oct-2003 12:35	28k	
output001.txt	14-Oct-2003 12:44	28k	
output01.txt	14-Oct-2003 12:43	28k	
output1.txt	14-Oct-2003 12:42	28k	
phs_fnc.f	14-Oct-2003 23:05	3k	
qscat.f	14-Oct-2003 12:44	2k	
qscat.o	14-Oct-2003 12:44	6k	
x100n01.txt	14-Oct-2003 23:07	9k	

NASA GISS: Scattering -- T-Matrix Codes

http://www.giss.nasa.gov/~crmim/t_matrix.html

Goddard Institute for Space Studies
New York, N.Y.

+ NASA Portal
+ Goddard Space Flight Center
+ GSFC Earth Sciences Division

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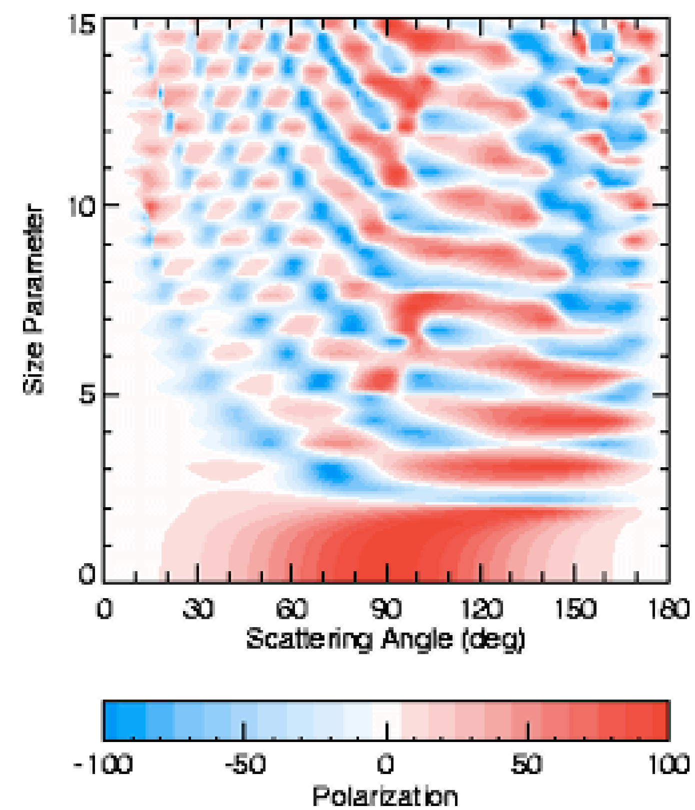
_T_-Matrix Codes for Computing Electromagnetic Scattering by Nonspherical and Aggregated Particles

By Michael I. Mishchenko, Larry D. Travis, and Daniel W. Mackowski



This web site provides free public access to four *T*-matrix codes for the computation of electromagnetic scattering by homogeneous, rotationally symmetric nonspherical particles in fixed and random orientations, a superposition *T*-matrix code for randomly oriented two-sphere clusters with touching or separated components, and superposition *T*-matrix codes for multi-sphere clusters in fixed and random orientations. All codes are written in Fortran-77. Each code is extensively documented and provides all necessary references to relevant publications.

The double-precision and extended-precision versions of the regular *T*-matrix codes are essentially identical. The extended-precision versions are a factor of 5-8 slower than their double-precision equivalents, but allow computations for larger (a factor of 2-3) particles. The extended-precision codes have a more detailed documentation of all the subroutines used.

The regular *T*-matrix codes are applicable to rotationally symmetric particles with equivalent-sphere size parameters exceeding 100. At present, the *T*-matrix method is the fastest exact technique for the computation of nonspherical scattering based on a direct solution of Maxwell's equations. The *T*-matrix codes are orders of magnitude faster than those based on the DDA, VIEF, and FDTD techniques.

The regular *T*-matrix codes for randomly oriented particles are based on the analytical orientation averaging procedure described in the paper M. I. Mishchenko, J. Opt. Soc. Am. A 8, 871-882 (1991). This efficient procedure makes the codes 1 to 2 orders of magnitude faster than *T*-matrix codes based on the standard numerical averaging approach. The superposition bisphere and multi-sphere *T*-matrix codes are based on similar analytical approaches and are described in the papers M. I. Mishchenko and D. W. Mackowski, Opt. Lett., vol. 19, 1604- 1606 (1994) and D. W. Mackowski and M. I. Mishchenko, J. Opt. Soc. Amer. A., vol. 13, 2266-2278 (1996). In application to bispheres, the multi-sphere *T*-matrix code is slower than the bisphere code. However, it can be applied to clusters with a number of components larger than 2.

A general **review** of the *T*-matrix method can be found in the paper M. I. Mishchenko, L. D. Travis, and D. W. Mackowski, J. Quant. Spectrosc. Radiat. Transfer 55, 535-575 (1996) (available in the electronic form at www.giss.nasa.gov/~crmim/publications). To receive a reprint of this paper, leave a message at crmim@giss.nasa.gov indicating your name and mailing address. A detailed **user guide** to the regular random-orientation *T*-matrix codes was also published [JQSRT 60, 309-324 (1998)] and is available here in the pdf format. A **user guide** to the *T*-matrix codes for nonspherical particles in a fixed orientation [Appl. Opt. 39, 1026-1031 (2000)] is available here in the pdf format. A

Scattering and Absorption of Light by Small Particles

http://www.astro.princeton.edu/~draine/DDSCAT.6.0.html

ddscat

[Back to B.T. Draine's home page.]

The Discrete Dipole Approximation for Scattering and Absorption of Light by Irregular Particles

DDSCAT, a Fortran code for calculating scattering and absorption of light by irregular particles, has been jointly developed by Bruce T. Draine (Dept. of Astrophysical Sciences, Princeton University) and Piotr J. Flatau (Scripps Institution of Oceanography, UCSD); the current version is DDSCAT.6.0 . This code is publicly available (see below). If you choose to use it, please send email to <draine@astro.princeton.edu> "registering" as a user; registered users of DDSCAT will be notified when updates to the code are made.

User Guide for DDSCAT.6.0

An extensive User Guide is available: "User Guide to the Discrete Dipole Approximation Code DDSCAT.6.0", by B.T. Draine and Piotr J. Flatau. A copy of this document (postscript or pdf) can be obtained from astro-ph/0309069 and can be cited as

> Draine, B.T., and Flatau, P.J. 2003, "User Guide to the Discrete Dipole Approximation Code DDSCAT.6.0", http://arxiv.org/abs/astro-ph/0300969.

The following files are of interest:

- astro-ph/0309069.ps.gz: User Guide for DDSCAT.6.0 (gzipped postscript)
- astro-ph/0309069.pdf: User Guide for DDSCAT.6.0 (pdf)

Downloading the DDSCAT Code

Unix users will find it most convenient to download

- ddscat.6.0.tgz: gzipped tarfile containing complete source code and documentation for DDSCAT.6.0

Non-unix users can use anonymous ftp to download the code (*.FOR files), documentation (UserGuide.ps), and sample parameter files (ddscat.par and diel.tab).

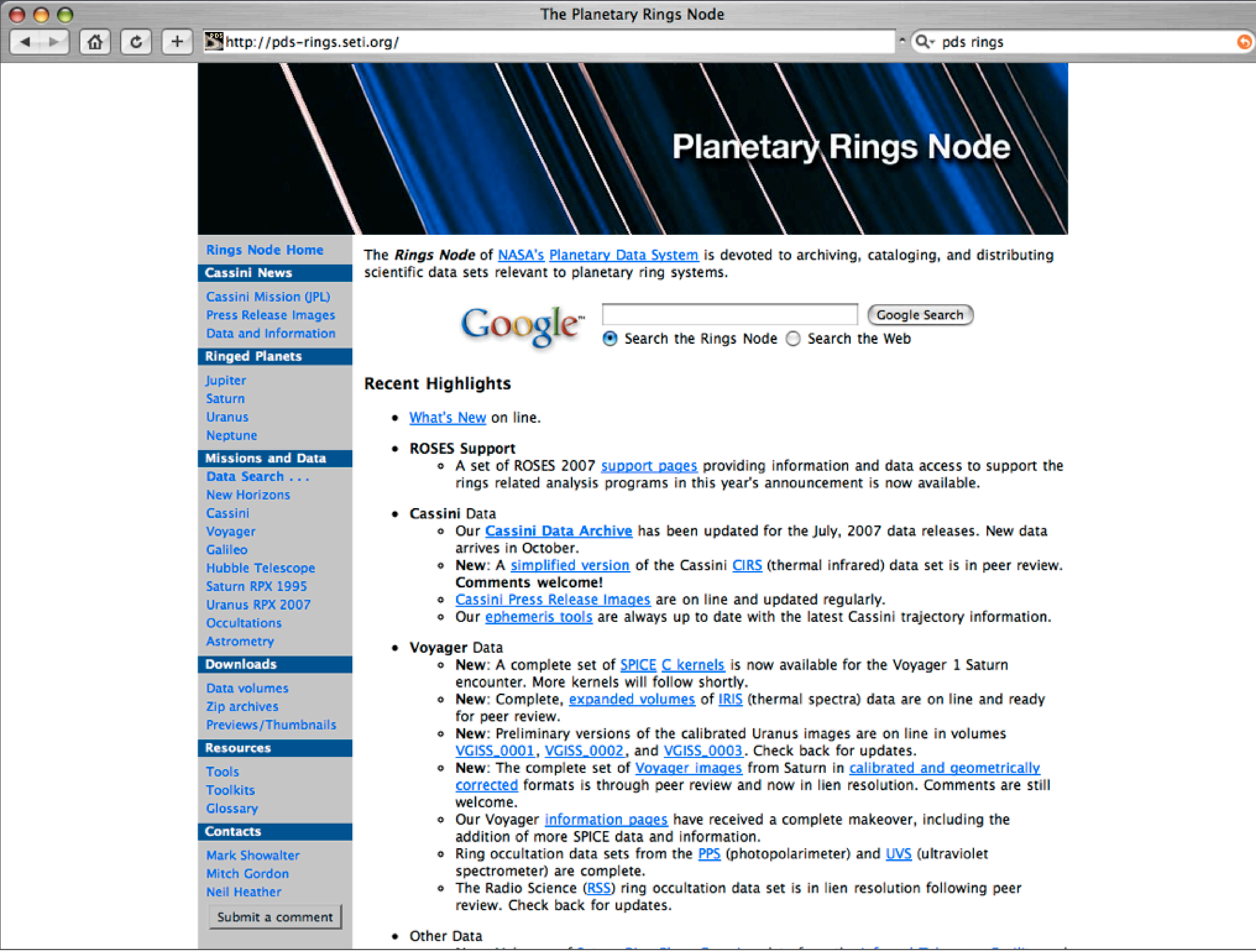
History of recent releases:

