The NOAO Survey for Ionization in Neutral Gas Galaxies

Patricia Knezek (WIYN), Gerhardt Meurer (JHU) & the SINGG team

Cosmological evolution is mapped using tracers of star formation, yet the true amount and distribution of ongoing star formation in the local universe is still poorly determined. One reason is that most studies of star formation focus on samples that are biased toward galaxies with high star formation rates and/or high stellar content. Is our understanding of star formation in galaxies severely biased as a result?

To address this question, Gerhardt Meurer (Johns Hopkins University) and a team of 18 other astronomers are carrying out a NOAO survey program known as the Survey for Ionization in Neutral Gas Galaxies (SINGG). The goal of the survey is to provide a measure of the star formation rate (SFR) density of the local universe based on the potential for star formation (i.e., the presence of an interstellar medium), rather than on the ongoing star formation rate. Thus, the sample is drawn from the HI Parkes All Sky Survey (HIPASS).

Since the resulting sample is free from optical biases, the survey is well suited to addressing such questions as "If fuel for star formation is present, does star formation always occur? If it does, what form does it take?" Other goals for the survey include determining how the HII region luminosity function varies from galaxy to galaxy; examining the SFR distributions as a function of morphological type, galaxy mass, and environment; providing a morphological survey of star formation properties such as bursts and galactic winds; determining gas consumption timescales; and, ultimately, creating a reference Hα survey of the local universe for the astronomical community.

The sample consists of approximately 500 galaxies that evenly sample the HI mass distribution from ~2×10^7 to 7×10^{10} M_{sun}. The lowest ($<10^8$ M_{sun}) and highest ($>3\times10^{10}$ M_{sun}) mass bins are volume limited. For all other bins, the closest galaxies have been selected to maximize the spatial resolution. The galaxies are imaged in *R* and *Hα*,

A montage of six representative galaxies from the SINGG sample. Shown is the continuum-subtracted Hα emission (seen largely as bright knots over the galaxy disks) superposed on the R-band image (the smooth, underlying component). Note the diversity of the amount and location of star formation.

continued

Ionization in Neutral Gas Galaxies continued

primarily with the CTIO 1.5-m telescope, using custom-built 35 Å FWHM filters, as well as standard NOAO 75 Å filters. Since the CTIO 1.5-m telescope is now dedicated to spectroscopy, the survey will be continued with the CTIO 0.9-m telescope.

Some interesting results have already emerged. One primary result is that nearly all the HIPASS targets have been detected, and there are no firm nondetections among the extragalactic HI sources. Apparently, wherever significant neutral gas exists, stars form. The optical morphology of the sample includes low surface brightness galaxies, giant spirals, mergers and interacting galaxies, starburst galaxies, and residual star formation in early disks. Many of the highest HI mass systems ($>10^{9.5}$ M_{sun}) turn out to contain multiple Hα emitting galaxies. Preliminary results suggest that starburst galaxies comprise approximately 15 percent of the sample, and that galactic winds are common.

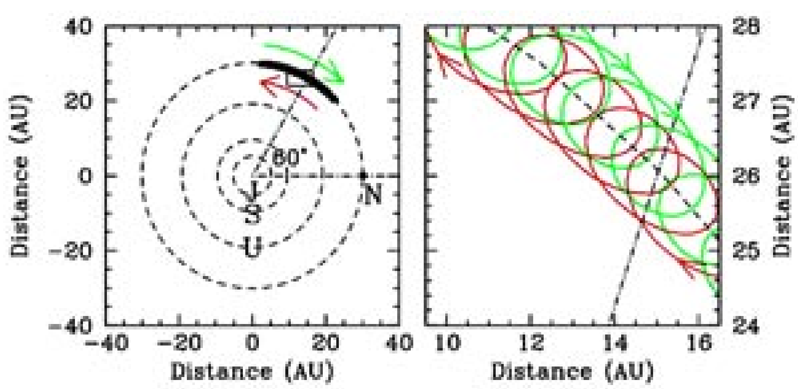
The survey has also detected a number of faint unresolved emission sources located as far as 30 kpc from the host galaxy. A recent follow-up study (Ryan-Weber et al. 2003, in preparation) on 13 of these "Emission Line dots," or ELdots, has confirmed that five of the ELdots are at velocities consistent with the host galaxies. The five ELdots are found in three systems, two of which have tidal HI features. The Hα luminosities are consistent with an ionizing flux of only a few O stars in each ELdot. If these stars formed in situ, they represent atypical star formation in the low density outer regions of galaxies. Although the calculated star formation rates are low ($\sim3\times10^{-3}$ M_{sun} /year), if it is continuous, this may provide a way to enrich the intergalactic medium. Further information on the survey, including publicly released data, is available at *www.stsci.edu/ftp/science/singg*.