- DDSCAT.5a9 was released 1998 December 23. It fixes a bug in DDSCAT.5a8, which resulted in incorrect evaluation of elements of the Mueller scattering matrix (other than S_11, which was correct) for scattering planes other than phi=0.
  - A new version of orient.f was released 1999 March 16. Orientational averages are now evaluated as described in the UserGuide; prior to this date averaging over cos(Theta) was evaluated by dividing the range of cos(Theta) into NTHETA equal intervals, evaluating the scattering at the midpoint of each interval, and taking the mean. With the new version of orient.f, Simpson's rule is now used for the quadrature when an odd value of NTHETA is specified by the user.
- DDSCAT.5a10 was released 2000 August 9. It provides a new target option -- NSPHER -- to create targets consisting of the unions of N spheres (possibly overlapping) of arbitrary sizes and locations. It also uses a more recent version of the LAPACK code used by subroutine PRINAXIS.
  - A new target option -- PRISM3 -- to generate a triangular prism was added to DDSCAT.5a10 on 2002.02.12

PDS Rings Node

pds-rings.seti.org

- Google (TM) search of our site.
- On-line ephemeris and planetary diagramming tools: /tools
- Browsable views of all Cassini and Voyager images: /previews
- Software toolkits in C and FORTRAN: /toolkits
- Voyager and Galileo catalogs, functional but being phased out: /catalog
- New general catalog in development: /demo


The Planetary Rings Node
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Cassini Mission (JPL)
Press Release Images
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Ringed Planets
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Contacts
Mark Showalter
Mitch Gordon
Neil Heather
Submit a comment
The Rings Node of NASA's Planetary Data System is devoted to archiving, cataloging, and distributing scientific data sets relevant to planetary ring systems.
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Search the Web
Recent Highlights
What's New on line.
ROSES Support
A set of ROSES 2007 support pages providing information and data access to support the rings related analysis programs in this year's announcement is now available.
Cassini Data
Our Cassini Data Archive has been updated for the July, 2007 data releases. New data arrives in October.
New: A simplified version of the Cassini CIRS (thermal infrared) data set is in peer review. Comments welcome!
Cassini Press Release Images are on line and updated regularly.
Our ephemeris tools are always up to date with the latest Cassini trajectory information.
Voyager Data
New: A complete set of SPICE C kernels is now available for the Voyager 1 Saturn encounter. More kernels will follow shortly.
New: Complete, expanded volumes of IRIS (thermal spectra) data are on line and ready for peer review.
New: Preliminary versions of the calibrated Uranus images are on line in volumes VGISS_0001, VGISS_0002, and VGISS_0003. Check back for updates.
New: The complete set of Voyager images from Saturn in calibrated and geometrically corrected formats is through peer review and now in lien resolution. Comments are still welcome.
Our Voyager information pages have received a complete makeover, including the addition of more SPICE data and information.
Ring occultation data sets from the PPS (photopolarimeter) and UVS (ultraviolet spectrometer) are complete.
The Radio Science (RSS) ring occultation data set is in lien resolution following peer review. Check back for updates.
Other Data

Rings Node On-line Tools

http://pds-rings.seti.org/tools/

Planetary Rings Node

- Rings Node Home

Cassini News

- Cassini Mission (JPL)
- Press Release Images
- Data and Information

Ringed Planets

- Jupiter
- Saturn
- Uranus
- Neptune

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- Voyager
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- Saturn RPX 1995
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- Tools
- Toolkits
- Glossary

Contacts

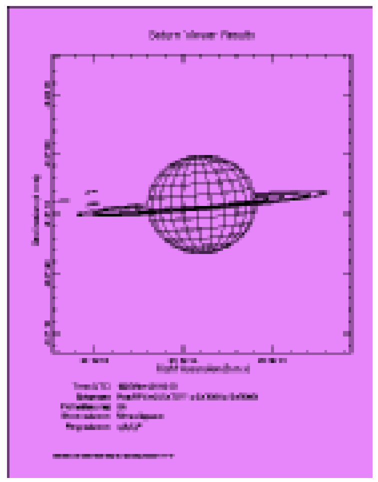
- Mark Showalter
- Mitch Gordon
- Neil Heather

Submit a comment

Rings Node On-line Tools

A set of tools to assist planetary scientists in the planning, acquisition and interpretation of observations of the ringed (and possibly-ringed) planets.

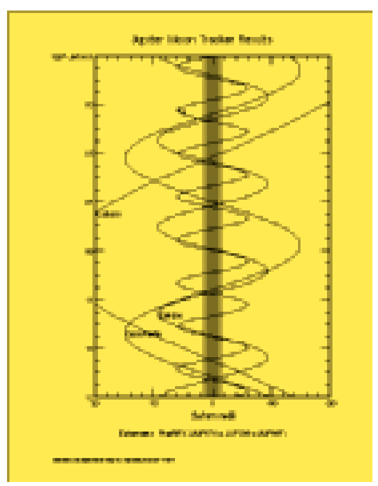
Versions of these tools are now available to support the Cassini Mission and the New Horizons Jupiter flyby.



Planet Viewers

These forms enable you to generate a diagram showing the appearance of a planetary system at a specified time. Bodies and rings are rendered with terminators and shadows as appropriate. The viewpoint can be Earth's center, a particular Earth-based observatory, or a spacecraft.

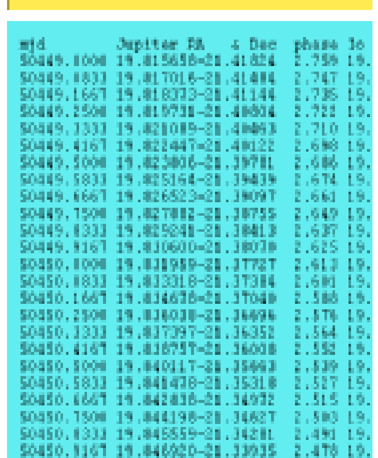
Click for Jupiter, Saturn, Uranus, Neptune, or Mars.



Moon Trackers

These forms enable you to generate a diagram showing the apparent east-west motion of one or moons relative to the disk of a planet, within a specified time period.

Click for Jupiter, Saturn, Uranus, Neptune, or Mars.



Ephemeris Generators

These forms enable you to generate a table listing useful information about the viewing geometry for a planet and/or any of its moons as a function of time. You are free to specify which of a variety of useful quantities to tabulate (e.g. RA and dec, phase angle, ring opening angle, distance, lunar phase, etc.).

Click for Jupiter, Saturn, Uranus, Neptune, or Mars.

Cassini/Saturn Viewer 1.4

http://pds-rings.seti.org/tools/viewer2_satc.html

Cassini/Saturn Viewer 1.4

Click here for help, or click on individual highlighted items.

Note that this tool is identical to the Saturn Viewer 2.5 but with a streamlined form and the viewpoint hard-wired to Cassini. For other viewpoints (Voyager, Earth, or a particular observatory), follow the link above.

Observation Time

2007-07-25 12:00 **(Required)**

Field of View:

6 Saturn radii **(Required)**

Ephemeris Options

- ○ New Prometheus fit (SAT077 + SAT086 + SAT081 + SAT060 + SAT101 + DE405)
  2004-May-29 to 2008-Aug-08 for most satellites
  2004-May-29 to 2004-Dec-31 for Prometheus, Pandora and Pan
- ○ Prometheus fit 2002 (SAT077 + SAT086 + SAT081 + SAT060 + SAT127 + DE405)
  2004-May-29 to 2008-Aug-08 for all satellites except Pan
  2004-May-29 to 2004-Dec-31 for Pan
- ◉ Pre-Cassini (SAT196 + SAT207 + Pan + DE405)
  1938-Sep-15 to 2019-Dec-03 for Mimas-Phoebe
  1980-Jan-20 to 2009-Jan-11 for small satellites
  1998-Jan-01 to 2009-Dec-31 for Pan

Diagram center:

- ◉ Body: Saturn
- ○ Ring ansa: A Ring east
- ○ J2000 RA and Dec: hours degrees
- ○ Star name: (Click here for the current list.)

Moon Selection:

- ○ Mimas-Phoebe (S1-S9)
- ◉ ...plus Janus & Epimetheus (S10 & S11)
- ○ ...plus Helene, Telesto & Calypso (S12-S14)
- ○ ...plus Prometheus & Pandora (S16 & S17)
- ○ ...plus Atlas (S15)
- ○ ...plus Pan (S18)

Saturn Viewer 2.5 Results

http://pds-rings.seti.org/cgi-bin/tools/viewer2_sat.pl

Field of View Description (J2000)

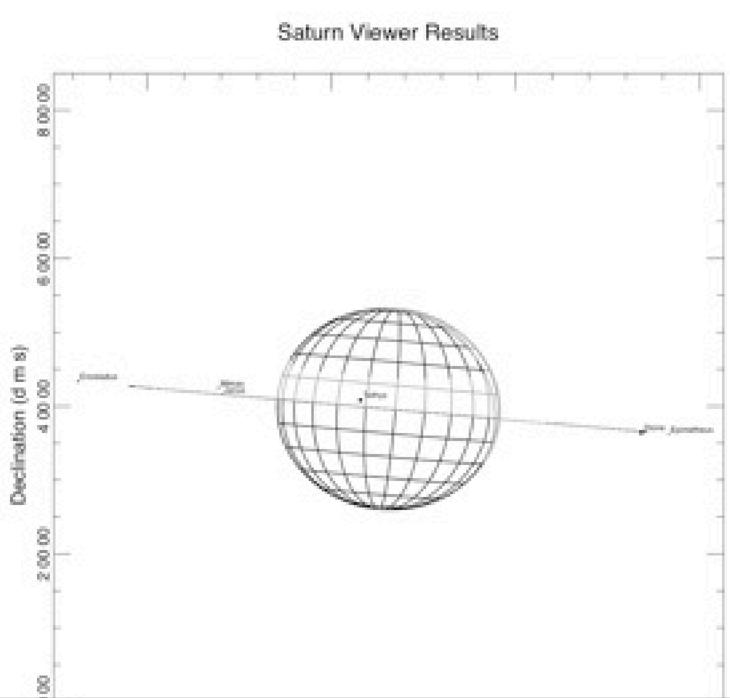
	Body	RA	Dec	dRA (")	dDec (")
699	Saturn	11h 16m 53.3880s	3d 57m 42.346s	0.000	0.000
601	Mimas	11h 26m 08.4123s	4d 14m 38.800s	8305.469	1016.454
602	Enceladus	11h 33m 44.8546s	4d 19m 37.833s	15135.742	1315.487
603	Tethys	11h 18m 25.2529s	4d 04m 50.235s	1374.680	427.889
604	Dione	11h 03m 09.6365s	3d 38m 09.124s	-12326.747	-1173.222
605	Rhea	11h 42m 41.5239s	4d 22m 41.401s	23166.546	1499.055
606	Titan	12h 17m 10.5303s	5d 07m 37.133s	54127.480	4194.787
607	Hyperion	10h 08m 40.2850s	1d 32m 40.526s	-61249.831	-8701.820
608	Iapetus	10h 44m 32.5026s	10d 24m 56.422s	-29043.712	23234.076
609	Phoebe	12h 23m 40.7994s	3d 36m 01.281s	59967.528	-1301.065
610	Janus	11h 25m 55.9615s	4d 09m 47.664s	8119.153	725.318
611	Epimetheus	11h 01m 40.4823s	3d 37m 03.642s	-13660.863	-1238.704

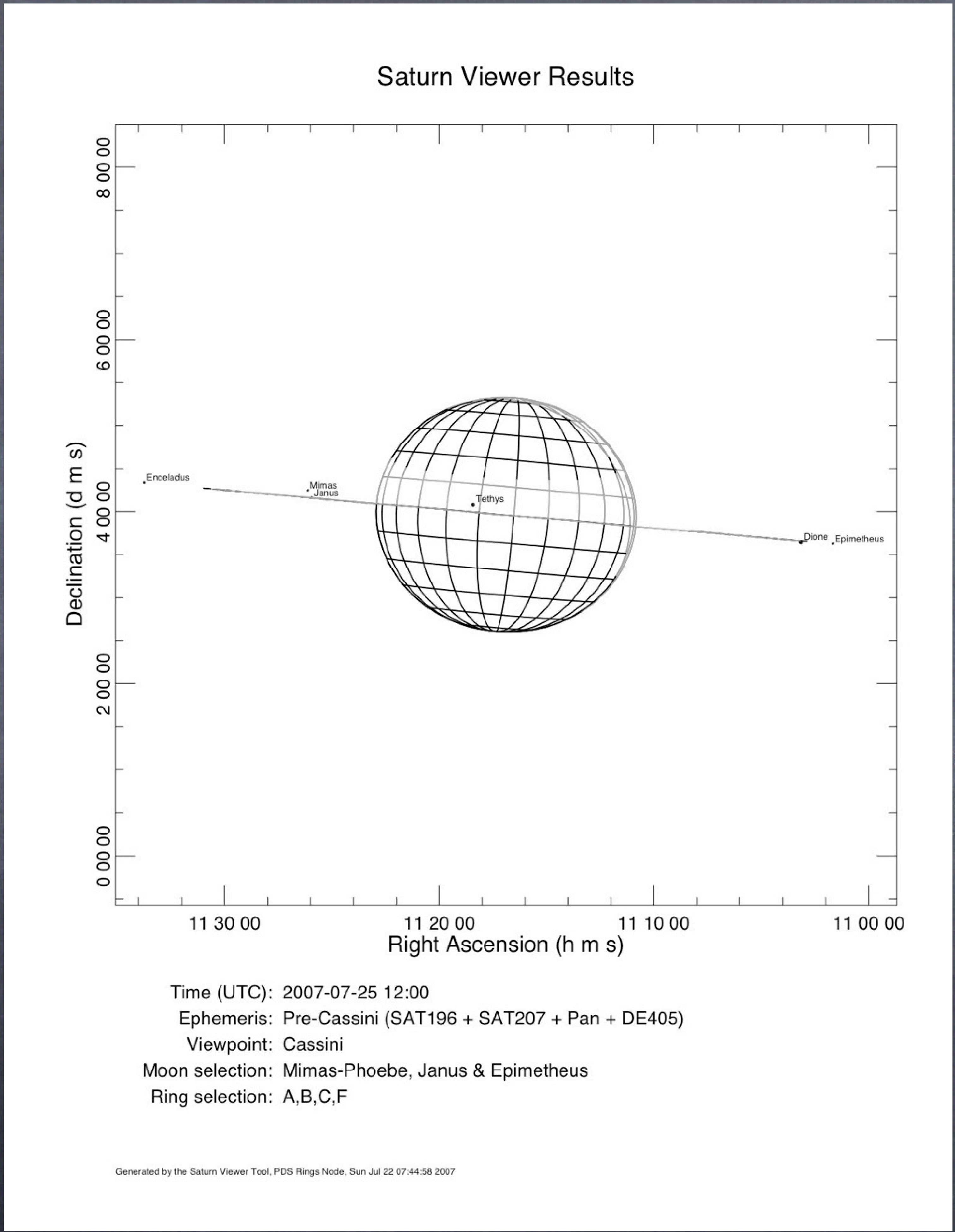
```
     Sub-solar latitude (deg): -11.42301  (-11.45191  to -11.39412)
     Ring opening angle (deg):   0.08539  (unlit)
            Phase angle (deg):  21.18831
    Sub-solar longitude (deg): 200.90068  from ring plane ascending node
 Sub-observer longitude (deg): 218.81475

     Sun-planet distance (km):  1380.150526 x 10^6
Observer-planet distance (km):     2.285400 x 10^6
      Light travel time (sec):     7.623273

      F Ring pericenter (deg): 281.77575  from ring plane ascending node
   F Ring ascending node (deg): 152.94911
```

Preview:




Saturn Viewer Results
Declination (d m s)
8 00 00
6 00 00
4 00 00
2 00 00
0 00 00
Enceladus
Mimas
Janus
Tethys
Dione
Epimetheus
11 30 00
11 20 00
11 10 00
11 00 00
Right Ascension (h m s)
Time (UTC): 2007-07-25 12:00
Ephemeris: Pre-Cassini (SAT196 + SAT207 + Pan + DE405)
Viewpoint: Cassini
Moon selection: Mimas-Phoebe, Janus & Epimetheus
Ring selection: A,B,C,F
Generated by the Saturn Viewer Tool, PDS Rings Node. Sun Jul 22 07:44:58 2007

VG_0005/BROWSE/S_RINGS/C3499XXX

http://pds-rings.seti.org/browse/VG_0005/BROWSE/S_RINGS/C3499XXX/

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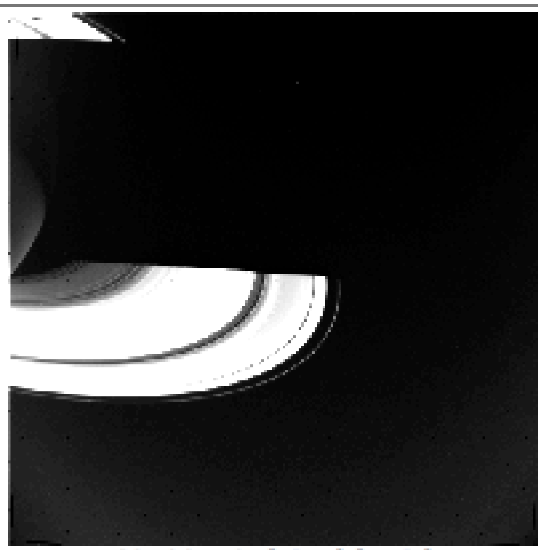
VG_0005/BROWSE/S_RINGS/C3499XXX