Resonant Kuiper Belt Objects Discovered by the Deep Ecliptic Survey

Eugene Chiang, University of California at Berkeley

Since the discovery of minor planet (15760) 1992 QB_1 (in 1992 by David Jewitt and Jane Luu), we now know that the space just beyond Neptune's orbit is populated by tens of thousands of asteroid-sized bodies bound to the Sun. These Kuiper Belt Objects (KBOs) are survivors from the era of planet formation, during which the outer solar system was crowded with gravitationally interacting, physically colliding bodies interspersed among the nascent giant planets. From a dynamicist's point-of-view, KBOs furnish a remarkable ensemble of test particles whose orbits record the history of events during that formative time.

Discovering KBOs and accurately measuring their orbits is the ongoing mission of the Deep Ecliptic Survey (DES), a NOAO survey program that is being carried out using the Mosaic imagers on the Mayall and Blanco



Trajectory of 2001QR322, the first Neptunian Trojan discovered by the Deep Ecliptic Survey (Chiang et al. 2003), in a quasi-Neptune-centric frame. The left-hand panel displays a bird's-eye view of the outer solar system, with the giant planet orbits shown schematically. The dark tube of points lying on Neptune's orbit marks the computed path of the Trojan. The Trojan shuttles back and forth as indicated by the red and green arrows. Each shuttling, or libration, takes about 10^4 years to complete. The small inset rectangle is magnified in the right-hand panel to show the fast corkscrewlike (epicyclic) motion. Each corkscrew takes about one orbital period of Neptune, or about two hundred years, to complete.

continued

Resonant Kuiper Belt Objects continued

4-m telescopes. Begun in 1998 under the direction of Bob Millis of Lowell Observatory, the team now includes members from the Massachusetts Institute of Technology, the Institute for Astronomy in Hawaii, the University of Arizona, the University of Pennsylvania, and the University of California at Berkeley. DES has already discovered the most KBOs of any survey to date, but by the time the survey is complete (around 2005), it will have examined over 1,000 square degrees of sky near the ecliptic, down to *V*=24, and cataloged approximately 500 KBOs with precisely measured orbits.

DES has recently found that the Kuiper Belt is replete with "resonant KBOs" (objects whose orbital periods are nearly perfectly commensurate with that of Neptune). For example, "Plutinos" occupy the 3:2 resonance; they orbit the Sun three times, on average, for every two revolutions of Neptune. Resonances afford KBOs dynamical stability for reasons analogous to those that protect a pair of dancers from stepping on each other's toes. Plutinos were known to exist prior to 1998, but since then DES has reported that occupied resonances include the 5:4, 4:3, 5:3, 7:4, 9:5, 2:1, and 5:2 resonances. Rigorous testing for resonance membership is made possible using orbit fitting and integration software developed at the University of California at Berkeley and Lowell Observatory.

Resonant KBOs strongly support the notion that Neptune was once mobile, and that it was gently propelled to greater heliocentric distances by several AUs via the gravitational scattering planetesimals. As Neptune migrated outward, resonances swept across the primordial belt, capturing planetesimals. The preponderance of resonant KBOs is the most direct evidence we have that planetary migration (which is also invoked to explain the orbits of close-in extrasolar planets) is a real phenomenon.

In a related development, DES has also reported the discovery of the first Neptunian Trojan—an object that is in a 1:1 resonance with Neptune. The famous Jovian Trojans occupy two clusters that lie along Jupiter's orbit, displaced forward and backward of Jupiter's longitude by 60 degrees. Neptune was long thought to carry its own retinue of co-orbital Trojans. This belief was finally vindicated by the DES discovery of an object about 130–230 km in diameter that co-orbits with Neptune, remaining nearly 60 degrees ahead of it.

Extrapolations based on the amount of sky surveyed by DES to date indicate that Neptune's Trojans are likely to rival, and even exceed, Jupiter's set in both number and mass. Neptunian Trojans were likely captured as the host planet accreted the bulk of its mass. Their existence points to a relatively placid growth period for Neptune during which it was not scattered violently to and fro across the solar system, contrary to some recent speculations.