^Up

<Prev Page 1/5 Next>

Complete File List

Image Credit: NASA/JPL



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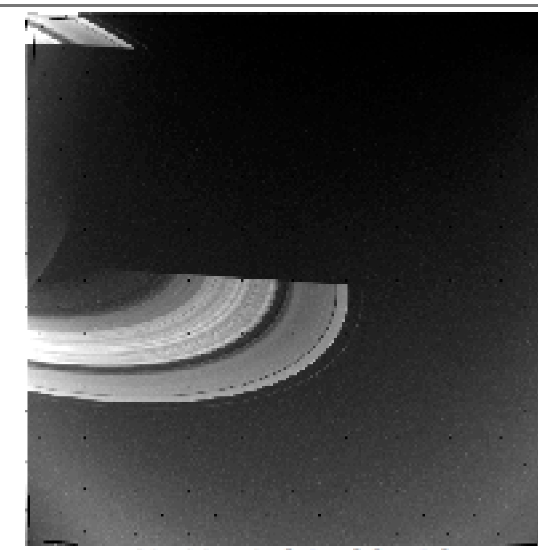

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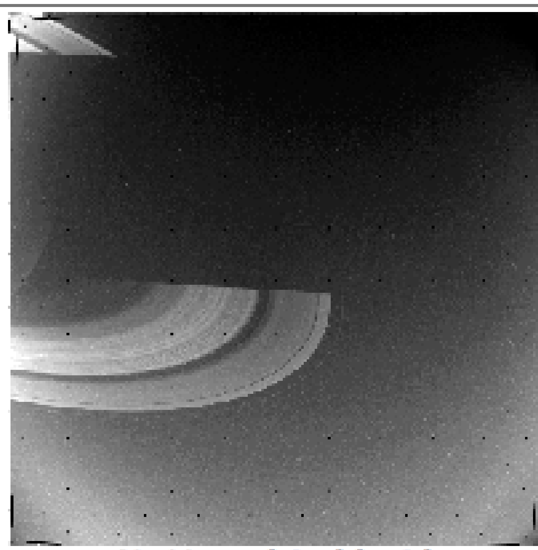

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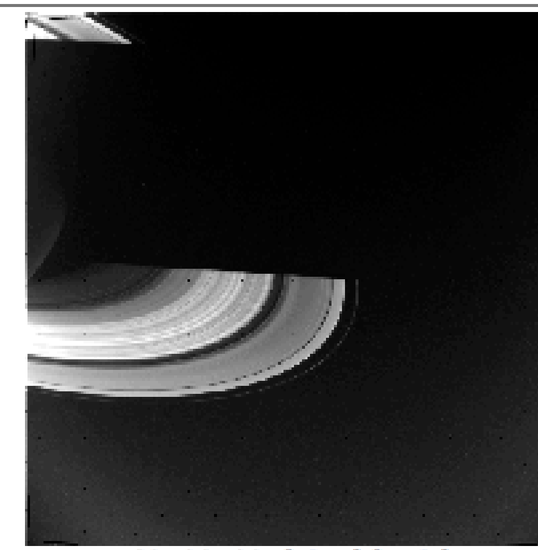

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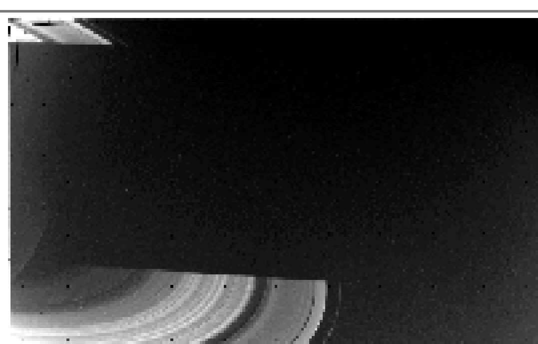

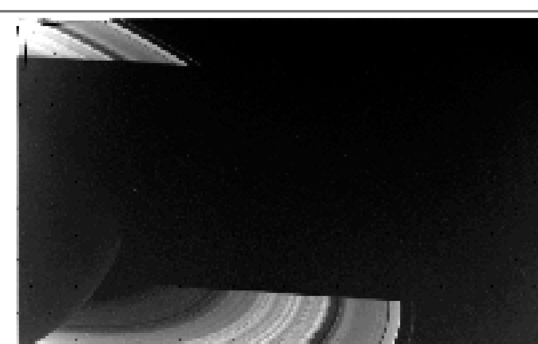

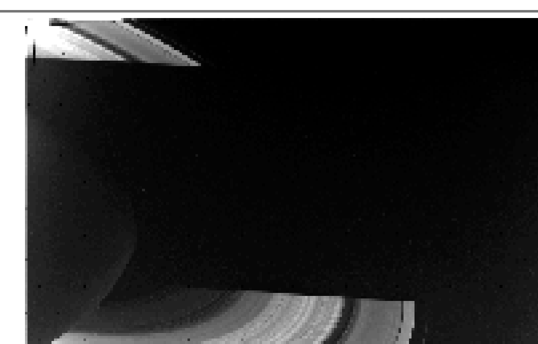

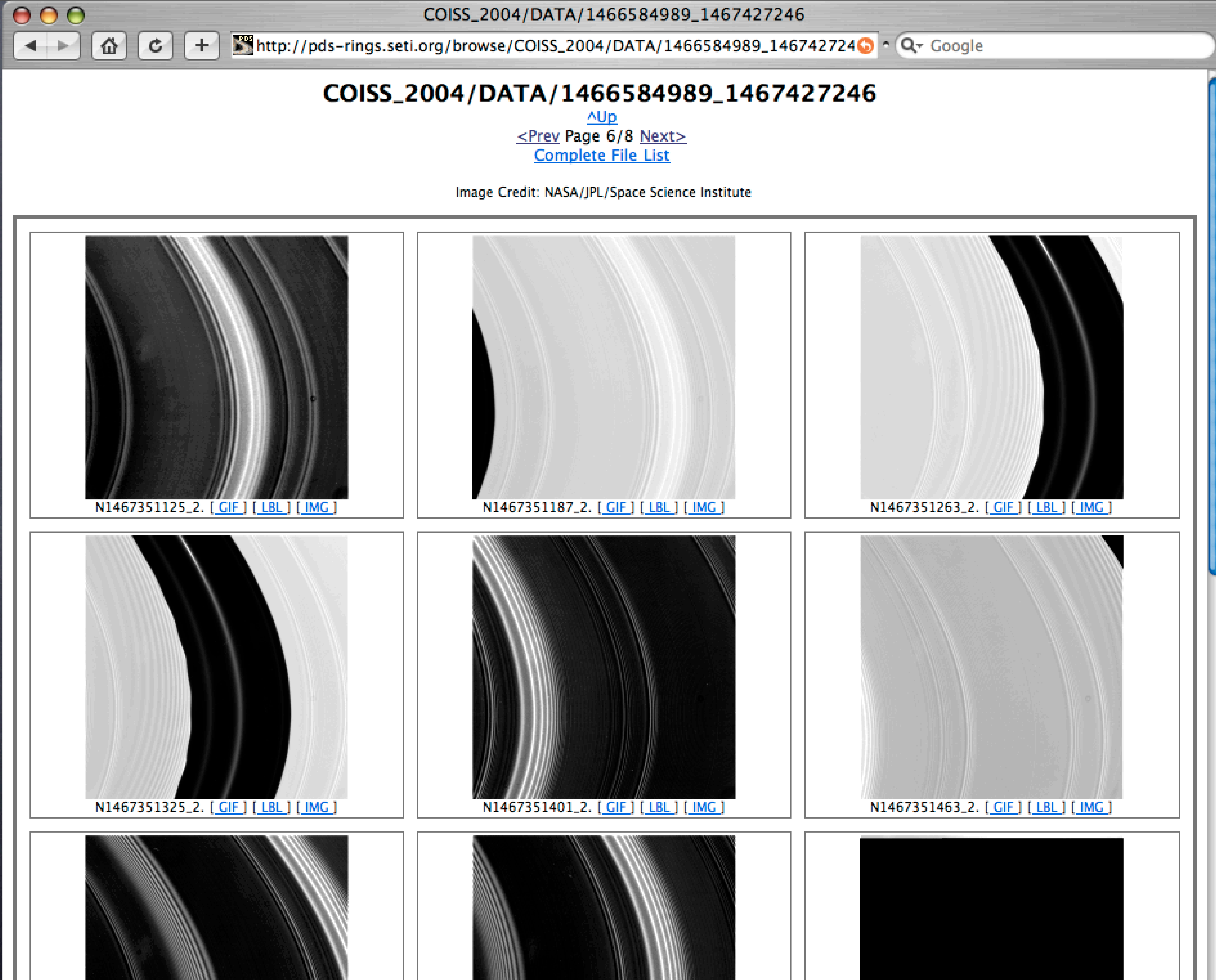
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http://pds-rings.seti.org/browse/COISS_2004/DATA/1466584989_146742724
Google
COISS_2004/DATA/1466584989_1467427246
^Up
<Prev Page 6/8 Next>
Complete File List
Image Credit: NASA/JPL/Space Science Institute
N1467351125_2. [GIF] [LBL] [IMG]
N1467351187_2. [GIF] [LBL] [IMG]
N1467351263_2. [GIF] [LBL] [IMG]
N1467351325_2. [GIF] [LBL] [IMG]
N1467351401_2. [GIF] [LBL] [IMG]
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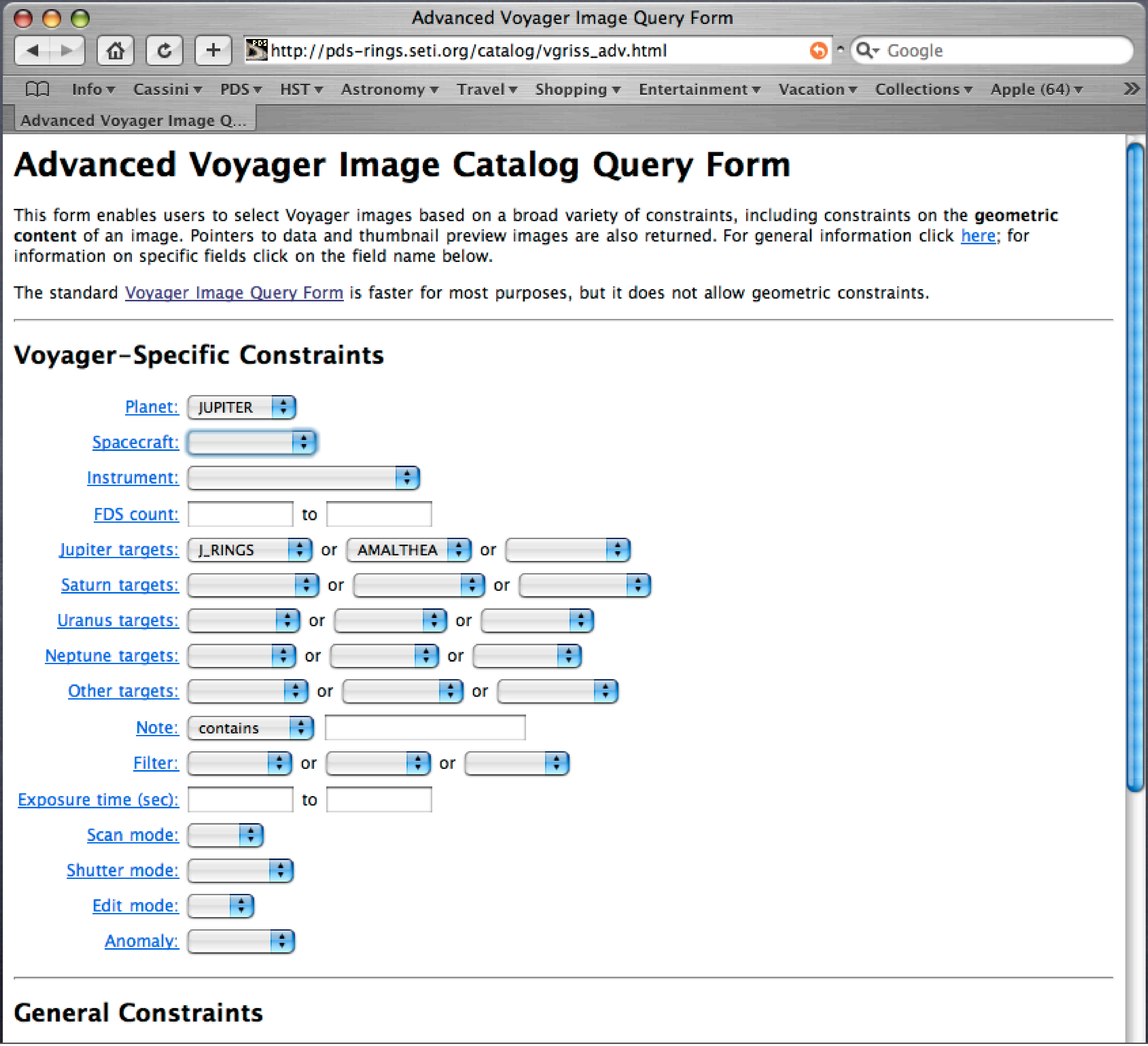


Advanced Voyager Image Query Form

http://pds-rings.seti.org/catalog/vgriss_adv.html

Info Cassini PDS HST Astronomy Travel Shopping Entertainment Vacation Collections Apple (64)

Advanced Voyager Image Q...

Advanced Voyager Image Catalog Query Form

This form enables users to select Voyager images based on a broad variety of constraints, including constraints on the **geometric content** of an image. Pointers to data and thumbnail preview images are also returned. For general information click here; for information on specific fields click on the field name below.

The standard Voyager Image Query Form is faster for most purposes, but it does not allow geometric constraints.

Voyager-Specific Constraints

Planet: JUPITER

Spacecraft:

Instrument:

FDS count: to

Jupiter targets: J_RINGS or AMALTHEA or

Saturn targets: or or

Uranus targets: or or

Neptune targets: or or

Other targets: or or

Note: contains

Filter: or or

Exposure time (sec): to

Scan mode:

Shutter mode:

Edit mode:

Anomaly:

General Constraints

Voyager Image Query Results

http://pds-rings.seti.org/cgi-bin/catalogc/vgriss_adv

Info Cassini PDS HST Astronomy Travel Shopping Entertainment Vacation Collections Apple (64)

Voyager Image Query Results

The SQL query...

```
select *
from vgr_iss,ring_observation
where vgr_iss.ring_observation_id = ring_observation.ring_observation_id
and   mission_phase_name = 'JUPITER_ENCOUNTER'
and   target_name in ('J_RINGS', 'AMALTHEA')
order by vgr_iss.ring_observation_id, vgr_iss.occurrence_number
```

Listing type: Detailed
Include previews: No
Records to skip: 0

Records found: 132
Records returned: 100

Note: This query listing is limited to 100 matches. You may view the remainder of the list by using the "Skip the first ___ records" option.

Top | Summary listing | Detailed listing | Help

SUMMARY LISTING

Click on record number to jump to detailed entry.
Click on FDS count for thumbnail preview image.

#	FDS	Planet	Vgr	Camera	Target	Filter	Texp	Scan	Shutter	Ring?
001	15508.28	JUPITER	1	NARROW	AMALTHEA	CLEAR	0.960	1:1	BSIMAN	NO
002	15508.29	JUPITER	1	WIDE	AMALTHEA	CLEAR	0.360	1:1	BSIMAN	NO
003	15933.37	JUPITER	1	NARROW	AMALTHEA	CLEAR	0.960	1:1	NAONLY	NO
004	16079.23	JUPITER	1	NARROW	AMALTHEA	ORANGE	0.960	1:1	BSIMAN	NO
005	16079.25	JUPITER	1	NARROW	AMALTHEA	GREEN	0.720	1:1	BSIMAN	NO
006	16079.27	JUPITER	1	NARROW	AMALTHEA	VIOLET	0.480	1:1	BSIMAN	NO
007	16103.57	JUPITER	1	WIDE	AMALTHEA	CLEAR	0.360	1:1	WAONLY	NO
008	16104.02	JUPITER	1	NARROW	AMALTHEA	CLEAR	0.960	1:1	BSIMAN	NO
009	16104.03	JUPITER	1	WIDE	AMALTHEA	CLEAR	0.360	1:1	BSIMAN	NO
010	16137.11	JUPITER	1	WIDE	AMALTHEA	CLEAR	0.360	1:1	WAONLY	NO
011	16137.16	JUPITER	1	NARROW	AMALTHEA	CLEAR	0.960	1:1	BSIMAN	NO

Voyager Image Query Results

http://pds-rings.seti.org/cgi-bin/catalogc/vgriss_adv#detailed123

Info ▾ Cassini ▾ PDS ▾ HST ▾ Astronomy ▾ Travel ▾ Shopping ▾ Entertainment ▾ Vacation ▾ Collections ▾ Apple (64) ▾

Voyager Image Query Results

```
                      VG_0025/J_RINGS/C2069257.IMQ [GIF]
       Browse Image: VG_0008/BROWSE/J_RINGS/C2069257.IBG [GIF]
                      VG_0025/BROWSE/J_RINGS/C2069257.IBG [GIF]
```

Top | Summary listing | Detailed listing | Help

```
        Query Record: 123 [PREVIEW]
 Ring Observation ID: J/IMG/VG2/ISS/20693.01/N
    Ring Information: YES
           FDS count: 20693.01
            Image ID: 0214J2+001
       Mission Phase: JUPITER_ENCOUNTER
          Spacecraft: VOYAGER_2
          Instrument: NARROW_ANGLE_CAMERA
              Target: J_RINGS
              Filter: CLEAR(0)
 Exposure Time (sec): 96.005
           Scan Rate: 5:1
           Edit Mode: 1:2
           Gain Mode: LOW
        Shutter Mode: NAONLY
                Mask: 11111111
             Anomaly: NONE
                Note: SCAN ALONG RING FOR BRIGHTNESS IN FORWARD SCATTERING
          Event Time: 1979-07-11T01:19:10.000
 Earth Received Time: 1979-07-11T02:11:08.000
    Ring radius (km):  128488.530 to  332525.038
Ring resolution (km):      14.086 to     570.460
     Incidence (deg):  89.972
      Emission (deg):  88.122
         Phase (deg): 173.512
    Observation time: 1979-07-11T01:17:33.995 to 1979-07-11T01:19:10.000
     Ring event time: 1979-07-11T01:17:28.815 to 1979-07-11T01:19:04.820
 Wavelength (micron): 0.460 (0.280 to 0.640)
    Compressed Image: VG_0008/J_RINGS/C2069301.IMQ [GIF]
                      VG_0025/J_RINGS/C2069301.IMQ [GIF]
        Browse Image: VG_0008/BROWSE/J_RINGS/C2069301.IBG [GIF]
                      VG_0025/BROWSE/J_RINGS/C2069301.IBG [GIF]
```