Signatures of Large-Scale Coronal Eruptive Activity, Associated Flares, and Propagating Chromospheric Disturbances

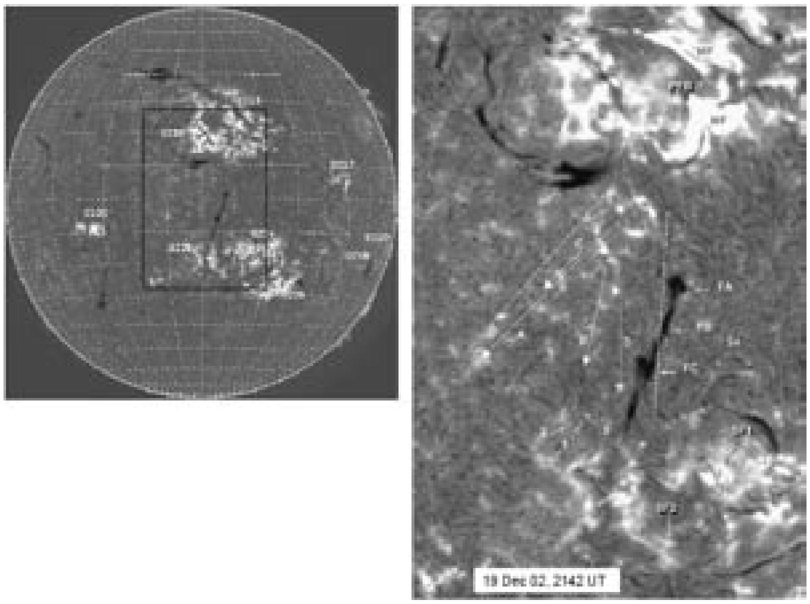
Donald F. Neidig (AFRL/VSBXS), K. S. Balasubramaniam, Alexei Pevtsov (NSO), Edward W. Cliver (AFRL/VSBXS), C. Alex Young (EER Systems, NASA/GSFC), Sara F. Martin (Helio Research) & Alan L. Kiplinger (University of Colorado)

Analyses of multiwavelength data sets obtained on 19 December 2002 at approximately 21:50 universal time show evidence of a large-scale, transequatorial coronal eruption associated with simultaneous flares in active regions in both hemispheres. The coronal manifestations, based on the SoHO Extreme ultraviolet Imaging Telescope (EIT), Large Angle and Spectrometric COronagraph experiment (LASCO), and Transition Region and Coronal Explorer (TRACE) images, include a large coronal dimming, an opening/restructuring of magnetic fields, the formation of a transient coronal hole, and a halo coronal mass ejection (CME). In the chromosphere, Improved Solar Observing Optical Network (ISOON) Hα images show distant flare precursor brightenings and several sympathetic flares.

Originating near the main flare is a rapidly propagating (800 km/s), narrowly channeled disturbance that is detectable through the sequential brightening of numerous preexisting points in the Hα chromospheric network. This disturbance is not a chromospheric Moreton wave, but it

continued

Coronal Eruptive Activity continued



Left: Limb darkening subtracted full-disk ISOON Hα image obtained on 19 December 2002. Right: A region of large-scale disturbance, across multiple active regions. PFB: Preflare brightening; arrows indicate the propagation direction of disturbances A, B, C, and D, with speeds of 800 km/s, as measured by sequentially brightened network points in a time sequence. These disturbances move the filaments at locations FA, FB, and FC, partially erupting the filament at FC. Sympathetic flares are seen in the southern hemisphere at SF1 and SF2. SoHO/MDI magnetograms show that the brightened network points are all of same polarity. The coronal manifestations of this large-scale event include transequatorial loops and coronal dimming, as observed by SoHO/EIT. These and similar events recorded by ISOON show that such large-scale coronal eruptive events trigger near-simultaneous surface activity separated by distances on the same scale as the coronal structures involved in the eruption.

does produce a temporary activation of a transequatorial filament. This filament does not erupt, nor do any of the other filaments in the vicinity. Michelson Doppler Imager (MDI) magnetograms show that the brightened network points are all of the same polarity (the dominant polarity among the points in the disturbance's path), suggesting that the affected field lines extend into the corona, where they are energized in sequence as the eruption tears away.

Three other similar eruptive events (nontransequatorial) that we studied, while less impressive, show most of the same phenomena, including distant sympathetic flares and a propagating disturbance showing close adherence to the monopolarity rule. Two of these events include filament eruptions near the main flare. We conclude that the observations of these four events are consistent with large-scale coronal eruptive activity that triggers nearly simultaneous surface activity of various forms separated by distances on the same scale as the coronal structures themselves. A filament eruption at the main flare site does not appear to be a necessity for this type of eruptive activity.