Top | Summary listing | Detailed listing | Help

```
        Query Record: 124 [PREVIEW]
```

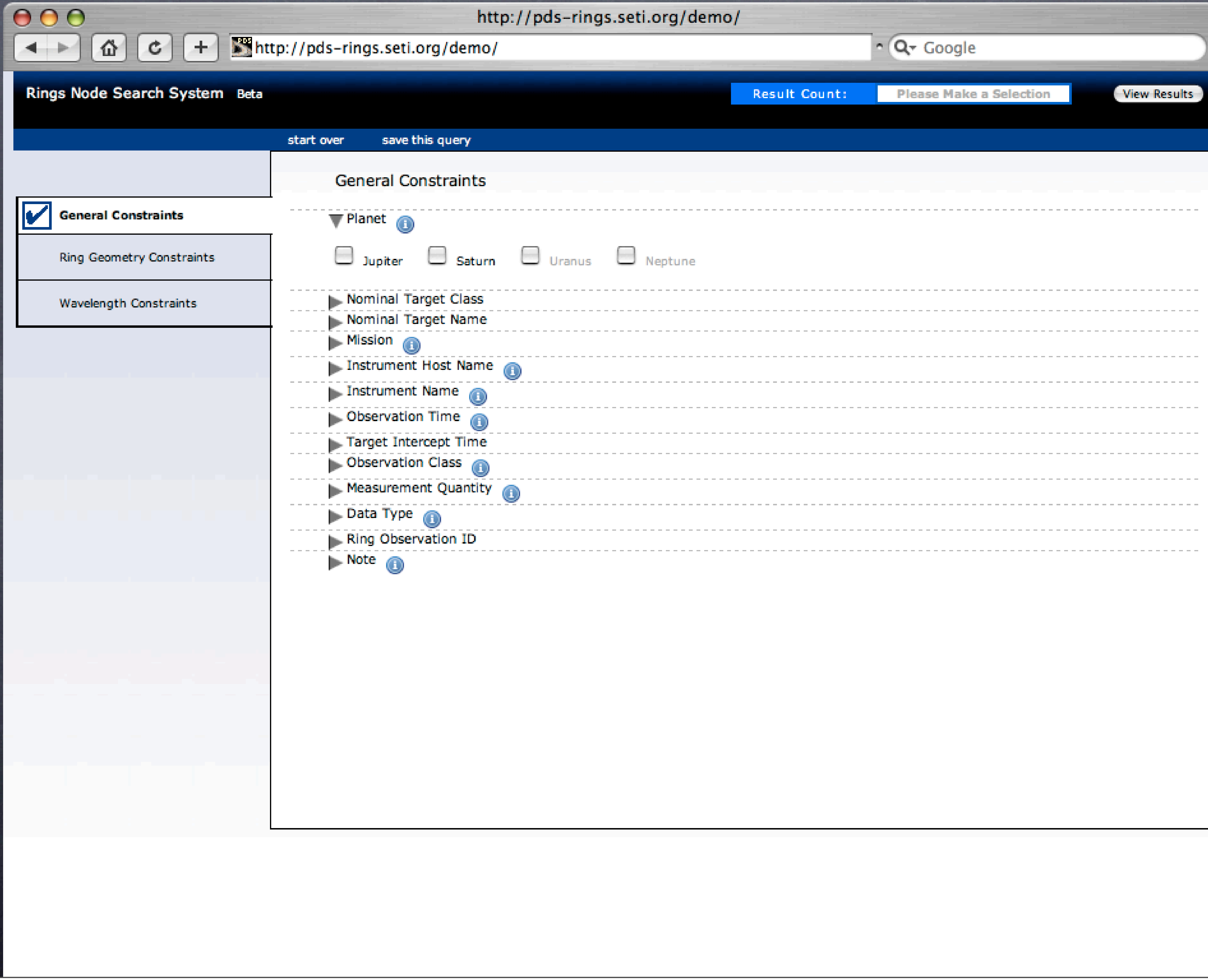
Temporary GIF Generator

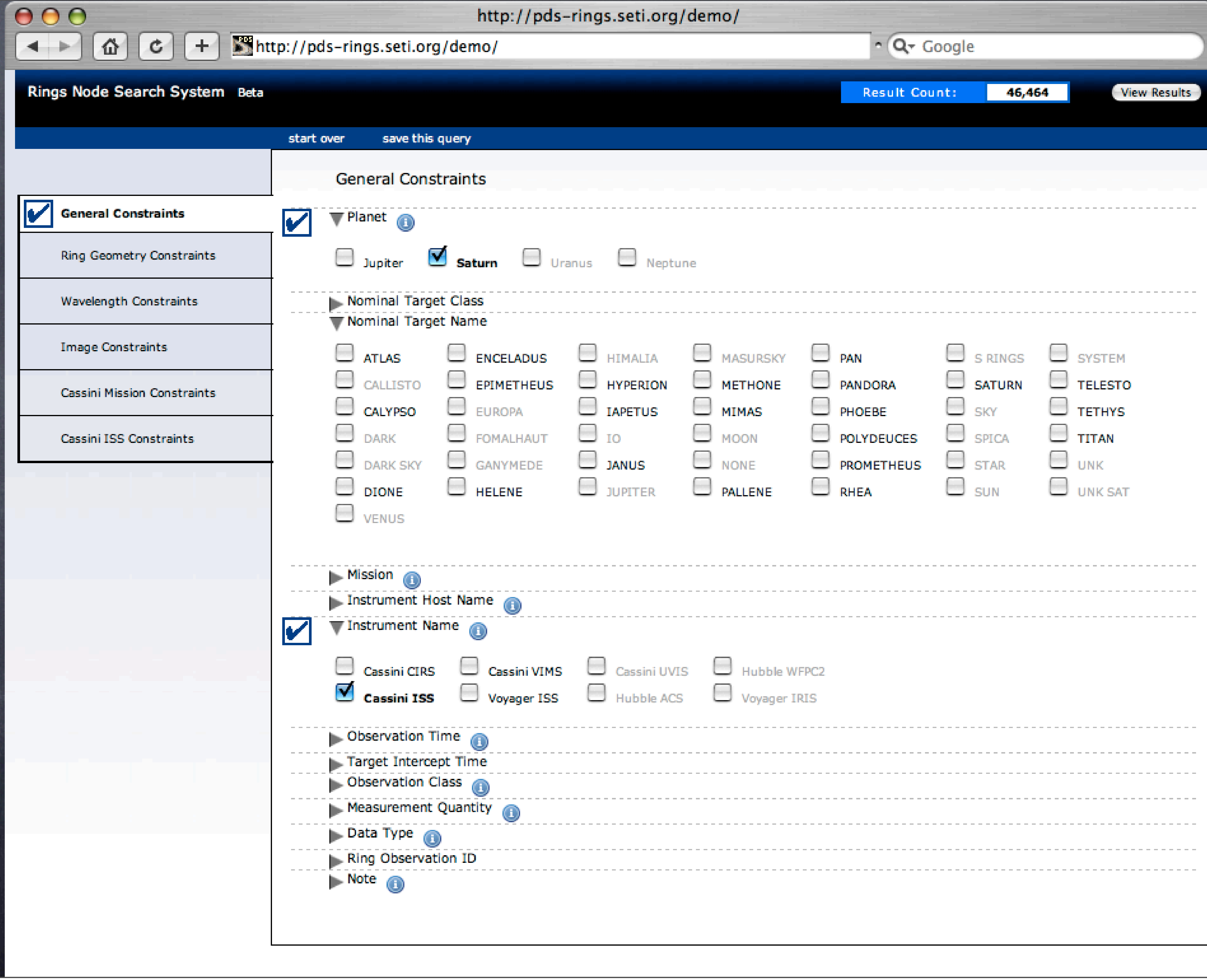
http://pds-rings.seti.org/cgi-bin/tempgif.pl?file=VG_0008/J_RINGS

Info ▾ Cassini ▾ PDS ▾ HST ▾ Astronomy ▾ Travel ▾ Shopping ▾ Entertainment ▾ Vacation ▾ Collections ▾ Apple (64) ▾

Temporary GIF Generator

Your GIF image:
(Note: temporary images remain available only for 2 hours)
VG_0008.J_RINGS.C2069302.GIF


http://pds-rings.seti.org/demo/
Google
Rings Node Search System Beta
Result Count:
Please Make a Selection
View Results
start over
save this query
General Constraints
Ring Geometry Constraints
Wavelength Constraints
General Constraints
Planet
Jupiter
Saturn
Uranus
Neptune
Nominal Target Class
Nominal Target Name
Mission
Instrument Host Name
Instrument Name
Observation Time
Target Intercept Time
Observation Class
Measurement Quantity
Data Type
Ring Observation ID
Note


http://pds-rings.seti.org/demo/
Google
Rings Node Search System Beta
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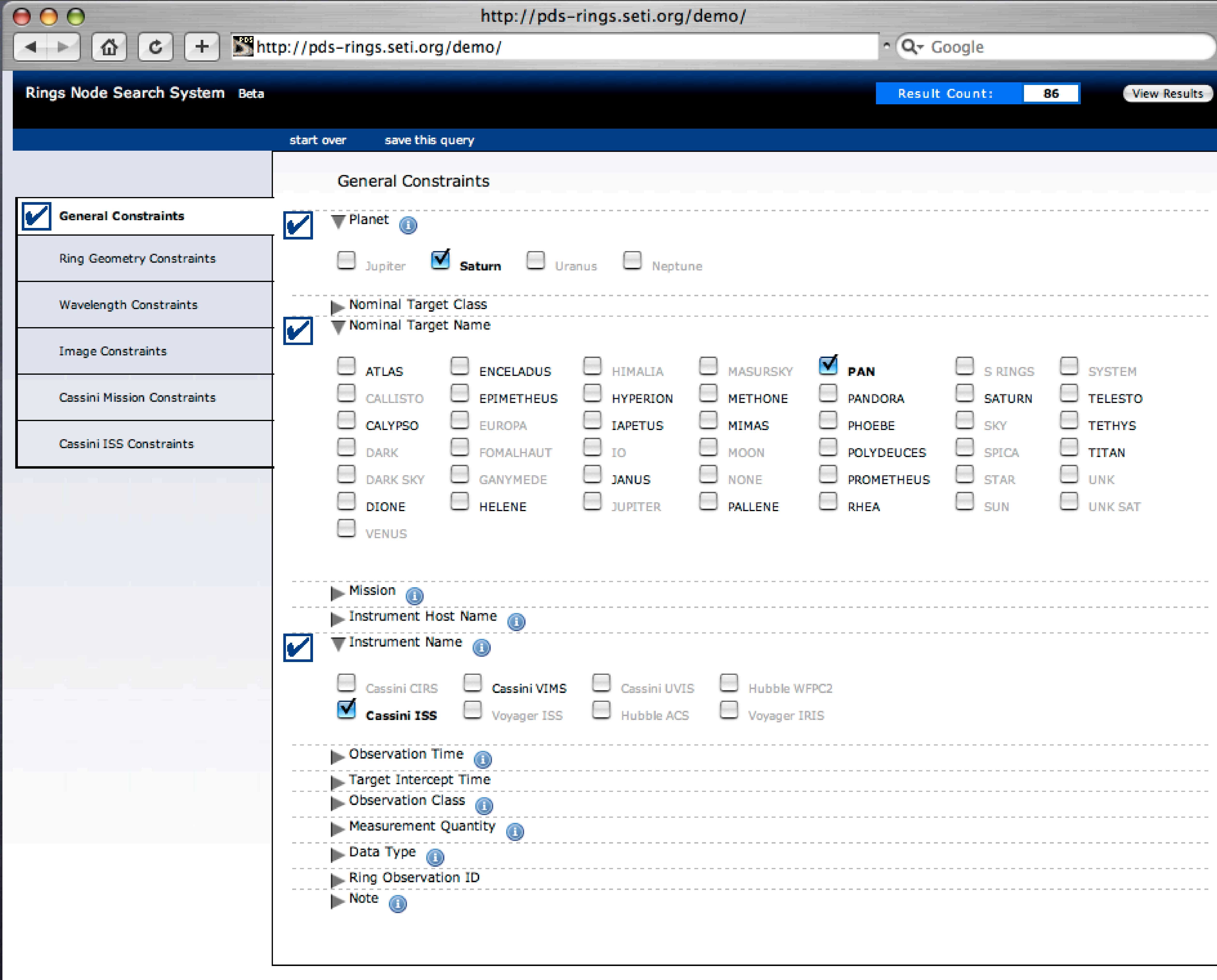
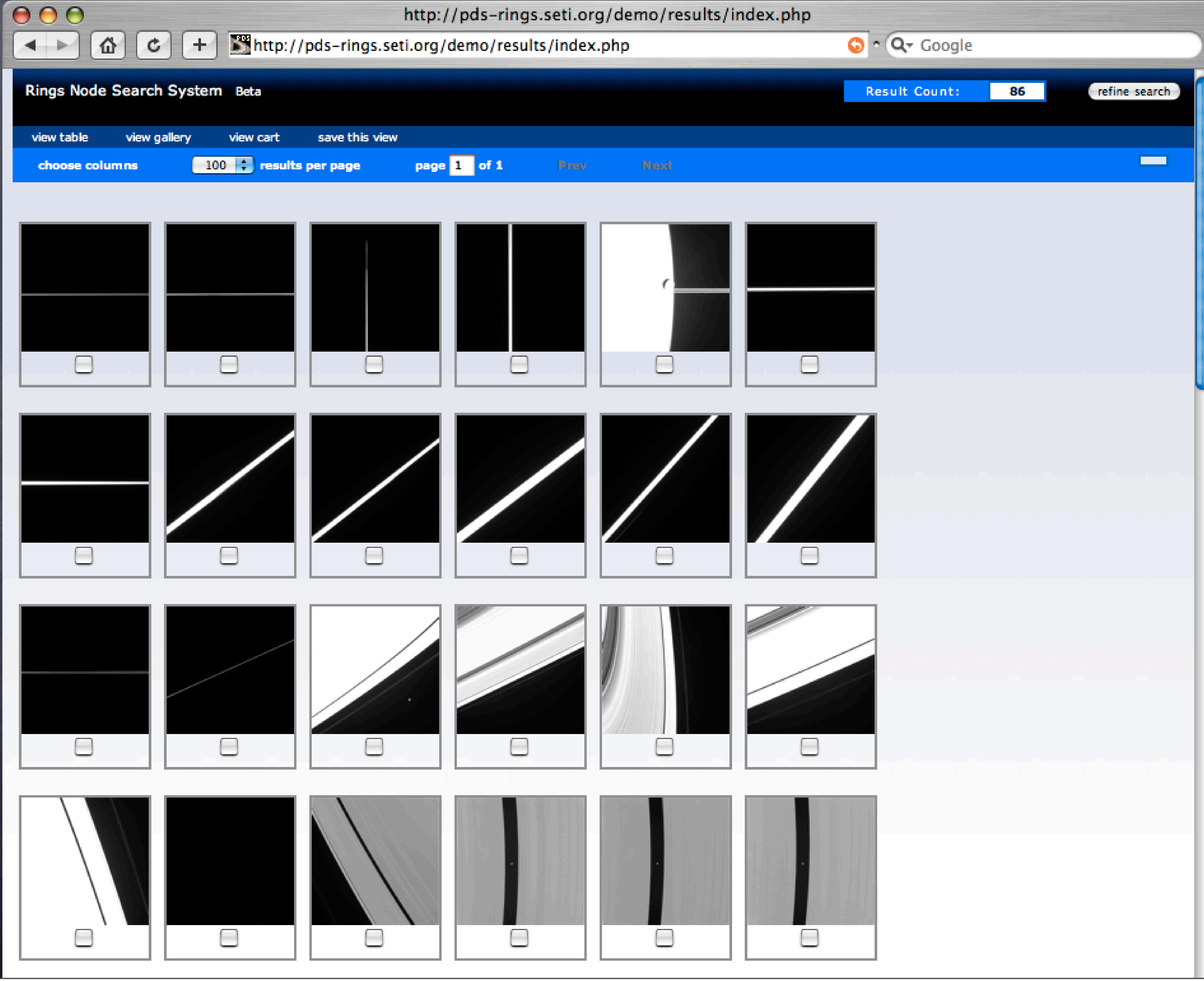
View Results
start over
save this query
General Constraints
Ring Geometry Constraints
Wavelength Constraints
Image Constraints
Cassini Mission Constraints
Cassini ISS Constraints
General Constraints
Planet
Jupiter
Saturn
Uranus
Neptune
Nominal Target Class
Nominal Target Name
ATLAS
ENCELADUS
HIMALIA
MASURSKY
PAN
S RINGS
SYSTEM
CALLISTO
EPIMETHEUS
HYPERION
METHONE
PANDORA
SATURN
TELESTO
CALYPSO
EUROPA
IAPETUS
MIMAS
PHOEBE
SKY
TETHYS
DARK
FOMALHAUT
IO
MOON
POLYDEUCES
SPICA
TITAN
DARK SKY
GANYMEDE
JANUS
NONE
PROMETHEUS
STAR
UNK
DIONE
HELENE
JUPITER
PALLENE
RHEA
SUN
UNK SAT
VENUS
Mission
Instrument Host Name
Instrument Name
Cassini CIRS
Cassini VIMS
Cassini UVIS
Hubble WFPC2
Cassini ISS
Voyager ISS
Hubble ACS
Voyager IRIS
Observation Time
Target Intercept Time
Observation Class
Measurement Quantity
Data Type
Ring Observation ID
Note


http://pds-rings.seti.org/demo/
Google
Rings Node Search System Beta
Result Count: 86
View Results
start over
save this query
General Constraints
Ring Geometry Constraints
Wavelength Constraints
Image Constraints
Cassini Mission Constraints
Cassini ISS Constraints
General Constraints
Planet
Jupiter
Saturn
Uranus
Neptune
Nominal Target Class
Nominal Target Name
ATLAS
ENCELADUS
HIMALIA
MASURSKY
PAN
S RINGS
SYSTEM
CALLISTO
EPIMETHEUS
HYPERION
METHONE
PANDORA
SATURN
TELESTO
CALYPSO
EUROPA
IAPETUS
MIMAS
PHOEBE
SKY
TETHYS
DARK
FOMALHAUT
IO
MOON
POLYDEUCES
SPICA
TITAN
DARK SKY
GANYMEDE
JANUS
NONE
PROMETHEUS
STAR
UNK
DIONE
HELENE
JUPITER
PALLENE
RHEA
SUN
UNK SAT
VENUS
Mission
Instrument Host Name
Instrument Name
Cassini CIRS
Cassini VIMS
Cassini UVIS
Hubble WFPC2
Cassini ISS
Voyager ISS
Hubble ACS
Voyager IRIS
Observation Time
Target Intercept Time
Observation Class
Measurement Quantity
Data Type
Ring Observation ID
Note


http://pds-rings.seti.org/demo/results/index.php
Google
Rings Node Search System Beta
Result Count: 86
refine search
view table
view gallery
view cart
save this view
choose columns
100 results per page
page 1 of 1
Prev
Next

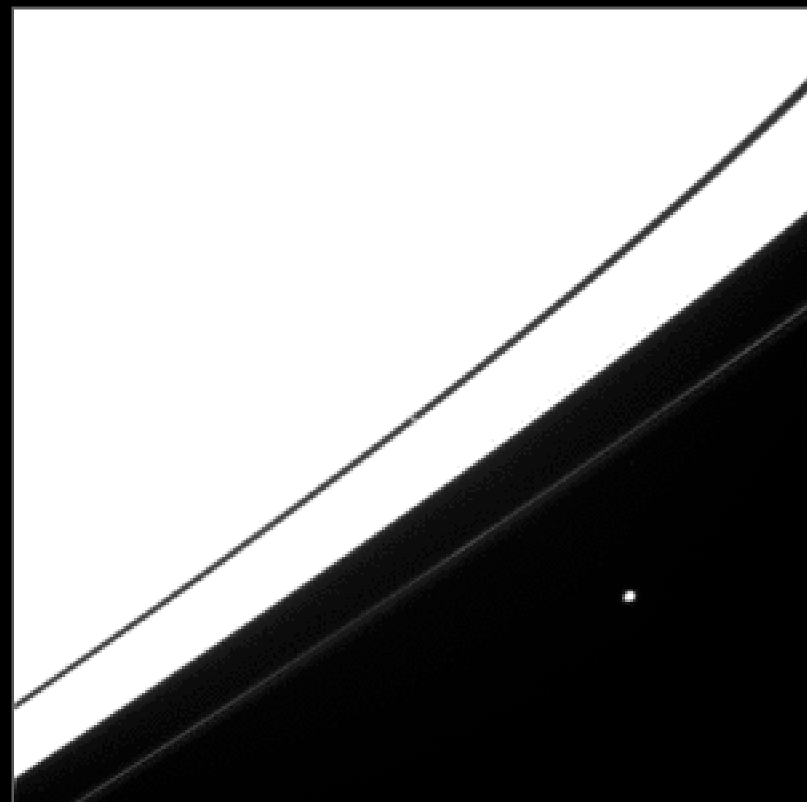
S/IMG/CO/ISS/1492024160/N

http://pds-rings.seti.org/demo/info_page/index.php?ring_obs_id=S/IMG/CO/I

Rings Node Search System Beta

Result Count: 86

Back to Results



S/IMG/CO/ISS/1492024160/N

Products

1 Product Found:

download now add to cart:

FILE_SPECIFICATION_NAME: data/1491988345_1492054459/N1492024160_1.IMG
VOLUME_ID: COISS_2011
PRODUCT_TYPE: EDR
LABEL_TYPE: DETACHED
OBJECT_TYPE: IMG
FILE_FORMAT_TYPE: VICAR
INTERCHANGE_FORMAT: BINARY
INSTRUMENT_ID: COISS
note:

http://pds-rings.seti.org/demo/results/

Rings Node Search System Beta

Result Count: 86 | refine search

view table | view gallery | view cart | save this view

choose columns | 100 results per page | page 1 of 1 | Prev | Next

add all results to cart

add this page	Ring Observation ID	Planet	Nominal Target Name	Instrument Name	Observation Time	Camera	Exposure Duration	Filter Name
☐	S/IMG/CO/ISS/1488190255/N	Saturn	PAN	Cassini ISS	2005-058T09:44:23.830	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488273311/N	Saturn	PAN	Cassini ISS	2005-059T08:48:39.417	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488368442/N	Saturn	PAN	Cassini ISS	2005-060T11:14:09.817	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488485562/N	Saturn	PAN	Cassini ISS	2005-061T19:46:09.079	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488551713/N	Saturn	PAN	Cassini ISS	2005-062T14:08:39.662	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488711044/N	Saturn	PAN	Cassini ISS	2005-064T10:24:09.562	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488745124/N	Saturn	PAN	Cassini ISS	2005-064T19:52:09.343	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488812400/N	Saturn	PAN	Cassini ISS	2005-065T14:33:24.910	Narrow Angle Camera	680	CLEAR
☐	S/IMG/CO/ISS/1488826725/N	Saturn	PAN	Cassini ISS	2005-065T18:32:09.818	Narrow Angle Camera	680	CLEAR
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☐	S/IMG/CO/ISS/1489258067/N	Saturn	PAN	Cassini ISS	2005-070T18:21:09.045	Narrow Angle Camera	680	CLEAR
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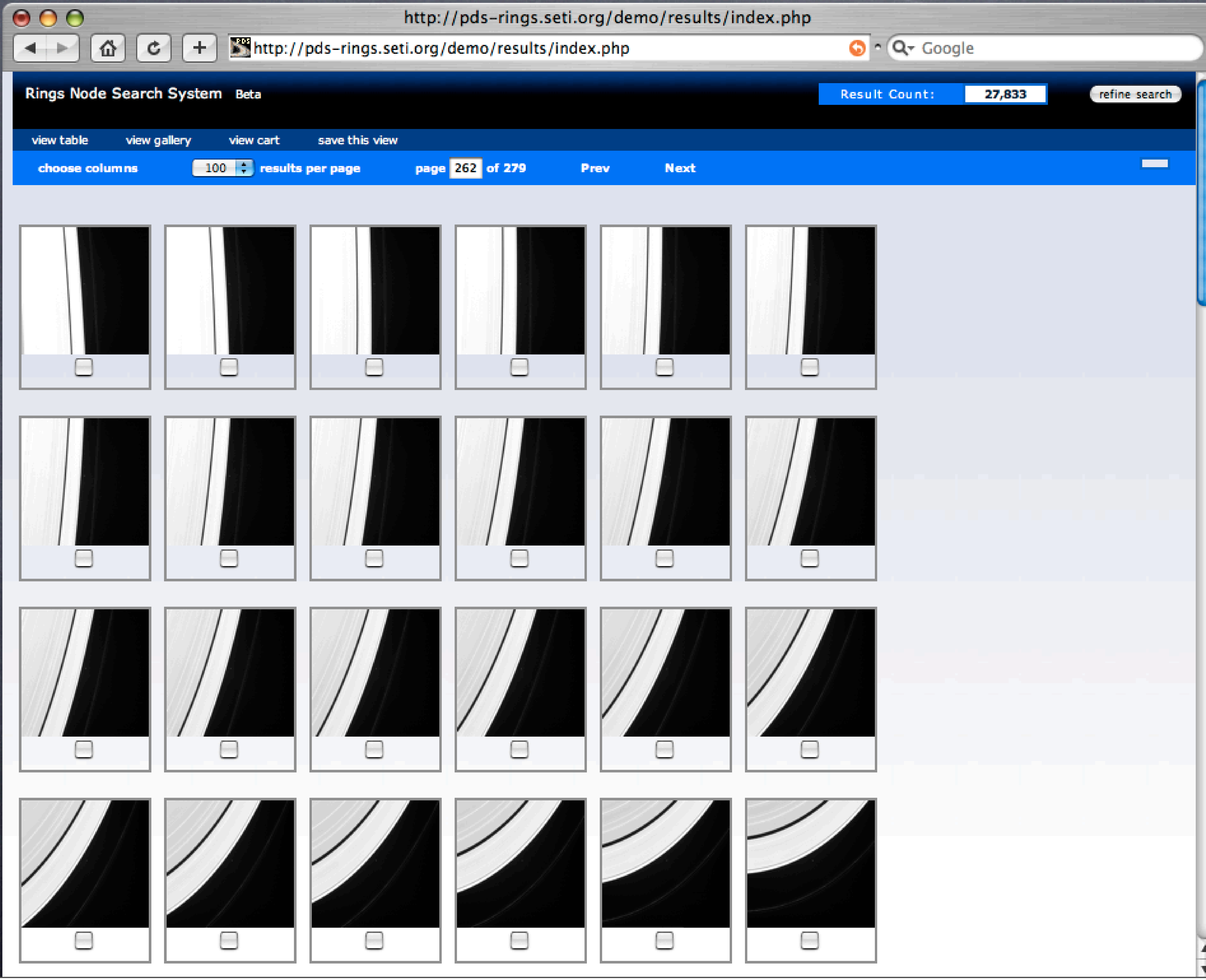
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Google
Rings Node Search System
Beta
Result Count:
27,833
refine search
view table
view gallery
view cart
save this view
choose columns
100
results per page
page
262
of 279
Prev
Next